GLOBEC INTERNATIONAL
NEWSLETTER
A CORE PROJECT OF THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME
http://www.globec.org

Vol.12, No.1 | GLOBAL OCEAN ECOSYSTEM DYNAMICS | APRIL 2006

Editorial: Links between GLOBEC and IMBER

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In 2003 the International Geosphere-Biosphere Programme (IGBP) decided to launch a new research structure of its core projects. Until then GLOBEC and JGOFS were the two core projects under the IGBP "Oceans" domain, with JGOFS completing its work in December 2003. In 2002 the IGBP and its marine partner the Scientific Committee on Oceanic Research (SCOR) started to develop a future scenario for a single IGBP/SCOR core project working on marine biogeochemistry and ecosystems. This plan needed to include the continuation of GLOBEC's planned activities until the end of 2009 and resulted in the development of the new project, IMBER (Integrated Marine Biogeochemistry and Ecosystem Research). The transition to a single marine project has IMBER and GLOBEC projects undertaking separate research activities in parallel as well as combined activities and a process of merging both projects in 2010. This editorial is intended to provide news and clarification as to this process, knowing that keeping the community well informed is crucial for our success.

Sardine schooling in captivity after acclimation see special section on GLOBEC Portugal on pages 7 to 31.

As is well known in the community IMBER has now been established, with a project goal to "*understand how interactions between marine biogeochemical cycles and ecosystems respond to and force global change*". An International Project Office headed by Dr Sylvie Roy has been established at the Institut Universitaire Européen de la Mer (IUEM) in Plouzané, France, and its Science Plan and Implementation Strategy has been published.

In October 2005 members of the Executive Committees of GLOBEC and IMBER and representatives of SCOR and IGBP, met in Plouzané, France for the first time. The objective of the meeting was to develop common research activities and to plan the process of parallel

Extracted points of the 2003 agreement between IGBP and SCOR with respect to their support to IMBER (named OCEANS at the time of the agreement) and GLOBEC (full text published in GLOBEC Newsletter 9.1, downloadable from www.globec.org).

- GLOBEC will continue to completion of the project in [December] 2009, as specified in its Implementation Plan.
- The new project [IMBER] will develop research activities with a ten-year life, with its scientific emphases thus extending until 2014. The project will be allowed to develop its own identity.
- The new project [IMBER] and GLOBEC will be encouraged to begin to develop joint activities starting in 2003. The two SSCs will be encouraged to hold back-to-back or overlapping meetings.
- The extent and speed of development of joint activities and project integration will be at the discretion of the SSCs for the two projects.
- There will be a single integrated ocean project that includes the scientific activities of GLOBEC and the new project [IMBER] in place by [end of] 2009.

implementation of both programmes until 2010. At the meeting the Executives evaluated the state of planned and existing GLOBEC-IMBER activities:

- **End-to end food webs task team – End-to-End food web studies were highlighted in the IMBER Science Plan as an area that required close implementation with GLOBEC. To facilitate the implementation GLOBEC and IMBER have jointly appointed a task team that would put together a short paper for publication in a high-impact journal laying out**:

  (i) why we need to tackle end-to-end food webs in our studies at this time,

  (ii) what the key challenges are and how we can meet them, and

  (iii) how we can make headway in the experimental, observational and modelling components of marine end-to-end food webs.

  The task team includes Drs Ken Denman (Canada), Dave Karl (USA), Fritz Köster (Denmark), Coleen Moloney (South Africa, co-chair), Mike St John (Germany, co-chair), Svein Sundby (Norway) and Rory Wilson (UK). They met in Hamburg, Germany, 14–15 December, 2005 and continue to operate by correspondence. The life span of the task team will end with the publication of their paper, but the group will make recommendations to the IMBER and GLOBEC SSCs regarding scientific issues and on ways to proceed with End-to-End food web research.

- **EUR-OCEANS European Network of Excellence:** EUR-OCEANS is a network of more than 60 research institutes from 25 countries (mostly from the European continent, but also including Algeria, Chile, Morocco, South Africa and Tunisia), co-funded by the Sixth Framework Programme for Research and Technological Development of the European Communities (FP6). EUR-OCEANS is a contributing project to both IMBER and GLOBEC. Its aims are to achieve lasting integration of European research organisations on global change and pelagic marine biogeochemistry and ecosystems, and to develop models for assessing and forecasting the impacts of climate and anthropogenic forcing on biogeochemistry and food-web dynamics of pelagic ecosystems in the open ocean. The network will favour the progressive integration of research programmes and facilities of major research institutes all over Europe

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towards a multi-site Institute for European Research on Ocean Ecosystems under Anthropogenic and Natural Forcings. Acknowledging the plans to merge IMBER and GLOBEC by the end of 2009, EUR-OCEANS provides leadership in this merger. For information on EUR-OCEANS visit www.eur-oceans.org and GLOBEC Newsletter 11.2.

- **ICED (Integrated Analyses of Circumpolar Climate Interactions and Ecosystem Dynamics):** ICED is being developed as a new GLOBEC/IMBER international project, to follow on the successful SO GLOBEC programme. The main research questions of ICED are a) how do climate processes affect the dynamics of circumpolar ecosystems? b) how does ecosystem structure affect circumpolar ocean biogeochemical cycles? and c) how should ecosystem structure and dynamics be included in the development of sustainable approaches to managing exploitation? A planning workshop was held at the British Antarctic Survey, Cambridge, England in May 2005 with the goal of producing an ICED science plan. The plan will be published jointly by IMBER and GLOBEC later this year.
- **China GLOBEC III/IMBER I national research programme:** The 3rd phase of China GLOBEC will be implemented with the 1st phase of China IMBER in a single research programme on "Key Processes and Mechanisms of Sustainable Food Production of Marine Ecosystems in China". An article on the kick-off symposium for what is known as programme 973-2 is included in this Newsletter.

The Executive Committees also discussed the process of parallel implementation of IMBER and GLOBEC and the process of transition to a single research programme beyond 2010. The main decisions taken by the Executives are as follows:

- **Existing GLOBEC activities** will continue under the GLOBEC umbrella until the conclusion of GLOBEC in December 2009, but those continuing beyond this deadline need to have mechanisms to be included in the post-2010 scenario. It was agreed that the process of transferring GLOBEC activities will be developed by a GLOBEC-IMBER Transition Task Team, to initiate its work in 2007. However, it was acknowledged that national-level activities could be co-sponsored by both IMBER and GLOBEC, and that both programmes must be flexible in facilitating this process.

  The two projects will hold joint meetings of their Executive committees or SSCs on an annual basis and the Chairs of each project will be invited to participate in the SSC meeting of the sister project, to facilitate good co-ordination and collaboration between the two projects.
- **Drafting of an addendum to the IMBER Science Plan** was considered necessary. This will include ongoing research from GLOBEC programmes as well as science issues identified in the GLOBEC synthesis that need to be addressed. It is suggested to start this process at the 2007 GLOBEC-IMBER Executive meeting with the formation of a Task Team to develop the addenda to the science plan.

New members of the GLOBEC SSC

Six new members have joined the GLOBEC SSC in 2005, replacing Patrick Lehodey, Geir Ottersen, Marten Scheffer and Qisheng Tang, who are thanked for their support to GLOBEC during their mandates.

Kevern Cochrane

Kevern Cochrane is a Senior Fisheries Officer in the Marine Fishery Resources Service of the Food and Agriculture Organization of the United Nations (FAO), based in their headquarters in Rome, Italy. Prior to that, he was head of the Stock Assessment Division at Marine and Coastal Management (then the Sea Fisheries Research Institute) in Cape Town, South Africa, where he was also Chair of the Benguela Ecology Programme from 1992 to 1994. He was Visiting Professor at Green College, University of British Columbia, Canada for the winter semester of 2002 and, within the context of GLOBEC, was a member of the International Committee for SPACC in 1995 and 1996. He holds a PhD in fish ecology and population dynamics from the University of the Witwatersrand, South Africa. His work at FAO is diverse but, at present, focuses mainly on facilitating implementation of the ecosystem approach to fisheries and the role of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) in relation to commercially-exploited aquatic species. Amongst his current responsibilities, he is the International Project Coordinator for a cooperative project between the GEF Benguela Current Large Marine Ecosystem project and FAO on "Ecosystem Approaches for Fisheries (EAF) Management in the BCLME". His interest in integrating the impact of wider ecosystem influences with conventional approaches to stock assessment and fisheries management goes back to his earliest work on the Lake Tanganyika sardine *Limnothrissa miodon* in Lake Kariba, Zimbabwe. While at MCM and as part of the Benguela Ecology Programme, he worked on the effects of environmental influences on recruitment of the commercially important small pelagic species of the Benguela Upwelling System. The current global drive to promote ecosystem approaches to fisheries provides a challenging opportunity for pursuing his interest in the broad theme of fisheries-ecosystem interactions, amongst others.

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Astrid Jarre

Dr Astrid Jarre is a fisheries ecologist of the Danish Institute for Fisheries Research specialising in ecosystem-based fisheries management. Her research interests include the development of methodology related to the inclusion of ecosystem indicators into fisheries management, nonlinear modelling and multivariate analytical methods. She has previously conducted research on trophic flows in marine ecosystems and population dynamics. Developing scientific advice for management has brought Astrid into contact with social scientists, a line of collaborative cross-disciplinary research that she would like to expand in the future.

Astrid's research focuses on exploited marine ecosystems driven by pronounced environmental signals, e.g. large marine upwelling ecosystems and the ecosystem off West-Greenland. Her experience includes data-limited situations as experienced in many developing countries. During 2006, she will be based at the University of Cape Town, South Africa.

Astrid is a member of the Scientific Steering Committee of the new GLOBEC Regional Programme, Ecosystem Studies of Sub-Arctic Seas (ESSAS).

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Salvador E. Lluch-Cota

Salvador Lluch-Cota is a fisheries oceanographer working for the Fisheries Ecology Program at the Northwest Biological Research Centre, Mexico (CIBNOR). He received his undergraduate degree in marine biology from the Autonomous University of Baja California Sur (UABCS), his masters from the Interdisciplinary Centre for Marine Sciences (CICIMAR) and his doctorate from CIBNOR. His work has focused on the effects of climate variations on marine ecosystems, especially the low frequency fluctuations in small pelagic fisheries. His background includes analyses of satellite-derived information, ecological effects of ENSO and development of monitoring and forecasting models for physical-dependent ecological processes. He currently serves as a PI on a project called "Climate change impacts and adaptations in the Gulf of California region" and as Co-PI on a NSF-Biocomplexity project a "Linking human and biophysical processes in coastal marine ecosystems of Baja California". He has been involved in several PICES and GLOBEC activities during the last few years, including the organisation of the PICES-GLOBEC North Pacific Transitional Areas International Symposium (La Paz, Mexico, 2002) and the International Course on Coupling Physical Circulation and Individual Based Models (GLOBEC International Newsletter 8(2)) and as chapter author in the PICES North Pacific Ecosystem Status Report.

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Olivier Maury

Olivier Maury (PhD, ENSAR 1998 in fishery science, speciality in numerical modelling of fish population dynamics) is a senior scientist at the Institut de Recherche pour le Développement (IRD, France). He is currently based at the Centre de Recherche Halieutique Méditerranéenne et Tropicale (CRH) in Sète. He is co-chair of the GLOBEC regional program CLimate Impacts on Oceanic TOp Predators (CLIOTOP) and had a leading role in the launching of the program since 2001. He leads the modelling component of the research unit THETIS and focuses his research on the development of the ecosystem model Apex Predators ECOSystem Model (APECOSM). APECOSM aims at representing the basin-wide spatialised dynamics of open ocean pelagic ecosystems, from phytoplankton up to fishing, with a special emphasis on top predators. Olivier is a member of the IOTC Scientific Committee and has been involved as an expert in the International Commission for the Conservation of Atlantic Tunas (ICCAT; 1997-2001) and the Indian Ocean Tuna Commission (IOTC; 1999-2005) Working Parties for which he developed several new stock assessment models and software which are routinely used in ICCAT and IOTC. His scientific priority is that climate and fishing influences on marine ecosystems be considered simultaneously in an integrated end-to-end view of marine ecosystems, closely combining modelling and observational studies at various scales.

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Yasunori Sakurai

Yasunori Sakurai is a professor at the Graduate School of Fisheries Sciences, Hokkaido University, Hakodate, Hokkaido, Japan. He started his scientific career as a marine biologist at the Graduate School of Fisheries, Hokkaido University in 1977 and later took a PhD degree in reproductive biology of walleye pollock, *Theragra chalcogramma*. He has worked with the reproductive biology, strategy and stock fluctuations of gadid fish (walleye pollock, Pacific cod and Arctic cod), cephalopods (Japanese common squid and loligo squid) in relation to climate change. He has also worked on the biology of marine mammals and has been working with using both captive and field observations. As a professor at the Hokkaido University he is lecturing in marine ecology. Sakurai was a member of Japan-GLOBEC, the Cephalopod International Advisory Council (CIAC) and the PICES Programme in the early 1990s. He became the Chair of the Japan-GLOBEC Programme in 2004. He has directed a number of national research projects and programmes focusing on sustainable and responsible fisheries and ecosystem-based management affected by climate change and human activity. Sakurai is a member of the Scientific Steering Committee of the new GLOBEC Regional Programme, Ecosystem Studies of Sub-Arctic Seas (ESSAS).

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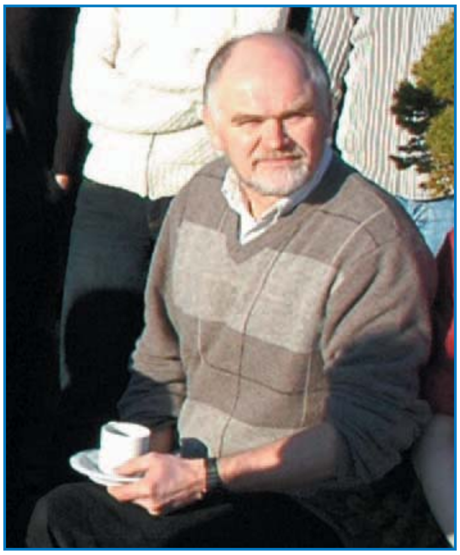

Svein Sundby

Svein Sundby is principal oceanographer at the Institute of Marine Research, Bergen, chief scientist at the Bjerknes Centre for Climate Research and associate professor at the Geophysical Institute, University of Bergen. He started his scientific career as a physical oceanographer at the Institute of Marine Research in 1975 and later took a doctorate degree in marine ecology. He has worked with fish recruitment processes in arctic and boreal ecosystems as well as in upwelling ecosystems in the southern hemisphere with an emphasis on physical-biological interactions and ocean climate effects. He has been working with both modelling and field observations. As professor at the Geophysical Institute he is lecturing in physical-biological processes. Sundby knew GLOBEC from its early days. He was part of the small group of scientists that developed the ICES Cod and Climate Change Programme in the early 1990s. He was a member of the GLOBEC Interim Steering Committee and later the GLOBEC SSC that developed the Science and Implementation Plans until he stepped down from the committee in 1998. He was a member of the IGBP/SCOR Task Team that developed the IMBER plan during 2002-2004. Under EUR-OCEANS European Network of Excellence he is leading System 1 on the Arctic and Nordic Seas. He has directed a number of national research projects and programmes.

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GLOBEC Portugal: an overview from the past a view into the future

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Member of the Portuguese Committee for IGBP and GLOBEC Portuguese Representative

We could say that the Portuguese participation in GLOBEC started in 1999 in the frame of the projects SURVIVAL (Assessing the impact of hydrodynamical forcing on the survival of small pelagic fish early life stages of western Iberia, PRAXIS-POCTI/CTA/11282/98) and PO-SPACC (Portuguese small pelagic fishes and climate change program: a comparative retrospective analysis, PRAXIS-POCTI/CTA/ 11281/98) coordinated by IPIMAR and funded by FCT – the Portuguese Science Foundation (Santos and Borges, 2000). This road has not been easy to follow because until recently there was not a true organised Portuguese National GLOBEC programme, with a basic funding that allowed to sketch and develop a long term strategic plan to avoid the fragmentation that is inherent to the short term and unforeseeable project-derived funding. However, the Portuguese marine scientific community has shown a persistent and, in my opinion, very successful research related to GLOBEC issues, as can be seen in the following contributions of this section on GLOBEC Portugal. Furthermore the National Committee for IGBP is trying to convince and bring to this 'boat' more researchers involved in subjects of relevance to GLOBEC, but also to Portugal, since our history is linked to the sea for several centuries and it has been and is a source of identity, inspiration and way of life – in conclusion a national purpose. The next four years (to 2010) will focus on integration and synthesis, and thus is of great importance for GLOBEC and for the preparation for its merger with IMBER (Integrated Marine Biogeochemistry and Ecosystem Research), the new IGBP Project on ocean biogeochemistry and ecosystems. This is a new challenge for the Portuguese GLOBEC community and the important relationship (as well as, involvement) with GLOBEC Portugal and other programmes and projects (e.g. GEOHAB, NoE EUR-OCEANS, IBI-ROOS a regional programme of EUROGOOS) is a major value in which the National Committee wants to proceed, stimulate and develop furthermore.

In this special section of GLOBEC Portugal it is our intention to present a synthesis of the main results achieved in recent years under several projects and programmes, but also to reveal ongoing and new approved relevant projects. The contributions in this section report results and activities on several areas from physical oceanography to small pelagic fish, and include the full range of trophic levels (phyto-, zoo-, ichthyoplankton, adult crustacean and fish) and their interactions with their environment. Although the outputs of SURVIVAL and PO-SPACC projects were a major contribution to GLOBEC Portugal, they will not be presented here if they have already been presented extensively in other issues of this Newsletter (Santos, 2001; Santos and Peliz, 2003).

I thank all the authors for their time and effort that make possible this overview of the activities of GLOBEC in Portugal.

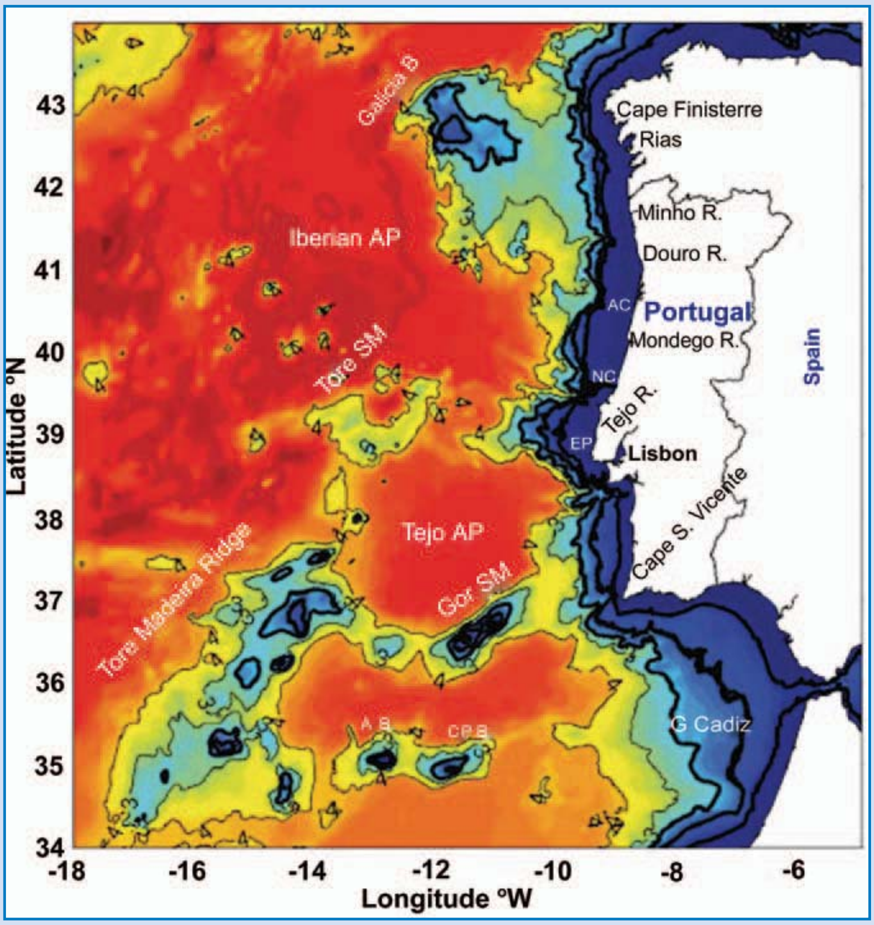

Figure 1. GLOBEC Portugal main study region. The colours represent depths from shallow (blue) to deep (red) zones (adapted from Peliz et al., 2005).

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Inner shelf circulation off southwest Iberia

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Continental shelves assume a disproportional importance in ocean processes compared to their surface area. The continental shelf represents the interface between the populated coastline and the open ocean and most of the human-induced influence on the coastal ecosystems occurs through the inner part of the shelf. During the last decade the inner shelf has received much more attention from oceanographers than before. Such interest relies on the increasing perception that the inner shelf dynamics are somewhat independent from the outer shelf dynamics. Traditionally physical processes over the continental shelf are defined in terms of Ekman dynamics which predict that cross-shelf transport is proportional to the wind stress and associated alongshore currents due to geostrophic adjustment. As we move onshore into reduced water depth, the surface and bottom boundary layer tend to overlap, reducing the cross-shelf transport predicted by Ekman theory over the inner shelf, which lays inshore of the upwelling or downwelling front (Austin and Lentz, 2002). This fact has ecological consequences by breaking the transport between the inner shelf and the outer shelf, prevailing the alongshore dispersion and consequent retention of larval stages, phytoplankton and detritus over the inner shelf. In the absence of strong Ekman dynamics, the nearshore region is exposed to forcing factors other than the wind stress.

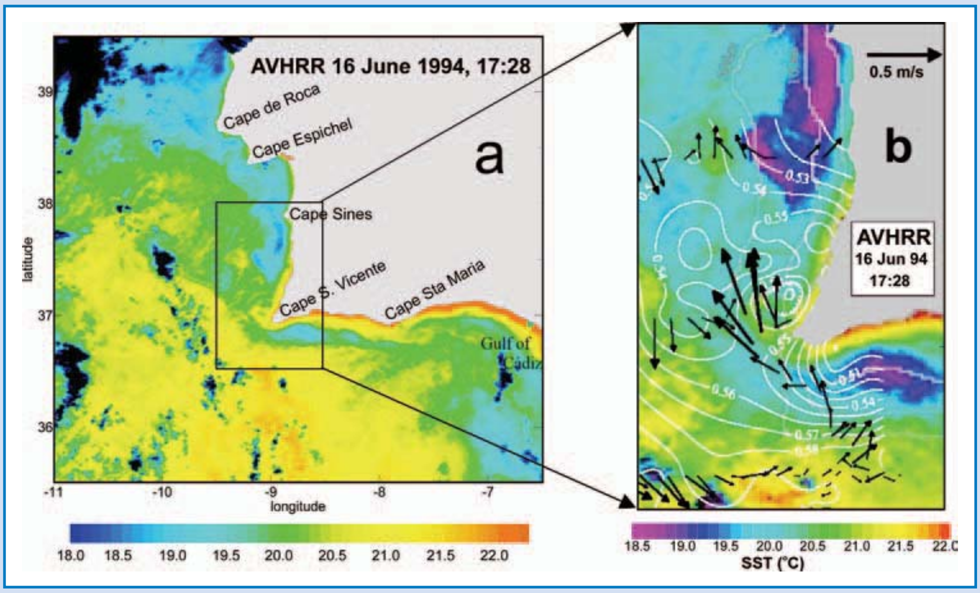

Figure 1. Satellite SST image showing the progression of the warm countercurrent from the Gulf of Cadiz in June 1994. Inset shows the vessel mounted ADCP vectors around Cape São Vicente.

Since the early nineties the Centro de Investigação Marinha e Ambiental (CIMA) at the University of Algarve has developed research focused on inshore counter-currents and inner shelf circulation off southwestern Iberian Peninsula. Satellite sea surface temperature imagery show the recurrent development during the upwelling season of a warm countercurrent over the inner shelf, progressing from the Gulf of Cadiz, often turning poleward around Cape São Vicente (Fig. 1a). This feature, 15 to 25 km wide, is associated with periods of weakening or relaxation of upwelling favourable winds. Analysis of tide gauge data reveal the existence of a negative alongshore pressure gradient, which is stronger during the upwelling season, forcing a "poleward" coastal flow against the alongshore circulation associated with the upwelling mechanism

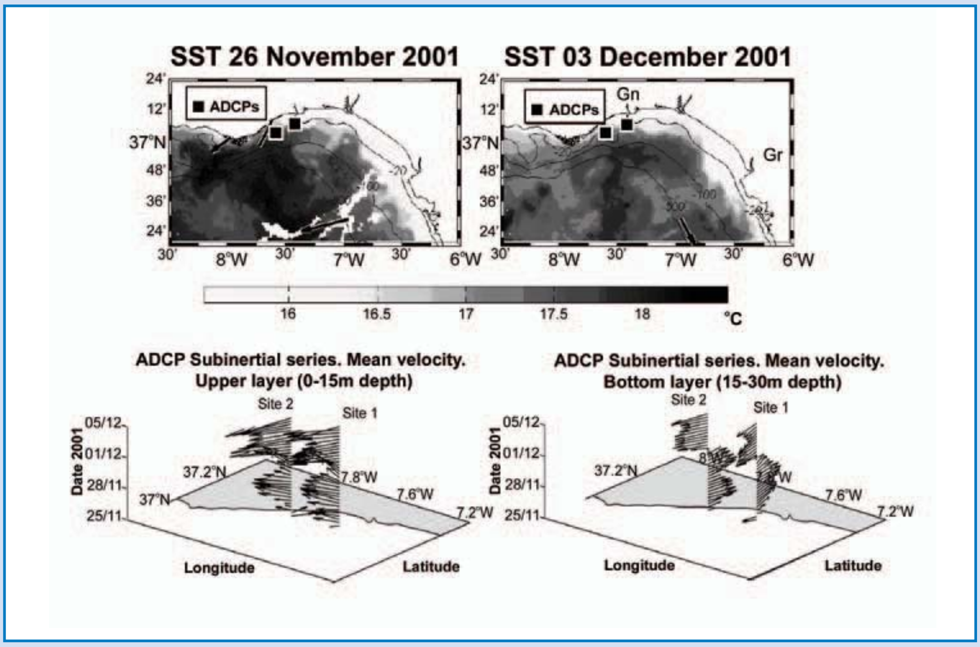

Figure 2. Satellite infrared images and time series of the ADCP vectors at the two sites in the northern margin of the Gulf of Cadiz showing the flow reversal in the upper (left) and bottom (right) layer. Maximum vector intensity, 0.25 m/s. Gn indicates the Guadiana river and Gr the Guadalquivir.

(Relvas and Barton, 2002). Direct observation of the inshore counterflow carried out in June 1994 revealed velocities of up to 0.4 m/s (Fig. 1b; Relvas and Barton, 2005). Direct observations taken from two upward looking 600 kHz ADCPs moored at ~30 m depth in the Gulf of Cádiz between 25 November and 7 December 2001 revealed the alternating nature of the coastal flow along the SW Iberian Peninsula, featuring a sharp current inversion on time scales of less than 2 days (Fig. 2). The subinertial flow drastically changed from ~0.25 m/s westward to ~0.17 m/s eastward and was parallel to the bathymetric contours and uncorrelated with the local wind stress (Sanchez *et al*., in press). Such observations, one in the summer upwelling season and the other in winter under non-upwelling conditions, show the dominant alongshore flow in the inner shelf off the northern margin of the Gulf of Cadiz, with implications in the ecosystem behaviour and particularly in harmful algae blooms transport in the region (Amorim *et al*., 2004).

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Project ATOMS: characterisation of an upwelling filament off Cape São Vicente, SW Iberia

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Filaments of upwelled waters are recognised to have strong hydrodynamic activity and conspicuous flow patterns, accompanied by changes in biological and chemical fluxes. High concentrations of chlorophyll due to an excess of nutrients are observed and consequently primary production is high. The offshore transport in the filament structures may represent an efficient way to exchange mass with the open ocean.

The Cape São Vicente is an upwelling centre under favourable wind conditions and is the origin of one of the major and more recurrent cold filaments observed along the coast of Iberia. The fact that Cape São Vicente is associated to singular cold filaments makes it an interesting target region to investigate such features. In addition, the excess of offshore transport of mass, nutrients and phytoplankton due to these features was never estimated for filaments off Portugal. Direct observations were carried out in the frame of the ATOMS project during a sea campaign in late October 2004 on board the oceanographic vessel NRPD Carlos I, from the Portuguese Navy, operated by the scientific staff of Instituto Hidrográfico and CIMA (University of the Algarve). A total of 42 CTD stations with nutrients and chlorophyll *a* water sampling at selected levels from the surface to a maximum depth of 400 m were carried out. Simultaneously, continuous onboard wind records and flow field data from the vessel mounted ADCP were acquired.

Horizontal velocity fields revealed the complex offshore jets inside the filament and the associated return flows. Subsurface hydrology showed the upward doming associated with the Cape São Vicente filament and quantified the vertical and horizontal gradients (Fig. 1). The filament sea surface temperature anomaly revealed by direct observation, has an evident fingerprint in the chlorophyll *a* distribution, spreading spatially over 100 km from the coast (Fig. 2). At surface the nutrient concentrations were lower than expected, due to their effective consumption by phytoplankton. The strongest horizontal and vertical gradients were found between 50 and 75 m depth. The highest concentration of chlorophyll *a* (3.6 µg/l) was found at the nearshore stations at 20 m depth and represents a high value for this time of the year. Although the offshore decrease of chlorophyll *a* concentration, relatively high values (≥0.3 µg/l) can be found at 60–80 km from the coast along the filament axis. An estimate of the total amount of chlorophyll present in the filament was 66 tonnes. Estimated values of fluxes and transport of nutrients and chlorophyll *a* revealed that filament structures represent an efficient method of exchange with the open ocean and have an important impact on the control of the primary production.

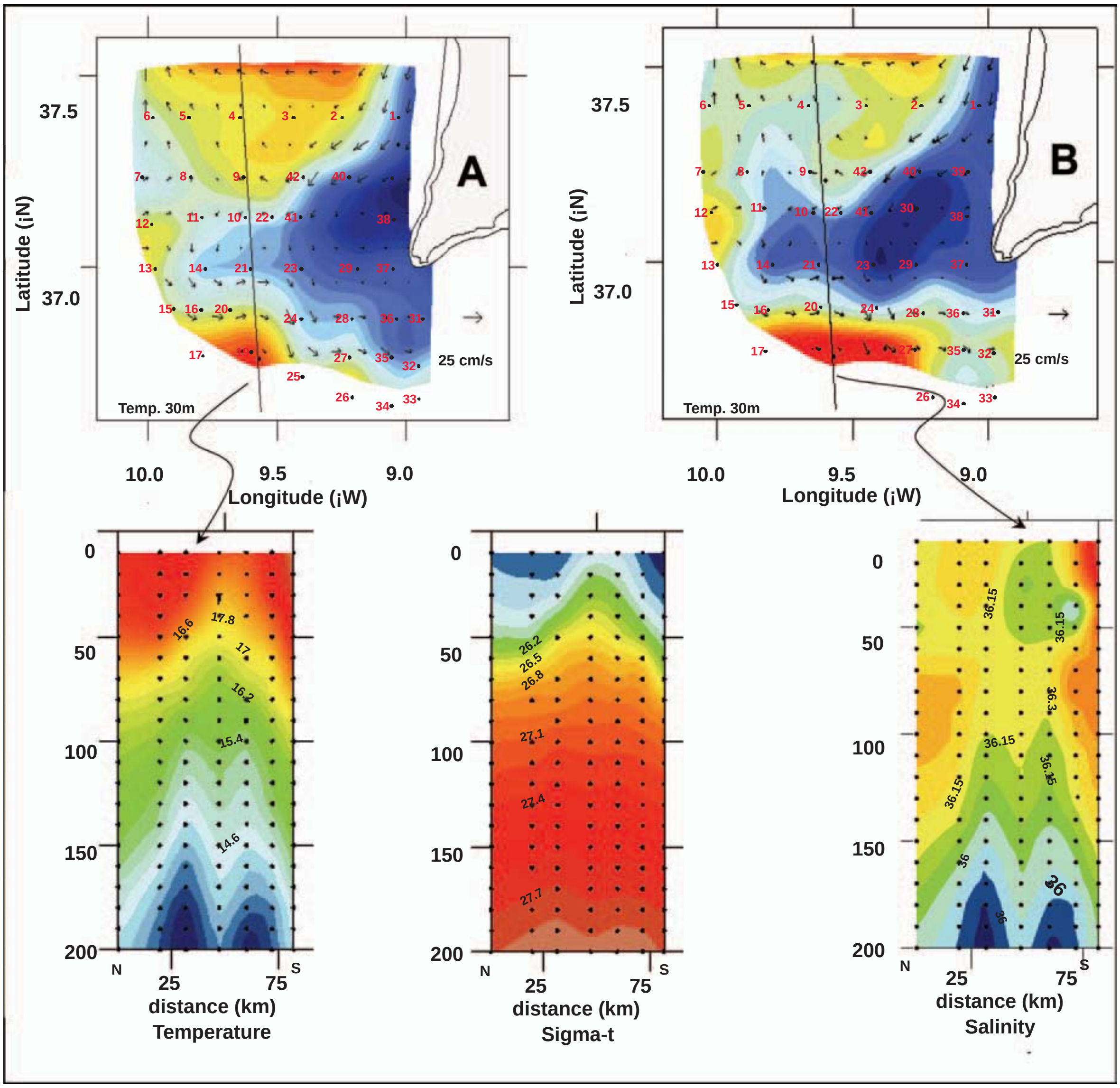

Figure 1. Horizontal and vertical fields from in situ observation: temperature (A) and salinity (B) at 30 m depth, superimposed on the geostrophic velocity field referred to 400 m.

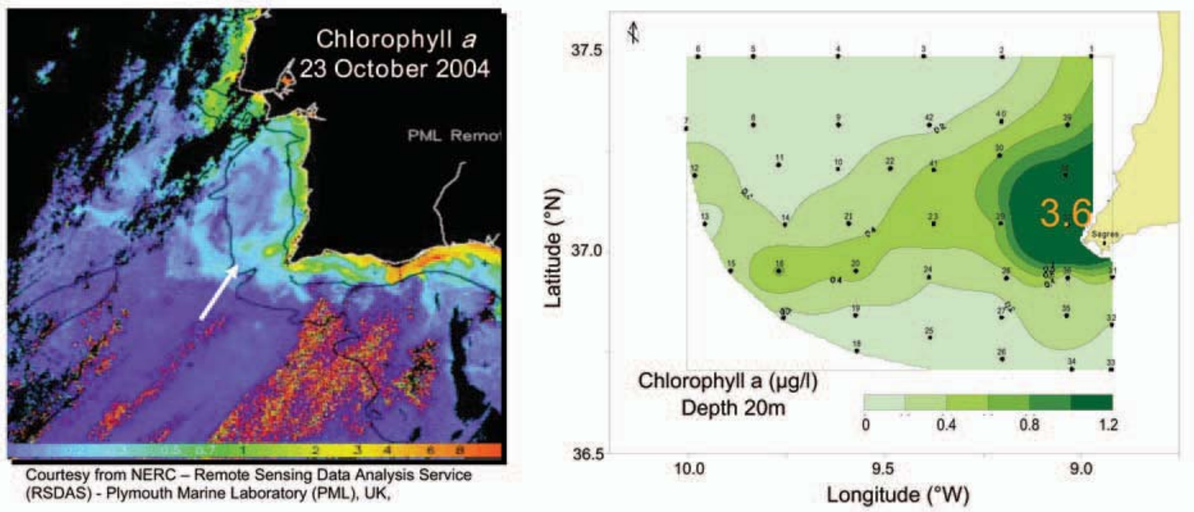

Figure 2. Satellite image of chlorophyll a concentration (left) and correspondent horizontal surface field from direct sampling during ATOMS sea trial.

Copepod grazing on a toxic *Dinophysis acuta* thin layer bloom

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In September 2003, Moita *et al*. (in press) detected for the first time in the Iberian waters, a bloom of the dinoflagellate *Dinophysis acuta* (diarrhetic toxin producer), distributed within a 5 to 10 m thick layer, extending 20 km offshore (Fig. 1). The bloom occurred under upwelling relaxation conditions and strong thermal water column stratification. Due to the lack of information about the effects of such thin toxic layers on the grazing behaviour of copepods, the present study intends to make a first field evaluation of the importance of *D. acuta* in the diet of different size-class species of local abundant copepods.

Copepods were sampled in a cross-shelf transect off the NW coast of Portugal, covering 2 depth strata: 0–25 m and 25–50 m (Fig. 1). Samples were preserved in 4% buffered formalin and the digestive content of 5 herbivore/omnivore copepod species was analysed.

The copepod community reached high densities in the study area, with a maximum of 17800 ind.m^{-3} and an average of 8000 ind.m^{-3}. The results (Fig. 1) indicate a generally low ingestion of *D. acuta* by copepods and suggest that grazing was highly dependent on cell concentration. Only the 2 larger copepods, *Calanus helgolandicus* and *Centropages*

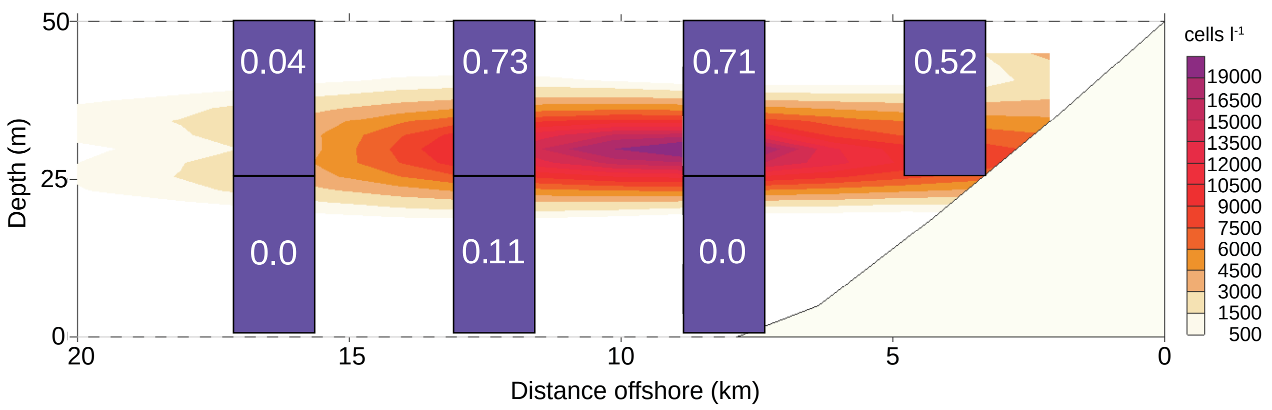

Figure 1. Spatial profile of the average number of D. acuta present in the gut content of copepods (cells/copepod) for each vertical haul (shaded blue). In the background is illustrated the D. acuta thin layer distribution.

D. acuta cells/copepod				
0.28	1.04	0.03	0.11	0.0
Calanus helgolandicus	*Centropages chierchiae*	*Clausocalanus* spp.	*Temora longicornis*	*Paracalanus parvus*

Figure 2. Mean presence of D. acuta cells in the gut content of each selected copepod species. Note: specimens are depicted in the same scale.

chierchiae, show a relevant degree of grazing (Fig. 2), although restricted to *D. acuta* concentrations higher than 9000 cells l^{-1}. These two species have strong filtering capacities, probably capable of capturing large mobile cells like *D. acuta*. The results for *C. chierchiae* (a maximum of 10 cells were observed inside one individual) can be justified by its omnivore-raptorial-feeding behaviour and/or by a possible immunity to *D. acuta* toxins. On the contrary, the 3 smaller copepod species presented insignificant ingestion values, probably because of their relatively weak filtering capacities and/or of active avoidance related to the dinoflagellate toxins. As these 3 small species were the most abundant (45% of all mesozooplankton), we can speculate that, despite the high potential grazing pressure present in the area, the thin layer bloom of *D. acuta* was not top-down controlled. Knowing the important mobility of copepods, the almost non-existence of ingested *D. acuta* cells immediately below the thin layer (between 25 m and 50 m) allows us to hypothesise that this type of bloom could be acting as a toxic barrier, disrupting vertical migrations.

The above results support and encourage the development of future projects including "zooplankton-toxic microalgae interactions", in association with the GEOHAB Programme. Future Portuguese studies must include additional preservation methods, namely on-board deep-freezing of copepod material.

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Recruitment to populations of littoral crabs – contrary to expectations, upwelling may be a good thing

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Many invertebrate and fish species that live in coastal and estuarine systems have a larval phase that develops in coastal waters. At the end of the planktonic development, larvae must return to the habitat where they will recruit to the adult population. Physical processes that force transport of planktonic larvae of invertebrates are responsible for some of the spatial and temporal variability in recruitment. Generally, it is accepted that mechanisms that rule cross-shelf dispersal and return migration of larvae are separated in two steps (Boehlert and Mundy, 1988; Shanks, 1995): (1) the transport of the larvae from the shelf to the coast and (2) the passage through inlets and upstream movement until an appropriate environment for settlement is found. In each step, larval behaviour interacts with the physical forcing in order to accomplish successful recruitment.

The ProRecruit project (Shelf processes controlling recruitment to littoral populations in an eastern oceanic boundary: using barnacles and crabs as models-POCTI/1999/BSR/36663), funded by the Portuguese Science Foundation (FCT), aimed to investigate the processes in the west coast of Portugal, which lies close to the northern limit of the North East Atlantic upwelling system. The main objective of ProRecruit was to describe the temporal variability of recruitment of coastal invertebrate species having a planktonic larval phase in their life cycle and to understand the interactions of physical forcing and larval biology that control the supply of larvae to coastal systems.

One of the biological models used in ProRecruit was the portunid littoral crab *Carcinus maenas*, which forms large populations in Portuguese estuaries. This crab has a planktotrophic larval phase that develops in shelf waters, composed of 4 zoeal and 1 megalopa planktotrophic stage. First stage zoeae are hatched near the mouth of the estuaries during night ebbs of neap tides and rapidly spread into coastal shelf waters. An endogenous rhythm of vertical migration synchronised with the tide favours this process, maximising downstream transport (Zeng and Naylor 1996a; Duchêne and Queiroga; 2001). Development up to the megalopa stage occurs in shelf waters and, depending on water temperature, can take from 4 to 6 weeks. The megalopa is the stage that reinvades estuaries and uses selective tidal stream transport (STST) to travel upstream against the net seaward. STST is

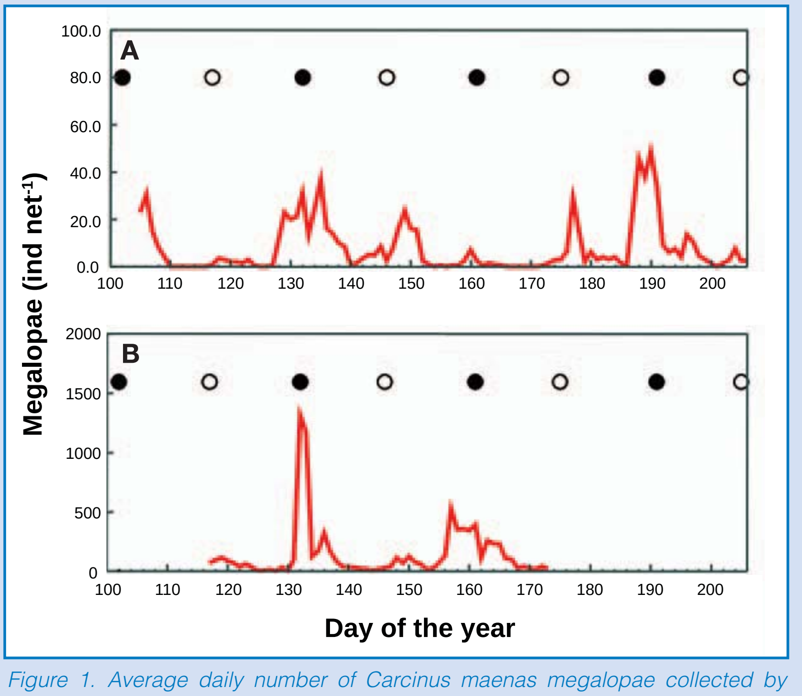

Figure 1. Average daily number of Carcinus maenas megalopae collected by passive nets in Mira Estuary (A) and Ria de Aveiro (B). (Adapted from Queiroga et al., 2006)

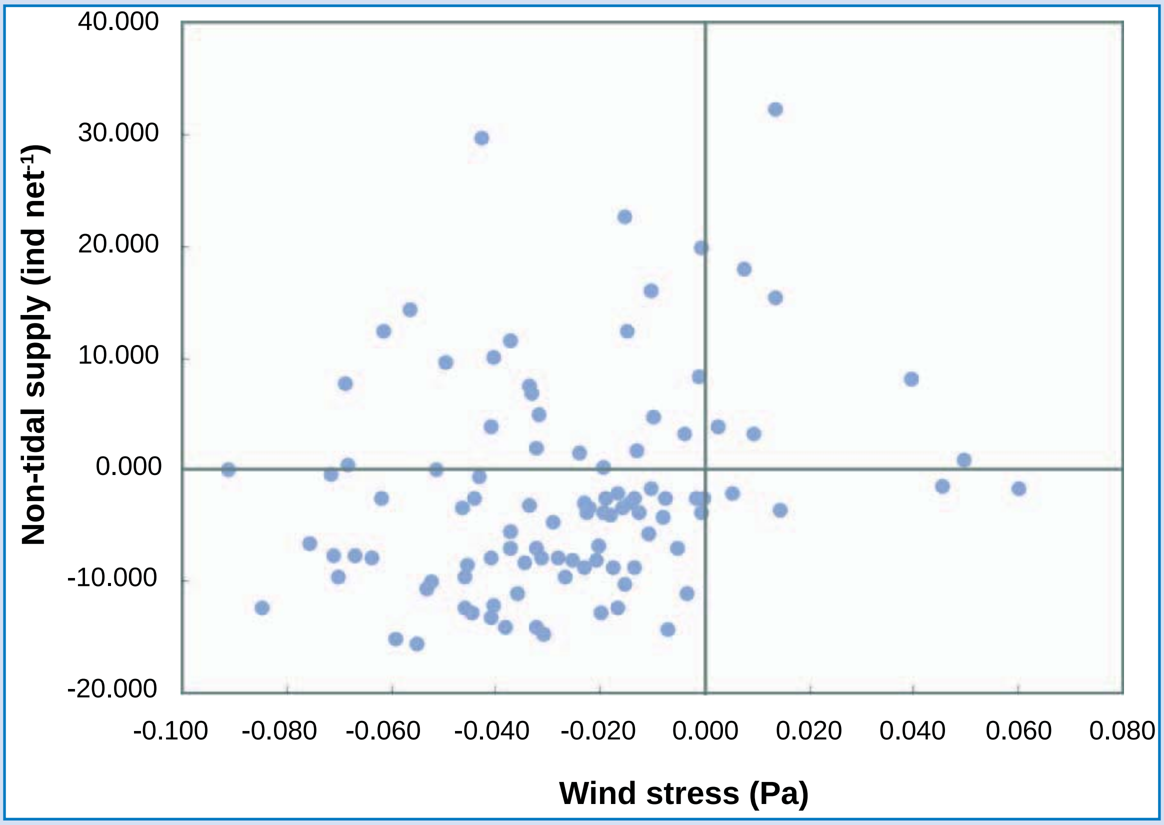

Figure 2. Relationship between non-tidal supply and along shore wind stress obtained for the Ria de Aveiro. Non-tidal supply was estimated as the residuals from a multiple periodic regression accounting for the semilunar cycle of tidal range. In this example, wind stress was calculated as the sum of the average daily wind stresses of the day and the day before.

accomplished by swimming from the bottom to the overlying water column during night flood tide and settlement to the bottom during the following ebb (Queiroga *et al.,* 1994; Queiroga, 1998; Zeng and Naylor, 1996b).

In order to describe the intra-year variability of larval supply to estuaries in the Portuguese west coast 2 estuaries were selected, one located in the northwestern (Ria de Aveiro) and one in the southwestern (Mira Estuary) coasts. Measurement of megalopal supply was accomplished by the use of passive plankton nets (Queiroga *et al.,* 2006). These biological measurements were related to several physical variables, namely, wind stress, surface sea level (SSL) and sea surface temperature (SST) and tidal range, for periods of several months during the reproductive season of *C. maenas*, at both locations. Supply of *C. maenas* megalopae followed a cyclic pattern with a semilunar period, with higher supply around spring tides (Fig. 1). Non-tidal supply, calculated as the residuals from a multiple periodic regression accounting for the semilunar cycle, was positively related with along-shore wind stress at both locations (Fig. 2), with delays of 0 to 2 days. These results support the hypothesis that onshore convergence of the surface layer caused by relaxation or reversal of northerly winds, which favour upwelling, are responsible to transport *C. maenas* megalopae shoreward. Supply to the estuaries appears to occur by selective tidal stream transport. Involvement of internal waves and internal tidal bores could not be ruled out, but very particular periodicities of the generating mechanisms would have to be assumed to account for the observed time lags (Pineda, 1995).

A second study included in ProRecruit used a modelling approach to test the hypothesis that diel vertical migration (DVM) may constitute a mechanism for retention of larvae of littoral invertebrate species in the northwest Iberian upwelling system (Marta-Almeida *et al.*, 2006). Nocturnal DVM is a widespread behaviour in larvae of decapod crustaceans and these larvae have swimming abilities that allow them to cross vertical distances in the order of several tens of metres during the course of the migration (reviewed by Queiroga and Blanton, 2004). Recent observations in the Portuguese coast (A. dos Santos, IPIMAR unpublished data) describe a very clear pattern of nocturnal migration of decapod larvae, spanning most of a 65 m water column.

A 3D numerical model of the circulation in the region incorporating routines to simulate vertical migration of decapod larvae was used. Different wind-forcing conditions, simulating typical non-upwelling and upwelling regimes and vertical migration scenarios with and without DVM, were tested. Results showed that particles with DVM were more retained in the inner shelf during upwelling than in any other combination of migration scenario and wind regime (Fig. 3). This was accomplished by a larger proportion of time spent in the onshore underflow, which dragged the particles further shoreward, than at the surface. On the other hand, dispersal was highest and retention was lowest when particles were not subjected to

DVM, even when upwelling events were less frequent and of short duration.

The results of the simulations show that, for larvae of littoral species exhibiting DVM over a large expanse of the water column, upwelling may actually be a mechanism that enhances retention over the shelf. This mechanism may be especially useful in coasts lacking topographic singularities that may originate retention areas, such as the northwest coast of Portugal and provide a general mechanism to increase retention in shelf waters subjected to upwelling.

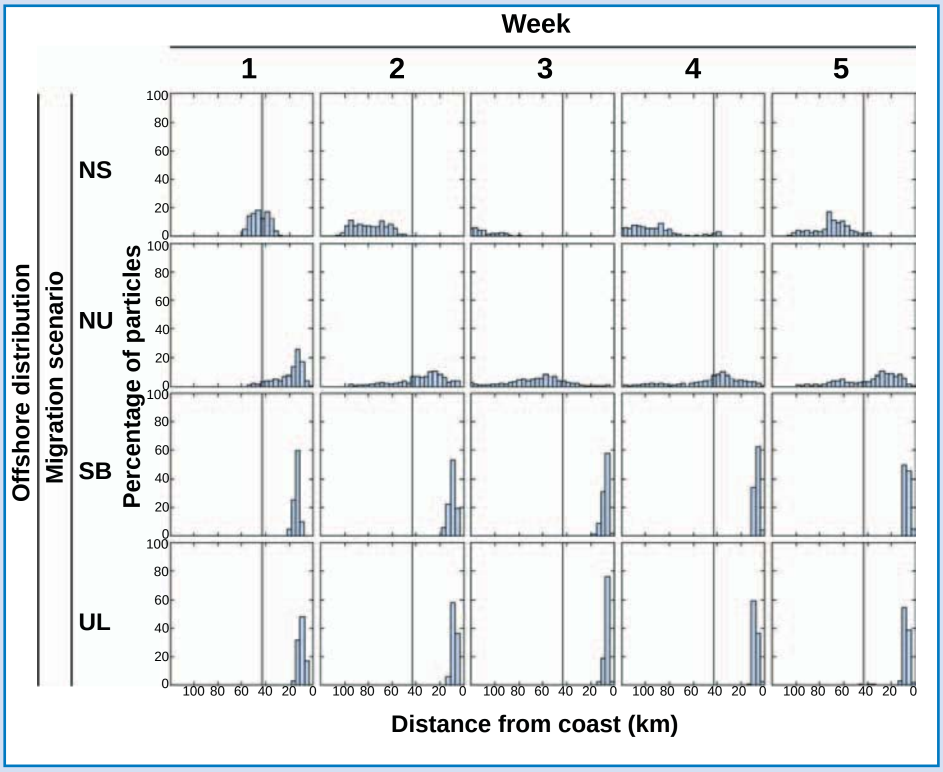

Figure 3. Results of the cross-shelf distribution of total number of particles for the spring simulation, under upwelling conditions. The coast lies on the left at 0 km and the vertical line at 43.1 km indicates the average position of the shelf break. NS: no migration and surface distribution; NU: no migration, uniform distribution; SB: nocturnal DVM between surface and bottom; UL: nocturnal DVM between upper layer and lower layers. (Adapted from Marta-Almeida et al., 2006)

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Sardine egg parasitism by *Ichthyodinium chabelardi*

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Assessment of parasitism prevalence in sardine (*Sardina pilchardus*) eggs from Iberian waters has been carried out within the framework of IPIMAR's programme "Pelagicos" (FCT PLE-13) and project "NeoMAv" (FEDER 22–05–01-FDR-00012); sampling has been supported by the EU Data Collection Regulation (DCR). NeoMAv's objectives include the development of methodologies for fish assessment and population modelling, including the identification and estimation of causes of mortality.

Studies of parasitism by *Ichthyodinium chabelardi* (Hollande and Cachon, 1952) in pelagic fish eggs have shown that it

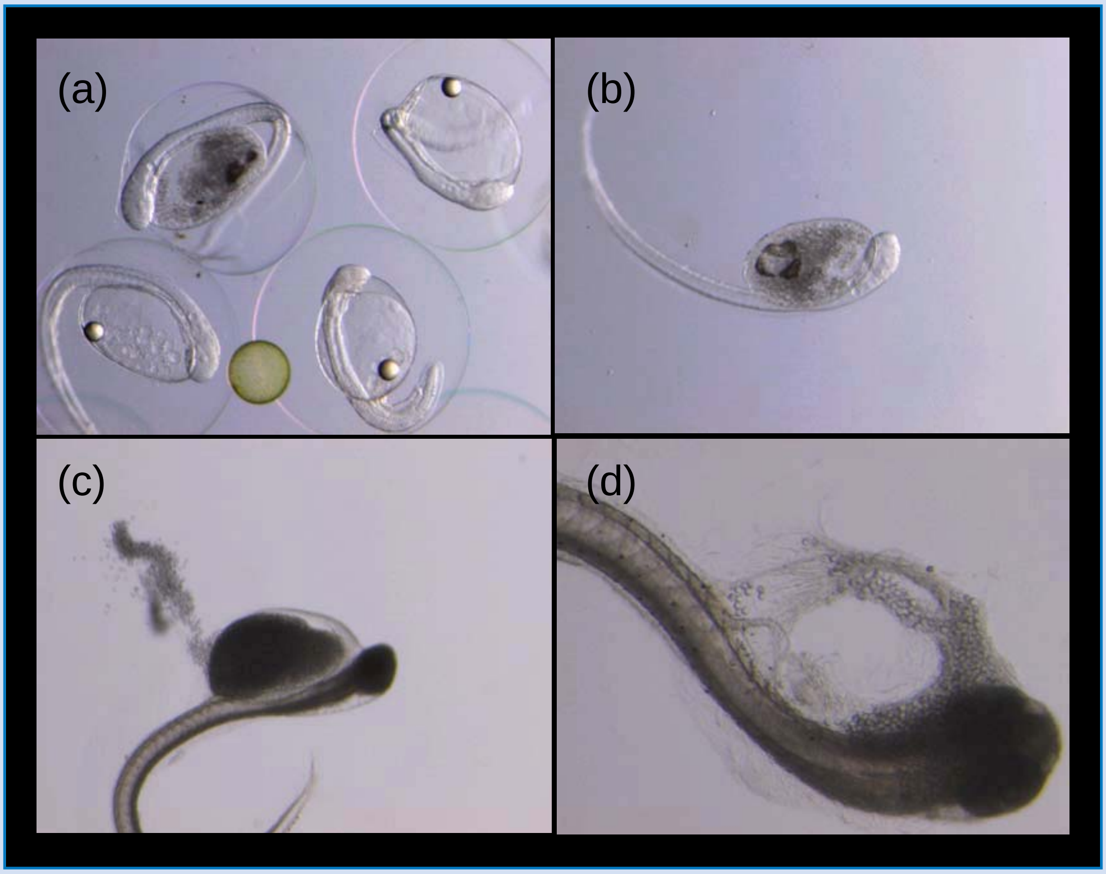

Figure 1. Infected sardine eggs (a) and larvae (b-d) from NW Portugal, collected and reared in December 2005. Approximately 70% of the eggs from this sample were infected. (a) eggs; (b) larva with yolk-sac infected by I. chabelardi; (c) yolk-sac burst with parasite cells beeing released to the water; (d) almost empty yolk-sac. Release of the cells took about 5 minutes.

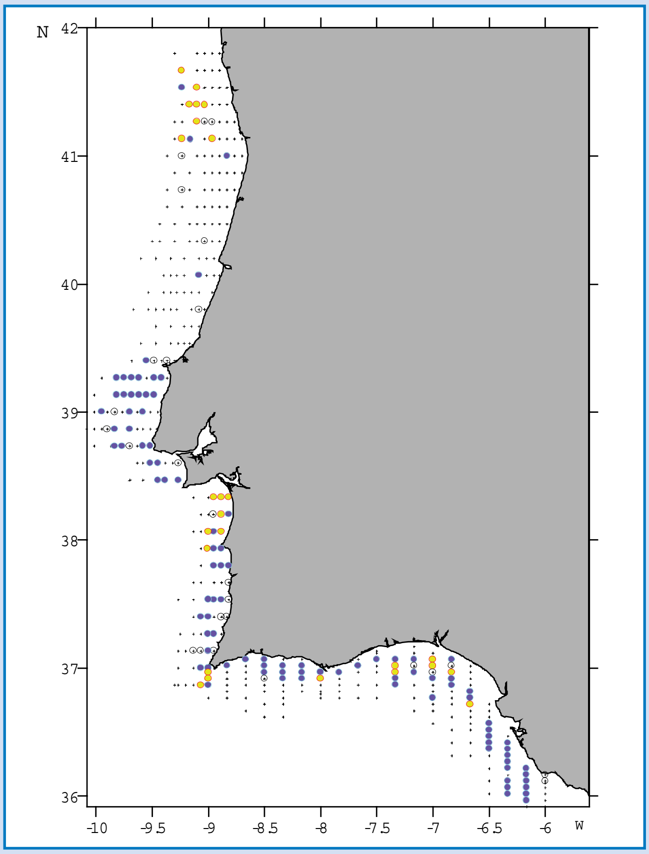

Figure 2. Stations analysed for sardine egg infection by Ichthyodinium chabelardi in January/February 2005. +: stations without sardine eggs; circles with a cross in: stations where all the sardine eggs were at stages before blastopore closure; blue circles: stations where none of the sardine eggs were infected; yellow circles: stations with infected sardine eggs.

can be an important mortality factor (Stratoudakis *et al.,* 2000; Meneses *et al.,* 2003). This dinoflagellate was reported in the yolk-sac of different fish eggs such as, *Scomber* spp, *Gadus morhua*, *Scophthalmus maximus*, *Trachurus trachurus* and *Engraulis encrasicolus* (Marinaro, 1971; Pedersen and Køie, 1994; Stratoudakis *et al.,* 2000). Infected sardine eggs will die soon after hatching, since the parasite depletes all the energy sources necessary for larval survival and the yolk-sac ultimately bursts, releasing parasite cells to the sea water (Fig. 1).

The proportion of infected sardine eggs (~0.30) nearest to hatching in samples from 1997 and 1999 (Stratoudakis *et al.*, 2000) was within the range of daily mortality estimates by other authors (0.06–0.76). The analysis of sardine eggs sampled in January/February 2005 off Iberian Peninsula (Fig. 2) using a Calvet net (150 µm mesh aperture), compared with results from 1997 and 1999, show temporal and spatial variability of infection. From the 147 observed stations, 0.17 had infected eggs and from the 1318 observed eggs, 0.05 were infected. The spatial variability observed resulted in low mean estimates of infection, although off the northern part of the study area (latitude >40°N), more than half of the samples had infected eggs (0.58). In this part of the coast, almost a quarter (0.23) of the eggs were infected (Fig. 2). The central west coast of the study area (38.5–40.0°N) had no infected eggs but, in the years 1997 and 1999, in the same area, infection prevalences were found higher than on the rest of the coast.

Further work should be conducted to follow fish egg mortality due to parasitism, and attention directed towards understanding of the relationships between environmental parameters and parasitism prevalence. Egg infection by *Ichthyodinium chabelardi* has been identifyed as an important cause of mortality during the early life stages and may have an impact on fish recruitment.

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Development of new methods for sampling and evaluation nutritional condition of marine fish larvae in estuarine and coastal areas

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This study is part of a new project called "Nutritional condition of fish larvae in two marine protected areas of the South of Portugal, Ria Formosa and Guadiana estuary (Guadiria) (POCTI/BIA-BDE/59200/2004)". The project is now testing new methods for sampling fish larvae, in order to minimise the physiological stress and the avoidance of traditional ichthyoplanktonic gears. A number of different methods are available to sample the complex assemblages of early-life-history stages. To catch larvae for the analysis of its nutritional condition, it is usual to use towed nets. However, the problem with this sampling strategy is that they cause the death of the larvae and also tend to under-represent late-stage larvae. In order to minimise the physiological stress caused by towed nets and to increase the size of fish larvae caught by the traditional ichthyoplanktonic gears, light traps could be a solution, especially because they allow live larvae to be caught. This is the innovative aspect of the study, which aims to compare the efficiency of two sampling strategies of capturing larvae (net tows and light traps) and their implications on the larval length of captured larvae and physiological condition by measurement of the RNA/DNA ratio. The light trap (Fig. 1) is a cylindrical acrylic tube (25 cm × 50 cm), with several holes that allow larvae to enter, but not to leave the trap. It is similar to the one used in coral reefs, but smaller, with high light intensity and more use of acrylic, in order to function at

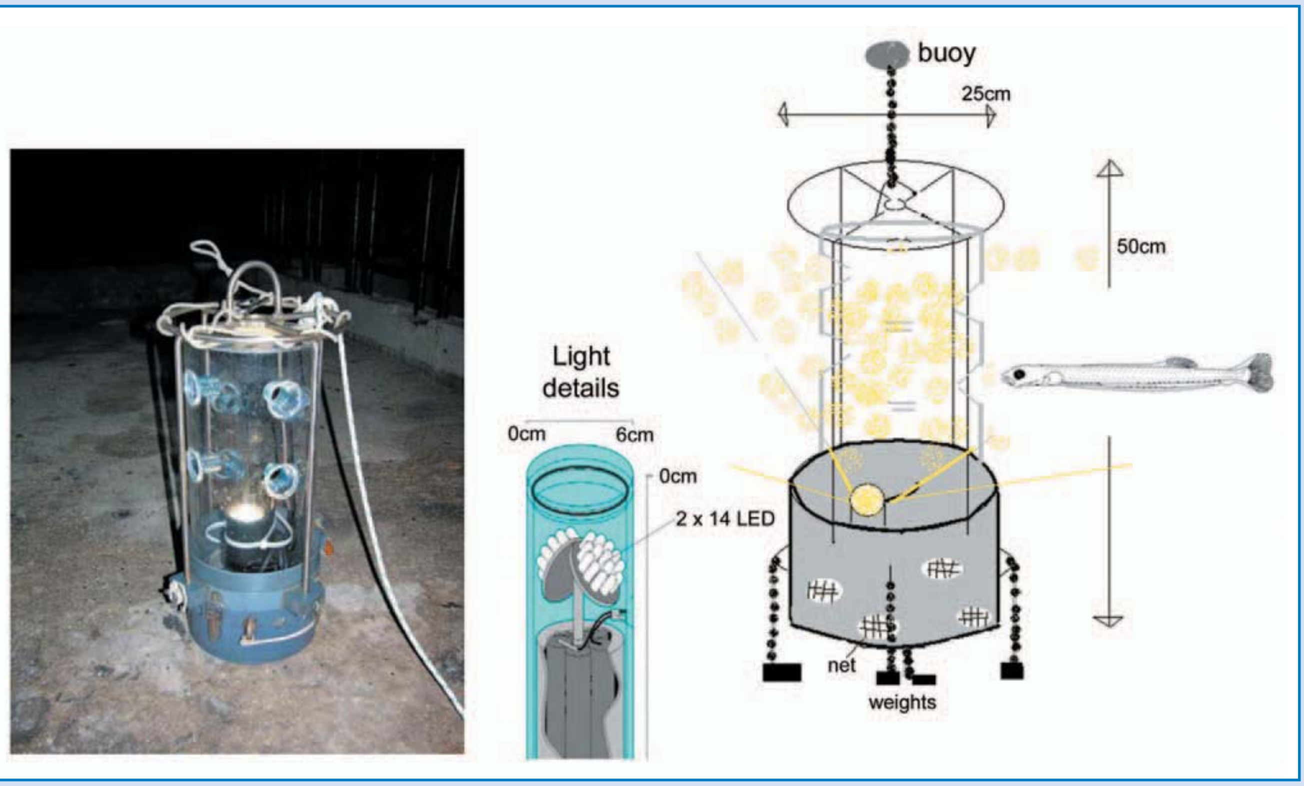

Figure 1. Light trap (left: photograph and right: schematic representation).

low depths and high turbidity, typical of coastal and estuarine areas.

The first results show that light traps allow live unstressed larvae to be caught, as well as bigger larval sizes than those collected by plankton nets. Nevertheless the specific diversity is low for samples collected with light traps. This can result from different behaviour of fish larvae from different species and in different development phases in relation to light. During the next phase of the project, larvae of species which react positively to the light trap, such as *Engraulis encrasicolus* and *Sardina pilchardus,* will be sampled and their nutritional condition, through RNA/DNA ratios, analysed. The sampling area is off the south of Portugal, outside and inside two important marine protected areas: the Ria Formosa and the Guadiana estuary. The key question to be answered is the following one: Is the nutritional condition of fish larvae higher inside these systems compared to ones captured in adjacent coastal areas?

PELAGICOS: Setting the scene for multidisciplinary research on small pelagics in Portugal

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The project PELAGICOS took place at IPIMAR from June 2001 to August 2005 and was funded by the Portuguese Ministry of Science within the framework of a national initiative for the restructuring of the State Laboratories. Unlike standard research projects, the emphasis in PELAGICOS was to integrate and complement existing research lines for small pelagics at IPIMAR and gradually initiate new ones (with the recruitment of young scientists). PELAGICOS aims to improve the understanding of the pelagic marine ecosystem structure and dynamics off Portugal and to translate this knowledge into useful information for end users (purse seine fishery, canning industry and national administration). To facilitate the communication between scientists and end users, a national representative of the Portuguese Association of Purse Seine Producer Organisations (ANOPCERCO) and a social anthropologist were involved in the project. So far, the project has contributed to 25 peer review publications and the establishment of links with scientists from Portuguese Universities and Fisheries Institutes around the world, mainly through collaborations in the 8 undergraduate project theses, 8 MSc theses, 5 PhD projects and 1 post-doctoral project supported by PELAGICOS. Finally, during the project, 6 scientists with extensive experience in the area of oceanography, stock assessment and fisheries biology from Canada, USA, Australia, South Africa, Morocco and Scotland were invited to participate in thematic workshops related to small pelagics at IPIMAR.

Figure 1. Drying-up of the purse seine net prior to the hauling of sardine on deck (left) and slipping of excess sardine catch after the filling of the daily vessel quota (right).

An example of the applied interest from the integration of distinct research lines within PELAGICOS is the identification of the complex relation between sardine (*Sardina pilchardus*) recruitment dynamics, schooling behaviour and purse seine fishing practices off Northern Portugal. Northern Portugal is the main recruitment area for sardine in the Iberian Peninsula, where the interaction of the Iberian Poleward Current (Peliz *et al.*, 2003) with the western Iberian Buoyant Plume (Peliz *et al.*, 2005) may create the necessary conditions for sardine larval retention, survival and growth (Chícharo *et al*., 2003; Santos *et al*., 2004; Ribeiro *et al.,* 2005). After a decade of weak recruitment in the 1990s, strong sardine recruitment was observed off northern Portugal in 2000 and 2004. It has been suggested that this may be linked to decadal changes in the local wind regime and the seasonal pattern and intensity of upwelling (Borges *et al*., 2003; Mason *et al*., 2005; Santos *et al.,* 2005), it is also reflected by a significant reduction in the local spawning area of sardine (Stratoudakis *et al*., 2003a). This strong sardine recruitment led to a considerable increase in local sardine abundance, as verified by the spring acoustic surveys of IPIMAR (Marques *et al*., 2003; Marques *et al*., 2005) and confirmed by local fishermen. Exploration of echograms prior to and after 2000 indicated that the increase in sardine abundance did not lead to an expansion of the local distribution area or to a consistent increase in the total number of sardine schools or school clusters in the area, but was associated to larger schools, larger number of dense schools, smaller distances between schools within clusters and smaller distances between clusters (Marques, per. com.).

The weak sardine recruitment throughout most of the 1990s led to a crisis in the Iberian purse seine fishery that was mainly felt off north-western Iberia (especially in Galicia but also in northern Portugal) and led to the adoption of a management action plan by Spain and Portugal in 1997. The plan introduced effort restrictions and stricter catch limitations that were translated into daily quotas per vessel that were administered by the local Producer Organisations. Daily quotas rapidly proved to be an efficient mechanism for market control (leading to a higher first sale price during the period of resource scarcity) and were thus practically unaltered after the strong recruitment of 2000. As a result, the increase in sardine abundance and the changes in schooling behaviour led to a higher catch per unit effort (catches >20 tonnes per set corresponding to dense marks in the echosounder were frequently observed in the summer of 2001) but this did not correspond to a significant increase in local annual landings. Although changes in the distribution pattern may have resulted in some reduction of fishing effort, the most likely reason for this discrepancy is the increase of slipping activity (Stratoudakis and Marçalo, 2002) in 2001 (when the 2000 year-class fully recruited to the fishery). Slipping is the process where an unwanted component of the total catch (in this case due to daily quota limitations) is allowed to swim away by lowering the headline of the purse seine net (Fig. 1). Onboard observations during the summer of 2001 and 2002 (Stratoudakis and Marçalo, 2002; Stratoudakis *et al.,* 2003b) and anecdotal information from the fishery in 2003 indicated that catch per unit effort and slipping were higher in 2001, suggesting a close relationship between year class strength, schooling behaviour and purse seine fishing practices off northern Portugal.

To explore the impact of slipping on sardine survival, the purse seine fishing activity off northern Portugal was intensively monitored by independent observers. Water samples collected in the vicinity of the fishing vessels showed a pulse increase in ammonia, urea, residual organic nitrogen and phosphate concentrations during the drying-up of the net, indicating that purse seine fishing practices are highly stressful (Stratoudakis *et al*., 2003b). This was confirmed by sardine blood samples collected during 10 commercial trips over the two hour period from the closure of the net to the completion of fish transfer onboard (Marçalo *et al*., in press). During the fishing operation, a steady increase in cortisol, glucose, chloride and sodium concentration and a steady decrease in haematocrit, haemoglobin, potassium and ATP concentration were detected, although there was no relationship with total catch in the set. To complement field observations and monitor ensuing mortality levels (unaccounted for in the catch data used in stock assessment), mixed trials of field and laboratory observations and experiments following the simulation of fishing in captivity are currently taking place in the Aquaculture Station of IPIMAR in Olhão. Early results indicate that mortality levels in the order of 30% can occur within the first week from fishing and can be affected by stocking density during transportation to captivity. Biochemical stress indicators are probably not sufficient to predict delayed slipping mortality, since death is usually associated with extensive scale loss, lesions and ensuing bacterial infections, while differences in stress variables between damaged and intact fish seem to be non-significant (Marçalo, per. com.).

Figure 2. Sardine schooling in captivity after acclimation (left) and experimental set-up for the study of feeding behaviour (right).

The acclimation and long term maintenance of sardine in captivity (Fig. 2a) has also opened up new opportunities for the study of sardine biology and ecology under controlled conditions. Some sardines have already been in captivity for more than two years, where unaided spawning took place on various occasions and led in one case to the survival of a post-larva for three months. Feeding experiments with a variety of prey composition, size and concentration (Fig. 2b) have demonstrated that sardines utilise distinct feeding modes depending on prey size, while the elicited response is modified according to the composition and density of the prey available (Garrido *et al.*, submitted). Sardines filter-fed when prey size ranged between 10–724 µm (phytoplankton, micro and meso-zooplankton), but switched to particulate feeding when prey larger than 780 µm (meso-zooplankton and ichthyoplankton) were offered. Clearance rate and swimming speed were generally higher during particulate feeding, while shoal integrity was lower. Sardines were able to feed selectively when prey was provided in mixed assemblages, with fish eggs being preferred to all the other prey, even to the larger fish larvae. Finally, the clearance rates of sardines were generally low when compared to other clupeoids (probably due to a smaller mouth gape and lower swimming speed), which can represent a disadvantage when competing for food with other planktivorous fish species.

The momentum created by PELAGICOS has led to a series of follow-up initiatives aiming towards the consolidation of research on small pelagic fish and their habitat at a national level and the collaboration with other institutions for integration at a regional level. The recently initiated project SARCAPT aims to optimise the long-term maintenance of sardine in captivity, provide conclusive results on the impact of fishing to sardine physical condition, physiology and survival and extend experimental work to other aspects of sardine biology and ecology. The experimental results on feeding are being complemented with regular biological monitoring (Cunha *et al.*, 2005) and point field observations (Costa and Garrido, 2005) to understand the impact of food availability on the distribution and population dynamics of sardine. The objectives of acoustic monitoring surveys off Portugal are being diversified (Marques *et al.*, 2005; Zwolinksi *et al.*, in press; Zwolinski *et al.*, submitted) and regional integration of methods and data has recently been initiated within the framework of the ICES Working Group ACEGGS. This Working Group also aims to consolidate methodological developments on the Daily Egg Production Method (Stratoudakis *et al.*, in press; Ganias *et al.*, submitted) and to provide data and tools for the spatial comparison of DEPM with acoustic estimates in the Bay of Biscay and off the Iberian Peninsula. Finally, local biological knowledge and regional data are being integrated under the ICES/GLOBEC Study Group SGRESP to provide working hypotheses for life history dynamics and habitat utilisation by pelagic fish in the north-eastern Atlantic.

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Modelling of larval dispersion in the western Iberian ecosystem

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A modelling experiment aiming to understand the processes of larval dispersion off northwestern Iberia is reported in Santos *et al*. (2004), where the relevance of different factors in sardine larval transport are discussed. The northwestern Iberian shelf circulation is strongly influenced by wind forcing and self-advecting river outflow plumes and the shelf circulation is constrained by the Iberian Poleward Current (IPC) flowing along the slope and the outer shelf. The joint action of these flow components generates several dispersal paths responsible for many of the larval distribution patterns that have been observed. Experiments conducted by Marta-Almeida *et al.* (2006) have shown that tides have little influence on the net transport of crab larvae at the shelf scale off northwestern Iberia.

A numerical modelling framework for larval dispersal studies off western Iberia needs to include a realistic representation of these dynamics. Model domains should be sufficiently large to include the large-scale circulation that forces the slope flow (Peliz *et al*., 2003) and need to be sub-mesoscale resolution to accurately reproduce the small scale structure induced by the joint action of wind and river plumes.

A first effort to develop such a framework is described in Peliz *et al.* (submitted). We have adopted the nesting approach to accommodate large domains with locally high resolutions using the Regional Ocean Modelling System (ROMS) with Adaptive Grid Refinement in Fortran (ROMS-Agrif: www.brest.ird.fr/ Roms_tools/) to produce model configurations with one-way online nesting as described in Penven *et al.* (2006) (two-way nesting is being developed). We have added realistic features to the ROMS-Agrif model including new capabilities to simulate river outflow plumes and realistic atmospheric fluxes using re-analysis data (e.g. National Centers for Environmental Protection, NCEP). A first application was conducted for the spring period of 1991, when WOCE observations (Hagen, 1994), simultaneously with a plankton survey targeting crab larvae, were taken off the Portuguese coast (Queiroga, 1996). Figure 1 shows the temperature and surface salinity (CTD) distributions of the WOCE survey on the left and the corresponding ocean model distributions on the right. An exact correlation between model and observations in a system with strong meso- and sub-mesoscale activity is difficult to achieve even in assimilation experiments (e.g. Wilkin *et al*., 2005). In our case, the model represents all the major features of the flow field like the jets and eddies associated with the IPC, the low salinity lenses and its offshore drift due to the upwelling events and finally the low salinity filaments (see the offshore salinity field at about 41°N) generated by interaction of the salinity plume with the slope eddies.

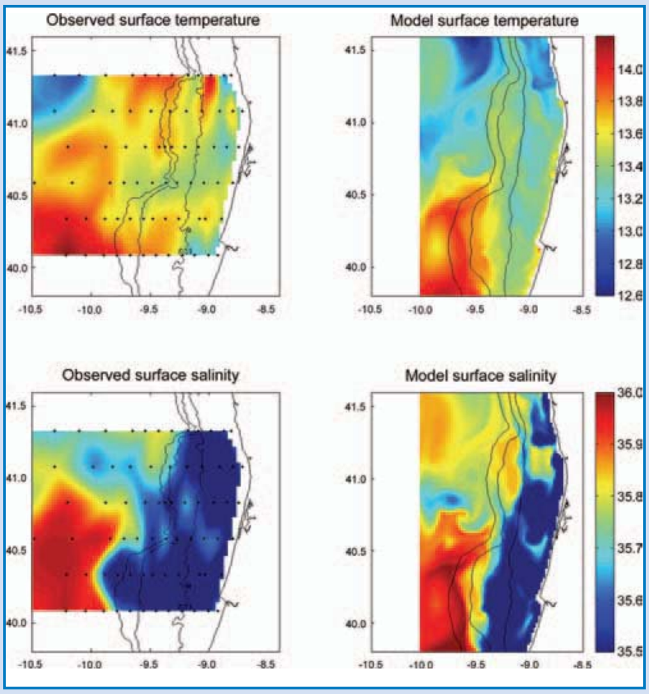

Figure 1. Temperature (upper row) and salinity (lower row) surface fields for the WOCE CTD observations in April 1991 (left) and the corresponding modelled fields with realistic atmospheric data (NCEP) for the same period.

The second stage in the numerical modelling study of larval dispersal concerns the implementation of the lagrangian dispersal sub-model. We have adapted and tested different implementations for the horizontal diffusion, vertical diffusion (Ross and Sharples, 2004) and vertical diel migration. Figure 2 shows the observations of *Carcinus maenas* larval concentration (1st row) and some model float concentration results (floats are released at the estuaries in periods of probable larval hatching). The model (base experiment in middle row) approximately reproduces the patches obtained in the larvae survey predominantly inshore of the 100 m isobath. In the case of no vertical diel migration (bottom row) the model fails to represent the major features of the observations.

Results have demonstrated the importance of a good representation of vertical migration (also studied in a Marta-Almeida *et al*., 2006), but also of other factors like diffusion (horizontal and vertical) and river plumes. The dispersal distances calculated from the model results match those calculated from the observations. Several aspects of population dynamics based on these studies are discussed in Peliz *et al.* (submitted). Mean dispersal distances of about 60 km strongly polarized along the slope are estimated. About 50% of the larvae remain over the shelf, inshore the 100 m isobath and close to their release site. The remaining are preferentially exported northwards (even with different wind scenarios). The estuaries on the northwestern Iberia coast most probably share larvae of this crab species, as far as the typical distance between the estuaries in the northwest Iberian coast is within the scale of the estimated dispersal length.

The southwestern Iberian System (south of Lisbon) is a significantly different case from an oceanographic point of view. The shelf is narrow and the topography/coastline is more complex with a lower isolation of the shelf zone and consequently a larger potential for cross-shelf transport (Peliz

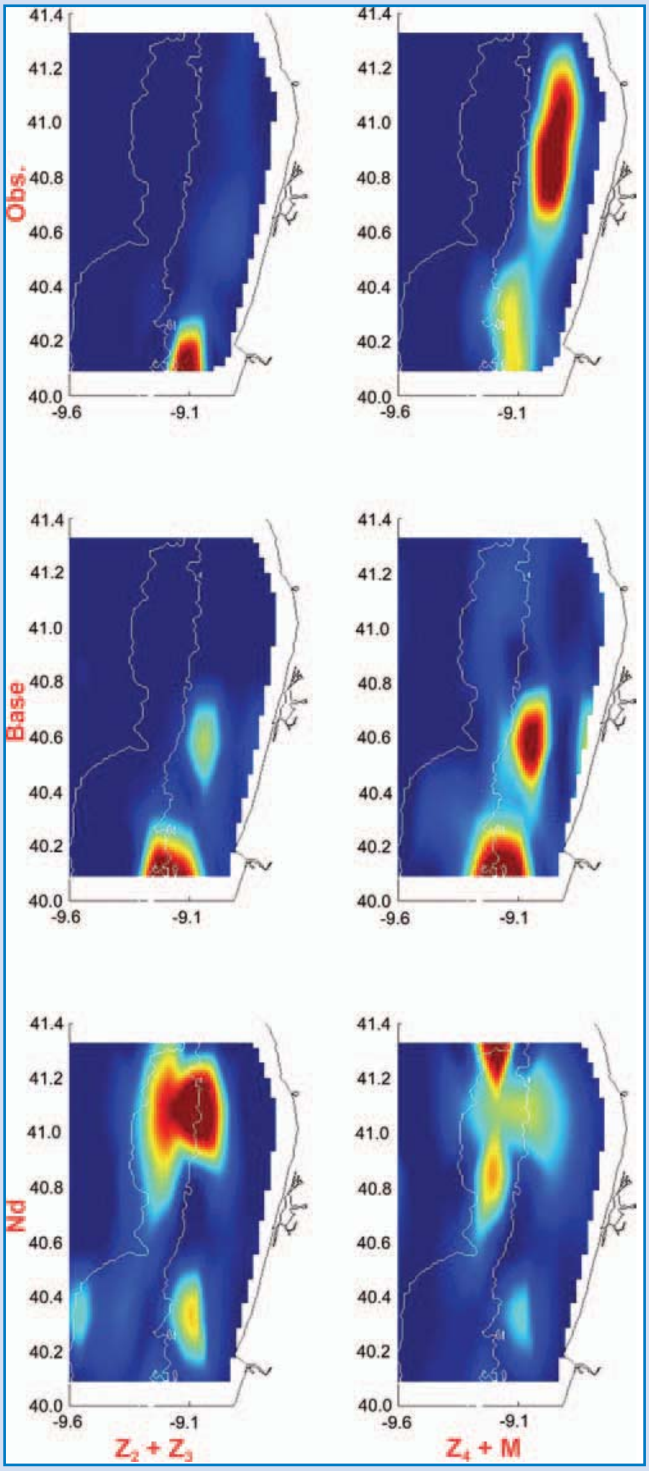

Figure 2. Maps of normalised larvae/float density (zoeae 2 + 3 left column; zoeae 4 and megalopae right column) for spring 1991 (Carcinus maenas). Data from observations (top row), from model results (middle row) and from the model with no diel migration (Nd) in the lagrangian model (bottom row). Isobaths (100 and 200 m) in white. Colour scale represents the normalised larval density (0 – blue to 1 – red). In the case of observations the values correspond to integrated larval concentrations (in each station) divided by the maximum concentration observed. In the case of the model, the concentration of floats in the vicinity of the cruise stations is calculated, the calculation of the normalised density is the same as for the larvae.

et al., 2004; dos Santos and Peliz, 2005). The exchange between the Mediterranean and the Atlantic through the Strait of Gibraltar induces circulation features that extend downstream for the Mediterranean undercurrent (e.g. meddy generation; Serra and Ambar, 2002) and upstream for the Atlantic inflow. Finally the sharp coastline orientation change at Cape of S. Vincent generates a heterogeneous wind field, especially in upwelling conditions that has a significant influence in upwelling filaments and coastal currents (Sanchez *et al.*, in press). As a result, modelling dispersal off southwest Iberia is even more challenging. New configurations (using ROMS-Agrif) that include the effects of Strait of Gibraltar exchange and meddy generation are under development. To resolve the wind forcing structure we are developing an off-line iterative system with ROMS-Agrif and the Weather Research and Forecast model (WRF).

The purpose of these configurations is to have the physical background for dispersal studies of larval Norway lobster, in the frame of the ongoing Portuguese program LobAssess (see dos Santos, this issue), also a future contribution to GLOBEC activities.

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CascaisWatch: a lighthouse into the future

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In the beginning of 2005, the CascaisWatch programme was initiated to obtain time series of physical and biogeochemical parameters to support studies on marine ecosystems and global change. Presently, this programme is conducted in the frame of the project "Geographical Information Applied to Fisheries-SIGAP" (22–05–01-FDR-00013), co-funded by FEDER and the Portuguese Government. The data collected will also be an important contribution to the project "ProFit – Interdisciplinary study of processes underlying the phytoplankton dynamics in the Portuguese upwelling system (PDCTE/CTA/50386/2003)", the European Networks of Excellence "European network for a overview of *Calanus helgolandicus* ecology in relation to climate change" and "EUR-OCEANS-EURopean network of excellence for OCean Ecosystems ANalysis", as well as to GLOBEC, GEOHAB and GOOS.

Since February 2005, monthly measurements are being carried out at a monitoring station (38°40'N; 09°26.2'W; bottom depth 36 m) in the Cascais Bay (coastal embayment at the mouth of the Tagus river), Portugal (called station A after the Portuguese Diplomat Aristides de Sousa Mendes). The observations are all made 1–2 hours before high tide and include CTD casts (Fig. 1a) to measure temperature, salinity and fluorescence; water samples (Fig. 1b, surface and Chl-*a* maximum) for nutrient and phytoplankton studies; and plankton hauls using a neuston and a WP2 net (Fig. 1c, d) for zoo- and ichthyoplankton sampling. At the same time female *Calanus helgolandicus* are caught and kept alive for estimations of the Daily Egg Production. In the future it is our intention to extend these estimations to species of the *Acartia* genus.

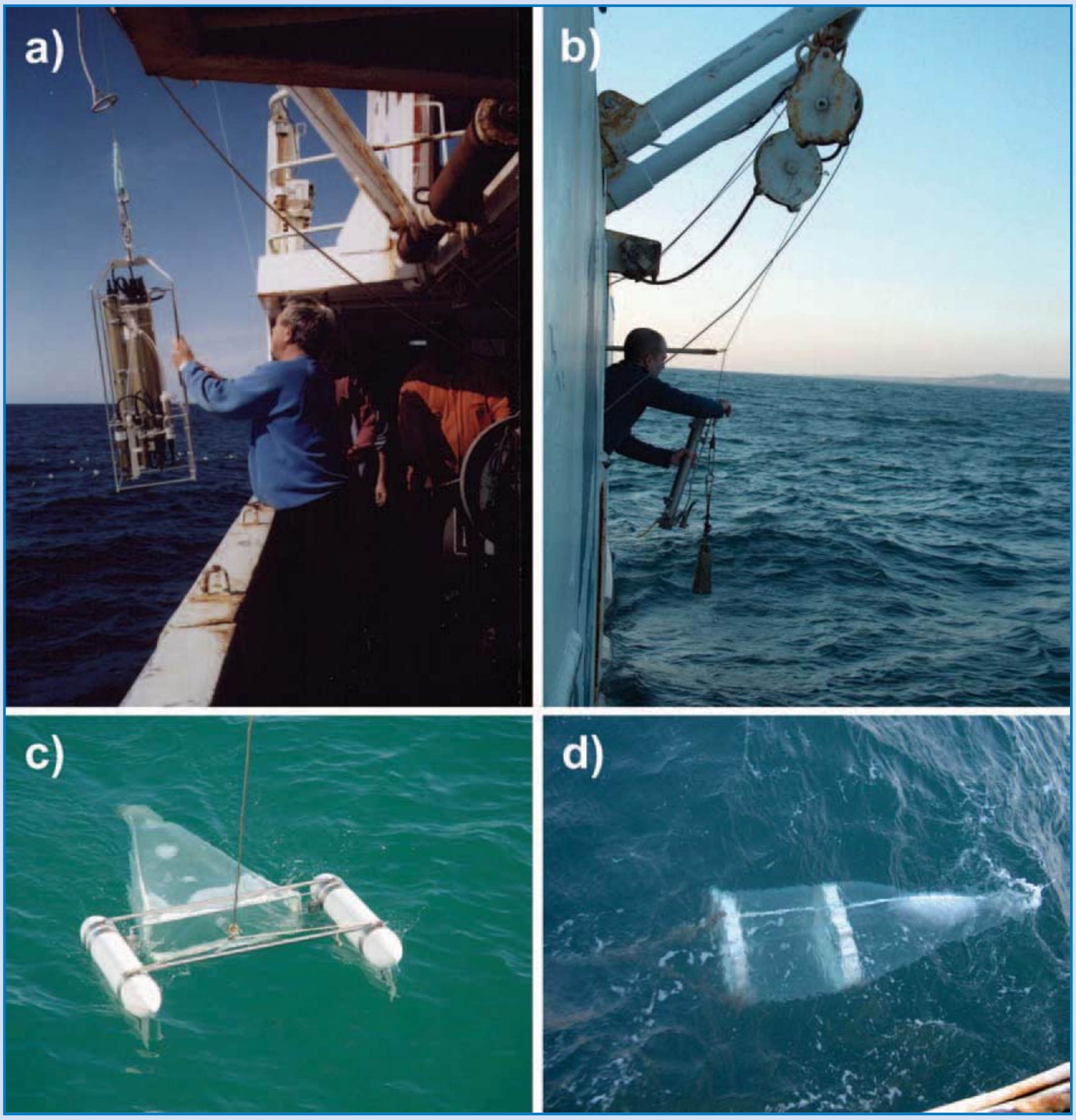
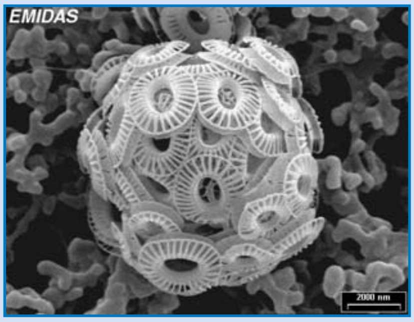


Figure 1. Cascais Watch observations on board IPIMAR's research vessels: (a) CTD cast; (b) water sampling using a Nansen bottle; and plankton hauls using (c) a neuston and (d) a WP2 net.

Figure 2. SEM image of the coccolithophore Emiliania huxleyi (Courtesy of Jörg Bollmann, University of Toronto, Canada and EMIDAS, Swiss, http: //www.emidas.org/).



First results show zooplankton biomass maxima during April, July and October, with *Copepoda*, *Appendicularia* and *Cladocera* being the most abundant taxa. In copepods, the species of the Acartia genus are responsible for the first two peaks (April and July) of abundance and the species of the *Calanoida* group for the October peak. A very preliminary estimation of the Daily Egg Production of *C. helgolandicus* is 6 eggs/female/day. Diatoms present peak concentrations in the spring and dinoflagellates in summer. The coccolithophore *Emiliania huxleyi* (Fig. 2) shows a maximum during April.

Characterisation of Lisbon Bay upwelling shadow ecosystem: starting up with numerical models, remote sensing and *in situ* observations

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Teams from IPIMAR and the Universities of Lisbon and Aveiro are currently involved in several projects (Table 1) whose aims include the characterisation of the upwelling shadow region off Lisbon using: *in situ* observations from research cruises and from a shore monitoring station at Cascais; remote sensing data from visible, infrared and radar instruments; and hydrodynamical numerical models.

From 30 August to 5 September 2005, a cruise was carried out on board IPIMAR's RV Noruega, with the participation of teams from IPIMAR and IO/Universidade de Lisboa. Standard hydrological data was obtained using a SBE 911 Plus CTD + SP fluorometer and a compact SBE 32 carousel equipped with twelve 8 litre bottles. The survey was conducted off Lisbon under light northerly winds and consisted of four parts (Fig. 1):

1. A coarser resolution (3′ lat/lon) rectangular grid of 78 stations distributed along 9 zonal transects (filled circles), water samples to describe the vertical distribution of the different chemical and biological parameters were collected at 7 vertical levels in all stations of the zonal transects at 38°30′ N, 38°39′ N and 38°45′ N (A,B,C in Figure 1);
2. A finer resolution nested grid (1.5′ lat/lon) of 82 stations covering 7 zonal transects (open triangles);
3. Repetition of 8 stations on the 38°39′ N transect for water sampling at 7 vertical levels; and
4. A 24 hour cycle of repeated CTD + fluorometer casts at a fixed position 38°39′ N, 9°28.5′ W, collecting water samples at hourly intervals.

At all stations, water samples were collected at the surface and fluorescence maxima for phytoplankton analysis using the standard Utermöhl technique for identification and counting, spectrofluorometry and High Performance Liquid Chromatography (HPLC). Meteorological data (wind speed and direction, air temperature, solar radiation, etc.) were acquired on board using the ship meteorological station. The position of the nested grid was decided during the cruise, just before completion of the coarser grid, based on the location and shape of the frontal structure at the southern boundary of the cold water core attached to Cape Roca (Fig. 2). An effort was made to match the date of the survey to the ENVISAT-SAR pass schedule and to ensure that at least one SAR image would be acquired during the cruise. A very fine SAR image was acquired on 31 August, revealing very interesting features associated to the mesoscale circulation and internal waves (Fig. 3). Reasonably cloud-free MERIS images were also acquired, which permitted the comparison with *in situ* data. Preliminary results show discrepancies between HPLC chlorophyll concentration estimates of surface samples and the estimates from MERIS data, with a

Table 1. Upwelling characterisation projects

Project	Grant	Topic	Institute	Contact	E-mail
CARECOS: Caracterização ecológica da zona costeira, Acção B, Plataforma continental	FEDER-QCAIII POPesca	Monitoring at the shore station and work at sea	IPIMAR	T. Moita	tmoita@ipimar.pt
ProFit Project: Interdisciplinary study of oceanographic processes underlying the phytoplankton dynamics in the Portuguese upwelling system	ESA-AOPT2313, FCT-PDCTE/CTA/ 50386/2003	Modelling activities	Universidade de Aveiro	P.B. Oliveira	pbo@ipimar.pt
ESA Projects ProFit and AMAZING: A multi-sensor analysis and interpretation system for the coastal zone remote sensing	ESA-AOPT2423, FCT-PDCTE/CTA/ 49953/2003	Processing and interpretation of remote sensing data	Institute of Oceanography, Universidade de Lisbon	J.C. da Silva	jdasilva@fc.ul.pt

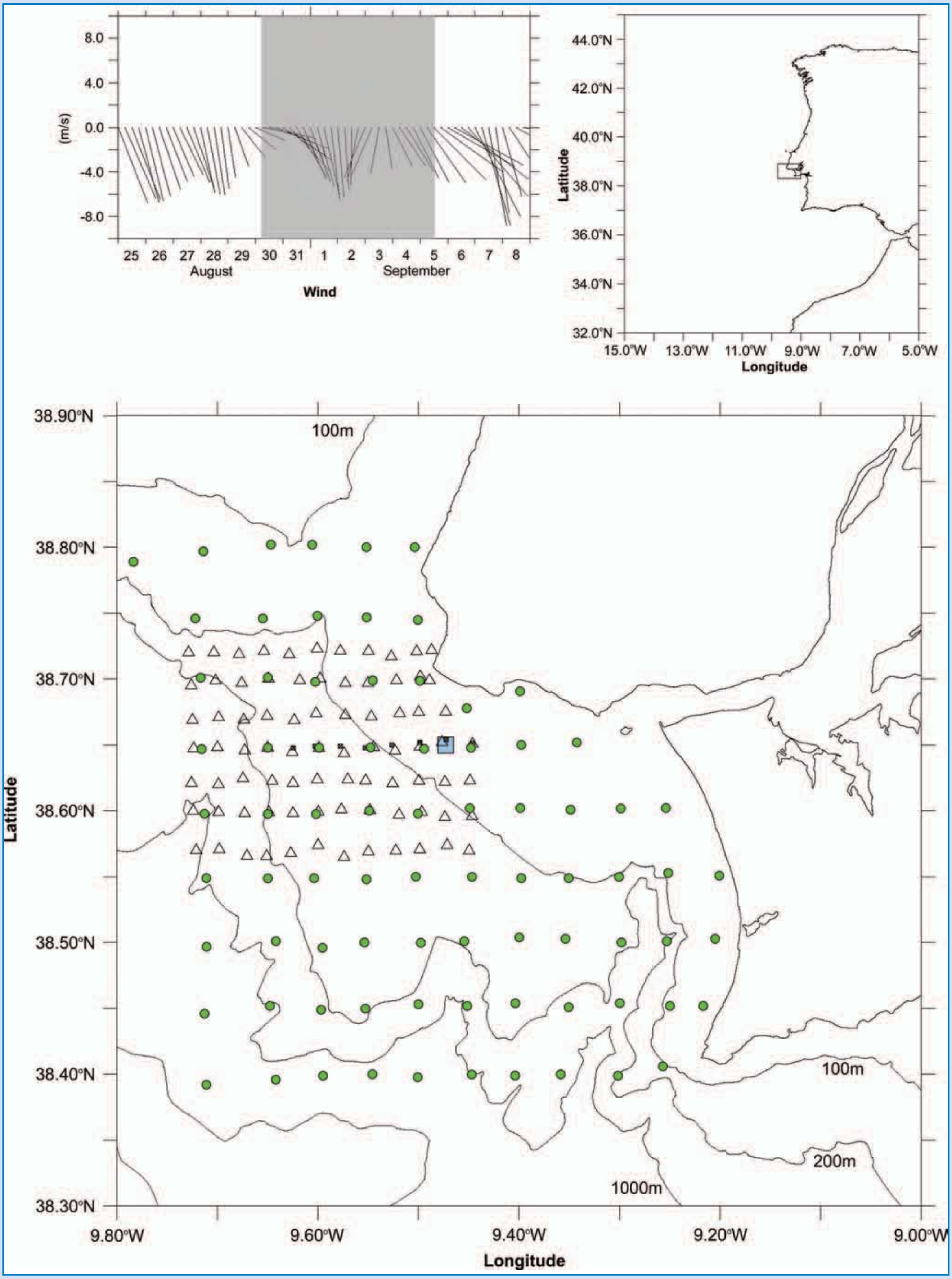

Figure 1. Stick diagram of wind (shaded area corresponds to cruise dates) and station map showing the four survey parts: (i) coarse grid - filled circles, (ii) fine grid - open triangles, (iii) zonal section at - squares, (iv) fixed location - solid square.

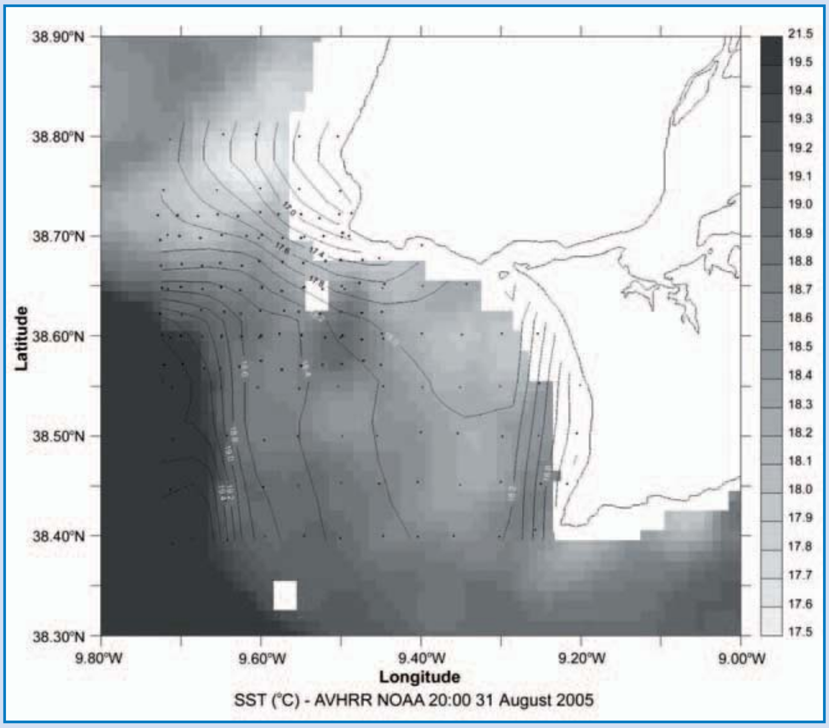

Figure 2. Overlay of 5 m temperature, fine grid station positions and 6 hourly composite of NOAA AVHRR sea surface temperature produced by O&SI SAF for 31 August 2005 at 20:00.

Figure 3. SAR image from 31 August 2005. Data from ESA

tendency for higher values on satellite-based estimates when chlorophyll concentrations are low (up to 0.4 mg/m^3) and lower values for concentrations greater than 0.6 mg/m^3.

It is expected that the data collected during this cruise could be a significant contribution for the characterisation of the upwelling shadow ecosystem off Lisbon, starting from the understanding of the phytoplankton dynamics in the region, namely the identification of ecological niches preferred by different phytoplankton species, with emphasis on toxin-producing species.

Acknowledgments

NOAA/AVHRR data were obtained from EUMETSAT Ocean and Sea Ice Satellite Application Facility (O&SI SAF) at Meteo-France. SAR and MERIS data were obtained from ESA

Sustainable estuarine zone management for control of toxic blooms, invasive species and conserving biodiversity, Guadiana demonstration site, Portugal

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Throughout the world, estuaries and coastal waters have experienced degradation. Present proposed remedial measures based on engineering and technological fixes are unlikely to restore the ecological processes of a healthy, robust ecosystem and will not reinstate the full beneficial functions of estuarine and coastal areas. The successful management of these waters requires an ecohydrology-based, basin-wide approach. The ecohydrology concept developed in the framework of the UNESCO International Hydrological Programme, demonstrated the possible use of

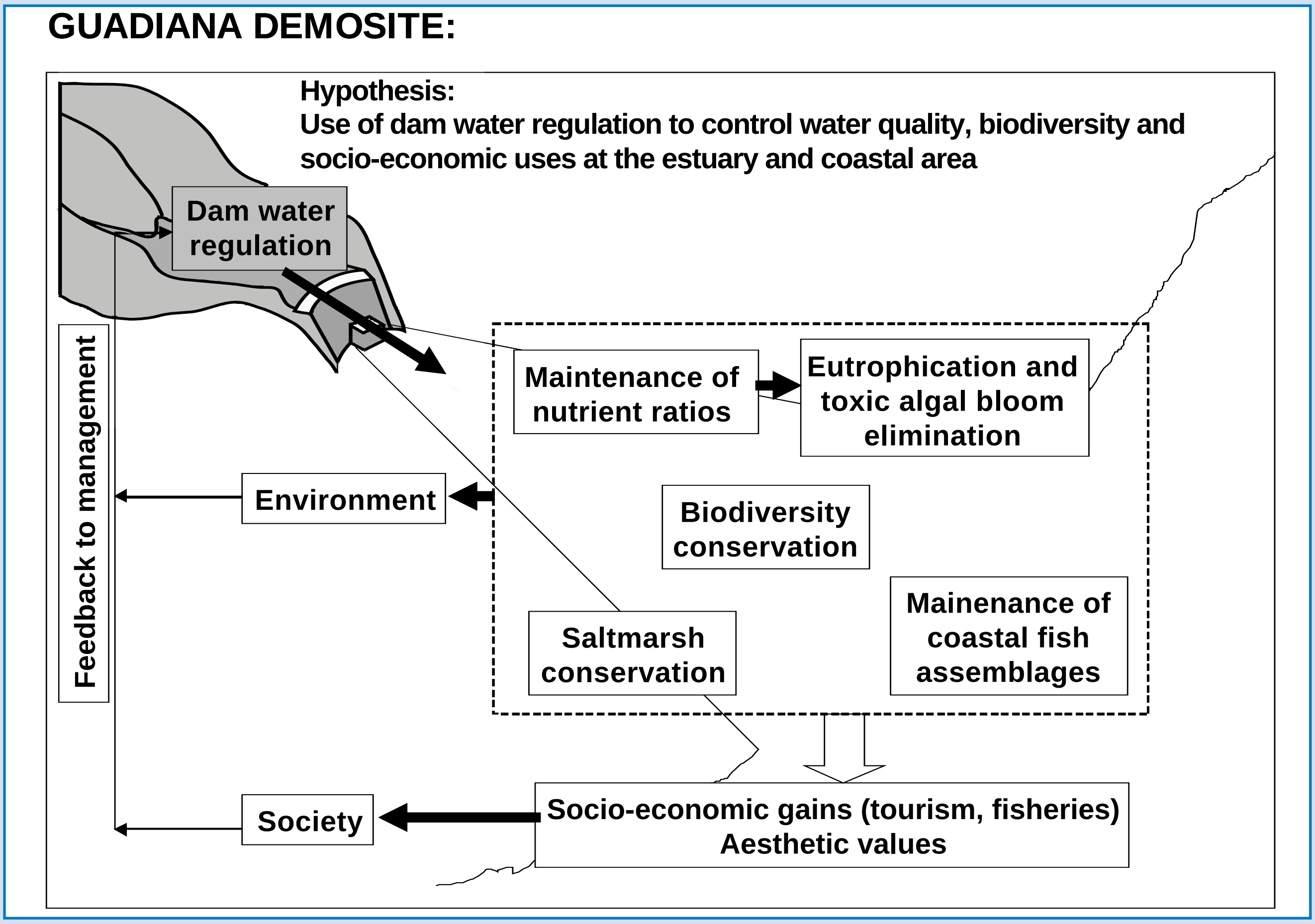

Figure 1. Conceptual Model of the Guadiana demo site.

hydrology to regulate biota dynamics and vice versa (Zalewski, 2000). The synergic integration at the basin scale of various ecohydrological measures based on mathematical modelling provides a scientific background for the enhancement of carrying capacity of the ecosystems (Wolanski *et al.*, 2004). This in turn improves ecosystem services and in consequence enables the creation of positive socioeconomic feedback between environmental quality and society.

The implementation of the UNESCO demo site in the Guadiana estuary represents an excellent opportunity to demonstrate how it could be possible to mitigate and restore the functioning of estuaries and coastal areas impacted by dam construction using ecohydrology solutions. Several estuaries worldwide are suffering similar impacts and the Guadiana demo site will act as a study case and mesocosm experiment for other systems. Considering the ecohydrology concepts and methods the following hypotheses are proposed to be tested in the Guadiana estuary demonstration site (Fig. 1):

1. Efficiency of pulses of freshwater inflow to control microalgal blooms by enhancing bottom-up control;
2. Efficiency of bivalve population to control microalgal blooms (top-down control);
3. Control of water quality using riparian vegetation and salt-marsh restoration;
4. Reduction of nutrient overload using macroalgae in floating systems.

The new solutions to be tested in this project were designed to contribute to the evaluation of how and to what extent biological processes might modify the flow of water, nutrients, sediments, and pollutants in aquatic ecosystems and the surrounding landscape and also to what extent the hydrological processes can be used to modify phytoplankton succession and enhance biota diversity, avoiding algal blooms and eutrophication. The hypothesis to be tested can therefore corroborate the logical fusion of the sciences of hydrology and ecology. Taking into account that the biodiversity of the region is endangered by various factors, such as the invasion of alien species, an improvement in the water quality will increase ecosystem health. In fact, restoration of saltmarshes and riparian vegetation will be crucial to the ecosystem, because they are the habitat of several endangered native species.

There are already several studies that have demonstrated that the amount of freshwater input into the sea explains coastal planktonic production (Cunha, 2001), fisheries landing (Erzini, 2005) and even continental slope productivity (Santos *et al.*, 2004, Ribeiro *et al.*, 2005). Moreover the recently developed ecohydrology model (Wolanski *et al.*, in press) for the Guadiana estuary links physical, chemical and biological processes over the entire estuary and coastal areas and for the entire food web as a function of freshwater catchment output and the oceanic open boundary condition. Despite, the fact that a number of simplifications have been made, the model is encouraging in that it satisfactorily reproduces the observations in 2001–2003 Guadiana estuary. These data are still sparse and the model may need improvements as additional data become available by the Guadiana demo site implementation.

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Basis for Norway lobster stocks assessment using information on larval production and ecology

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This work will be developed under the project "Norway lobster stocks in Portugal: Basis for assessment using information on larval production and ecology"- LobAssess (FEDER-POCI/ BIA-BDE/59426/2004), that started in September 2005. Two oceanographic surveys will collect larval Norway lobster *Nephrops norvegicus* (Fig. 1). The first survey (early 2006) will acquire information on the horizontal and vertical larval distribution off the Algarve (southern coast of Portugal), one of the main areas of adult abundance in Portuguese waters. Besides vertical stratified planktonic (Fig. 2) and hydrological measurements (Fig. 3) in the water column, the project will deploy a current meter mooring array to obtain information on currents. A second survey along the Portuguese coast will be carried out in the following year, based on the information on the vertical distribution of *Nephrops* larvae obtained in the first survey. The objective of this second survey is to collect information on larval distribution along the Portuguese coast and samples for genetic analyses, to link larval *Nephrops* to adult populations inhabiting the area. Local adult populations are open to interchange of individuals through larval dispersal, which may enhance stability of the stocks. LobAssess will estimate rates of larval flow over the adult populations and of interchange with neighbouring areas, through the development of a numerical model that integrates information on ocean circulation with larval behaviour. The results about the origin of larval recruitment to local adult populations will be supported by the genetic analyses, in which primers specifically developed for this species will be employed. LobAssess will also develop basic scientific knowledge for an independent estimation of the biomass of these stocks, based on the Annual Larval Production Method.

LobAssess project
POCI/BIA-BDE/59426/2004

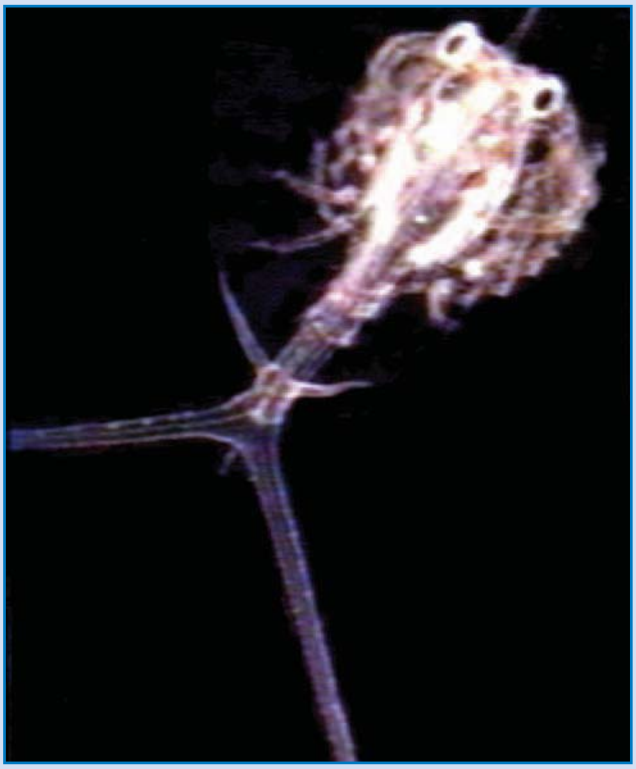

Figure 1. Zoeae of Norway lobster Nephrops norvegicus (Courtesy of R. Calado, LMG, Portugal).

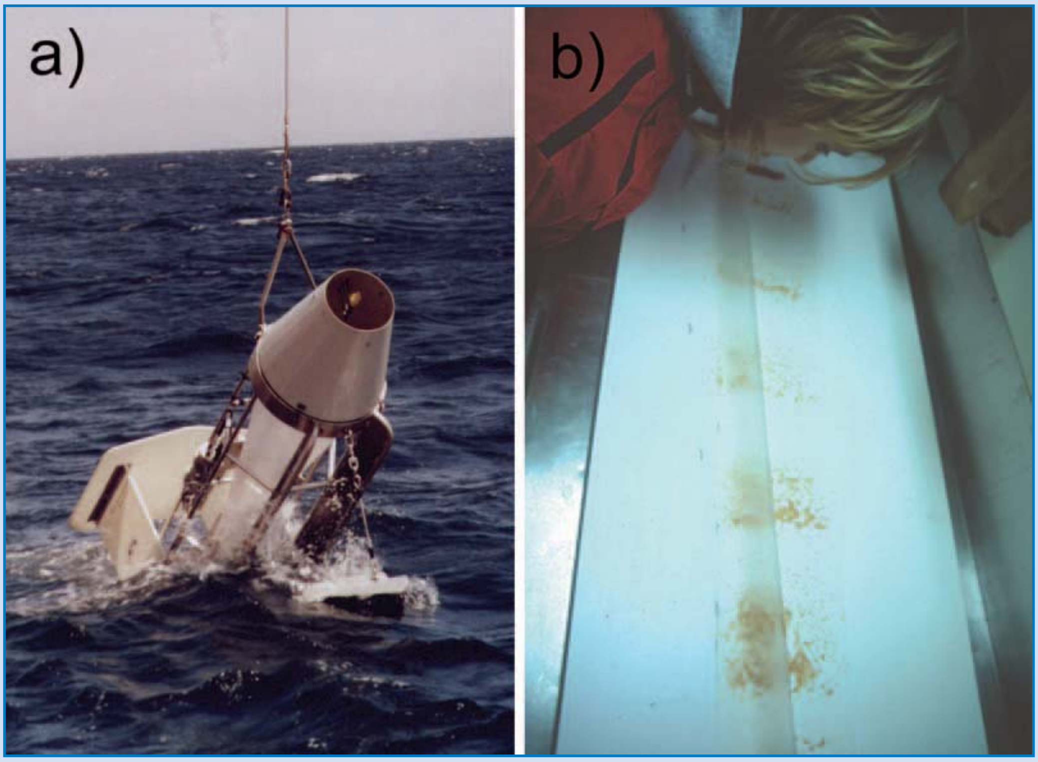

Figure 2. Plankton sampling off the Portuguese coast: a) The LHPR- Longhurst-Hardy Plankton Recorder; and b) LHPR samples collected after an oblique haul.

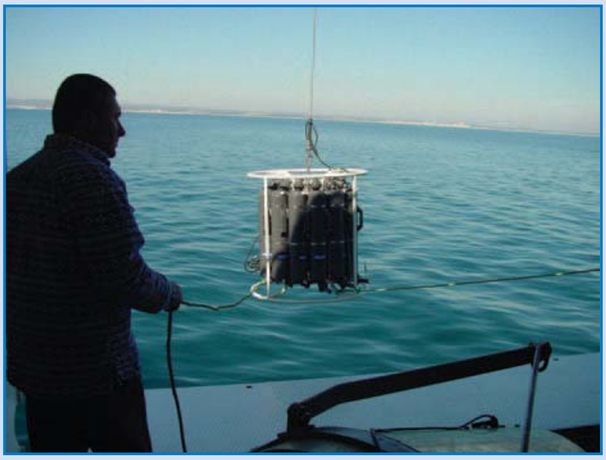

Figure 3. CTD+Rosette cast off Algarve (southern coast of Portugal).

The LobAssess research team includes members from the Instituto Nacional de Investigação Agrária e das Pescas (IPIMAR) and from the Universities of Aveiro and Algarve. IPIMAR has expertise in larval ecology and taxonomy, in addition to assessment. Researchers from the University of Aveiro have been working on biophysical interactions controlling dispersal and recruitment of decapod crustaceans, including numerical modelling. Members of the University of Algarve have skills in population dynamics, genetics and management of *Nephrops*.

One of the goals of LobAssess is to contribute to improve knowledge on the larval ecology of deep-sea resources, a subject that has been overlooked by fisheries biologists. It is also expected to produce relevant information for improving stock assessment and is necessary to apply realistic and socially acceptable management policies that take into account the links between local populations.

The POPEI project

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POPEI (High-resolution oceanic paleoproductivity and environmental changes: correlation with fish populations) is a new project funded by the Portuguese Science and Technology Foundation and FEDER, that will start during 2006. It focuses on the recognition of past oceanic/continental conditions that had an important role in primary productivity fluctuations and aims to acquire new data for the creation of ultra-high-resolution oceanic productivity time series, through a multiproxy approach. Selected proxies will mainly reflect productivity, chiefly calcareous nanoplankton, foraminifera (Fig. 1a), diatoms (Fig. 1b) and fish remains (Fig. 1c). Furthermore, pollen analyses will provide information about climate variability in the region. The correlation between these proxies and the

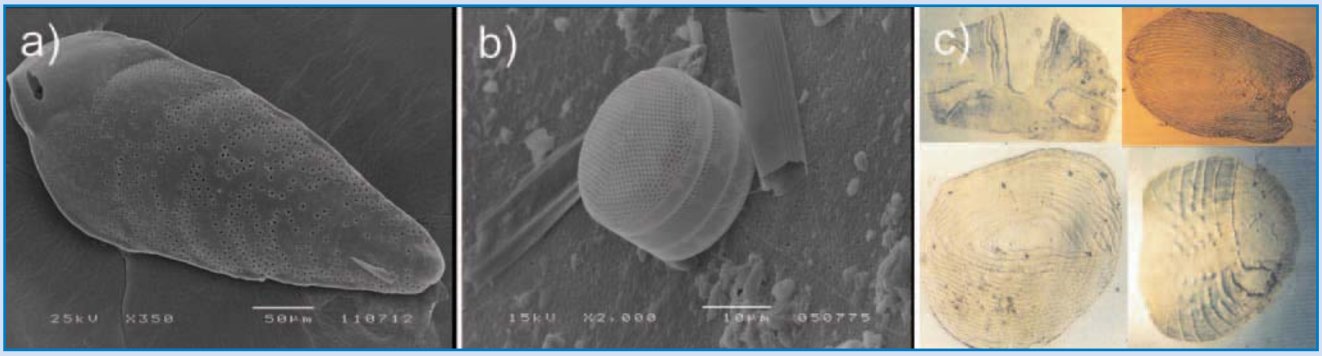

Figure 1. Productivity proxies: (a) SEM image of the foraminifera Brizalina spathulata (Courtesy of F. Fatela and F. Rosa, FCUL and Envi-Changes project, Portugal); (b) SEM image of a Thalassiosira sp. diatom (Courtesy of Alexandra Silva, IPIMAR, Portugal); and (c) Fish scales (Courtesy of Vicente Ferreira-Bartrina, CICESE, Mexico).

available fisheries data sets will provide the basis for the study of the fluctuations of small pelagic fish productivity beyond available data from the instrumental period and before major anthropogenic impacts. Expected results from this project will be a better understanding of oscillations of the productivity and its proxies (including seasonal variations) off Portugal, as well as new data concerning sediments from the continental margin. We hope that this knowledge could be an important contribution to fisheries management based on the understanding of present and past fluctuations of fish populations.

Several Portuguese research institutions will participate in this project which will be coordinated by the Portuguese Institute for Fisheries and Sea Research (INIAP-IPIMAR). These will include the Sea Institute (IMAR), the Faculty of Sciences of the University of Lisbon (FCUL), the University of Bordeaux I and the Hydrographic Institute of the Portuguese Navy (IH). Vicente Ferreira-Bartrina (CICESE, Mexico) will provide expertise in paleofisheries.

One of the main goals of the project is the exploration of potential sites for paleofisheries records in the Canary Current Upwelling Ecosystem to reconstitute fish productivity cycles based on counts of fish remains in geological records. Furthermore, it is envisaged that a Fish Scale Atlas will be developed for target species that will allow the development of reference material for the recognition of fish scales found in marine sediment records. The selection of coring sites will be done by analysis of existing sediment maps of the Portuguese continental margin using existing data on anoxic areas, seismic reflexion profiles and existing marine sediments, previously collected by IH in the continental margin off Portugal from depths of 500 m.

There will be two phases of fieldwork performed on board the IH vessel D. Carlos I. Firstly a mission for general prospecting purposes, where cores will be taken from 3–4 sites using box- and piston-cores, which will be used to identify appropriate locations for the second more in-depth survey. Core processing will include sedimentological (e.g. R_X analysis, textural analysis by laser difractometry), paleontological (e.g. nannoplankton (coccolithophores), foraminifers, diatoms, pollens and fish scale assemblages) and chemical and isotope (e.g. $^{18}O/^{16}O$ – sea temperature, ^{210}Pb – dating for the last 100 years, sedimentation rates and ^{14}C -radiocronology) analyses.

Finally, data integration and synthesis will be performed to obtain productivity profiles and correlation with fish population dynamics and environmental data (e.g. NAO, upwelling regimes).

CLIBECO: Climate changes in the Iberian Upwelling Ecosystem

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The project "Climate changes in the Iberian Upwelling Ecosystem: a regional retrospective and scenario study approach (CLIBECO; POCTI/CLI/57752/2004)" will start in May 2006 and is funded by the Portuguese Science and Technology Foundation and the Fundo Europeu De Desenvolvimento Regional (FEDER).

The project is coordinated by CESAM, a Centre of the University of Aveiro and will have the participation of INIAP-IPIMAR. The main purpose of the project is to gather meteorologists, physical oceanographers and marine biologists to address the following questions: Is the upwelling regime in the Iberian Upwelling Ecosystem (IUE) region

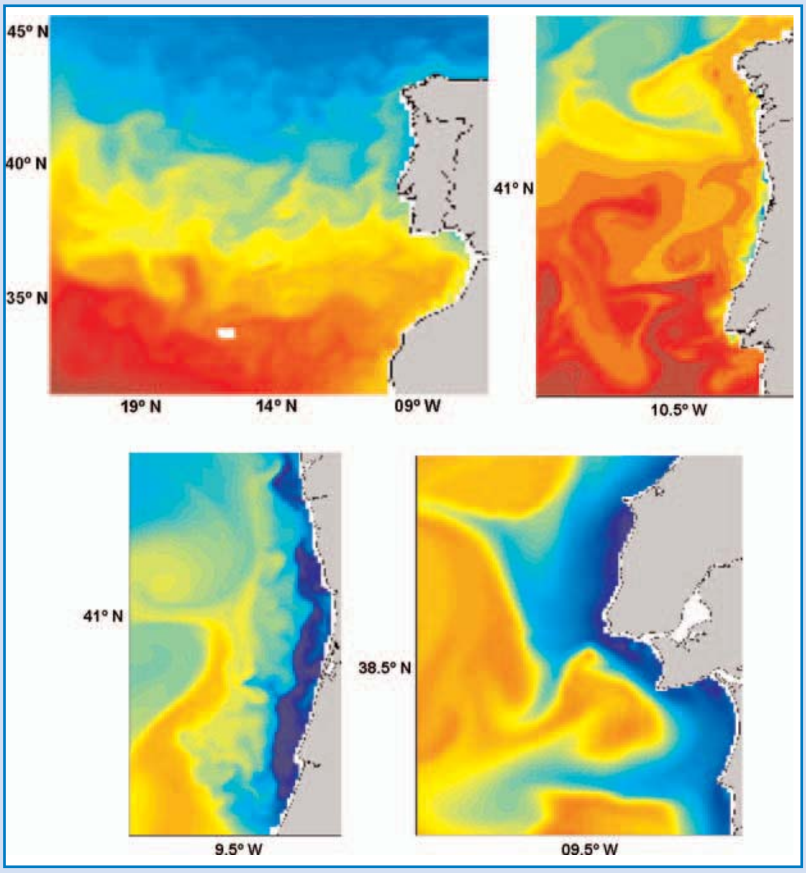

Figure 1. Results of the ROMS model for the Iberian Upwelling Ecosystem region with different scale resolution (courtesy of Álvaro Peliz, CESAM, University of Aveiro, Portugal).

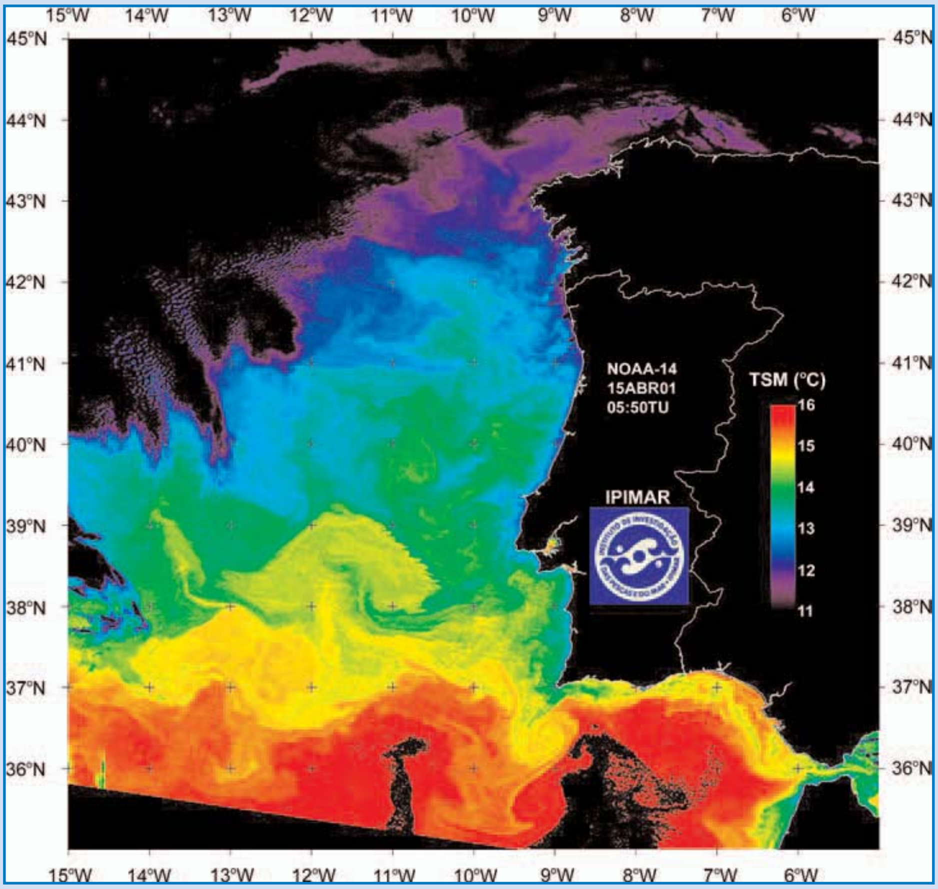

Figure 2. Satellite-derived SST distribution in April 2001 off the Iberian Upwelling Ecosystem region.

changing? How are these changes affecting the main patterns of circulation and dispersion? What is the impact in the lower levels of the food chains (primary production)? Is it possible to produce scenarios of the ecosystem response to the future climatic changes at a regional scale?

To answer these questions CLIBECO propose a study based mainly on modelling studies of climate change projections based on IPCC (IS92a and Special Report on Emissions Scenarios, SRES), which have been extensively adopted as standard scenarios for use in impact assessments and whose model data is widely available. The coarse atmospheric and oceanographic data generated from these scenarios will be downscaled by high-resolution models for the atmosphere and the ocean. The circulation patterns in the coastal zone generated by these oceanic models (Fig. 1) will in turn be used by some tools (biological and lagrangian sub-models) to assess the impact of the above mentioned changes in coastal ecosystems. This approach will include a retrospective component and a scenario study mainly using modelling tools.

The Western Iberian constitutes the northernmost limit of the Eastern Atlantic Upwelling System and partially incorporates the eastern edge of the Azores Front/Current System (Fig. 2). This is the route for the dispersion of Mediterranean Water into the Atlantic and is important for poleward transport of properties due to the slope current, the Iberia Poleward Current (IPC; Peliz *et al.*, 2003). These main factors determine the local oceanographic conditions but are also relevant for the eastern Atlantic as a whole and their joint role in the decadal variability constitutes a mainstream climatic issue to which CLIBECO intend to provide an important contribution. On the other hand, decadal fluctuations in the annual catches of sardine in IUE were observed during the 20th century (Borges *et al.*, 2003) and they seem to be largely environmentally driven, mainly related to upwelling strength variability (Santos *et al.*, 2001, 2005; Borges *et al.*, 2003).

Results from General Circulation Models (GCMs) are one of the most important tools to study the impacts of future climate change. These state of the art mathematic physically based comprehensive ocean-atmospheric models are currently limited to horizontal resolutions much greater than those required for some purposes. In these cases, this is a need to *"downscale"* the GCM results to much finer grids. This is done by performing simulations with mesoscale/regional models with initial and lateral boundary conditions obtained from the GCMs. This method is computationally exigent but more skilful than other statistically based methods because the spatial interpolation is physically based. In this project we intend to use mesoscale/regional models of the atmosphere to downscale GCM output obtained from a number of models. From the point of view of modelling in physical oceanography one of the most challenging problems is to solve phenomena of different scales at once. This is necessary when there is a need to solve phenomena like upwelling with typical scales of a few kilometres, including fronts, filaments, eddies (Peliz *et al.*, 2002) and in parallel with other large scale phenomena, like the IPC. For that purpose it is necessary to use a system of nested models which allow solving on both scales. This can be done using the state of the art model ROMS-AGRIF (Regional Oceanic Model system with Adaptive Grid Refinement in Fortran) technology (Penven *et al.*, 2006). The model can be forced with the results of the downscaled atmospheric numerical models.

Thus, we hope that the results and models obtained from CLIBECO will be of general interest to the understanding of the climate evolution of the eastern boundaries of the oceans and the identification of along and across shore fluxes during the forthcoming years which could be important for better management of living resources in the region.

CLIBECO is a national contribution to the International Geosphere-Biosphere Programme (IGBP), namely in frame of its Core Projects GLOBEC and AIMES (Analysis, Integration and Modelling of the Earth System), through the study of the responses of the marine ecosystems to global change (GLOBEC) and to the coupling of ocean and atmosphere models (AIMES).

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GLOBEC/SPACC workshop on image analysis to count and identify zooplankton (ZooImage)

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The GLOBEC/SPACC image analysis workshop organised by Xabier Irigoien, Philippe Grosjean and Angel Lopez Urrútia was held 1–3 November 2005 in the aquarium of the beautiful city of San Sebastián in the Spanish Basque region. The idea for this workshop stemmed from the increasing use of imaging techniques to count and size zooplankton. These techniques are essential to tackle the number of plankton samples from large-scale surveys. However, the disparity in techniques can make inter-comparisons difficult. The main objective was thus to develop a common platform by bringing together development and integrating methods. This would form the basis for a network of users where information could be shared, with the ultimate aim of being able to observe a global-scale (high resolution) distribution of plankton.

After some introductory talks on the advantages and ecological applications of image analysis, a number of different instruments currently used were presented. There was a clear division between *in situ* devices (Video Plankton Recorder (VPR), Shadow Image Particle Profiling and Evaluation Recorder (SIPPER), Dinoflagellate Categorisation by Artificial Neural Network (DICANN), Harmful Algal Bloom Buoy) and bench-top instruments (ZooScan, FlowCAM). The informal setting enabled open discussions to develop and the various limitations of each technique to be evaluated.

The next step was to develop a common framework with which to analyse the plankton images obtained by the different approaches. Philippe Grosjean presented the ZooImage software (http://www.sciviews.org/zooimage/) that had been developed by combining efforts with developers and the already available Plankton Visual Analyser software (http://www.azti.es/). ZooImage is the merger of two free pieces of software: Image J and R. The philosophy of ZooImage is one of free and flexible use, providing the opportunity to develop further to fit the different needs of the user. Images taken with all methods can be analysed with the ZooImage software. However, pictures for some devices recording video (like the Video Plankton Recorder) have to be processed with care as some animals may be present on several pictures of the video (depending on the towing speed and the angle of the video recording).

On Day 2, Philippe Grosjean explained how to use the ZooImage software (a free CD of the software was offered to each participant), showed how to classify the pictures and emphasized the need to create specific training sets for various studied areas of the ocean. To create these training sets 50 organisms for each studied or identified group are needed. The technology is not yet competitive with taxonomists in terms of fine taxonomic identification. However, new technologies, high resolution pictures (2400 dpi) and digital software already allow good recognition as underlined by Phil Culverhouse from the University of Plymouth, UK as outlined in the table below:

Machine	Level of identification	% of liability in the recognition
ADIAC	37 taxa	75–90%
ZOOSCAN	29 groups	75–85%
SIPPER	5 groups	75–90%
DICANN	3–23 species	70–87%
VPR	7 groups	72%

These approaches are not free of criticism. In fact, some severe constraints remain including (1) sea-water and sample turbidity are limitations on these techniques, (2) particle coincidence in images can confound the system, (3) coincidence in the shapes of different species, of copepods for instance, diminishes the resolution of species recognition and (4) there is a strong dependence on clean (detritus is problematic) and good contrast images (staining helps) and expert training of the "intelligent" software by taxonomists. Nevertheless, by using image analysis, abundance and size can be easily monitored with cheap and fast systems that do not destroy the

Workshop dinner at the Gastronomical Society of San Sebastian

Jesus Cabal (IEO Gijon-Spain) taking care of the seafood dish!

Aitor Albaina (AZTI-Spain) pouring the txakoli (young white wine from the Basque region)

sample. The ZooImage software for example has the capacity to count and "identify" 2000 to 3000 objects per sample in 7 to 9 minutes. Results also allow for easy comparison with other data sets. It is possible to import and process a range of zooplankton images efficiently, as well as to calculate a range of parameters such as the slope of the plankton size spectrum.

A comprehensive photo-library of images from different zooplankton can be used for automated species identification using such recognition systems. Global collaboration in creating a "goldcard" set of images of zooplankton was discussed with the intention of producing a library capable of recognising zooplankton from around the world. Participants were invited to contribute to the construction of plankton training sets. Coordinators for the collection of samples/images have been designated for different geographical areas: Luis Valdes (North East Atlantic); Maria Grazia Mazzocchi (North East Mediterranean Sea); Delphine Thibault Botha (Arctic), Stephane Plourde (North West Atlantic), Ruben Escribano (Chilean and Peruvian coasts and upwelling ecosystems) and Mark Benfield (images regarding *in situ* systems).

We were lucky to enjoy some fantastic weather during the first couple of days. Although there was no time to bask on the beach (in true Basque style) we had the wonderful opportunity to taste the culinary delights that the Basque region has to offer both in the pintxos (tapas-style) bars and the workshop dinner that was organised by the Gastronomical Society of San Sebastián. The seafood, txakoli (young white wine of the Basque region) and txistorra (local spicy sausage) helped participants to relax and talk over the events of the day.

Coffee break at San Sebastian Aquarium

The workshop was an overall success with up to 60 participants and 20 countries represented.

Outputs from the workshop:

The real success of the workshop will be seen in the future outputs. Decisions which were taken during the final discussion are summarised below:

- USA researchers that have a 5 year programme on automatic recognition (M. Benfield, M. Sieracki, M. Blashko etc) and researchers involved with ZooImage (P. Grosjean, X. Irigoien) agreed that ZooImage could be used as a common framework to implement the different techniques.
- A guide for users will be written up for the ZooImage software users.
- Creation of "gold-card" standards identified by qualified taxonomists including creation of training sets.
- A forum and a mailing list is being set up by Jens Rasmussen (FRS Aberdeen, UK) to allow interaction between individuals and users and developers of the software.
- A white paper on image recognition techniques and knowledge to be written (A. Lopez-Urrútia, H. Dam, F. Carlotti, P. Grosjean).
- A workshop and a poster session on automation and zooplankton applications to be proposed at the next Zooplankton Symposium in Hiroshima, Japan, 31 May-3 June 2007.

Synthesis and integration activities within SPACC: workshop and book

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The Small Pelagic Fish and Climate Change Program (SPACC) of GLOBEC began in 1994. It currently has four themes, each in regard to small, pelagic fish (SPF):

1. long-term changes in ecosystems,
2. comparative population dynamics,
3. reproductive habitats, and
4. economic implications of climate change.

Activities, including workshops, meetings and publications, have occurred within each of these themes. In January 2004, the SPACC Executive met in Concepción, Chile, in conjunction with a workshop and meeting on SPF spawning (GLOBEC Reports 21 and 22) and discussed synthesis and integration. The selected activities were a workshop (2006) and publication (2007) focused on the synthesis of SPACC activities to date. The workshop will be held 2–6 October 2006, at the Station de Biologique de Roscoff, France. An edited book will be published thereafter. Drafts of the book chapters are to be submitted and distributed to participants prior to and for discussion at the workshop. Focus will be on past and present activities as well as assessment and prediction of the future.

Following is a list of chapter titles, lead authors and summaries.

Chapter 1. Introduction (Juergen Alheit and John Field). Juergen, with John Hunter, founded SPACC. This chapter will present a brief history of SPACC, including information on current regional programs and related international research.

Chapter 2. History of exploitation of small, pelagic fish (Alec MacCall *et al.*). The history of fisheries for SPF in the five major temperate, sardine-producing systems: northeastern Pacific, southeastern Pacific, northwestern Pacific, southeastern Atlantic and northeastern Atlantic will be presented. Four recurrent groups of small, pelagic species occur in these areas, those being sardines (*Sardinops* or *Sardina* spp.), anchovies (*Engraulis* spp.), mackerel (*Scomber japonicus*) and jack mackerel (*Trachurus* spp.). Fishery history provides information on geographic and temporal patterns of abundance and on possible sequential relationships among these groups. Among-region comparison, including phase relationships of these patterns, provides insights on the nature of mechanisms causing so-called "regime shifts" in these systems and potentially may provide some predictability of future states of these systems.

Chapter 3. Reconstructing interdacadal through centennial variability of small, pelagic fish habitat from high-resolution depositional histories along continental margins (Tim Baumgartner *et al.*). The primary limitations to the use of scale deposition in reconstructing the histories of SPF and their habitats is the restriction of scale preservation to regions of hypoxic bottom waters and high rates of deposition at near-coastal sites located within favorable fish habitat. The potential and limitations for reconstructing and understanding the relationship of fish scale deposition to changes in the character and distribution of pelagic fish habitat over the past several centuries to millennia will be discussed. This will be followed by a presentation of progress in reconstructing variability in the histories of populations of small, pelagic fish, their habitat and their responses to climate change over the past 2000 years.

Chapter 4. Interdecadal variability in populations of small, pelagic fish (Juergen Alheit *et al.*). SPF populations vary on the scale of decades. Often, at least two (e.g. one anchovy and one sardine) species co-exist but with complementary distributions in time and space. This chapter will describe patterns of occurrence in Pacific Ocean ecosystems of the California Current, Japanese waters, and the Humboldt Current and Atlantic Ocean ecosystems of European shelf seas, the Canary Current and the Benguela Current. For each region, relevant aspects of the oceanography, plankton, SPF and their predators will be presented. For each ocean, basin-scale physical forcing and pan-ocean comparisons of SPF populations will be made.

Chapter 5. Life histories of stocks and their variation in relation to the environment (Leonardo Castro *et al.*). The life history characteristics of SPF that use different habitats during their life span will be compared. This will include populations of the same or closely related species that use different habitats and different species using the same or similar type of habitat. The characteristics to be compared concern reproduction (e.g. fecundity, spawning frequency, spawning season and age/size at maturity), early life (e.g. egg size, yolk size, development rates, larval growth rates and biochemistry) and, as feasible, the juvenile stage.

Chapter 6. Habitats of small, pelagic fish (Dave Checkley *et al.*). Habitats of the major stocks of small, pelagic fish (genera *Engraulis*, *Sardinops*, *Sardina*, *Scomber* and *Trachurus*) will be characterised and compared. Emphasis will be on spawning habitat, as this is best known for most stocks, but nursery, juvenile and adult non-reproductive habitats will also be considered. A focus will also be on the relative importance of geography and hydrography in regard to species, stage and region.

Chapter 7. Trophic dynamics: interactions of small, pelagic fish with their planktonic prey (Carl van der Lingen *et al.*). First, literature on the trophic ecology and interactions of SPF with plankton across of a range of systems, from upwelling to temperate non-upwelling to tropical, will be summarised. Second, consistent patterns will be identified, including the relative importance of phyto- and zooplankton. Finally, we will pose hypotheses on the potential effects of climate and ocean change on trophic dynamics and whether one taxon will be favoured over another in particular cases.

Chapter 8. Effects of small, pelagic fish on the ecosystem (Lynne Shannon *et al.*). The theme of this chapter will be to define and quantify disruptions of food webs mediated by SPF. First, a conceptual model based on a wasp-waist ecosystem structure will be presented as a basis from which to explore the theme question: if the typical wasp-waist ecosystem (with SPF as the wasp-waist group) is disrupted, what are the implications for the ecosystem in terms of changes to energy flows. Second, food web collapses mediated via SPF will be explored by means of simulations using trophic models of the Southern Benguela, Northern Benguela, South Catalan Sea and Southern Humboldt. Additional ecosystems, including the Northern Humboldt, will also be considered. Effects of particular interest are bottom-up control, top-down control and fisheries on both SPF and other affected species. Particular attention will be paid to the scale (local vs global) of effects and the economic and ecological impacts of SPF exploitation.

Chapter 9. Assessment and management of small, pelagic fish (Manuel Barange *et al.*). Seventeen stocks of anchovy, herring, sardine and sprat in the Atlantic and Pacific Oceans and the Baltic, Black and Mediterranean Seas will be considered. For each, information will be provided on monitoring surveys (e.g. acoustic and egg and larva surveys to estimate catch, spawning stock biomass, recruitment and fishing mortality), stock management (e.g. population modelling and management) and issues (e.g. efficacy of management, uncertainties and major problems). Procedures, results and future avenues will be presented.

Chapter 10. Global production and economics of small, pelagic fish (Sam Herrick *et al.*) Chapter 10 will focus primarily on sardine, anchovy and herring fishery production in the California Current, Humboldt Current, Benguela Current, Norwegian Sea and Indonesian Sea ecosystems. A historic review of each region's production of SPF species will attempt to cover patterns of landings, ex-vessel values, corresponding effort/harvesting capacity, disposition of these harvests and their movement through value-added chains to final markets. Characteristics and changes in supply and demand, as well as related impacts on regional SPS fisheries economic activity will be highlighted. We will conclude with a forward-looking discussion of anticipated economic consequences and the conservation and management policy implications - at the national, regional and international levels - of major alterations in SPF fisheries due to expected climate change.

Chapter 11. Hypothesised mechanisms (Alec MacCall *et al.*). Mechanisms proposed to explain historical patterns of fluctuations in SPF will be described. Intense fisheries undoubtedly have impacted abundance, distribution and age structure, but ecological and oceanographic mechanisms

Buying dried juvenile pelagic fish at the Tokyo fish market (Photo: Manuel Barange).

appear to exert equally large (and confounded) influences. Strong interdecadal patterns of oceanographic conditions, including current strength and vorticity, sea surface temperature and primary and secondary production have been observed and have many possible connections with Bakun's triad of enrichment, concentration and retention. Ecological interactions, ranging from competition and predation to behavioural micro-evolution, have also been proposed as possible mechanisms. Most of these hypothesised mechanisms are not mutually exclusive. (Note: this chapter was only recently proposed and a final decision on inclusion is pending).

Chapter 12. Predicted effects of climate change on SPACC systems (Pierre Freon *et al.*). Different scenarios of climate change and physical oceanography in light of state-of-the-art modelling will first be reviewed. Three processes of expected main ecological change will then be discussed. First are latitudinal shifts and their effects on exploitation. Second are changes in circulation and their effects on recruitment. Third are changes in productivity and their effects on the food web. For each process, the most appropriate SPACC ecosystem will be discussed. Finally, research gaps will be identified.

Chapter 13. Challenges for SPACC research in the 21st century (Andrew Bakun *et al.*). This chapter will stress the need for a shift in viewpoint of the role of the SPF in whole ecosystem dynamics. This is essential to preserve marine biodiversity and ecosystem resilience through the expected period of rapid climate change and increasing demand for marine ecosystem goods and services. Gaps in knowledge include the roles of feedback instabilities and distributional dynamics in unwelcome shifts in marine ecosystems, of density dependencies and "low biomass refuges" in preventing extinctions and of gelatinous predators in seizing the zooplanktivore function of SPF. Do lessons learned for anchovies, sardines and sprats in SPACC regions lend insight to other taxa and regions? What technological needs exist for the future?

Chapter 14. Synthesis and future (Workshop participants). This chapter will derive from discussions at the Roscoff workshop. It is not possible to predict what this chapter will compromise. However, it will include a joint effort to synthesize the information available to the workshop participants, including drafts of Chapters 1–13 provided before the workshop and other relevant information. The primary focus, however, will be the grand challenge: to assess and predict the effects of climate change on SPF.

Chapter 15. Conclusions (Dave Checkley and Claude Roy). A summary of conclusions from the workshop and preceding chapters.

The final composition of the book may change slightly in conjunction with the workshop. The focus of the workshop and book is the synthesis and not simply the review of past work on small, pelagic fish. The grand challenge is to speak with confidence about the future. It is incumbent on SPACC to do so. Populations of anchovy and sardine, the taxa having received the most attention in SPACC, have been shown to vary in size, distribution and in relative and absolute abundance. They are known to be important ecosystem components. Progress has been made in the past decade in documenting this variability and relations between fish and their environment. However, a mechanistic understanding, let alone prediction, of the dynamics of populations of small, pelagic fish remains elusive. Such predictive ability is necessary for management and policy. The major goal of the workshop and book is to bring together knowledge and people from the different SPACC themes to synthesize the current understanding of the effects of a changing climate on the past and future of populations of small, pelagic fish and their ecosystems and to propose future activities.

Where is CCCC in relation to integration and synthesis? An introduction to the PICES/GLOBEC Symposium

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Atmospheric forcing, ocean structure and ecosystem structure and population dynamics vary on many spatial and temporal scales. Dominant temporal scales are diel, seasonal, interannual and longer. In the past ten to fifteen years, marine scientists have begun to document evidence that basin-wide or large-scale changes might be significant forcing for decadal to millennium-scale changes in marine ecosystems. Since the Climate Change and Carrying Capacity (CCCC) Program (a regional program of the IGBP/SCOR/IOC GLOBEC International Project) was established under the North Pacific Marine Science Organization (PICES) in 1994, scientists from the Pacific-rim nations have sought to understand the structure and function of Pacific marine ecosystems under the changing climate. During serial topic-based workshops of the CCCC program, regional and basin scale changes in ecosystems were identified, including several unusual phenomena, such as hypoxic conditions, or greatly delayed "spring transitions" in the Northeast Pacific. Productive discussions during the workshops were followed by international coordination which have contributed towards building a new paradigm that climate regime shifts cause massive reorganisation, with consequences for the marine organisms and communities inhabiting those systems.

However, activities of the CCCC on climate-ecosystem linkages were mostly on regional scales, conducted through the research frameworks of individual nations and programs, until the early 2000s and scientists felt a lack of interdisciplinary or multi-regional comparisons on this specific science. Therefore they planned to hold an international symposium presenting a synthesis of the effects of seasonal to multi-decadal variability on the structure and function of the North Pacific that goes beyond the analysis and understanding developed from studies of a single trophic level, process or region – a True Synthesis. The CCCC Topic Session on "The impacts of large-scale climate change on North Pacific marine ecosystems" at PICES XIII was a preliminary step toward a symposium on "***Climate Variability and Ecosystem Impacts on the North Pacific: a Basin-scale Synthesis***".

This international symposium will occur in Honolulu, on 19–21 April 2006. The goal of this symposium is to bring together scientists that have been examining the influence of climate variability and change on marine ecosystems of the North Pacific and adjacent seas. Research on this topic has been worldwide, but there have been, to date, few attempts to bring together the entire research community to examine the temporal scales and coherence of these climate impacts. This symposium is attempting to achieve such a synthesis. Specifically, this symposium will help to develop better understanding of how climate variability affects productivity of North Pacific marine ecosystems and their ability to support sustainable commercial and subsistence harvests.

The organisers and the scientific steering members have identified several themes for the symposium, which will attract broad participation by scientists from countries bordering the North Pacific. The three sub-themes identified are (1) Regime shifts, (2) Ecosystem productivity and structural responses to physical forcing, and (3) Pan-Pacific comparisons.

Theme 1: Regime shifts, especially, examination of the ocean and ecosystem responses to known strong, infrequent changes in the North Pacific, such as those that occurred in 1977, 1989 and 1998;

Theme 2: Ecosystem productivity and structural responses to physical forcing, with an emphasis on shorter than inter-decadal time-scales-interannual (El Niño-La Niña), seasonal and event scales; and

Theme 3: Pan-Pacific comparisons, with an emphasis on comparisons of similar species or processes from multiple coastal ecosystems and of open ocean-coastal linkages and climate connections.

As of February 2006, a total of 84 abstracts from scientists from 9 countries were submitted for oral and poster presentations. 155 scientists have registered for the symposium. In the interest of achieving synthesis, the program is structured to be entirely plenary without overlapping sessions. This encourages all participants to attend all 36 oral presentations – a necessary prerequisite to achieving a synthesis. At the end of symposium, two "perspective" talks and a panel discussion will preceed the closing. Posters will be displayed for 2.5 days, providing plenty of opportunity for viewing and discussion.

Products of the synthesis symposium will be 1) sharing of data sets on climate change and ecosystem impacts, 2) improved biophysical models of basin-scale "regime shifts" and 3) an improved understanding of how climate warming and climate variability may impact North Pacific Ocean ecosystems. The symposium proceedings will be published in Progress in Oceanography. The editor of Progress in Oceanography has agreed to publish a selection of papers resulting from the CCCC symposium. We will be limited to *ca.* 500 pages maximum, which should allow publication of 18–25 papers.

For the success of this milestone event, several organisations are providing financial support for the symposium. Primary sponsors of the symposium are PICES and GLOBEC International. The following organisations have agreed to co-sponsor the symposium (at various financial commitments): Western Pacific Fisheries Management Council; Pelagic Fisheries Research Program of the University of Hawaii; North Pacific Fisheries Management Council; NOAA Fisheries, the North Pacific Research Board, US GLOBEC, the Korea Ocean Research and Development Institute (KORDI) and the Scientific Committee on Oceanic Research (SCOR). We are grateful to all of these sponsors for their support.

Where is the CCC in relation to integration and synthesis?

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Cod and Climate Change (CCC) was the first regional programme to be established within GLOBEC and is also a Working Group within ICES (International Council for the Exploration of the Sea). The key question for the programme is "how does climate variability affect the productivity and distribution of cod stocks?" Cod (*Gadus morhua*) was chosen as the principal target species because its biology is well known, it is a major component of most North Atlantic ecosystems and its abundance and distribution have been shown to be sensitive to environmental variability. A range of scientific disciplines and scales of investigation are applied within CCC, from the effects of small-scale turbulence on encounter between fish larvae and their prey, to large-scale effects of interdecadal changes in wind fields on circulation and transport of heat, plankton and young fish. Much of the CCC initiated science is centred on *Workshops*, dedicated to a specific topic, such as larval transport, cod growth or links between zooplankton and cod. Recent workshops have all been followed up by *Theme sessions* at the ICES Annual Science Conference, thus reaching a broader group of scientists. In January 2004 a Revised Strategic and New Action Plan for CCC was launched, outlining the main activities within the group for its final phase 2005–2009:

- *Fisheries Management:* To incorporate environmental information into fisheries management.
- *Zooplankton-Cod Linkages:* To understand the relative importance of zooplankton in determining the variability in cod abundance and production.
- *Comparative Analyses:* To understand the relative importance of climate variability in causing fluctuations in North Atlantic cod stocks by means of comparative studies.
- *Climate Change:* To evaluate the impact of climate change scenarios on cod distribution and production throughout the North Atlantic.
- *Tropho-dynamics of Cod Ecosystems:* To understand the role of cod in the ecosystem and the importance to cod of climate-induced variability in their prey and predators.
- *Synthesis:* To provide a synthesis of the research information obtained on cod stocks.

Several major contributions related to the integration and synthesis of the CCC programme have recently been made or will be finalised by the end of 2006. These are i) a book on cod and climate variability, ii) the proceedings of the symposium on the Influence of Climate Change on North Atlantic fish stocks and iii) a report on the life history aspects of cod stocks throughout the North Atlantic. In addition three recent workshops have synthesized work taking place within specific topics. Further workshops are scheduled in the near future to continue the integration and synthesis. Some of the methods used should be applicable to other species and regions.

Book on cod

A major component of CCC synthesis activities is the publication of a book on cod. At the 2002 meeting an outline including specific chapters was adopted and lead co-authors were suggested with Keith Brander and Ken Drinkwater agreeing to be the co-editors. In 2003, a synthesis workshop was held to discuss in detail what each of the chapters would cover, coordinate the chapters and to agree upon formats, audience, publication and timetable. The book is mainly a review, synthesizing current knowledge about the effect of climate variability on cod and in particular similarities and differences between the various stocks. Main chapters deal with stock structure and history, the physical and biological oceanographic setting, growth and condition, recruitment, larval transport, distribution and migration, the role of cod in the ecosystem and implications for fisheries management, respectively. In 2005, presentations based on each of the book chapters were given in a special theme session at the ICES Annual Science Conference. The book, in the Springer IGBP series, is due to be published by the end of 2006.

Symposium on the Influence of Climate Change on North Atlantic Fish Stocks

The WGCCC initiated the ICES Symposium on the Influence of Climate Change on North Atlantic Fish Stocks held 11–14 May 2004 in Bergen, Norway. Following the opening talk by Jim Hurrell (USA) 62 talks and 35 posters, organised into five major sessions, were given. These sessions were on Zooplankton, Distribution Shifts, Production (which included sub-sessions on Ecosystems and Trophic Interactions, on Growth, Condition, Reproduction and Mortality and on Recruitment and Abundance), Climate Change Impacts and Management under a Changing Climate. For each session invited papers were given, by M. Heath (UK) on zooplankton, G. Rose (Canada) on distribution, G. Marteinsdottir (Iceland) on production, L. Richards (Canada) on climate change and C. Bannister (UK) on management issues. The quality of the invited and submitted papers was very high, with much evidence of steady progress in the field. Many of the presentations and posters can be viewed at http://www.imr.no/2004symposium/web/index.html and 32 of them have recently been published in a special issue of the ICES Journal of Marine Science (Vol. 62 No. 7) co-edited by K. Drinkwater (Norway), H. Loeng (Norway), B. Megrey (USA), N. Bailey (UK) and. R. Cook (UK).

Report on the cod stocks around the North Atlantic

This synthesis of information on spawning and life history of North Atlantic cod stocks is an update of *ICES Cooperative Research Report* 205, published in 1994, which has been completely re-written. The editor, Keith Brander, has compiled an enormous body of new information, which has become available over the intervening decade. Contributions have been made by 35 different authors covering the 20 main cod stocks all around the North Atlantic (Brander, 2005). In addition

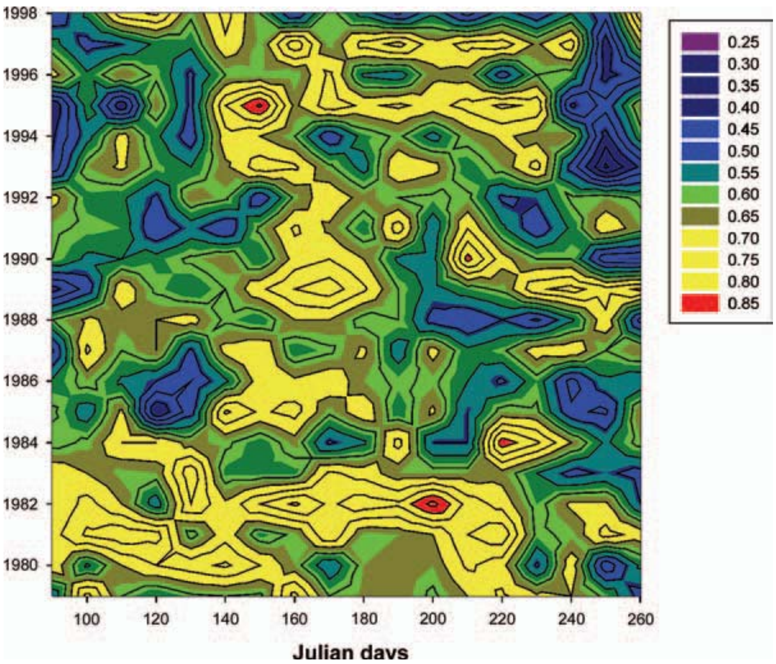

Figure 1. Modelled potential spatial overlap between cod larvae and prey in the Baltic after 10 days of drift. From Hinrichsen et al., Appendix 6 of ICES CM 2005/C:08 (http://www.ices.dk/products/CMdocs/2005/C/WKIZC05.pdf).

to chapters on each stock, summary tables present key life history information on all stocks, facilitating comparison. Single chapters or the full report may be downloaded from http://www.ices.dk/globec/CRR/life%20history/CRR%20274.pdf. A searchable reference database of 2000 articles referred to in the report has been compiled. This database can be downloaded in RIS format from the ICES/GLOBEC website.

Recent workshops

Growth and condition

Growth rate is known to vary widely both among cod stocks and within single stocks over time. This latter variation in growth rate has important consequences for the productivity of these stocks. It may reflect effects of temperature change, density dependence, changes in maturation schedules, changes in size-selective fishing mortality or genetic variation. An understanding of the causes of variation in growth rate between and within cod stocks may lead to improved forecasts of stock biomass and productivity and is required to assess the likely impacts of climate change on cod populations. On this background a workshop (co-conveners: N. Andersen (Denmark), G. Ottersen (Norway) and D. Swain (Canada)) followed up by a theme session at the 2001 ICES ASC (co-conveners: L. Buckley (USA), J.-D. Dutil (Canada) and C.T. Marshall (then Norway)) focused on the importance of cod growth dynamics (ICES, 2002a). Between them the workshop and theme session covered a wide range of topics. Results were presented from laboratory, mesocosm, field and modelling studies and varied from the emphasis on the molecular level to individuals to populations. Several novel approaches were identified including genetic techniques to examine the parental effects on growth and mortality.

A number of studies demonstrated that changes in growth were related to temperature, food availability (per capita), maturation and other factors. These are in turn a consequence of shifts in the distribution and abundance of cod and their prey and possibly also of selection due to fishing. Based on the presentations it was clear that better understanding of variations in growth and condition requires models and data studies across stocks in contrasting environments. As part of the aim to synthesize our knowledge of cod, a simple across-stock growth model was assembled. Furthermore, in a follow-up article, productivity was compared between 15 different stocks by means of cluster and canonical discrimination analysis (Dutil and Brander, 2003).

Transport of larvae

The drift of cod larvae has significant implications for both the dynamics of individual cod stocks and for fisheries management practices in several regions of the North Atlantic. For example, the larvae of Icelandic cod frequently drift west across the Denmark Strait toward Greenland. When environmental conditions are suitable off West Greenland, these cod thrive and subsequently return to Iceland to spawn. This return migration can result in large uncertainties in the assessment of the Icelandic stock, the 1945 year class alone represented an unpredicted additional 700,000 tonnes of 8 year old fish (Dickson and Brander, 1993). A workshop to explore transport processes and their role in the life histories of the affected cod stocks was therefore held by CCC (ICES 2002b; co-conveners B. Ådlandsvik (Norway) and J. Quinlan (USA)). The workshop dealt with interannual variability in transport within a stock as well as transport across stock boundaries. Circulation models were used to explore the physical processes that lead to the variability in transport of larvae and comparisons were made between different regions and stocks. It was concluded that the physical transport of cod eggs and larvae has the potential to link stocks at both local and larger scales. In addition, attempts were to be made to determine whether larval transport indices, derived from model results and observations can be used to improve assessment models.

Zooplankton and cod

Links between zooplankton and fish are at the heart of GLOBEC science and *Calanus finmarchicus* is a major component of the larval diet in most stocks of cod. It was therefore natural for CCC to take the initiative to arrange a workshop in 2005 focusing on "The Impact of Zooplankton on Cod Abundance and Production" (ICES 2005; co-conveners: Ø. Fiksen (Norway), C. Möllmann (Denmark) and J. Runge (USA)). The workshop documented much new evidence of large-scale changes in planktonic communities and consequences of this for other trophic levels, including fish. Relationships between indicators of plankton variability and fluctuations in recruitment or growth are in most cases supported by information about the underlying processes.

Many research groups are currently engaged in efforts to build coupled biophysical models including the spatial and temporal interactions between zooplankton and larval cod, i.e. the integration of general circulation models with biological formulations of growth, feeding and behaviour of larval fish.

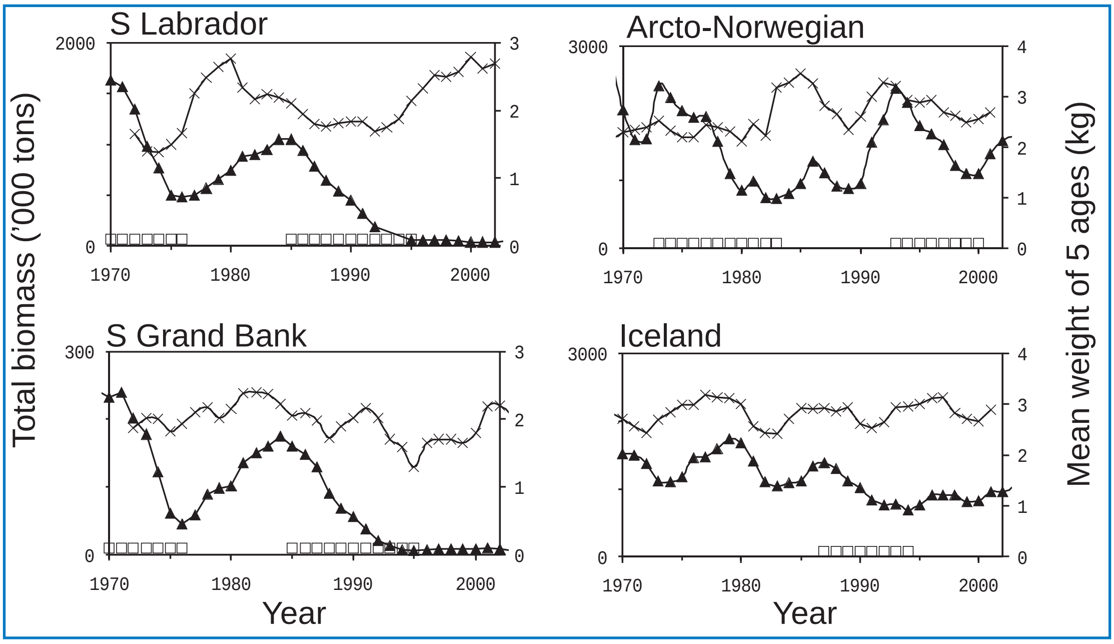

Figure 2. Change in stock biomass and mean weight at age for four large cod stocks. Black triangles are total biomass, crosses are mean weight at age, open squares correspond to prolonged periods of decline in biomass. (http://www.ices.dk/globec/workshops/Decline/WKDRC.htm).

These models are the main tools to integrate research from laboratory studies on sensory ecology, environmental effects on feeding and growth processes with large-scale fluctuations in oceanography and productivity of marine ecosystems driven by climatic forcing. The models are maturing, but still have important limitations, e.g. in the representation of small-scale predator-prey interactions, the distribution of prey at a sub-grid scale and in realistic representation of larval behaviour and physiology.

The effects of physical and biological forcing on cod need not be either linear or additive and reductions in stock biomass due to intensive fisheries may have increased their sensitivity to climatic fluctuations.

Future activities

Workshop on decline and recovery of cod stocks

Many cod stocks display similar trends in abundance, from high values in the 1960s that in some cases persisted through into the 1970s and 1980s, followed by a decline to relatively low levels. In addition, many stocks displayed declines in size at age and age of maturity during the same period.

Building upon the work of Dutil and Brander (2003) that showed the effects of temperature on cod production and the updated information on cod stocks throughout the North Atlantic (Brander, 2005) a Workshop will compare the changes that have occurred in all of the cod stocks around the Atlantic to assess the relative importance of climate-induced ecosystem changes and fishing as causes of the observed declines. One approach will be to apply a tropho-dynamic perspective. The role of forage species will be reviewed, particularly that of capelin in the Barents Sea and Icelandic waters and sprat in the Baltic. This thus addresses the question of cod from a more ecosystem-based perspective. Questions to be answered include: To what extent are observed changes in cod stocks due to climate-induced variability in their principal prey species? What is the role of climate change on predators of cod? A vital aspect of the workshop is the comparative approach. It is difficult to isolate effects of the fishery, climate variability and predator-prey interactions within a single time-series, but there may be much to learn by comparing events across many stocks. The workshop will take place in St Johnís, Canada, 9–12 May 2006 (co-conveners: G. Lilly (Canada), B. Rothschild (USA), S. Sundby (Norway) and K. Wieland (Greenland)).

Workshop on the Future of Cod in a Changing Climate

The response in abundance, distribution and production of cod to climate scenarios for the future will be examined. Results from statistical and dynamic downscaling of output from General Circulation Models will be applied. Established climate-cod relations will be utilised whilst taking into consideration that simple linear extrapolation of established relations may be inappropriate due to non-linearities in either climate itself, in the climate-ecology impacts or in the links between cod and other trophic levels. The workshop will build upon the 1997 ICES/GLOBEC Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic (ICES, 1998), which for the first time brought atmospheric climatologists into the WGCCC community to discuss prediction, climate variability and responses in North Atlantic ecosystems. It will also use information obtained from the CCC program linking the physical environment to distribution, growth, maturity, recruitment, etc. and recent work on the impact of climate change on cod (Drinkwater, 2005a; Drinkwater 200b; Fig. 3). The workshop will take place in 2007 (co-conveners: K. Drinkwater (Norway) and others).

Fisheries management

It remains difficult to pull the detailed process information, which has emerged from large scale national and regional GLOBEC programmes into a form which finds a use in ICES fish stock assessments and advice. However, the incorporation of environmental variability and climate change scenarios into medium and long-term projections of fish stock assessments, e.g. through the inclusion of environmental variables in stock-recruitment models, has received increasing attention. In a few cases routine stock assessments carry out sensitivity analysis to explore the consequences of alternative environmental scenarios, but in general environmental variability is treated as noise. This situation may change as the effect of a changing climate becomes more clearly visible. Discussions within and

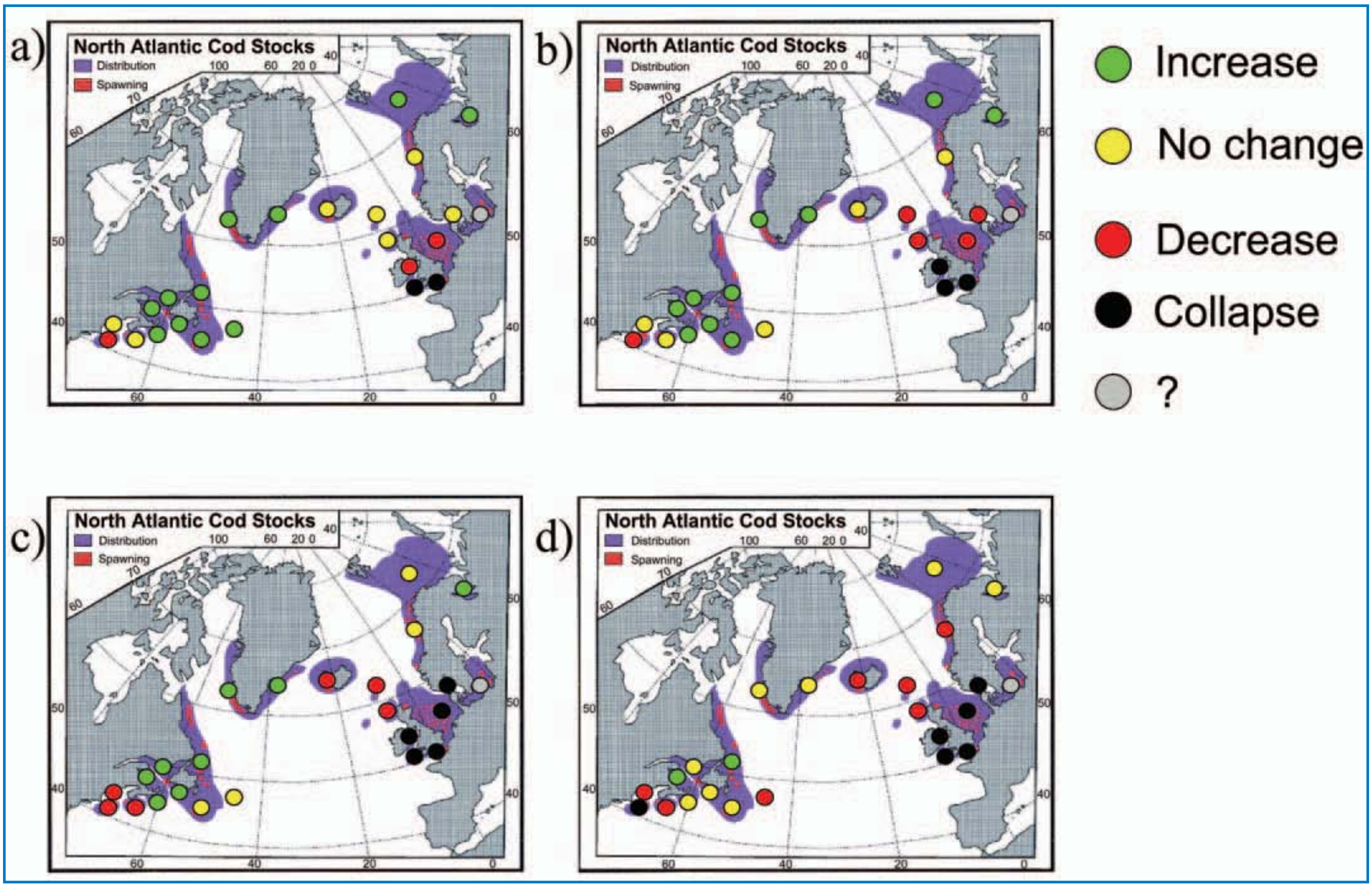

Figure 3. Expected changes in the abundance of North Atlantic cod stocks with a temperature increase of a) 1°C, b) 2°C, c) 3°C and d) 4°C. Adapted from Drinkwater (2005b).

related to the CCC programme suggest that the implementation of alternative approaches is an important future task, which will be tackled by a workshop planned for 2008.

Application of knowledge gained from GLOBEC and the CCC programme

The GLOBEC programme is concerned with "understanding how global change will affect the abundance, diversity and productivity of marine populations". Such understanding is frequently sought in relation to policy making on the issues of climate change, biodiversity and ecosystem management. Many of the scientists involved in national and regional GLOBEC programmes (including CCC) contribute to reports and presentations on these subjects, but because their work is generally funded from other sources, it is difficult to claim GLOBEC ownership. However the ICES/GLOBEC coordinator has been involved in a number of recent activities which illustrate the scope of the applications. These include:

- The Arctic Climate Impact Assessment (http://www.acia.uaf.edu/). The chapter on marine systems included three CCC members among its ten authors.
- Lead author on fisheries for the IPCC Fourth Assessment Report.
- Chapter on Climate Change and Fisheries for the German Advisory Council on Global Change.
- Paper on "Climate change and fisheries management" given at International Conference on "Biodiversity: Science and Governance" convened by President Chirac and for the EU Green Week in Brussels.
- Talks on monitoring and on biodiversity for the North Sea Commission.
- Representing GLOBEC at the ICES Regional Ecosystem Group for the North Sea and co-convening ICES Theme Session in September 2006.

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Integrated analyses of circumpolar Climate interactions and Ecosystem Dynamics in the Southern Ocean (ICED) Science Planning Workshop, Cambridge, UK, 24–26 May 2005

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The Southern Ocean is a key system in the global ocean and there are important climate influences from lower latitudes across the Southern Hemisphere. Understanding the processes that control variability in the structure and dynamics of Southern Ocean ecosystems is increasingly recognised as one of the major challenges for future scientific effort. The last two decades has seen the development of a number of national programmes and the emergence of well-coordinated international programmes. During the last decade, the focus for Southern Ocean ecological programmes has shifted to encompass the whole system, from studies of ocean circulation and chemistry, through to analyses of organisms (from microbes to whales) at different trophic levels in the food web. Results from these studies will be the focus of synthesis and modelling activities in the coming years, as well as providing the basis for additional focused process studies.

An emerging result of these national and international programmes is a better understanding of circumpolar climate variability and its influence on the regional dynamics of Southern Ocean ecosystems. Similarly, there is now a better understanding of the importance of ecosystem structure in determining ecosystem function. For example, it is now recognised that carbon cycling, its retention in the surface waters and its export to depth, are functions of regional ecosystem structure. This type of holistic approach to understanding Southern Ocean ecosystems is even more vital now, given the impending climate change scenarios envisaged for this region. The next major steps in Southern Ocean ecosystems and biogeochemical research require integrated and coordinated circumpolar analyses. Although there has been a high level of coordination within the various international programmes this has often been limited in geographical coverage and generally focused on only one or two tropic levels or aspects of ecosystem operation.

The Integrated analyses of circumpolar Climate interactions and Ecosystem Dynamics in the Southern Ocean (ICED) is a new international and multi-disciplinary programme designed to address the need to understand how climate and anthropogenic forcings may affect the ecosystems of the Southern Ocean. ICED forms part of the new joint Scientific Committee on Oceanic Research (SCOR) and International Geosphere-Biosphere Programme (IGBP) initiative entitled Integrating Marine Biogeochemistry and Ecosystem Research (IMBER). ICED will build upon the research and experience of the recently completed Southern Ocean Joint Global Ocean Flux Study and the soon to be completed Southern Ocean Global Ocean Ecosystems and Dynamics (SO GLOBEC) programme. ICED will participate in the synthesis phase of SO GLOBEC and will integrate activities of the Climate Variability

Figure 1. Participants in the ICED workshop (left to right; back to front) are: J. Watkins, N. Johnston, W. Fraser, P. Chernyshkov, E. Pakhomov, M. Meredith, C. Summerhayes, G. Hosie, R. Holt, J. Turner, T. Trull, E. Hofmann, S. Blain, S. Nicol, F. Dehairs, D. Agnew, C. Lancelot, A. Atkinson, W. Smith, A. Sanchez, U. Bathmann, A. Worby, A. Beckmann, S. Reilly, P. Trathan, H. Wiemerskirch, T. Odate, K. Reid, E. Murphy and H-C. Shin. Absent from photo: J. Hall and G. Henderson. D. Theile and G. Sarthou contributed to workshop but could not attend.

and Predictability/Climate and Cryosphere (CLIVAR/CliC) programme, International Polar Year (IPY), Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), International Whaling Commission (IWC), GEOTRACES and the Surface Ocean-Lower Atmosphere Study (SOLAS).

To launch ICED, EUR-OCEANS, the Natural Environment Research Council, Scientific Committee on Antarctic Research (SCAR), SCOR, IMBER and SO GLOBEC funded the programmeís first workshop in May 2005. The workshop was held at the British Antarctic Survey, UK and involved 34 participants from 14 countries (Fig. 1).

During the first part of the workshop presentations were delivered by representatives of national Antarctic programs (Australia, Belgium, France, Germany, Japan, Republic of Korea, Russia, UK and USA) and international initiatives with a Southern Ocean research component (IMBER, SO GLOBEC, CLIVAR/CliC, IPY, CCAMLR, IWC, GEOTRACES and SOLAS) summarising their current research foci and highlighting key logistic and fieldwork issues.

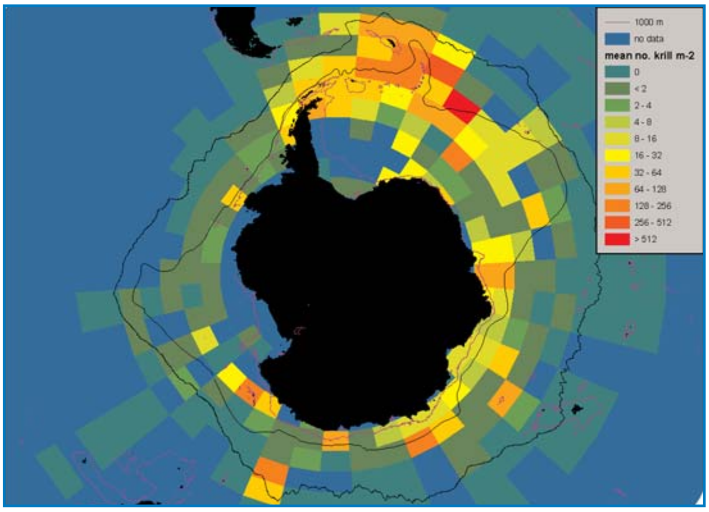

Figure 2. Mean density of Antarctic krill (Euphausia superba) (numbers per m^2) across the Southern Ocean. Data based on 6675 net samples taken between 1926 and 2003. Source Atkinson et al., (2004).

During the second part of the workshop presentations were given by invited delegates on scientific issues in Southern Ocean ecosystems research under the following scientific themes: 1) Atmosphere-ice-ocean connections, 2) Biogeochemistry and nutrient chemistry, 3) Ecosystem structure and dynamics, 4) Sustainable management and ecosystem structure and 5) Circumpolar models. The workshop discussed the above scientific themes and identified two major aspects:

1. The potential value of large-scale comparative studies of the operation of whole ecosystems. This could be between major regions such as the Weddell Sea and Ross Sea;
2. The importance of circumpolar integration studies linking across climate, biogeochemical and ecosystem processes.

The need for large-scale comparative studies is highlighted by a recent study (Atkinson *et al*., 2004) showing changes in the distribution of two important grazers, Antarctic krill (*Euphausia superba*) and salps (*Salpa thompsoni*), in the Southern Ocean food web (Fig. 2). The changing sea ice (Fig. 3) environment is just one of many ecosystem components that link and integrate biogeochemical and ecosystem processes at a circumpolar scale. The ICED Program is focused on important circumpolar questions that will be the major challenge for Southern Ocean science over the next ten years. To achieve this requires an interdisciplinary approach at the circumpolar scale and not just research effort at the local or regional scale.

The third part of the workshop was aimed at identifying key questions and issues that should be addressed by ICED to ensure circumpolar coverage and integration of Southern Ocean research. To achieve this, delegates dispersed into separate groups and discussed 1) Data collection and management (including data mining and synthesis), 2) Field plans (including process studies) and 3) Model developments. The outcomes and recommendations were then presented to the whole delegation for consideration. The key outcomes from these discussions were that:

1. Previous studies and programmes have generated extensive data series that would be extremely valuable for examining large-scale ecosystem operation, variability and change in the Southern Ocean. These data are stored in a wide range of formats including original notebooks, individual data holdings and fully accessible electronic databases. Focusing effort on developing access to historical data archives will be an important task for ICED.
2. Although extensive data sets exist, there are major gaps in our knowledge of key ecological processes and geographical regions. For example, how ecosystems operate from “end-to-end”, how they vary and are connected around the Southern Ocean. Although a wide range of studies are planned over the next 5 to 10 years they are fragmented and do not give complete circumpolar coverage. Further field work will be required linking analyses of climate influences on the Southern Ocean with studies of biogeochemistry and the ecology of key species as part of wider studies of the operation of Southern Ocean food webs. Integrating these studies so they focus on key questions within ICED will be extremely important.
3. A coordinated approach to modelling studies is required. Much of the modelling effort undertaken previously has been focused on particular geographic areas or upon limited questions that address a small number of species or interactions in the food web. There is therefore a pressing need to increase the spatial and biological coverage of the available models. This is particularly timely given the focus that IMBER has placed upon the need to better understand the role of food-web processes in developing analyses of the role of ecosystems in global biogeochemical cycles. ICED aims to develop complex models for assessing and forecasting the impacts of future climate. A major focus will be the extension of existing biological and circulation models to the circumpolar scale and development of

circumpolar "end-to-end" ecosystem models that integrate nutrient cycling and the dynamics of microbes to higher predators.

The final part of the workshop was dedicated to planning the future development of ICED. This included discussion of an appropriate timeline, mechanisms for spreading excellence (e.g. training courses, workshops, meetings and a website), building upon and linking to other programs and initiatives and the anticipated outputs of ICED.

The outcomes of the workshop are currently being collated and will form the basis of the ICED Science Plan. Information on the progress of ICED is available at www.antarctica.ac.uk/Resources/BSD/ICED/. As a follow up to the Science Plan, ICED will hold a special science session at the Scientific Committee on Antarctic Research (SCAR) Open Science Conference in Hobart, Australia between the 12th and 14th of July 2006 to ensure the international development of ICED.

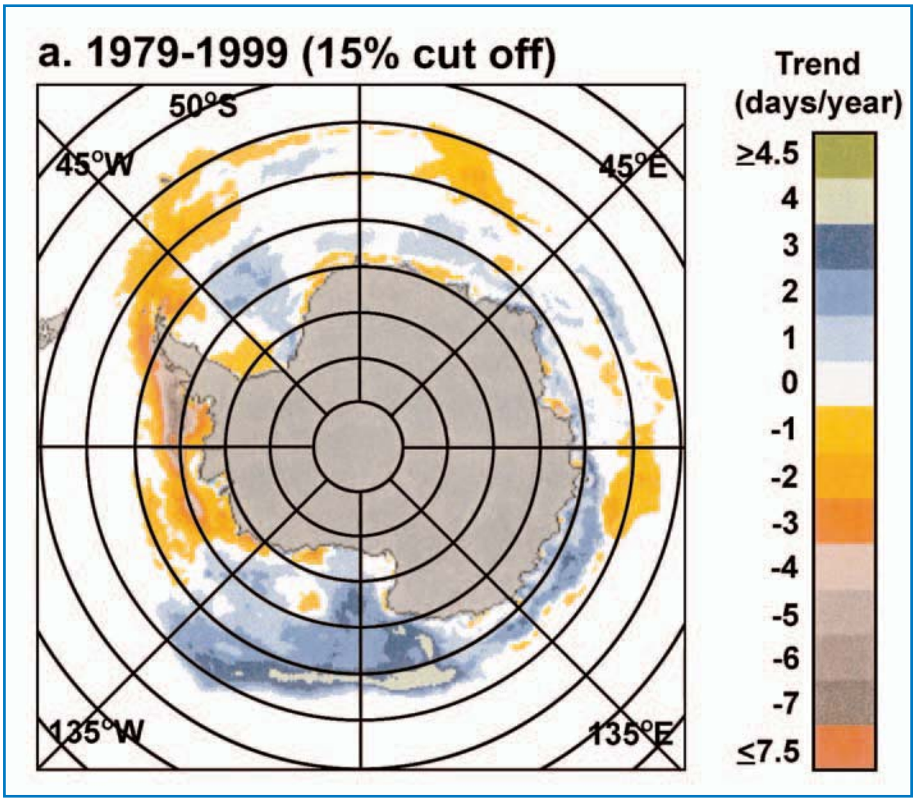

Figure 3. Changes in duration of the Southern Ocean winter sea ice season (d yr^{-1}) between 1979 and 1999. Source Parkinson (2002).

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Atkinson A., V. Siegel, E. Pakhomov and P. Rothery. 2004. Long-term decline in krill stock and increase in salps within the Southern Ocean. Nature 432:100–103.

Parkinson C.L. 2002. Trends in the length of the Southern Ocean sea-ice season, 1979-99. Annals of Glaciology 34:435–440

For further information see:

ICED: www.antarctica.ac.uk/Resources/BSD/ICED

ICED-IPY: www.ipy.org/development/eoi/proposal-details. php?id=92

EUR-OCEANS: www.eur-oceans.org

Framework 6: www.fp6.cordis.lu/index.cfm?fuseaction= UserSite.FP6HomePage=IMBER: www.imber.info

International Whaling Commission-Southern Ocean GLOBEC Workshop

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In 1992, the Scientific Committee of the International Whaling Commission (IWC) established a Standing Working Group on Environmental Concerns with the long-term objective of "defining how spatial and temporal variability in the physical and biological environment influence cetacean species in order to determine those processes in the marine ecosystem which best predict long-term changes in cetacean distribution, abundance, stock structure, extent and timing of migrations and fitness". Three specific objectives were further defined under this overall objective: 1) to characterise foraging behaviour and movements of individual baleen whales in relation to prey characteristics and physical environment; 2) to relate distribution, abundance and biomass of baleen whales species to the same for Antarctic krill in a single season; and, 3) to monitor interannual variability in whale distribution and abundance in relation to physical environment and prey characteristics.

Figure 1. Minke whale in the sea ice along the west Antarctic Peninsula observed during the US SO GLOBEC 2002 austral winter cruise (Photograph by D. Costa, University of California-Santa Cruz).

As part of efforts to address these objectives, the IWC participated as a full partner in the Southern Ocean Global Ocean Ecosystems Dynamics (SO GLOBEC) field studies undertaken by Australia, Germany, United States and United Kingdom. This participation allowed studies of linkages between particular baleen whale species, such as minke (*Balaenoptera bonaerensis*; Fig. 1) and humpback (*Megaptera novaeangliae*) whales, Antarctic krill populations and habitat. The IWC observers on SO GLOBEC cruises did sighting surveys along transects during daylight hours, photographic and video recordings of individuals and groups for species identification, group size verification, observations of feeding and other behaviour, sea ice and oceanographic habitat use and obtained tissue biopsies of individuals for genetic and population

Figure 2. Participants in the IWC-SO GLOBEC Workshop (L-R): A. Friedlaender, S. Reilly, A. Worby, J. Klinck, K. Daly, M. Dinniman, E. Chapman, E. Hofmann, A. Sirovic, D. Thiele, K. Stafford, L. Dalla Rosa.

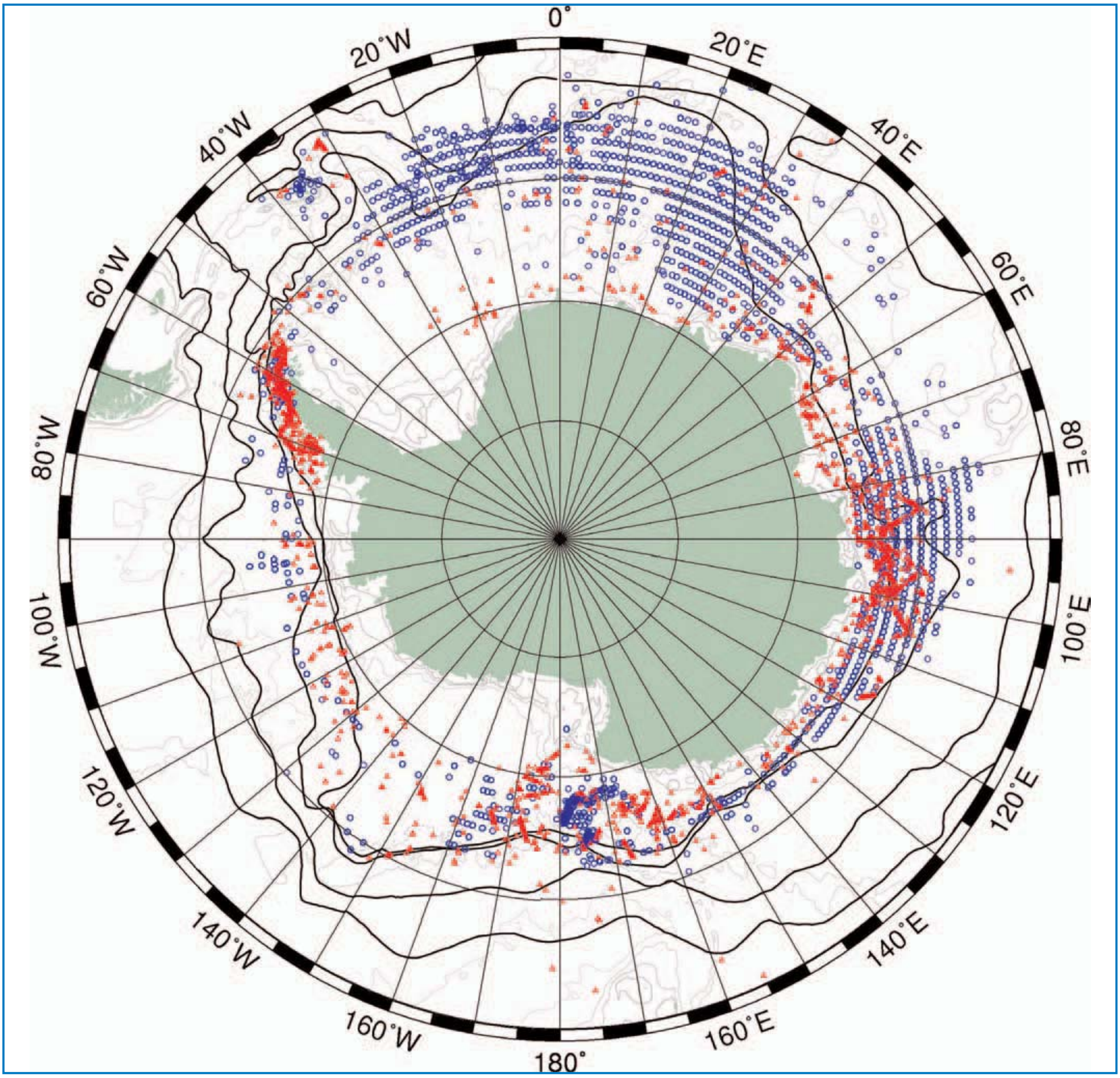

Figure 3. Circumpolar distribution of humpback whales constructed from IWC catch data (blue circles) and data from research programs undertaken in the last 30 years (red triangles). The climatological distribution (Orsi et al. 1995) of the fronts associated with the Antarctic Circumpolar Current (ACC) are shown by the solid lines and are (north to south) the Subantarctic Front, Polar Front, Southern ACC Front and Southern ACC Boundary.

studies. The whale observations were taken concurrently with a comprehensive suite of marine science sampling programs, covering the physical environment, prey distribution and abundance and many other environmental parameters. Additionally arrays of passive acoustic moorings were deployed along the west Antarctic Peninsula to provide information on whale distribution by acousticians from Scripps Institute of Oceanography.

These data sets allow a unique view of baleen whale biology and ecology in Antarctic coastal waters. Combining these recent data with existing historical data sets on Southern Ocean whale abundance and distribution provides an extensive basis for understanding processes controlling whale distribution and abundance and for the development of future Southern Ocean whale studies.

To facilitate the start of synthesis, integration and modelling studies based on these data sets, a joint IWC-SO GLOBEC workshop on Cetacean-Environmental Linkages was held from 2–4 November 2005 at the Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, VA. The objectives of the workshop were to: 1) identify needs for the next generation of surveys/field work in the Southern Ocean and Antarctic waters; 2) develop sampling plans and strategies for whale research; 3) develop a concept paper on future directions for Southern Ocean whale-ecosystem studies; and 4) develop collaborative modelling and research projects.

The workshop was attended by 12 scientists (Fig. 2), representing the research areas of whale biology and ecology, seabird ecology, sea ice processes, acoustic sampling for whales, prey distributions, circulation processes and modelling, and ecosystem modelling. There was a strong focus on including doctoral students currently working in these fields. The workshop began with overview presentations of the current research in each of these areas. Following the presentations, the workshop discussions centered on data analyses and modelling studies.

Considerable discussion was focused on the adequacy of the existing data sets to support the development of ecosystem-based models, the adequacy of existing models for understanding ecosystem linkages and processes that are of importance to whales and approaches for melding the data sets and models. A general consensus emerging from these discussions was that the physical and biological processes that underlie the observed distribution and abundance of Southern Ocean whale populations are still relatively unknown. Therefore, in order to move forward from correlative models to predictive models, a high priority was placed on designing analyses of historical and recent data sets that define linkages and relationships that underlie circumpolar whale and environmental distributions, and provide insights into responses of different whale species and stocks to habitat variations (Fig. 3).

It was noted that all current Southern Ocean baleen whale populations have been depleted or reduced to some extent by whaling (commercial and scientific) and that depleted populations are likely distributed differently from when in their non-depleted states. Thus, understanding the effects of exploitation of Southern Ocean whale stocks was recognised as an important factor that needs to be accounted for in any data interpretation, especially for historical data sets and inferences derived from the present occurrence and distribution of whales need to made within the context of this major influence. Distinguishing between the synergistic effects of depletion of whale stocks from whaling versus those arising from a changing environment in a core habitat was considered to be a critical issue.

One suggested approach for including this effect is to evaluate habitat and prey use patterns using a "basin model" approach (MacCall, 1990), which views habitat quality as a basin or sink, with best conditions (e.g. highest energy content prey in densest, most accessible concentrations) in the deepest area and marginal conditions on the edges. Depleted populations are expected to contract to the deepest parts of the basin. Less depleted populations would be more widespread and less could be inferred from their distributions regarding quality of habitat in the same areas.

The "basin model" was suggested as an approach for determining the best quality habitat that defines the preferred range of Southern Ocean whale species. Example studies that would help define the basin concept for Southern Ocean whales are: understanding why minke and blue whales associate with ice edges and why fin whales are removed from ice edges, and understanding the relationship between minke and humpback whales and their relationship to characteristics of krill patches. Results from studies such as these will also provide a basis for development of predictive models of whale distribution and abundance.

The potential effects of climate variability on prey distribution and availability and habitat were discussed in terms of modifications to the basin concept. The response of individual whale species and stocks to temporal and regional changes in habitat was considered to be an integral component of defining the implications of environmental variability for Southern Ocean whale conservation.

Recommendations from the workshop focused on development of a suite of data products designed to facilitate study of whale-environmental linkages, the development of ecosystem-based models for whale studies and the development of field sampling approaches for whales that will result in data products for predictive modelling that can be incorporated into future Southern Ocean studies. This latter recommendation provides a basis for developing a framework that can be incorporated in to future programs, such as the Integrated analyses of circumpolar Climate interactions and Ecosystem Dynamics in the Southern Ocean (ICED) Program (Murphy *et al.*, 2006). The recommendations from the workshop are being summarised in a report and are the basis for a concept paper that is in preparation. The workshop and its results are a contribution to the synthesis and integration phase that is now underway as part of the larger US and International GLOBEC programs.

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GLOBEC

CLimate impacts on Oceanic TOp Predators

CLimate Impacts on Oceanic TOp Predators (CLIOTOP) activities: Working groups, 1st Steering Committee and participation to the 13th Ocean Science meeting, 20–24 February 2006, Hawaii, USA

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The GLOBEC regional program CLIOTOP held its first steering committee meeting in Hawaii, from 27 February to 1 March 2006. The SC meeting was held back to back with the 13th Ocean Sciences Meeting jointly organised by the American Geophysical Union (AGU), the American Society of Limnology and Oceanography (ASLO), The Oceanography Society (TOS) and the Estuarine Research Foundation (ERF) at the Hawaii Convention Center (http://www.agu.org/meetings/os06/). Three CLIOTOP Special Sessions were organised during the OSM.

Proposing CLIOTOP sessions in this large audience symposium covering a wide-range of topics in physical, biogeochemical and biological oceanography was a good opportunity to increase the interest and potential interactions between these communities and the biologists, fisheries oceanographers and modellers involved in CLIOTOP. One oral and one poster session were organised as well as a special event called a "Town Hall meeting" which aimed at a more general presentation of the program. Cisco Werner, chair of the GLOBEC SSC, presented the general structure of GLOBEC, its organisation and the objectives of the synthesis and integration phase. Olivier Maury, co-chair of CLIOTOP provided a detailed description of CLIOTOP scientific objectives, structure and rules of functioning.

The following discussion with the participants quickly focused on funding and project affiliation issues. It was indicated that CLIOTOP, as with many other international collaborative projects, does not provide direct funding for research projects but is actively investigating potential funding sources (in addition to the support provided by GLOBEC) to organise collaborative activities, such as workshops, symposia and publications. The CLIOTOP SC will also promote the CLIOTOP program goals to be endorsed officially by several national and international funding bodies with interest in this area. Such recognition is expected to increase the chance of success of research proposals affiliated to CLIOTOP which are seeking funds. Furthermore, affiliation to CLIOTOP provides an additional value by enabling collaborative and comparative analyses to be conducted within the working groups of the program. Participants of the project involved in working groups participate in internationally acknowledged research efforts, access innovative approaches, data and techniques, develop and use standardised methods and increase opportunities of collaborative publications through review papers and synthesis books.

Figure 1. Cisco Werner (chairman of the GLOBEC SSC) presenting the GLOBEC synthesis phase during the CLIOTOP "Town Hall Meeting" of the OSM and Olivier Maury (co-chair of CLIOTOP) on his right.

To be affiliated to CLIOTOP a project needs to address at least one key question

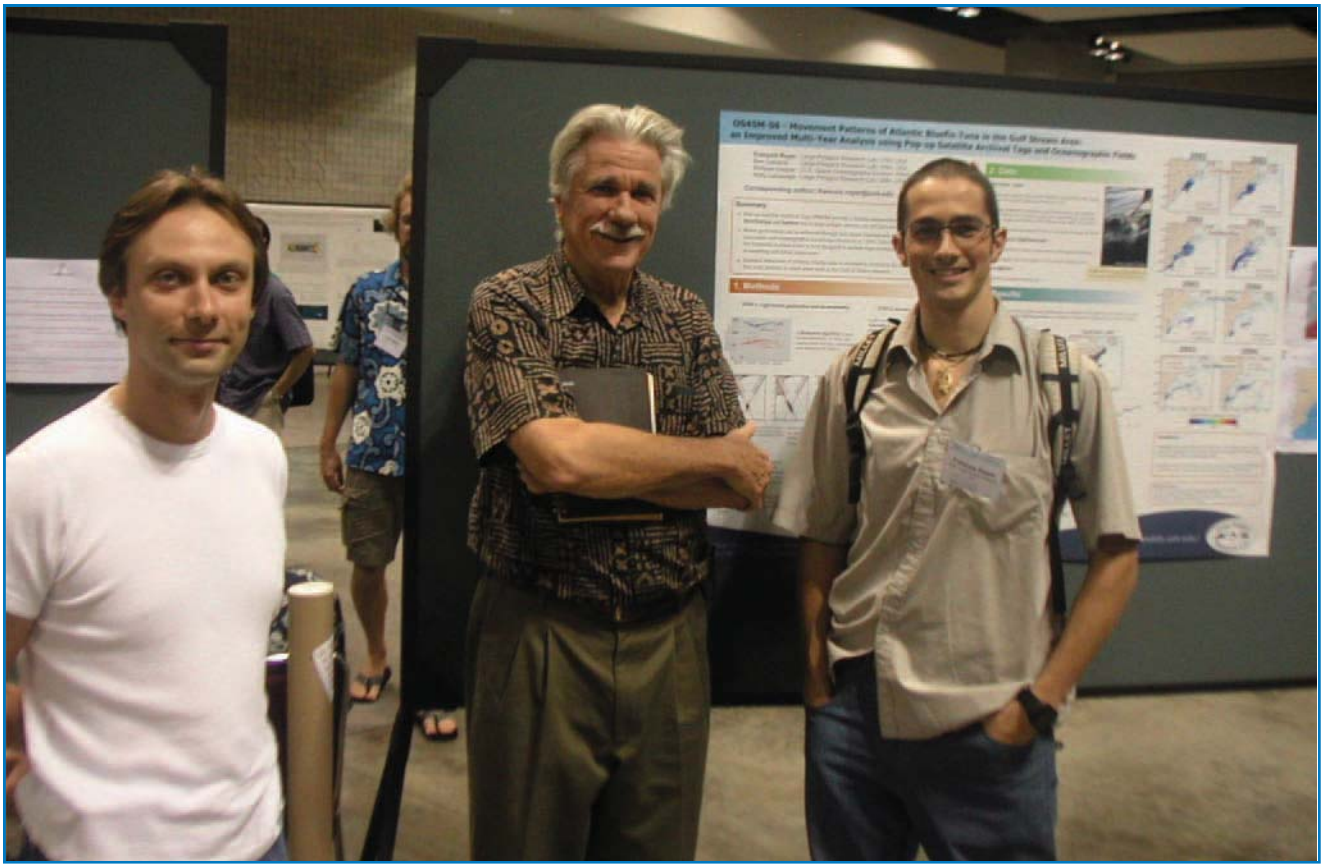

Figure 2. John Sibert (manager of the PFRP program in Hawaii and member of the CLIOTOP SC) discussing with two post-doctoral students (Anders Nielsen on the left and François Royer on the right) during the CLIOTOP Poster Session of the OSM.

Figure 3. Some of the presenters of the CLIOTOP Oral Session of the OSM discussing with CLIOTOP SC members. From left to right: Patrick Lehodey, Gary Sharp, Brittany Graham, Dan Costa, Olivier Maury, Alistair Hobday, Francis Marsac and Raghu Murtugudde (behind).

identified in the Science Plan, to participate in comparative approaches developed through the WG activities, to agree with the data sharing policy of CLIOTOP, to provide a short annual activity report to the SC and to acknowledge CLIOTOP affiliation in presentations and publications. Projects or proposals requiring affiliation must submit a summary of their objectives and planned activities to the CLIOTOP SC. After a confidential review to check the relevance of the project to CLIOTOP and the fulfilment of affiliation criteria, participation in WG activities will be proposed to the project participants. The list of criteria required for affiliation will soon be posted on the CLIOTOP website.

The poster session, on Thursday afternoon, included 14 posters. It aroused the interest of many participants as demonstrated by the numerous questions directed at the authors until the very last minutes of the session. On Friday morning, the special CLIOTOP oral session consisted of 6 presentations of 15 minutes each and also reached a large audience. The high quality talks covered a variety of topics, providing a good overview of all aspects that CLIOTOP is encompassing.

Finally, these three events organised during the OSM have been felt by the attendees to be very successful in extending the interest of CLIOTOP to the diverse communities of marine sciences.

Members of the CLIOTOP Scientific Committee met together for the first time at the East-West Center of the University of Hawaii at Manoa, with the generous support of the Pelagic Fisheries Research Program PFRP (http://www.soest.hawaii.edu/PFRP/).

CLIOTOP Scientific Committee:

Dr Patrick Lehodey, CLIOTOP co-chair
CLS, MEMMS, France

Dr Olivier Maury, CLIOTOP co-chair
IRD, CRH, France

Dr John Sibert
PFRP, University of Hawaii, USA

Dr Yuji Uozumi
NRIFSF, Japan

Dr Molly Lutcavage
University of New Hampshire, USA

Dr Heidi Dewar
IATTC, USA

Dr Sung Kwon Soh
Ministry of Maritime Affairs and Fisheries, Korea

Dr Raghu Murtugudde
ESSIC, University of Maryland, USA

Dr Shiham Adam
Marine Research Centre, Ministry of Fisheries, Agriculture and Marine Resources, Maldives

Dr Kathleen Miller
ISSE, National Center for Atmospheric Research, USA

Dr Alistair Hobday
CSIRO Division of Marine Research, Australia

Dr Henry Weimerskirch
CEBC-CNRS, France

The agenda of this first meeting presented an impressive list of tasks. The SC first discussed the long term timelines for the CLIOTOP program and decided that the general framework summarised in Figure 5 should serve as a guideline for the project development and the Science Plan implementation. This framework has of course to be seen as a 2006 perspective and it will be modified and updated according to the program development.

Past and future activities of the 5 working groups were reviewed. Among the main highlights, it is worth noting that WG 1 (Early life history) published the report of its last workshop that was held in Malaga, Spain, in October 2005 with the support of the Spanish Institute of Oceanography (see CLIOTOP website: http://www.pml.ac.uk/globec/structure/regional/cliotop/publications.htm). Future activities that the WG would like to promote include:

- investigation of the effects of mesoscale patterns on spawning habitats using satellite and field studies data,
- a comparative study of bluefin tuna spawning grounds in the three oceans,
- development of new techniques for calibrating growth and mortality of larvae,
- modelling larval production.

WG 2 (Physiology, behaviour and distribution of top predators) is planning a workshop in Sète, France with a provisional date of 12–15 December 2006 and WG 3 (Pathways in the open ocean pelagic ecosystems) also proposes to organise a workshop in September 2006 in Nouméa, New Caledonia, with

Figure 4. Seven of the twelve members of CLIOTOP SSC during their first meeting at the University of Hawaii. From left to right: Dr Kathleen Miller (NCAR), Dr John Sibert (PFRP), Dr Heidi Dewar (IATTC), Dr Patrick Lehodey (CLS), Dr Olivier Maury (IRD), Dr Alistair Hobday (CSIRO), Dr Molly Lutcavage (UNH).

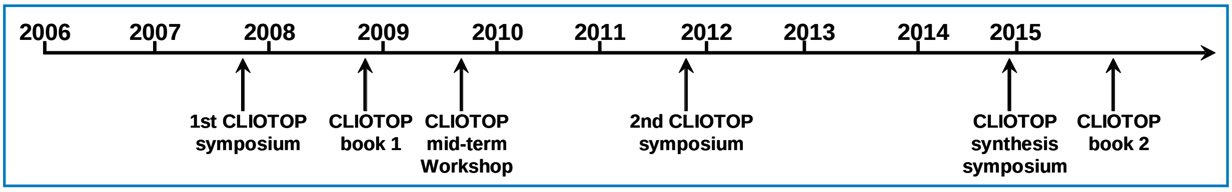

Figure 5. Long term timelines for CLIOTOP.

the objective of developing, updating and comparing trophic models of large pelagic marine ecosystems.

WG 4 (Modelling and synthesis) held its last workshop at the Southwest Fisheries Science Center's (SWFSC, US National Marine Fisheries Service) La Jolla Laboratory during 8–10 November 2005 (report on the CLIOTOP website). Most of the time was spent outlining two research proposals. The first proposal addresses most of the elements in the work plan that was originally proposed during the first WG4 meeting in Hawaii, i.e. comparative analyses of hindcasts produced by the two spatial ecosystem models SEAPODYM and APECOSM. The objective of this proposal is to understand how climate variability at various scales propagates up to top predators and to determine whether inter-basin differences in the environment explain most of the observed differences in the dynamics of tunas (albacore, bigeye, skipjack and yellowfin) in the Atlantic, Indian and Pacific Oceans. The second proposal addresses a separate element of the work plan that was originally proposed in Hawaii and the Working Group's desire to expand the scope of its work by considering top predators other than tunas. It outlines a research plan to study how climate affects the association of tunas, dolphins and seabirds.

WG 5 (Socio-economic aspects and management strategies) is investigating the evolution of harvesting efforts and the development and functioning of international fishery management organisations. The main issues and trends in marine fisheries are the growing demand for fish, the increasingly sophisticated technology/gear and the race for fish fuelled by common pool nature of resource and government subsidies, resulting in an intense harvesting pressure producing economic and biological damage, substantial levels of bycatch and discards, illegal, unregulated, unreported (IUU) fishing and excess capacity leading to ecologically damaging practices. Funding was obtained to organise a large workshop on "Climate, Uncertainty and Multilateral Management of Harvested Highly-Migratory Marine Fish Stocks" that will take place in Santa Barbara, USA, in July 2007. This meeting should lead to a special issue of a scientific journal.

Another central issue discussed during the SC meeting was the organisation of the first CLIOTOP symposium in 2007. A tentative date of 3–7 December 2007 is proposed and the definitive date and venue will soon be advertised. The symposium should be another large step forward in building up the CLIOTOP community.

For more information, contact Patrick Lehodey (PLehodey@cls.fr) or Olivier Maury (maury@ird.fr). Reports of working groups and steering committee meetings are published on the CLIOTOP website: http://www.pml.ac.uk/globec/structure/regional/cliotop/cliotop.htm

Update of the Ecosystem Studies of Sub-Arctic Seas (GLOBEC-ESSAS) regional programme

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The goal of the ESSAS Regional Programme of GLOBEC is *to compare, quantify and predict the impact of climate variability and global change on the productivity and sustainability of sub-Arctic marine ecosystems*. Geographically, it includes the northern North Pacific (the Sea of Okhotsk, the Oyashio system, the Bering Sea) and North Atlantic (Hudson Bay, the Gulf of St. Lawrence, Labrador/Newfoundland region, Greenland shelves, Icelandic region, the Nordic Seas and the Barents Sea). The program developed because (1) marine populations of several Sub-Arctic Sea ecosystems have shown unexpected changes in abundance or distribution that, in many cases, correlate with physical variability; (2) these areas are predicted to experience the largest temperature changes under anthropogenic forcing other than the high Arctic and (3) climate-forced changes in these systems will have major economic and societal impact because they support stocks of commercial fish that generate a major portion of the fish landings of the nations bordering them.

Following acceptance of ESSAS as a Regional Programme in 2005 by GLOBEC's Scientific Steering Committee (SSC) and publication of its Science Plan (Hunt and Drinkwater, 2005), an ESSAS SSC was established that presently consists of 12 scientists from 7 countries representing 8 Sub-Arctic regions. As one of the "new kids on the block", ESSAS is not quite ready to undertake a full integration and synthesis, however, the idea of synthesizing existing knowledge of ecosystem processes is at the forefront of ESSAS even now. Below are some of the activities within ESSAS.

Initial symposium

As a kick-off to the ESSAS program, a highly successful multi-national Symposium on the Effects of Climate Variability on the Ecosystems of Sub-Arctic Seas was held in May of 2005 in Victoria, British Columbia, Canada. One of the purposes of the Symposium was to review and synthesize what is known about the ecosystems of different Sub-Arctic Seas and especially their responses to climate variability. The symposium also presented recent research results, including a session devoted to the human dimension aspects of climate change, and provided the opportunity for an exchange of ideas between researchers from different disciplines and different Sub-Arctic seas. Further details on the Symposium can be found in the last GLOBEC Newsletter (Vol. 11(2), p.14–17). Progress in Oceanography agreed to publish the proceedings. A total of 54 papers were submitted with 40–45 expected in the dedicated Symposium volume, which is scheduled to be published before the end of 2006. This volume will provide a benchmark to gauge future progress within ESSAS.

Immediately following the Symposium, a 1-day ESSAS Implementation Workshop was held. Eighty-seven registered participants from 11 nations (Canada, China, Germany, Greenland, Iceland, Japan, Norway, Poland, Russia, UK, US) attended the workshop, underscoring the science community's interest in the ESSAS programme and the study of Sub-Arctic seas in general. They provided input and guidance on the ESSAS Implementation Plan. The first ESSAS SSC meetings were also held, two during the Symposium and one after the Workshop to discuss and plan the ESSAS implementation.

Establishment of Regional ESSAS Programs

One of the first aims in the ESSAS implementation plan was to establish regional programs in each of the Sub-Arctic Seas with emphasis on (1) determining the external forcing functions linking climate processes to the physical oceanography of the Sub-Arctic Seas and (2) the response of the ecosystem to the variability in climate. Although the effect of climate is the primary focus, it is recognised that major impacts to the ecosystem are also imposed directly by humans through harvesting and hence an important aspect of the work will be to determine the relative importance of climate forcing compared to fisheries or internal ecosystem dynamics as well as the interaction between climate and fishing. Some regional Sub-Arctic programs influenced by the ESSAS ideas have already been established.

In recent years weather patterns over the Bering Sea have led to a sharp reduction in seasonal sea ice, and much of the southern portion of the eastern shelf has experienced little or no sea ice. As a consequence, water column temperatures are rising sharply, stratification is increasing, and there appear to be major changes in the zooplankton community from a system dominated by cold-water, arctic species to a temperate system. Jellyfish populations have come and gone and there have been dramatic declines in seal and sea lion populations, as well as salmon runs in western Alaska. The Bering Ecosystem Study (BEST) was established to better understand the processes through which climate affects the marine ecosystems of the eastern Bering Sea in order to predict possible future changes. BEST is complemented by a closely associated social science program on the human dimension of ecosystem change. In September 2005, the US National Science Foundation Office of Polar Programs released an Announcement of Opportunity that included a call for proposals for work within BEST, which would see field studies from March to June 2007 through 2009, with an additional year for synthesis and writing of papers. Over forty proposals were received by the December "deadline", and the ratio of funds requested to funds available was about four to one. It is expected the funding decisions will be made by July 2006. The BEST SSC felt that the highest priority would be to investigate the role of seasonal sea ice in setting up the Bering Sea ecosystem and in determining the amount, timing and fate of the spring bloom. The Implementation Plan for BEST therefore called for work commencing about 15 March each year and continuing through 30 June, with an icebreaker working within the pack ice from March through late-April, and an ice-strengthened vessel working the open water and ice edge from mid-April to the end of June.

The Barents Sea contains a large cod population. With the region expected to undergo extensive warming under climate change, Norway is concerned about the possible implications for this valuable fish resource. One of the results was that the Research Council of Norway funded the Norwegian component of ESSAS (NESSAS) whose objective is to quantify the impact of climate variability on the structure and function of the Barents Sea marine ecosystem in order to predict the ecosystem response to possible future climate change and its possible economic impact. The latter includes not only predictions on the effects of fish production on the value of the species and the potential employment opportunities but also the possible effects of distributional shifts on Norwegian-Russian fish treaties. A major aspect of NESSAS is to undertake comparisons of ecosystem responses to climate variability with other Sub-Arctic Seas. NESSAS will run from 2005–2008 and is primarily a combination of retrospective analyses and modelling studies.

Recently, capelin off Iceland have shifted their distribution northwards, most likely in response to the observed warming conditions. This fish stock is extremely important to Iceland, not only because of a directed fishery but it is also the primary food source for adult cod, the main demersal species in Icelandic waters. Furthermore, capelin is a major food constituent for other predators, such as Greenland halibut, saithe, seabirds and whales. Wanting to understand what might happen to capelin stocks in the future, Iceland has established a 4 year research study, the Iceland Sea Ecosystem Programme, focusing on this species. The aim of the programme is to quantify the environmental and biological factors that determine the distribution and production of capelin in order to enable better forecasting of the development of the stock in a varying environment. Ecosystem surveys that include work on physical oceanography, chemistry, phytoplankton, zooplankton and capelin began this year in the region between Iceland, Greenland and Jan Mayen, with more scheduled in later years. At that time, it is also planned to include components on seabirds and marine mammals into the programme.

Other ecosystem studies of interest to ESSAS, and whose scientists have expressed interest in joining ESSAS, include Russian research on the Barents and Bering Seas and the Sea of Okhotsk, by Japan and Korea in the Sea of Okhotsk and Japan in the Oyashio, by Canada in the Labrador Sea, Hudson Bay and the Gulf of St. Lawrence, by Greenland/Denmark off West Greenland, and several others.

Comparative programs

A major emphasis and undertaking of ESSAS is comparative analysis between Sub-Arctic Seas as a means to gather

Animation showing sea ice cover over the Arctic on March 11, 2005, derived from AMSR-E. Perennial arctic sea ice is decreasing at a rate of 9% per decade since the 1970s. Dwindling sea ice has direct impacts on the ecology of sub-arctic ecosystems. Visualisation courtesy of NASA/Goddard Space Flight Centre Scientific Visualization Studio.

insights that could not be achieved within the regional studies alone. One such program underway is the Norway-Canada Comparison of Marine Ecosystems (NORCAN), for which the Research Council of Norway and Fisheries and Oceans Canada in St. John's, Newfoundland, provided seed money to develop proposals for a new multi-year research programme that could then be submitted to the two nations for funding. A workshop was held on 5–7 December 2005 in Bergen, Norway, that discussed potential foci and the nature of the comparisons between the two regions. In addition, several comparative papers that could be started in the near future were identified along with potential authors including ones on physical forcing of the two regions, the response of primary production to climate variability, zooplankton ecology, capelin and cod, and marine mammals. A second Workshop will be held in St. John's in May 2006 to complete the project with a report due in June.

International Polar Year (IPY)

The IPY is meant to generate concentrated field activities which will take place during March 2007 – March 2009. On behalf of ESSAS, an Expression of Intent (EOI) was submitted to the IPY Office in January 2005, and was subsequently selected by the IPY Joint Committee as a "lead project". Currently, we have fifteen projects (EOIs) that are integrated under the ESSAS led ESSAR (Ecosystem Studies of Subarctic and Arctic Regions). ESSAR addresses how climate variability and change affects the marine ecosystems of the polar (Subarctic and Arctic) seas and their sustainability. It includes scientists from 12 nations and covers all of the ESSAS area as well as a significant portion of the Arctic. Field studies on physics, plankton, benthos, fish and shellfish, marine mammals, sea birds and the human dimensions will be carried out in the Atlantic, Pacific and Arctic Oceans during 2007–2008. We expect that participation in IPY activities will help catalyse funding for national ESSAS programs and provide increased resources for field studies within the ESSAS region and beyond.

ESSAR will assemble historical data on the physical oceanography and collect new data to fill in critical gaps in our knowledge, such as moored current measurements in the Davis Strait-Hudson Strait-Labrador Shelf region. Results from past and present studies will be assembled to document distributional shifts of several marine species from plankton to marine mammals and seabirds. The relationship between thermal heating of the waters and changes in ice coverage, including various feedback mechanisms, will be explored through new field studies.

Nutrient, chlorophyll, ice algae, chemical tracers, phyto-plankton and zooplankton measurements will determine the effect of ice decline on biological processes. An important change following the reduction in ice will be an increase in light levels. Detailed studies of the role of light levels on primary and secondary production along the latitudinal gradients from 45°N to near the pole will determine how light levels and day duration modify ecosystem function. The effects of water mass transformations on plankton production will be compared and contrasted with the effects of sea ice and light to determine their relative importance.

Our understanding of the sources and variability in zooplankton and their role in the food chain varies regionally. Data are relatively scarce in the Labrador Sea, therefore, under ESSAR, concentrated zooplankton studies, especially on *Calanus finmarchicus*, will be carried out. Field-based studies will also focus on the effects of the physical variability on the energy flow through Arctic and Sub-Arctic marine food webs from plankton through fish to marine mammals and seabirds, e.g. in the Barents Sea, the Norwegian Sea, Lancaster Sound and Hudson Bay. From the human perspective, certain marine species are more important than others because of their commercial or subsistence values. The physical environment also influences these species, but our understanding of the mechanisms is limited.

One of the most important commercial species in the Northwest Atlantic is shrimp (*Pandalus borealis*), therefore, studies of the role of physical oceanography and biological production cycles in recruitment, abundance and distribution of shrimp will take place in Davis Strait, off West Greenland, on the Labrador Shelf and in the Gulf of St. Lawrence. At the upper ends of the food web, marine mammals and seabirds will be affected by changes in the lower ends. Studies will determine the role of changes in sea ice and warming waters on marine mammal fitness, including whales, walruses, seals and polar bears.

Seabirds respond relatively quickly to changes in their prey and can often be monitored relatively easily compared to their prey in the marine environment. ESSAR, through the Circumpolar Seabird Group (CBird) and the members of Conservation of Arctic Flora and Fauna (CAFF), will monitor how changes in productivity of Arctic and Sub-Arctic seas affect circumpolar seabird populations. Seabird diet studies will also be carried out and compared with similar studies conducted in the 1970s and 1980s as a means of detecting if and how the marine ecosystem has changed. Detailed studies in the smaller region of Svalbard will also be carried out to investigate the changes in seabird community structure as a function of temperature and zooplankton. The effects of these changes to the bird community on the terrestrial ecosystem through the guano deposited back on land will also be part of this study.

Finally, comparisons between the results from the various geographic regions will be an important component of ESSAR.

Funds for these projects must come from national funding agencies. Several of the countries have initiated calls for IPY proposals and proposals under ESSAR have been submitted or are in the process of being written. It is hoped that significant numbers of these will be funded.

St. Petersburg Workshop

An ESSAS Workshop to compare the marine ecosystems of the Okhotsk Sea/Oyashio region, the Bering Sea, the Newfoundland/Labrador Shelf and the Barents Sea will be held on 12–14 June 2006 in St. Petersburg, Russia. Co-sponsored by PICES and GLOBEC, the goals of the workshop are: 1) to lay the groundwork for developing the data sets needed to achieve the appropriate comparisons and, 2) to commence developing the teams necessary to synthesise available data and develop models for predicting the effects of climate variability on these ecosystems. While several synthesis products are available and provide an excellent compendia of information about a particular sub-Arctic ocean basin, few have explicitly compared mechanisms and responses to climate forcing across basins or between Atlantic and Pacific systems.

If the comparative method is to be used successfully, it will be necessary to identify important underlying structuring features of the ecosystems and how climate forcing, acting on those mechanisms, will result in ecosystem change. It will also be necessary to develop data sets that can be used in predictive modelling efforts. These data sets will have to be sufficiently closely aligned that inter-regional comparisons will be fruitful. Although all systems are unique, there must be a search for basic elements common to many, if not all, that can be usefully employed in a comparative approach. It is expected that the ESSAS St. Petersburg Workshop will also, through its review of the existing syntheses of North Pacific data sets and comparisons with data from North Atlantic systems, provide a solid basis for the development of revisions and updating of the first version of the PICES North Pacific Ecosystem Status Report.

Following the Workshop the SSC will meet to further discuss how to advance the programme and to plan the necessary activities in the coming years in order to achieve the ESSAS objectives as laid down in the Science Plan

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summer school

Towards ecosystem oceanography:

Identification and modelling of controls in marine ecosystems

18-28 June 2006, Dragerup field station, Denmark

Overview

Acknowledging that the major scientific gaps concerning the development of an Ecosystem Approach to Marine Resources (EAMR) lie in our understanding of species interactions and their link with climate and other environmental factors, this course focuses on controls in marine ecosystems. It covers:

- the detection and quantification of species interactions and the impact of climate, using long time series;
- the modelling of controls and ecosystems dynamics using: (a) individual-based models (IBM); (b) size spectra and size-based models; and (c) mathematical network models.

Course details

The programme will include:

- Introduction (Dr Philippe Cury, IRD, France; leader of the EAMR/WP6 group within EUR-OCEANS; organiser);
- Time series analyses (Prof. Nils Stenseth, University of Oslo, Norway);
- Size-spectra and life history invariants (Prof. Henrik Gislason, Danish Institute for Fisheries Research, Denmark; organiser);
- Networks models in ecology (Dr Christian Mullon (IRD, France);
- Individual Based Models and ecosystem models (PD Dr Volker Grimm (UFZ Centre for Environmental Research Leipzig-Halle, Germany).

Audience

The course is primarily intended for young researchers at the PhD or postdoctoral stage in their careers and whose institution is a member of one of the funding organisations. However, applications from other international candidates (including confirmed researchers and practitioners, as well as researchers whose institutions are not related with the funding organisations) will be considered.

Prerequisites

Previous knowledge in ecological modelling and basic skills in programming.

Course website

For more details about the course please see the course website at http://www.eur-oceans.org/eamr/school/

Practical information

Information will be posted in due time on the course website. Dragerup is a field station situated in a forest at the waterfront of Isefjorden and is a one-hour drive from Copenhagen airport.

A EUR-OCEANS summer school
co-organised by SLIP/Fishnet
endorsed and sponsored by GLOBEC

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GLOBEC and PICES to sponsor workshop on sub-Arctic seas

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The North Pacific Marine Science Organization (PICES) and the International Project Office of GLOBEC will jointly sponsor a workshop to compare four Sub-Arctic marine ecosystems, those of the Okhotsk Sea/Oyashio region, the Bering Sea, the Newfoundland/Labrador Shelf and the Barents Sea. The workshop will be held in St. Petersburg, Russia from 12 to 14 June 2006 and will provide a foundation for the new GLOBEC regional program, Ecosystem Studies of Sub-Arctic Seas (ESSAS). The aim of ESSAS is to develop an understanding of how climate variability, at a number of temporal scales, will influence the sustainable productivity of the sub-Arctic seas.

PICES and ESSAS share the goal of developing comparative studies of the sub-Arctic seas and understanding how climate variability will affect their productivity and ability to support sustainable commercial and subsistence harvests. The goals of the workshop will be: 1) to lay the groundwork for developing the data sets needed to achieve the appropriate comparisons and, 2) to commence developing the teams necessary to synthesize available data and develop models for predicting the effects of climate variability on these ecosystems.

It is expected that the workshop will build upon extant syntheses and on-going and planned synthesis efforts. For example, the syntheses in the PICES North Pacific Ecosystem Status Report and the ESSAS Science Plan and the Appendix to the ESSAS Science Plan that assembled data from each of the sub-Arctic seas should provide much basic information. Additionally, papers such as those by Aydin *et al*. (2002) examining the similarities and differences between the eastern and western Bering Sea, Hunt and Megrey's (2005) comparison of the Bering and Barents Sea ecosystems and the recent work by Ciannelli *et al*. (2005) comparing the Barents Sea and the Gulf of Alaska systems will provide a solid basis for moving forward with the analyses of these ecosystems.

The workshop will also take advantage of advances made in a planned PICES Climate Forcing and Marine Ecosystem Response Task Team workshop in January 2006 on developing indices for North Pacific comparisons, and the results of workshops in the Norwegian funded program, Norway-Canada Comparisons of Marine Ecosystems (NORCAN), to be held in the autumn of 2005 and the late spring of 2006. The NORCAN workshops will develop specific plans for comparisons between the Barents Sea and the Labrador Shelf, including the use of biophysical models, and will initiate research on physical forcing, zooplankton dynamics and climate impacts on fish populations in these sub-Arctic seas.

Many of the synthesis products available to date have provided excellent compendia of information about a particular sub-Arctic ocean basin, but few have explicitly compared mechanisms and responses to climate forcing across basins or between Atlantic and Pacific systems. If the comparative method is to be used successfully, it will be necessary to identify important underlying structuring features of the ecosystems and how climate forcing, acting on those mechanisms, will result in ecosystem change. It will also be necessary to develop data sets that can be used in predictive modelling efforts. These data sets will have to be sufficiently closely aligned for inter-regional comparisons to be fruitful. Although all ecosystems are unique, there must be a search for basic elements common to many, if not all, that can be usefully employed in a comparative approach.

The proposed Workshop will be a significant step in achieving the goals of the CFAME task team in PICES of putting "Particular emphasis on testing ecosystem-level hypotheses, through review and examination in a collaborative environment, of (i) comparisons between regional and/or basin ecosystems, (ii) linkages in time, space, or seasonality between climate and ecosystems and (iii) responses of regional ecosystems to basin-scale forcing." The Workshop will, through its review of the existing syntheses of North Pacific data sets and comparisons with data from North Atlantic systems, provide a solid basis for the development of revisions and updating of the first version of the PICES North Pacific Ecosystem Status Report.

The workshop will consist of very few talks about the different regions on the first day and then a series of discussions, some in breakout groups, focusing on the mechanisms by which climate variability affects the sub-Arctic seas. To promote open discussions, the number of participants will be limited.

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North Atlantic climate impact on Mediterranean plankton communities

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For a long-time there was little attention focused on the effect of climate variability on pelagic populations in the Mediterranean basin, even though the Mediterranean is affected by both subtropical and temperate climatic modes. Considered as a model for many open ocean processes, the Mediterranean Sea is a particularly interesting zone to investigate the impact of climate on pelagic ecosystems. Understanding the links between large-scale climate patterns and the marine populations is therefore a necessary step to identify any change in the functioning of the Mediterranean marine ecosystem and to implement adequate policies to manage services arisen from it.

Here we introduce two recent findings on the impact of climate on pelagic copepods and jellyfish in the Western Mediterranean basin. Both copepods and jellyfish may play a key role in the temporal dynamics of small pelagic fish including European anchovy and sardine. Hence understanding how their year-to-year changes are controlled over long-time scales is necessary to develop prognosis models for fisheries management. These investigations were carried out under the framework of the project "Effects of global changes on marine and freshwater ecosystems in western Europe using plankton indicators" funded jointly by the Institut Français de la Biodiversité (IFB) and Gestion et Impact des Changements Climatiques (GICC) (APR 2003 N° 15-D; http://medias.obs-mip.fr/gicc/interface/projthem.php). The analysed time series take part of the monitoring program of pelagic communities performed by the Oceanography Laboratory of Villefranche since 1966 in the Ligurian Sea (NW Mediterranean) and is one of the longest for the Mediterranean basin. The investigated period spans from 1967 to 1993. Throughout the program a consistent sampling methodology has been maintained: vertical hauls of a zooplankton net (Juday-Bogorov 330 µm) from the bottom (80 m) to the surface. The sampling frequency and the plankton quantification techniques maintained throughout the observational period makes this time series an ideal tool to investigate links between climate and plankton variability.

The impact of the North Atlantic climate on plankton variability has been illustrated by i) the cascading effects linking climate at large, regional and local scales, and their consequences on copepod and jellyfish abundances (Molinero *et al.*, 2005a); and ii) the climate-driven phenological changes in two main copepods in the Mediterranean basin, *Centropages typicus* and *Temora stylifera* (Molinero *et al.*, 2005b).

These investigations documented the relationship between the North Atlantic climate variability and the NW Mediterranean. A downscaling approach showed that large-scale mechanisms connecting the two areas are linked to the processes governing long-term temperature forcing in the Northern Hemisphere (i.e. North Atlantic Oscillation, Arctic Oscillation and Gulf Stream North Wall; Molinero *et al.*, 2005a). Such climatic forcing mainly occurs during wintertime and drives moisture and heat fluxes, precipitation, sea level, wind intensity and water temperature over the Western Mediterranean (Send *et al.*, 1999; Trigo *et al.,* 2000; Fernandez *et al.*, 2003). Hence, climate alters hydrographic patterns through changes in atmospheric pressure and wind direction and intensity, whose effects further drive north-south shifts of the zonal storm-tracks and thus may reduce the intensity of the deepest Mediterranean cyclones (Trigo *et al.*, 2000). Subsequently, water flux in the Corsica Channel, from the Tyrrhenian (warmer) to the Ligurian basin (colder), varies according to the atmospheric conditions governing the North Atlantic sector (Vignudelli *et al.*, 1999) and is likely to affect the dynamics of mesoscale hydrological structures (i.e. strength of the Northern current, meandering in the limits of the Ligurian front).

In summary, the effects of the large-scale climate variability in the North Atlantic drive regional climate and hydrographic patterns and hence appear as a useful proxy for hydroclimatic conditions in the Ligurian basin, NW Mediterranean. Figure 1 (top panel) shows the tight link between climate at different scales: large (North Atlantic), regional (Ligurian basin) and local (Villefranche Bay). The consequences of the North Atlantic climate in the Ligurian basin led to a dominance of warmer and drier conditions, which strongly favoured the proliferation of jellyfish outbreaks throughout the 1980s. This enhanced predation pressure on copepods and modified the interplay between these functional groups leading to a drop in copepods during the late 1980s. The strength of the change in the interplay between copepods and jellyfish was highlighted by a stepwise change around 1987 (Fig. 1, bottom panel).

Regarding the link between North Atlantic climate in winter (as indexed by the NAO) and copepod abundance, Pearson product moment correlations showed significant links between time-series (residuals) of climate and the two species: $r = 0.43$ with $p < 0.01$ (*C. typicus*) and $r = -0.44$ with $p < 0.05$ (*T. stylifera*). The strength of the link was also evident over the low frequency variability of the time series, sorted by Eigen Vector Filtering (EVF). These results emphasized a remarkable synchrony of the long-term variations of NAO (PC1 43%), *C. typicus* (PC1 41%) and *T. stylifera* (PC1 45%; Fig. 2a and c). The timing of the seasonal peak appears further linked to such climate variability, however, again the two species showed opposite responses. The positive phase of the NAO, which largely dominated the late 1980s favoured the timing of the *C. typicus* peak to move forward (Fig. 2b), whereas during the same NAO state the peak of *T. stylifera* appeared delayed in time (Fig. 2d). The range of variability of the peak in the two species varies from

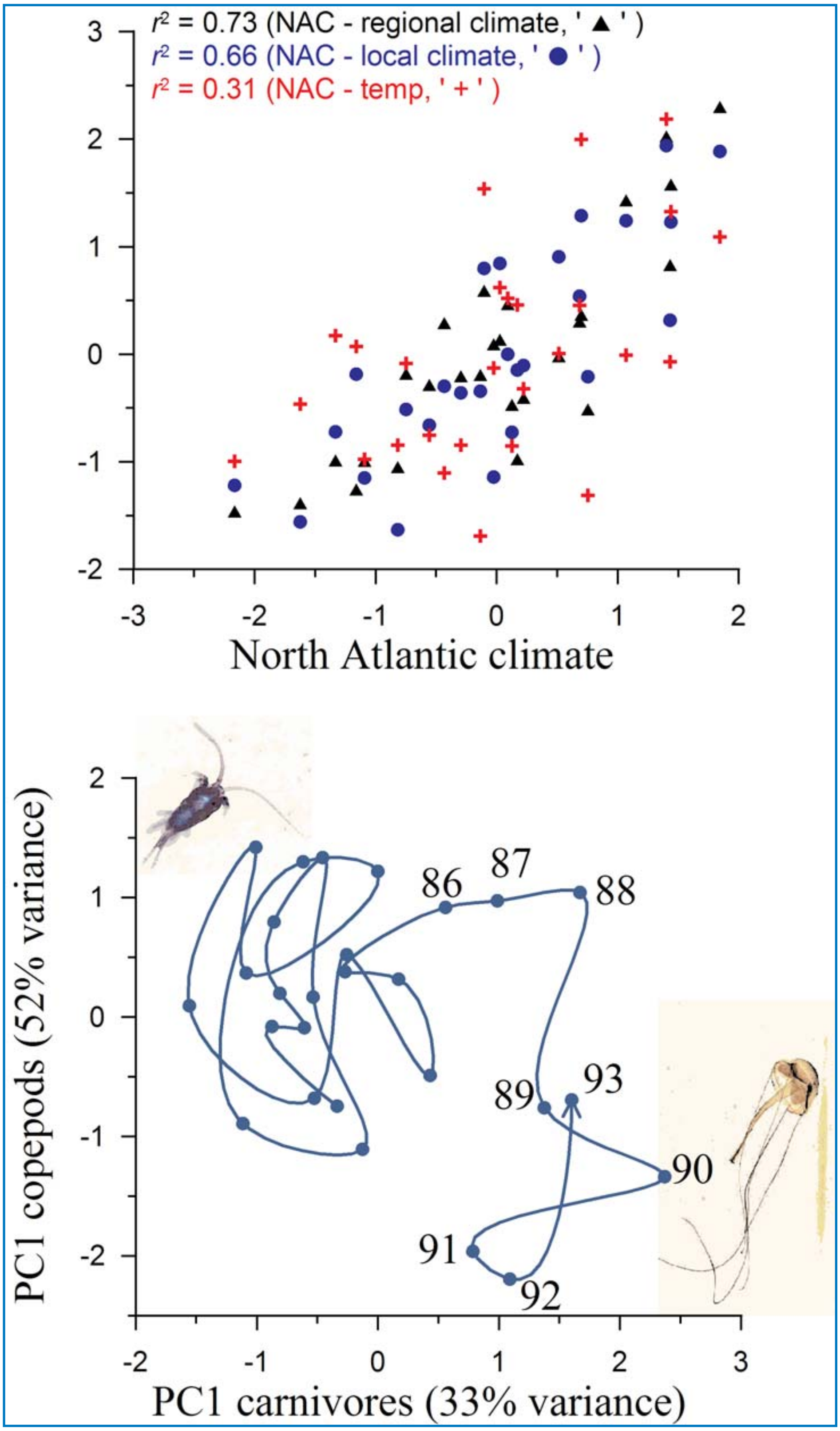

Figure 1. Top panel: dispersion diagram of the regional (Ligurian basin) and local climate (Villefranche Bay) variability, as well as water temperature against the North Atlantic climate. Bottom panel: variability of the relationship between copepods and jellyfish during the period 1967–1993. Each trophic group is represented by the first principal component (PC1). The dynamics observed during the years 1967–1985 shifted in 1986–1987, a period associated with higher positive temperature anomalies (modified from Molinero et al., 2005a).

March (during high NAO) to June (during low NAO) for *C. typicus* and from November (during high NAO) to July (during low NAO) for *T. stylifera*.

Clearly the most novel insight from these studies is the role of the North Atlantic climate variability as a valuable proxy for zooplankton variability in the Ligurian Sea. Furthermore, it has also become apparent what role the water temperature plays as mediator between large-scale climate and the interannual changes in zooplankton in the Ligurian Sea, whose effects shaped bottom-up and top-down controls. For instance, climate directly affected jellyfish, whose abundance was largely favoured by warm water temperatures and dry conditions and by subsequent water column stability. Conversely, climate affected copepods indirectly, through a higher predation pressure linked to the increase in jellyfish outbreaks. As shown here climate may change over time and lead to extreme changes in the interplay between trophic groups (i.e. copepods and jellyfish). Such extreme changes may be indicative of a major alteration in the functioning of the pelagic ecosystems (Fig. 1b), as has been observed in higher latitudes (Weijerman *et al.*, 2005). In addition, climate effects may further change between local populations. This was highlighted by the opposite responses of the two pelagic copepods *C. typicus* and *T. stylifera*. The effects on these species appeared linked to both changes in the microplankton composition as a consequence of the increasing temperature and to the increasing abundance of jellyfish that enhanced predation pressure.

These results clearly show that climatic and plankton variability in the Ligurian Sea is part of the large-scale, long-term changes experienced in the North Atlantic. We believe these findings deserve attention for the management of small pelagic fishes since their main food source and a key predator are closely linked to the coupled ocean–atmosphere system in the North Atlantic. In addition, these results also have implications on the assessment and modelling of the pelagic ecosystem and biogeochemical

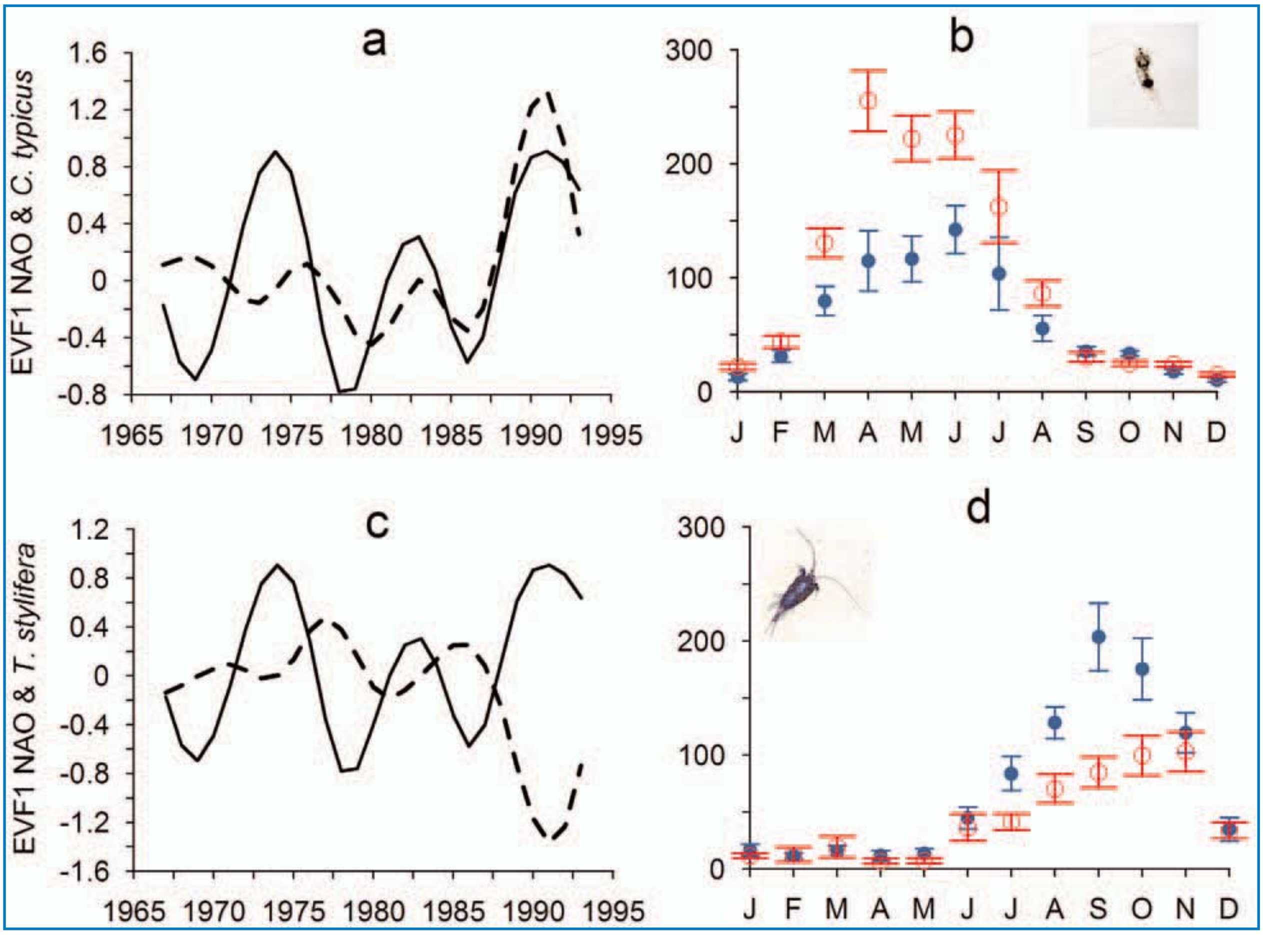

Figure 2. a) Low frequency changes of C. typicus (dashed line) and winter NAO (continuous line) obtained by Eigen Vector Filtering (EVF); b) Annual cycle of C. typicus cycle during positive (red) and negative (blue) NAO phases; c) Low frequency changes of T. stylifera (dashed line) and winter NAO (continuous line), same representation as a; d) Annual cycle of T. stylifera annual cycle during positive (red) and negative (blue) NAO phases. Values plotted represent the month mean ± 1 standard deviation (modified from Molinero et al., 2005b).

fluxes in the Western Mediterranean. Particularly, they stress that the emerging biological-physical modelling in the Ligurian Sea to investigate biogeochemical fluxes requires the incorporation of zooplankton diversity and dynamics of functional groups. This will improve understanding of the functioning of the pelagic ecosystem to enable better policies for the management of marine resources in the Ligurian Sea to be developed.

Acknowledgements

The authors wish to thank the staff of the Laboratory of Oceanography of Villefranche whose commitment to sampling and technical support has made this long-term survey possible. Particular thanks are addressed to Frederic Ibanez, Paul Nival, Serge Dallot and Emmanuelle Buecher. This is a contribution to the French IFB "Biodiversité et Changement Global" Programme, project APR 2003 No. 15-D.

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How can I use CPR Data?

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The Continuous Plankton Recorder (CPR) survey is the largest multi-decadal plankton monitoring programme in the world. It was initiated in 1931 by Alister Hardy, and up to the end of 2004 had counted 207,619 samples in the North Atlantic and identified 437 plankton taxa from a diverse range of groups (Fig. 1). The Survey has since evolved into a unique monitoring programme, providing the best long-term measure of plankton in the North Sea and North Atlantic.

This dataset has been the foundation for high-impact research over more than five decades, forming the basis of 23 Nature and Science articles and almost 1000 publications (Stevens *et al.,* in press, Reid *et al.,* 2003). Over recent years, CPR data have become increasingly important as a baseline to assess impacts of global change on pelagic ecosystems (e.g. Beaugrand *et al.,* 2002; 2003; Edwards and Richardson, 2004; Hays *et al.,* 2005; Reid *et al.,* 1998; Richardson and Schoeman, 2004; Thompson *et al.,* 2004). This role helps fulfil regional, national and international marine obligations concerned with biodiversity loss, climate change, eutrophication, pollution, harmful algal blooms and sustainable fisheries (Brander *et al.,* 2003).

Historically, data from the Survey have not been easily available to the research community. At the end of the 20th century, however, there was a sea change in the philosophy of CPR data accessibility. Data are now freely available through a licence agreement, and some data are currently available via the web and more are likely to be in the future. With this new, more open data access policy, the number of data requests for data has been growing steadily.

In view of the expanded use of the CPR dataset by the research community and its recent enhanced role underpinning marine management, we have now published a practical guide on how best to use CPR data, in the journal Progress in Oceanography (Richardson *et al.,* 2006).

The review begins by providing information on the CPR itself, routes sampled, how samples are counted and many of the biases associated with the data. We then supply information essential to using the data, including the semi-quantitative nature of CPR data, descriptions of each taxon counted, the idiosyncrasies associated with counting and changes in counting over the history of the Survey. We include for the first time a comprehensive description of all taxa counted. This 19 page table represents the combined knowledge from many people at the Survey over the last 40 years; an excerpt is shown in Table 1. This information forms the basis for a broader discussion on how to use CPR data for deriving ecologically meaningful indices based on size, functional groups and biomass. We conclude by providing information on concomitant environmental data.

We hope that this comprehensive description of the taxa counted in the Survey and how to use them will stimulate more robust and imaginative research using CPR data. Ensuring this invaluable dataset is utilised more widely and effectively in the future will hopefully contribute to the future security of the Survey.

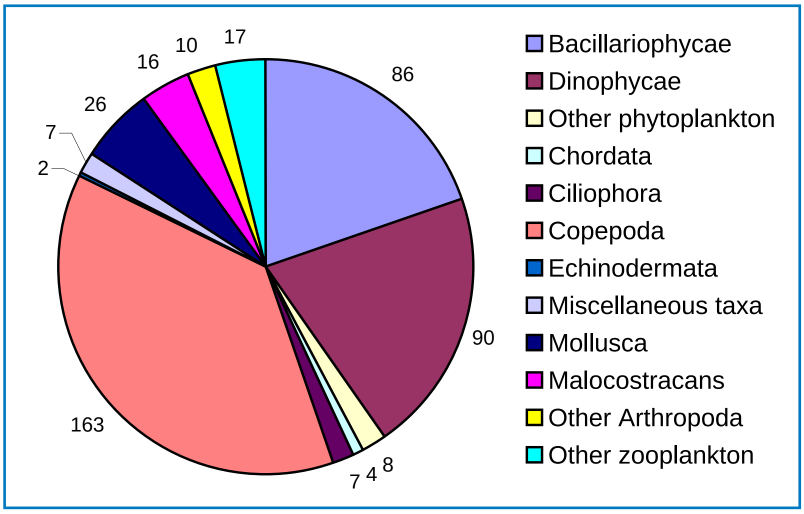

Figure 1. The number of taxa counted in the CPR survey separated into higher taxonomic groups.

Table 1. Excerpt from Table 5 in Richardson et al., 2006. All 437 taxa counted in the North Atlantic CPR survey arranged alphabetically within major taxonomic groups. For each taxon, there is information on its unique CPR identification number (ID), stage of analysis in which it is counted (Stage: P = Phytoplankton; T = Traverse; E = Eyecount) and the number of samples it has been found on up to the end of 2003 (No.). Also given is a brief description of taxa where appropriate. The dietary preference (H = Herbivore, O = Omnivore, C = Carnivore) for copepods is given. The last column gives total length (mm) for copepods and mass (µg per cell) for phytoplankton. Distribution maps of taxa marked are included in the CPR Atlas (Continuous Plankton Recorder survey team, 2004; http://www.int-res.com/abstracts/meps/CPRatlas/contents.html). Gridded and time-series products for taxa marked+ are included in WinCPR (Vezzulli et al., 2004; http://www.network-research-group.org/wincpr/). To calculate total copepod abundance or biomass, all copepod taxa should be summed except those marked#. Unless otherwise stated, consistent time series are available since 1958 for phytoplankton and from 1948 for zooplankton. All other years given for when a taxon was counted from are for January, unless otherwise stated.*

Group	Taxon	Description	ID	Stage	No.	Diet	Size
Copepoda	*Acartia negligens*		328	T	27	O	1.05[c,d]
	Acartia spp.*,+	Not identified to species. Mainly *A. clausi* and some "*Acartia longiremis*". Details in Colebrook (1982)	5	T	50620	O	1.15[d]
	Acrocalanus spp.	Not identified to species	301	T	3		
	*Aetideus armatus**		370	E	553	O	1.73[c,d,e]
	Alteutha spp.	Not identified to species. Mainly *A. interrupta* (M. Gee, pers. comm.). Not included in "Harpacticoida Total". Counted from 1994	985	E	103		
	Amallothrix spp.	Not identified to species	371	E	1		
	*Anomalocera patersoni**,+		372	E	574	C	3.20[d]
	Augaptilus spp.	Not identified to species	604	E	1		
	*Calanoides carinatus**		48	E	1474	H	2.18[c,d,f]
	*Calanus finmarchicus**,+	CV-CVIs. Recorded as a separate species from 1958. Included in "*Calanus* V-VI Total". Separated from "*Calanus helgolandicus*" by shape of inner margin of coxa of P5 and occasionally on shape of head and genital pore. Where large numbers of *Calanus* present, 20 individuals identified to species and scaled up to total number of "*Calanus finmarchicus*" and "*Calanus helgolandicus*"	40	E	67557	H	2.70[d,f]
	*Calanus glacialis**	CV-CVIs. Recorded since 1958. Separated from *C. finmarchicus* based on size alone (adult females >4.6 mm total length). Included in "*Calanus* V-VI Total"	42	E	1838	H	4.60

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Global zooplankton biomass (COPEPOD-2005)

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The World Ocean Atlas 2001 (O'Brien *et al.,* 2002) was an attempt to create a "global" field of zooplankton biomass from a collection of individual data sets. A major update to this initial work is now available in the ***C**oastal & **O**ceanic **P**lankton **E**cology*, ***P**roduction & **O**bservation **D**atabase* (COPEPOD; O'Brien, 2005). *"COPEPOD-2005"* features improved data content and preparation methods and offers new biomass fields (and the original data) in an online, easy-to-use data system.

COPEPOD-2005 has more biomass:

The most obvious difference between *World Ocean Atlas 2001* and *COPEPOD-2005* should be the significant additional coverage in the biomass fields. With the exception of the Arctic, the *COPEPOD-2005* fields are now truly global. Many of the new *COPEPOD-2005* data come from ongoing COPEPOD Plankton Data Search and Rescue efforts.

COPEPOD-2005 has less biomass:

A very observant reader may also notice that the *COPEPOD-2005* fields indicate less biomass than those of *World Ocean Atlas 2001*. Examining the two biomass figures, there is a decrease in carbon biomass values across the globe, with orange (value) regions becoming yellow, yellow regions becoming green and green regions becoming blue. This value shift is because the calculation methods used in World Ocean Atlas 2001 were found to greatly over-estimate carbon mass (doubling values in the >25 mg/m^3 range and quadrupling values in the <10 mg/m^3 range).

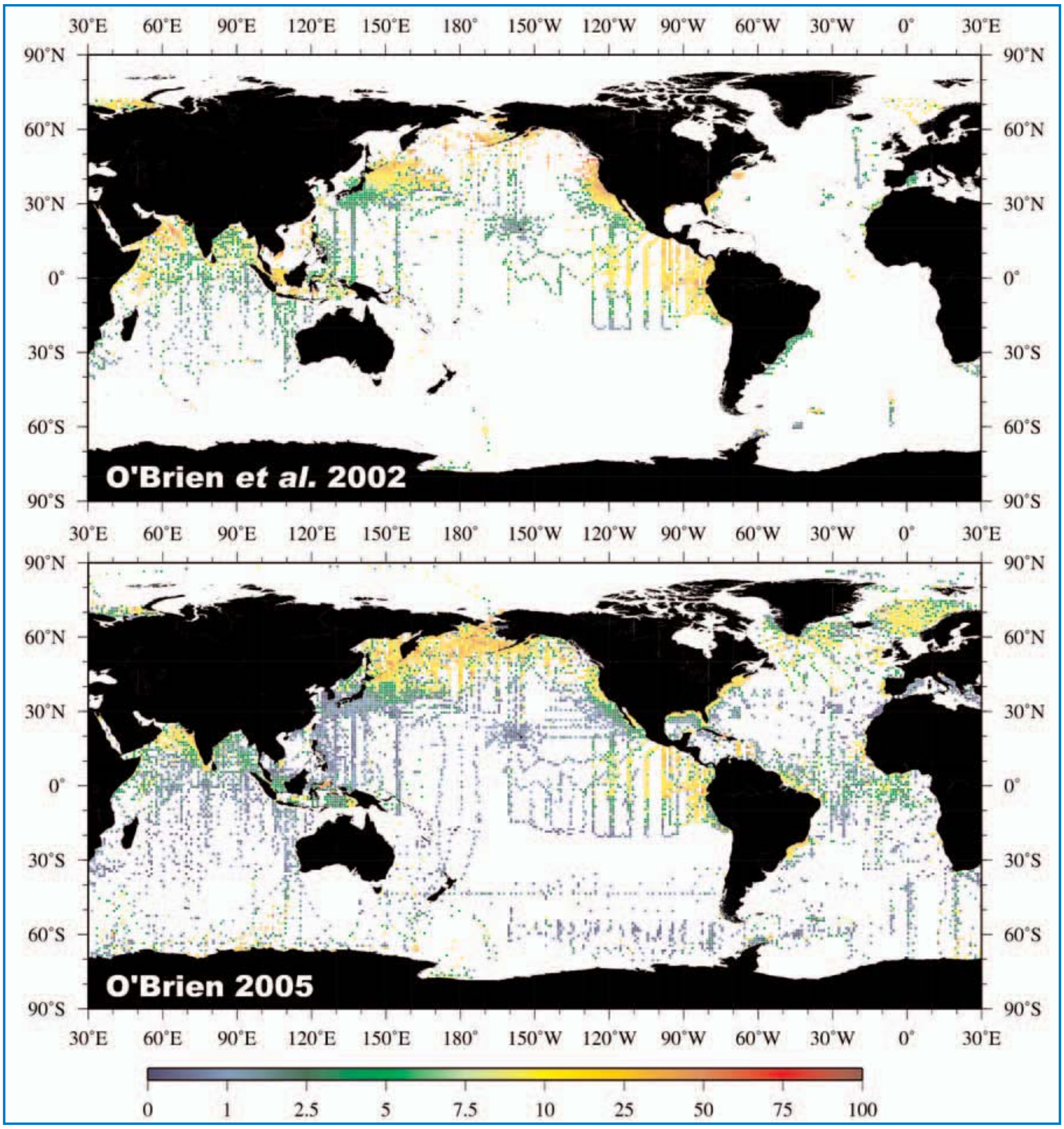

Figure 1. Zooplankton carbon mass (mg/m^3) from the World Ocean Atlas 2001 (O'Brien et al., 2002) and COPEPOD-2005 (O'Brien, 2005).

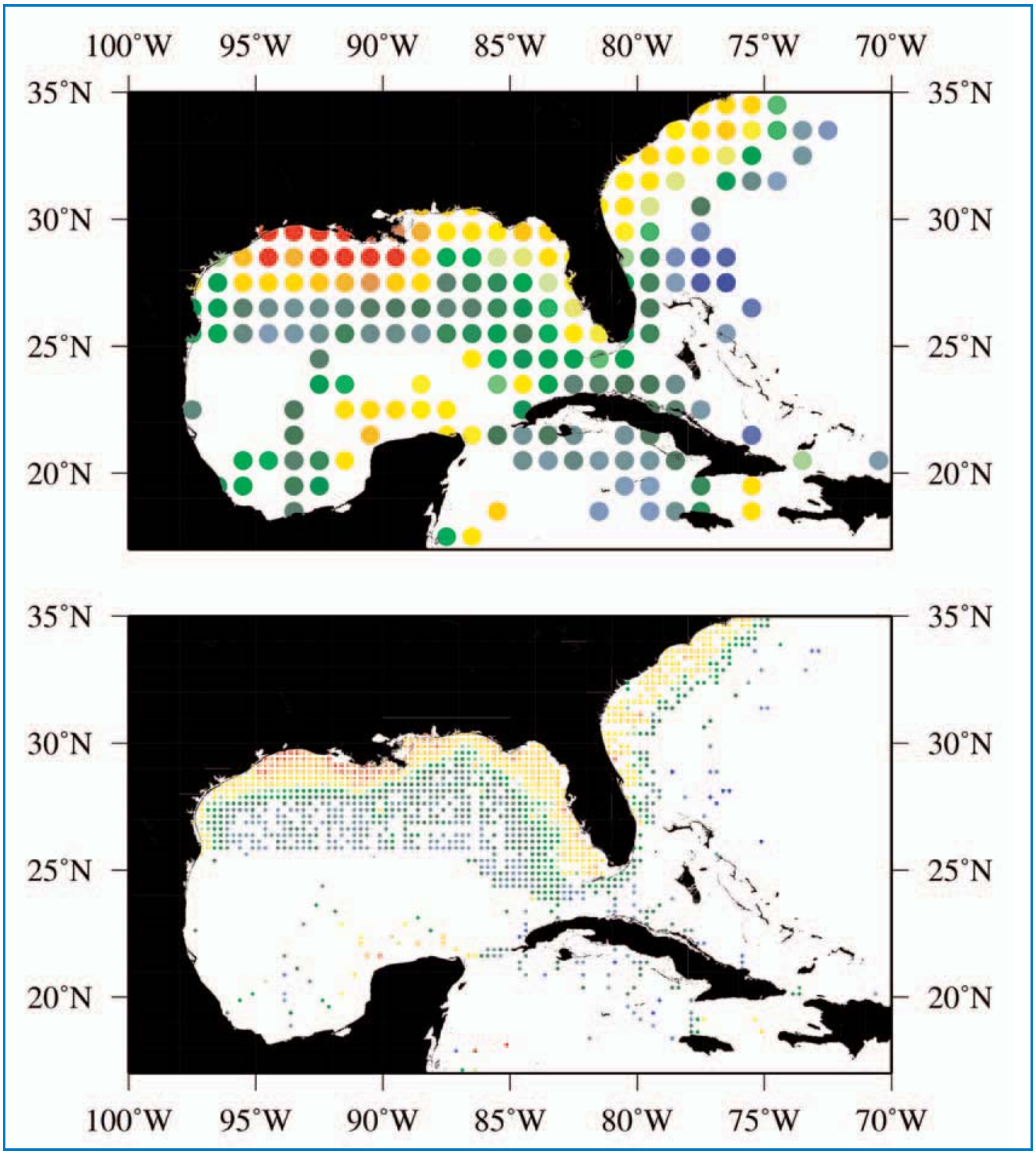

Figure 2. Gulf of Mexico zooplankton biomass displayed at one-degree (top panel) and quarter-degree (bottom panel) latitude-longitude gridded resolutions.

COPEPOD-2005 offers more choices:

The biomass fields of *World Ocean Atlas 2001* were only offered in a one-degree (latitude-longitude) gridded resolution. While this scale is useful for global examinations, it is not as amenable to the study of smaller regions such as the Gulf of Mexico. Many of the regions in *COPEPOD* now have sufficient data density to allow for higher resolution analysis. *COPEPOD-2005* therefore provides its biomass fields in both one-degree and quarter-degree resolutions, allowing the user to choose the resolution that best fits their specific region or application.

COPEPOD-2005 is available now:

The "*COPEPOD-2005*" Technical Memorandum is available as an online (full-colour) PDF file and as a printed (black and white) document. This Technical Memorandum also summarises the data processing procedures and plankton content of the *COPEPOD* database itself as of December 2005.

COPEPOD-2005 is available online at: www.st.nmfs.noaa.gov/plankton/copepod-2005.

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Long-term spatio-temporal variation of copepod community in the western North Pacific and influences of the North Pacific Decadal Oscillation

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The Oyashio (sub-arctic) and Kuroshio (sub-tropical) are the western boundary currents in the North Pacific. The Transition zone between the two currents is a highly variable complex environment. Dynamics of the Oyashio and Kuroshio influence biological production in the western North Pacific. The hydrographic conditions of both currents have been reported to vary on a decadal scale corresponding to the North Pacific Decadal Oscillation, which is closely related to the behaviour of the wintertime Aleutian Low (AL). After the intensification of the AL in 1976/77 (known as the major regime shift), enhancement of the subarctic circulation induced the southward shift of the Oyashio domain and also strengthening and northward shift of the Kuroshio occurred.

Our research team has been conducting a long-term ecosystem change study in the western North Pacific since 2003 using the Odate Collection, a 50 year zooplankton collection maintained by the Tohoku National Fisheries Research Institute. Through copepod community analysis, we have found a decadal change in phenology of the lower trophic levels in the Oyashio (Chiba *et al.*, in press). We recently investigated how the climatic forcing influences the regional lower trophic level ecosystem and detected decadal changes in distribution pattern of copepods in the Oyashio and Transition zone, which was associated with latitudinal shift of the currents.

To see the temporal variation in the lower trophic levels in the Oyashio domain and Transition zone (36–43°N, 142–150°E) for 1960–1999, we first applied the principal component analysis (PCA) on the annual abundance (May-Sept average) of major copepods species. The first principal component (PC1) accounted for 21% of the interannual variation in the copepod community. A "jump" of the PC1 value was detected in 1976 and 1988 based on the differences between 5-year means before and after a given year. Both "jumps" coincided with years of major and minor climatic Regime Shifts in the North Pacific. Copepod species whose interannual variation has a significant positive correlation with the PC1 mainly consisted of the large-sized, cold-water calanoid copepods (Table 1). As these species occurred at more than one-third of stations in the Oyashio domain (water temperature <5°C at 100 m deep), PC1 time-series suggested interannual variation of the abundance of "Oyashio assemblage" copepods. The second principal component (PC2) accounted for 15% of the variation and a jump year was observed in 1982. Copepod species with a significant correlation with PC2 time-series mainly consisted of the small-sized, warm water species including cyclopoids and poecilostomatoids (Table 1). As these species frequently occurred at the Transition zone stations (water temperature >5% at 100 m deep) but were rarely observed in the Oyashio domain, these species were defined as the "Transition zone assemblage" copepods.

Table 1. Copepod species lists of the Oyashio assemblage and the Transition zone assemblage. Average body size of female and classification for the cold water, mesopelagic, widely distributed and warm water species followed the description of Chihara and Murano (1997).

Oyashio assemblage = PC1 group

	species	female size (mm)
🔵	*Neocalanus cristatus*	8.4-9.3
🔵	*Metridia pacifica*	2.6-3.5
🔵	*Paraeuchaeta elongata*	4.1-8.0
🔵	*Pleuromamma scutullata*	3.6-4.0
🔵	*Neocalanus flemingeri*	4.2-5.2
🔵	*Metridia okhotensis*	4.5-4.8
🔵	*Eucalanus bungii*	6.5-8.0
🔵	*Acartia longiremis*	1.0-1.4
🔵	*Scolecithricella minor*	1.1-1.5
🔵	*Pseudocalanus minutus*	1.4-2.1
🟢	*Acartia omorii*	1.0-1.4
🔵	*Neocalanus plumchrus*	4.3-6.3
🔵	*Oithona atlantica*	1.1-1.4
🔵	*Pseudocalanus newmani*	0.9-1.5

Transition zone assemblage = PC2 group

	species	female size (mm)
🔵	*Oithona atlantica*	1.1-1.4
🟠	*Oithona plumifera*	1.1-1.4
🟢	*Corycaeus affinis*	1.0-1.3
🟠	*Oithona setigera*	1.1-1.9
🟢	*Acartia omorii*	1.0-1.4
🟢	*Ctenocalanus vanus*	0.9-1.3
🟠	*Oncaea mediterranea*	1.0-1.3
🟠	*Oncaea conifera*	0.9-1.2
🟠	*Clausocalanus acuicornis*	1.2-1.6
🟠	*Lucicutia flavicornis*	1.3-2.2
🟠	*Paracalanus aculeatus*	1.0-1.4
🟢	*Clausocalanus parapergens*	1.0-1.4
🟠	*Oithona longispina*	0.9-1.1
🟠	*Eucalanus californicus*	5.7-7.0

🔵 cold water or mesopelagic species 🟢 widely distributed species 🟠 warm water species

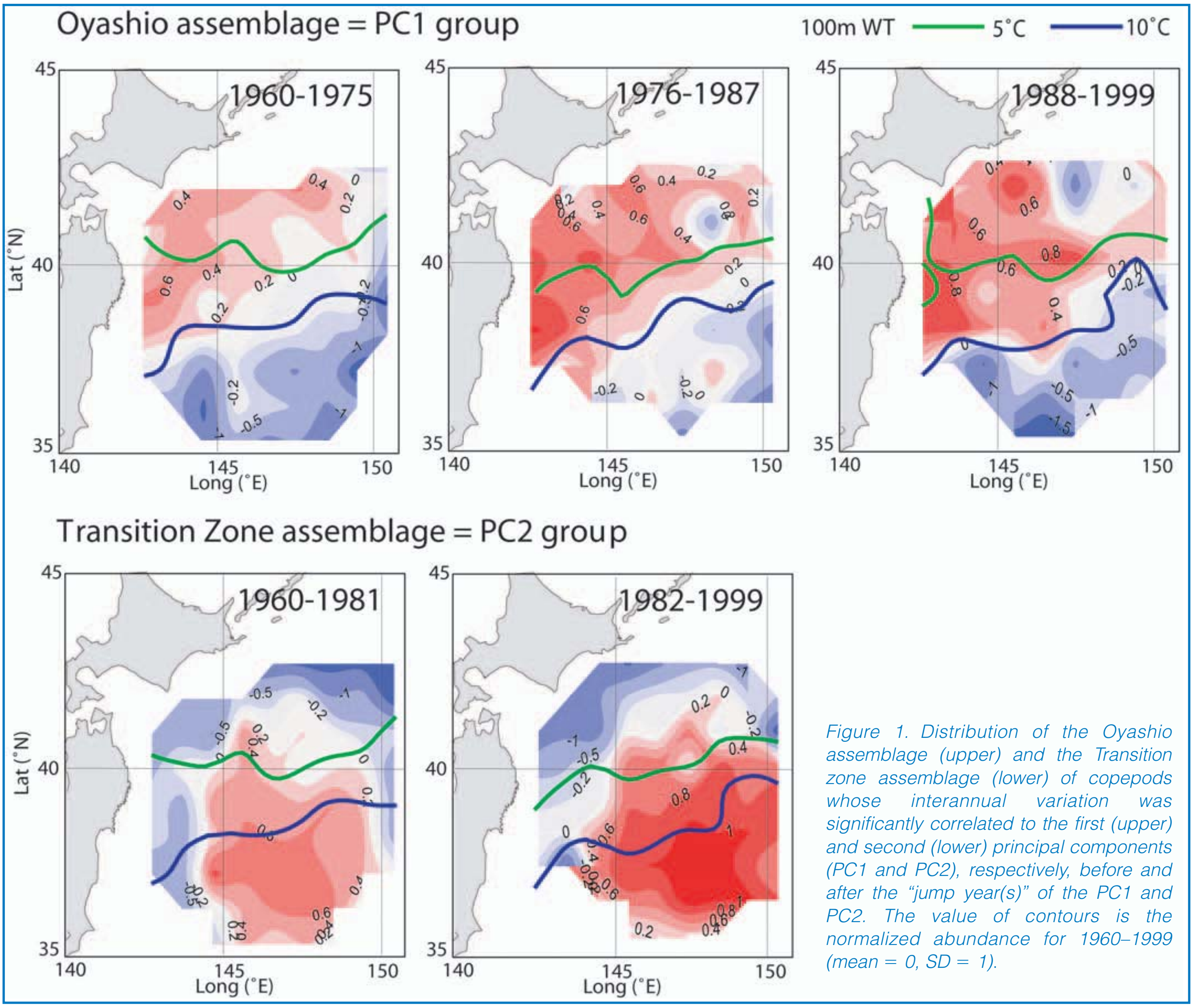

Figure 1. Distribution of the Oyashio assemblage (upper) and the Transition zone assemblage (lower) of copepods whose interannual variation was significantly correlated to the first (upper) and second (lower) principal components (PC1 and PC2), respectively, before and after the "jump year(s)" of the PC1 and PC2. The value of contours is the normalized abundance for 1960–1999 (mean = 0, SD = 1).

The geographical distribution of the Oyashio assemblage and Transition zone assemblage were compared before and after the jump year (Fig. 1). Central distribution of the Oyashio assemblage shifted southwestward clearly responding to the southern intrusion of the Oyashio after 1976. It further shifted west towards the Japanese coast after 1988, presumably due to the northern intrusion of the Kuroshio. There was no clear change in the distribution of the Transition zone assemblage before and after 1982. However, an increase in abundance was manifest, indicating the influence of the northward shift of the Kuroshio. Interestingly, increase of the geostrophic transport and northward shift of the Kuroshio was observed around 1982, several years after the southward shift of the Oyashio. Therefore, interannual distribution of the copepod community in the Oyashio and Transition zone was determined by the combined effects of both lagged and un-lagged hydrographic variations which are closely related to the Pacific Decadal Oscillation.

This finding implies the possibility of the spatial match-mismatch between the lower and higher trophic levels on a decadal scale. For instance, the Transition zone is known for the nursery ground of Japanese sardine (*Sardinops melanostictus*) and thus food availability there was crucial for its recruitment success. Previous study did not sufficiently explain the paradox of high standing stock of Japanese sardine while zooplankton biomass declined during the 1980s. Our study suggests that abundance increase of the small, warm water species in the Transition zone during the period might improve the food encounter rate for the juvenile sardine. It is worth noting that this scenario cannot be detected by conventional, biomass-based zooplankton data because the total zooplankton biomass is likely to be determined by a variation of several large-sized species, such as *Neocalanus* spp.

This study was financially supported by the Global Environmental Research Fund of the Japanese Ministry of the Environment.

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GLOBEC Germany

Progress of German GLOBEC Project

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The German GLOBEC project (www.globec-germany.de) entitled "**Trophic Interactions between Zooplankton and Fish under the Influence of Physical Processes**" aims for a better understanding of the trophodynamic interactions between zooplankton and fish under the influence of physical processes, in order to elucidate the principal mechanisms accounting for the high variability of copepod production and reproductive success of fish. The results will form the basis for strategic modelling of the recruitment success of pelagic fish in the Baltic and North seas. The first phase of the project started in early 2002. The final phase lasts from 2005 until the end of 2007. The period of intensive field sampling ended in 2005. At present, after processing most of the field data, the integration and synthesis of the results are under way and most PhD theses are in the final phase. The following collection of contributions from GLOBEC Germany is a representative presentation of the work done so far and updates the special section on GLOBEC Germany presented in GLOBEC's Newsletter 10.1.

Mesoscale plankton distributions across a tidal front in the Southeastern North Sea

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In the summer time, the German Bight exhibits a persistent tidal front, with stratified water offshore and well mixed water inshore (Budeus, 1989). At the same time, the net plankton of the southern North Sea is dominated by the dinoflagellate *Noctiluca scintillans*, an obligate heterotroph. *N. scintillans* exhibits a diversity of feeding mechanisms, including interception and mucoid feeding; it also colonizes and feeds upon diatom aggregations and marine snow (Kiørboe and Titelman, 1998). A poor swimmer, *N. scintillans* is thought to passively capture prey during upward ascent (it is also positively buoyant and forms surface-slick red tides during high abundance and calm periods) and through enhanced encounters caused by small-scale turbulent motions. As part of the GLOBEC Germany program, two cruises were conducted in the German Bight in May and June/July 2005, in order to more closely examine how fronts structure plankton communities. We present here some preliminary results from one of those cruises.

The data presented here are from a single north-south transect along 7°15'E, on 1–2 July 2005 (19:00–03:00 GMT) (Fig. 1). Plankton and hydrographic parameters were observed with a Seascan Video Plankton Recorder (VPR) and FSI CTD/fluorometer, mounted on a V-fin (Davis *et al.*, 2004); current velocities were measured with a ship-borne ADCP (600 kHz, 2 min ensemble, 1 m bins). The VPR images a small volume of water (~650 mm^3) at high frequency (25 Hz) as it is towed through the water (~2 m s^{-1}). To classify the collected images (~$3.5x10^5$ for this single transect) a training set was made from a small subset of images. Unclassified images were then further processed for focus (Sobel and Canny thresholding), then re-thresholded (chord method; Zack *et al.*, 1977) and various morphometric measurements made (length, width, aspect ratio, area, perimeter, total pixel intensity).

Preliminary identification of the unclassified images was then done with a Discriminant Function Analysis trained with

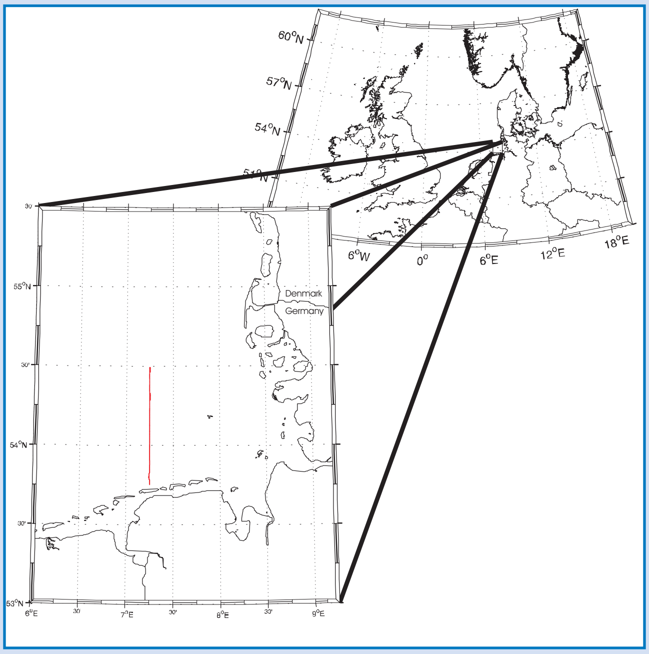

Figure 1. Location of the R/V Alkor transect in the German Bight.

the training set. Classified images were then inspected by eye for correspondence. Binned data (1 m bins) were interpolated with an anisotropic variogram and kriging, the variogram model was cross-validated (a = 0.05) with the Q_1 statistic of Kitanidis (1997).

The results of the data analyses are shown in Figure 2. The velocity shear was found highly variable and was highest in the stratified offshore region and near-bottom inshore of the front. The high variability is probably an artifact due to the way the ADCP data was handled. Single *N. scintillans* cells were most abundant inshore of the front and in the stratified region, a long tongue of higher abundance also extended through and underneath the front to seaward. Aggregated *N. scintillans* cells (multiple cells in contact with each other, without any aggregates visible) exhibited a similar pattern to single cells, but were particularly localised along the inshore side of the front.

Only a small number of the VPR images have been studied for the present purpose. Further work will include analysis of the remaining images from this and a cruise earlier in 2005. Due to the very large number of images this analysis has to be carried out using an automated system, which will be based on more than just simple shape metrics and which will include identification of many other taxa. We would also like to compare more closely the distribution of plankton with the velocity shear, especially at small scales. This requires that the ADCP data be analysed in a different way. The data material and the results of our studies may also be used in connection with modelling of particle aggregations.

Acknowledgements

We thank the officers and crew of the R/V Alkor. Klas Möller, Jens-Peter Hermann (both Institut für Hydrobiologie und Fischereiwissenschaft, Universität Hamburg) and Volker Mohrholz (Leibniz-Institut für Ostseeforschung, Warnemünde) are also participating in the project.

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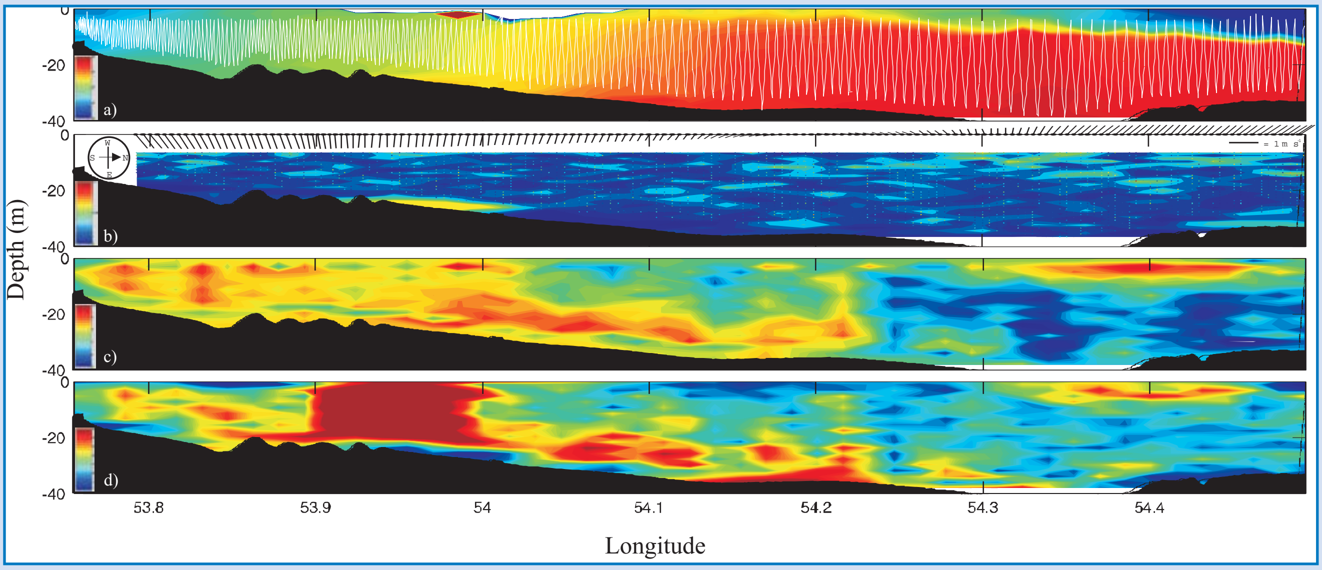

Figure 2. Observations along the transect of a) density minus 1000 kg m^{-3}, b) depth averaged current (stick plot at the top) and velocity shear calculated from the binned ADCP data, c) distribution of single N. scintillans cells (arbitrary log abundance units) and d) distribution of aggregated N. scintillans cells (arbitrary log abundance units). In a) the towed path of the VPR is indicated by a white line.

Effects of nutritional quality on copepod reproduction

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It is becoming increasingly clear that not only food quantity, but also food quality plays a pivotal role in determining reproductive success in marine zooplankton. Although quality differences between algal food sources as a result of differences in morphology or toxicity have been described in some detail in the literature, within-species differences caused by changes in growth conditions of the algae have been largely ignored (but see Jones and Flynn, 2005; Augustin and Boersma, in press). Growth conditions for algae vary widely throughout the season and in coastal seas regular depletions of silicon, phosphorus or nitrogen occur during spring and summer. This may have consequences for the primary consumers, hence we carried out a set of experiments investigating the effects of nutrient depletion of microalgae on the reproductive output of copepods.

In the first experiment we incubated the copepod *Acartia clausii* with differently cultured diatoms (*Thalassiosira rotula*). We observed that egg production of females grown on nutrient-limited algae was significantly lower than the egg production of *Acartia* individuals cultured with nutrient-sufficient algae (Fig. 1). Hence, this would imply that in the field when algae are nutrient-limited during summer, secondary production is much lower than what one would expect based on the standing stock of the algae alone. If this is such an important factor for copepods one would expect that they have mechanisms to differentiate between food that is nutrient-limited and

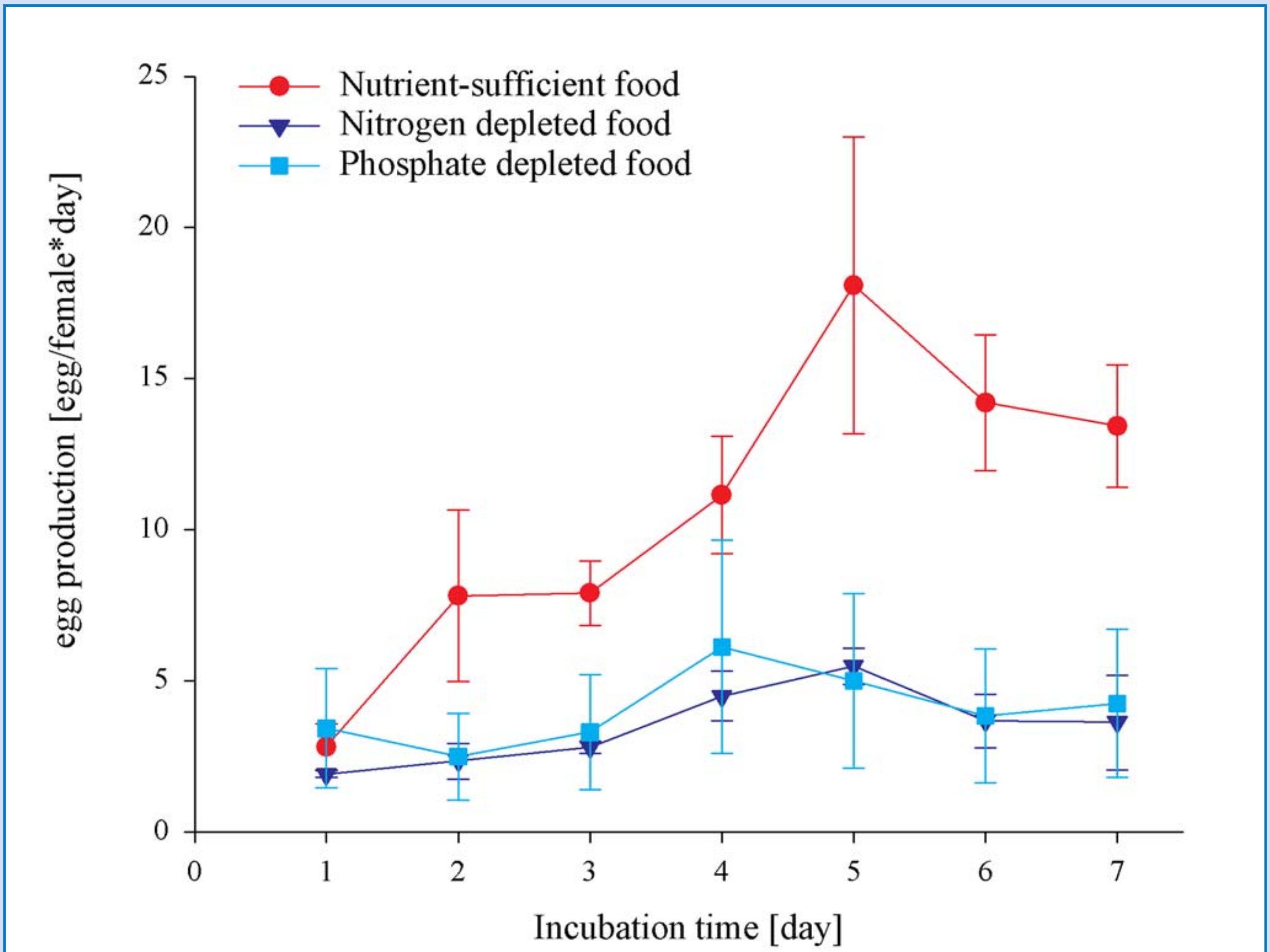

Figure 1. Reproductive output of Acartia clausii fed differently cultured Thalassiosira rotula. The egg production of animals fed with nutrient-limited cultures of the algae were much lower than of those animals that were given nutrient-sufficient algae.

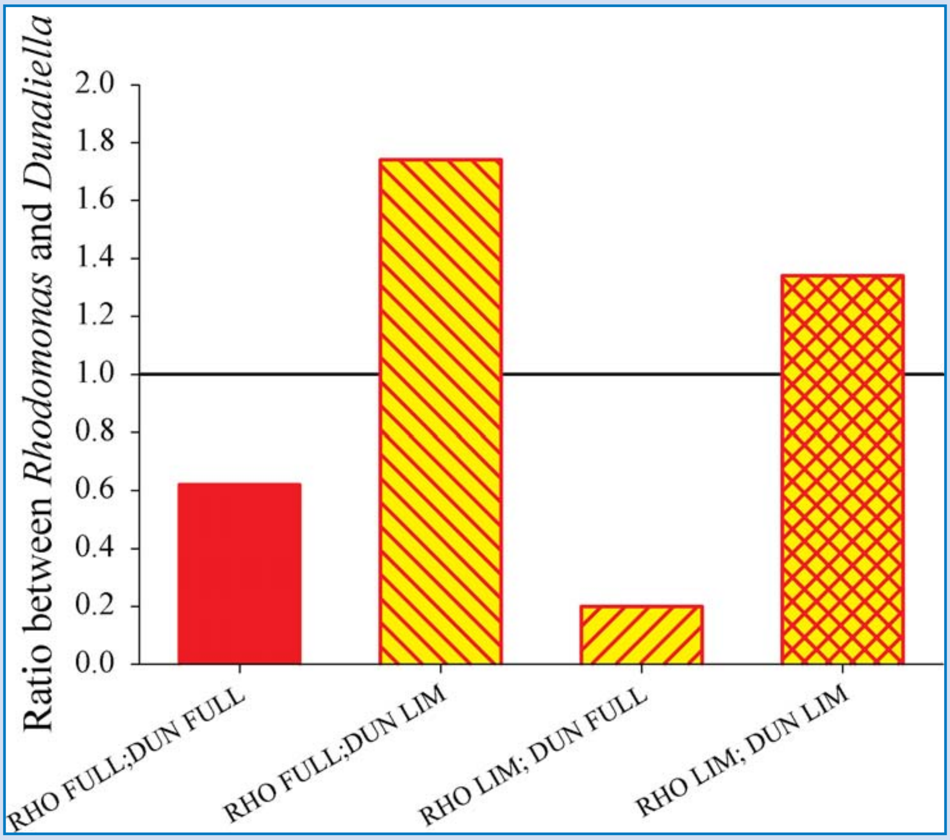

Figure 2. Relative amounts eaten by Temora longicornis of Dunaliella (DUN) and Rhodomonas (RHO) in different combinations of nutrient-sufficient (FULL) and nutrient-depleted algae (LIM). The algae were supplied in a 1:1 ratio and it is clear that when both algae are nutrient sufficient the animals consume more of Dunaliella (ratio Rhodomonas/Dunaliella < 1).

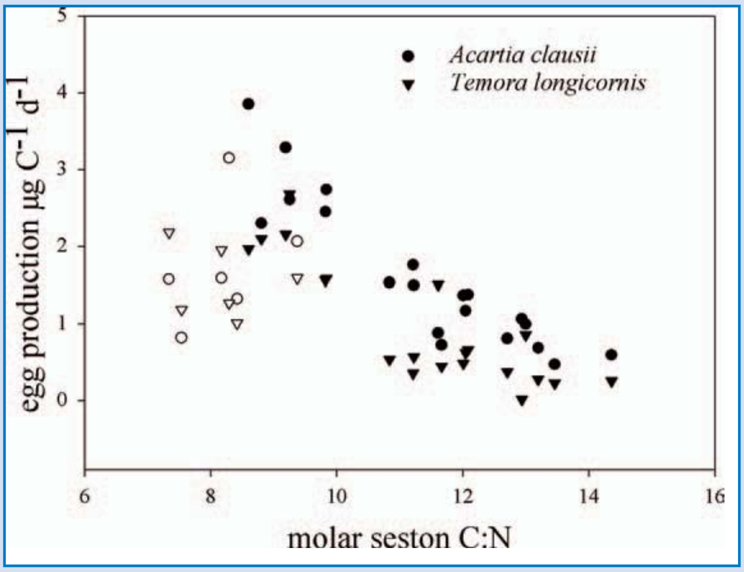

Figure 3. Egg production rates (standardised for changes in size of the females during the growing season), correlated with the C:N ratio of the seston for Temora longicornis and Acartia clausii. Open symbols indicate a bloom of Phaeocystis.

food that is nutrient-sufficient, especially since often spatial structures exist in the distribution of nutrients. We tested this by offering different combinations of food to the calanoid copepod *Temora longicornis*, N-limited and N-sufficient *Dunaliella* sp. combined with N-limited and N-sufficient *Rhodomonas* sp. We observed that, although the *Temora* females always seemed to prefer *Dunaliella* over *Rhodomonas* and this preference increased when the *Rhodomonas* cells were nutrient limited, the preference reversed when *Dunaliella* was N-limited and *Rhodomonas* was grown on N-sufficient media (Fig. 2). Hence, we conclude that *Temora* is very well able to differentiate between food particles of different quality, even within one single species. This is adaptive, as it implies that copepods should be able to increase their reproductive output by selecting for those nutritional particles that have the optimal nutrient content.

So, what do we find when we analyse egg production rates and seston parameters from the field? We did this in the spring of 2004 on a weekly basis using animals and seston collected from the Helgoland Roads, North Sea. We observed that the egg production of *Temora* individuals was highly correlated with the C:N content of the seston, except for the very low C:N ratios, but during this time the algal community was dominated by *Phaeocystis*, a notoriously bad food for most copepods (Fig. 3). Even when we corrected for the differences in temperature that accompanied the changes in C:N ratio of the seston, the significant correlation of C:N of the seston with egg production rates remained. These results indicate that we can transfer the laboratory results depicted in Figure 1 to the field.

In short, we have shown that reproduction in copepods can be severely affected by the quality of the food and that the C:N:P content of the food particles is at least one quality determining factor. More research is needed to determine whether this is a direct effect or whether the algae change their biochemistry as a result of the nutrient depletion.

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Copepods coping with a tough situation: temperature, salinity and calanoid vital rates in the Baltic Sea

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Calanoid copepods are vital to trophic structure and functioning in marine and estuarine systems as they form the main link between the microbial loop/short food chain and tertiary levels of production. Within the Baltic Sea, the general increase in the North Atlantic Oscillation (winter) Index in the 1990s has been correlated with increased water temperatures, decreased frequency and strength of inflow events of high salinity water into the deep basins of the Baltic proper and increased freshwater inflow via river runoff (Dippner *et al*., 2000; Hänninen *et al*., 2000). These changes in environmental conditions have been correlated with changes in the composition of the mesozooplankton community of the central Baltic Sea (Vuorinen *et al*., 1998; Möllmann *et al*., 2000). Within the German GLOBEC program, a series of laboratory experiments have been conducted to evaluate the effect of environmental factors on life-history traits/responses (vital rates) of the dominant Baltic calanoids in an effort to resolve the mechanisms affecting changes in the copepod abundance, distribution and community composition.

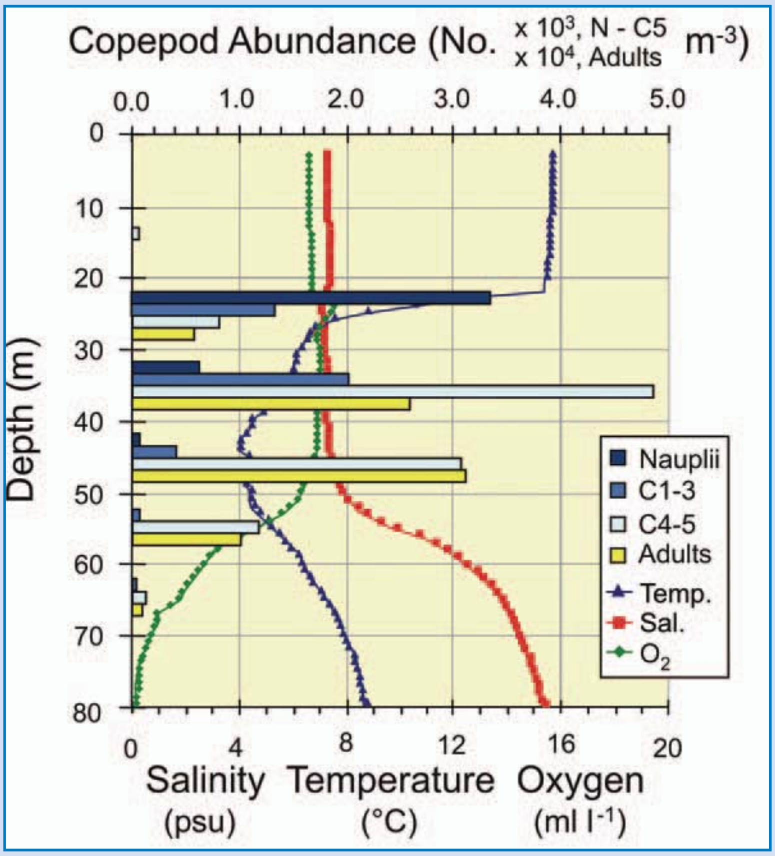

Figure 1. Depth profile of Baltic T. longicornis life stage abundance (multinet samples taken at 10-m depth intervals) and CTD water temperature, salinity and dissolved [O_2]. Samples and measurements were taken 25 July 2002 at one station in the Bornholm Basin (55.29°N, 15.75°E).

Depending upon the season and atmospheric conditions, Baltic Basins can have strong depth gradients in temperature (≥12°C change), salinity (~8 psu change) and oxygen concentration (from saturation to anoxic) which can prove challenging to animals living there. Similar to other calanoid copepods in these basins, the depth distribution of *Temora longicornis* (Müller) strongly corresponds to the strength and position of thermo-, halo- and oxyclines (Schultz *et al*., 2004). For example, during summer periods characterised by intense stratification, *T. longicornis* nauplii, copepodites and adults are absent from warm, low salinity surface waters but occur deeper in colder, slightly more saline water layers (Fig. 1). Our laboratory experiments have revealed that at least one of the reasons for this depth distribution is based upon limits in the temperature*salinity (*T*S*) tolerance of early life stages of a Baltic population of this species. For example, cumulative 48 h mortality of *T. longicornis* nauplii hatched and reared at six different temperatures (from 10 to 20°C) at 14 psu was much higher after exposure to a salinity challenge of 7 psu than after exposure to 20 psu water (Fig. 2). Naupliar mortality was temperature-dependent, especially at 7 psu where mortality increased from 26.7% at 10°C

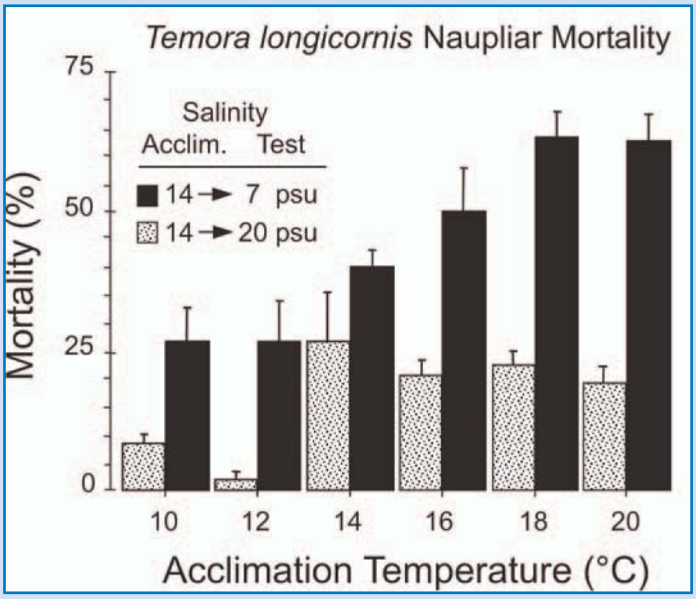

Figure 2. Effects of the interaction between temperature and salinity on mortality of T. longicornis nauplii. Nauplii acclimated to (produced at) each of the six temperatures were exposed to either an acute increase (stippled) or decrease (filled) in water salinity and mortality was measured every 12 hours for 48 hours (cumulative, 48h mortality shown).

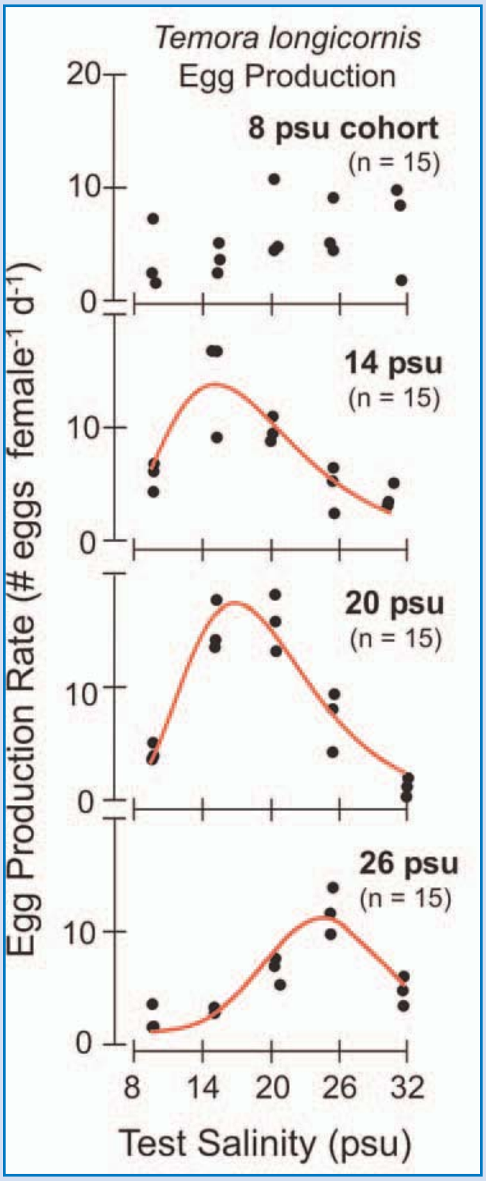

Figure 3. Effects of acclimation salinity on egg production by T. longicornis. Adults were from cohorts grown at 8, 14, 20 and 26 psu (different panels) and tested at 8, 14, 20, 26 and 32 (nominal) psu. Each datum is a mean value of three consecutive daily measurements. Adults were maintained in ad libitum feeding conditions at 12°C.

to 63.2% at 20°C. In contrast, mortality was relatively low for nauplii at all temperatures at the higher salinity. At 20 psu, mortality was only 1.7% at 10°C and increased to between 20% and 26.7% at higher temperatures. These results indicate that the observed summer depth distribution of *T. longicornis* is likely an obligatory response (avoiding warm, low salinity surface waters is a prerequisite for relatively high naupliar survival) and not merely a consequence of behavioural responses to other potential factors (e.g. depth-specific differences in predation pressure and/or food concentrations).

Other recent laboratory results indicate plasticity in the ability of a central Baltic (Bornholm Basin) population of *T. longicornis* to cope with different salinities. In this case, the rate of egg production (*EP*, # female^{-1} d^{-1}) by *T. longicornis* that had been acclimated to (grown at) four different salinities (8, 14, 20 or 26 psu) was measured at each of five salinities (8, 14, 20, 26 and 30 psu). Within unlimited feeding conditions at 12°C, mean *EP* was strongly influenced by the acclimation salinity of adults. The reproductive success for 14, 20 and 26 psu cohorts was highest when tested at the acclimation salinity and slightly lower when individuals experienced any acute salinity change (Fig. 3). Moreover, maximum *EP* was similar for adults reared and tested at 14, 20 and 26 psu. However, *EP* by adults reared at 8 psu, a commonly encountered salinity in Baltic surface waters, was relatively low at all test salinities – a pattern indicative of osmotic stress. Adult *T. longicornis* often cannot take advantage of deeper, higher salinity waters in the Baltic Basins due to extremely low oxygen concentrations and the decrease in food abundance at increased depths.

Maximum rates of egg production at a Baltic salinity in these laboratory studies (~10 eggs female^{-1} d^{-1} at 8 psu) agree well with those measured *in situ* for *T. longicornis* in the Bornholm Basin (~6–12 eggs female^{-1} d^{-1}; Dutz *et al.*, 2004). However, these Baltic rates are less than 20% of those typically measured for *T. longicornis* in the North Sea (~50 to 60 eggs female^{-1} d^{-1}; Kiørboe and Nielsen, 1994; Halsband and Hirche, 2001) indicating costs associated with a marine species coping with life in the Baltic. The results of these and other laboratory studies (Holste and Peck, 2006; Peck and Holste, in press) should be useful for understanding species-specific phenological changes in abundance and depth distributions and should aid efforts to parameterise stage-based models constructed to depict seasonal (and longer-term) changes observed for key calanoids in our GLOBEC study region.

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Does the calanoid copepod *Pseudocalanus acuspes* retain an arctic life cycle in the central Baltic Sea?

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Pseudocalanus acuspes is a key species of the mesozooplankton in the Baltic Sea, interlinking phytoplankton production with higher trophic levels. Next to *Acartia* spp. and *Temora longicornis*, *P. acuspes* serves as a major food source for commercially important fish, such as sprat, herring and larval cod, and determines their growth and survival. Long-term studies revealed inter-annual fluctuations of the *Pseudocalanus* standing stock with a significant relation to salinity (Möllmann *et al.*, 2003). A distributional gap between *P. acuspes* populations from Norwegian Seas and the Baltic Sea population suggests that this species belongs to the Baltic relict fauna.

The Baltic Sea provides a unique environment. A permanent halocline at around 60 m depth in its deep basins restricts water exchange with the upper layers and tops an oxygen minimum zone during long stagnation periods, when renewal by waters from the North Sea is lacking. Additionally, a summer thermocline develops between May and October and restricts species living in the lower part of the basin from direct utilisation of food produced in the euphotic zone.

Table 1. Stage duration of developmental stages in May and July 2003.

Date	Stage	Temperature (°C)	Stage duration D (days) range	Stage duration D (days) mean
May 03	CII	3.7	7.0 - 21.6	16.0
	CIII	3.7	7.5 - 30.0	14.3
	CIV-V	3.7	13.7 – 77.0	22.0
July 03	CIII	4	22.5 - 42.6	29.5
	CIV-V	4	23.5 - 42.0	29.4

Earlier studies showed that especially older stages of *P. acuspes* inhabit the layer below the halocline (Hernroth and Ackefors, 1979), where they are exposed to high predation pressure by adult herring and sprat (Möllmann *et al.*, 2004). Thus, this copepod has to cope with unfavourable environmental conditions, limited access to phytoplankton and predation.

Within the GLOBEC Germany programme the life cycle of *P. acuspes* was investigated by an extensive field programme covering the period from March 2002 to March 2003 on an almost monthly basis. Abundance and distribution data were determined and *in situ* egg production and moulting experiments performed by incubation experiments. Lipid contents of copepodite stage V (CV) and adult females (AF) were analysed using gas chromatography.

Weighted mean depth (WMD) of copepods showed nauplii and younger copepodite stages inhabiting intermediate layers, while adults lived near the halocline and performed a descent in spring (Fig. 1). Egg production peaked in April (Fig. 2) accompanied by a peak of nauplii. This peak was followed by a clear stage shift from younger copepodids in spring and summer to older stages in

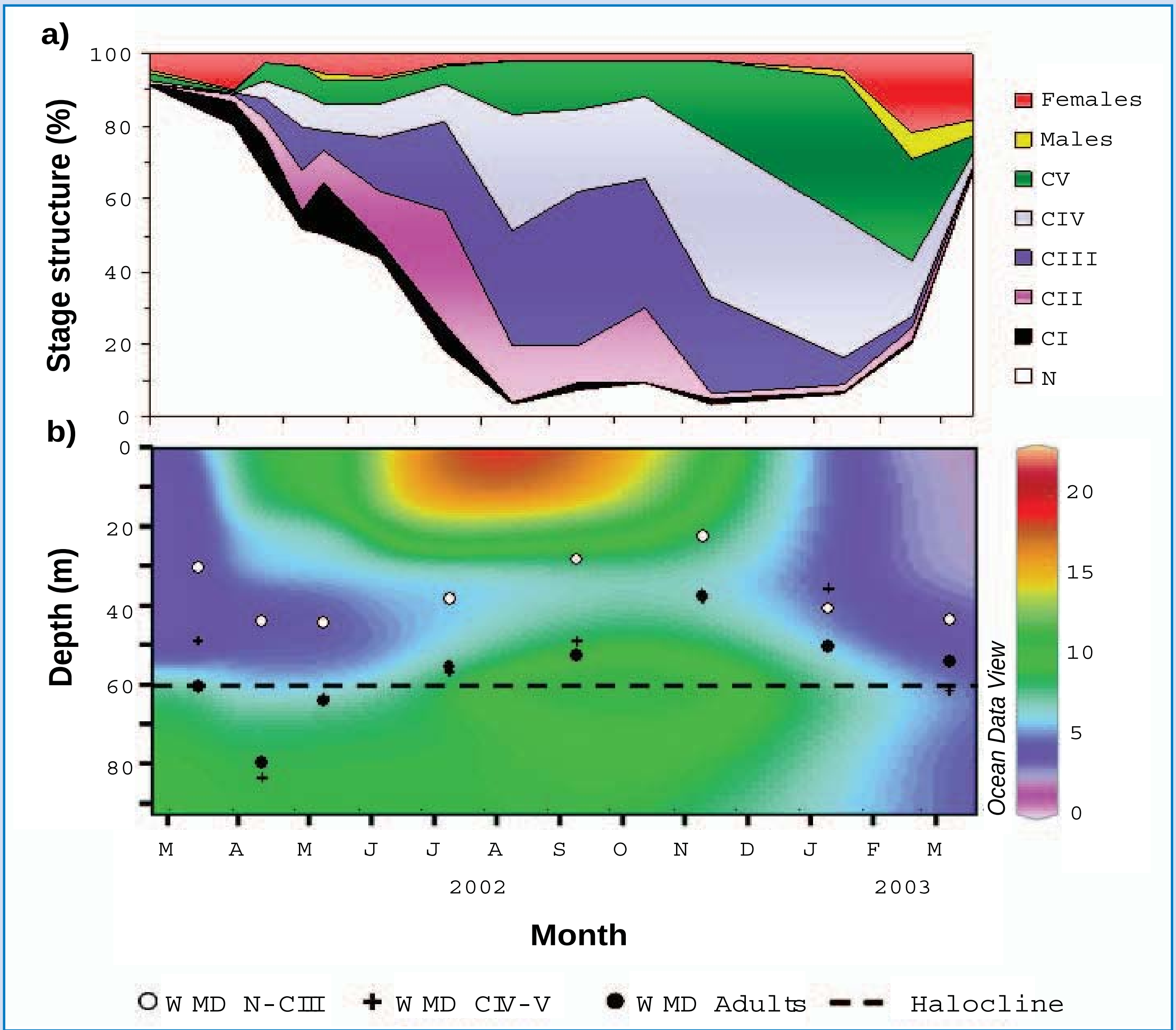

Figure 1. a) Stage composition of *P. acuspes* in the Bornholm Sea and b) hydrography and weighted mean depth (WMD) of nauplii-CIII, CIV–V and adults.

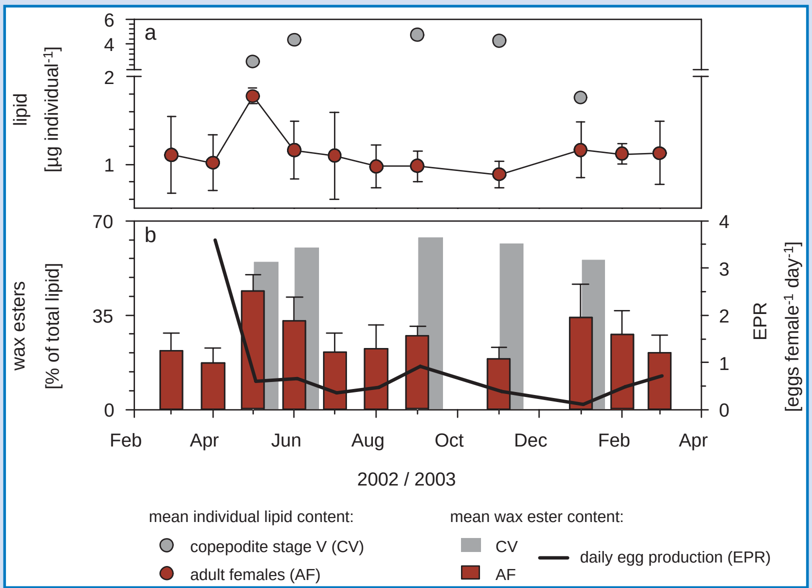

Figure 2. Seasonal variation in lipid content and egg production in the Bornholm Sea.

autumn and winter. The overwintering population was mainly represented by CIV and CV. Further information was derived from storage lipid contents. While in spring wax ester levels of CV and females hardly differed, significantly lower values were found for females during summer (Fig. 2). This seasonal divergence in lipid levels together with the stage structure data and the spring peak in egg production indicate a successive accumulation of overwintering copepodite stages, which suspend development but continue to feed and accumulate lipids. This is consistent with the extremely long stage durations derived from moulting experiments in May and July (Table 1). Thus, only a small number of individuals seem to complete the life cycle and continue to reproduce in summer and even in winter, although at low egg production rates. Food limitation is an important factor in the deep basins of the Baltic Sea during summer leading to sub-optimum growth conditions as indicated by low productivity and fast lipid depletion in reproducing females.

Similar life cycle strategies with maximum reproductive activities in spring, a successive accumulation of resting copepodite stages starting in early summer and a potential interposition of minor summer generations have been reported before, e.g. for *P. acuspes* in Nova Scotia (McLaren *et al.*, 1989) and *Pseudocalanus* sp. in the White Sea (Pertsova, 1982). Hence, the life cycle of *P. acuspes* in the Baltic Sea largely resembles that of arctic copepods and is in strong contrast to the 5–7 generations reported for *Acartia* spp. and *Eurytemora* sp. in the Baltic Sea (Line, 1979). Based on these fundamental analogies, we hypothesise that life cycle and lipid-storing strategies of *P. acuspes* in the central Baltic Sea originate from extant adaptations to high latitudinal habitats.

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Get it from the image - a new application for VPR derived images

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Production is one of the vital factors to understand the population dynamics of copepods. A common method to estimate production is through egg production experiments, where a number of females are caught, incubated in flasks for a defined time and the numbers of eggs per female are counted. This method is robust, but very time consuming. In the present contribution we show that, in addition to providing geographical distribution information, data from new optical gears can also be used to estimate egg production. Images from the Video Plankton Recorder (VPR, SeaScan) have the advantage that the organisms are enumerated undisturbed, i.e. the organisms are not damaged in nets. Egg sac carrying copepods such as *Pseudocalanus acuspes* (Fig. 1) can be observed and the size of the egg sack or clutch and of the individual eggs can be determined, enabling us to calculate an egg-per-female ratio. Combined with information on the temperature-dependent development rate of the eggs, an *in situ* egg production rate can be calculated. Here, we present an example using recordings from the Bornholm Basin (Baltic Sea) in two contrasting hydrographic situations, i.e. at the end of a long stagnation period and after a moderate inflow event. Using this approach, we test the hypothesis that this truly marine copepod should find better reproductive conditions after an inflow event, characterised by higher salinity and oxygen values (Dutz *et al.*, 2004). This is particularly relevant as Möllmann and co-workers reported a decline in the biomass of this species during a long stagnation period (Möllmann *et al.*, 2000), potentially the result of reduced reproductive success.

The egg sac and six eggs within each egg sac of each individual recorded dorso-ventrally or laterally were measured using the freely available software ImageJ. We used the formula for ellipsoid spheres to compute the volume (V) of the egg sac:

$$V = \frac{4}{3}\text{p}abb' \quad (1)$$

with a, b and b' being the length, width and depth of the measured clutch (Fig. 2). Width and depth were considered equal as only one dimension could be measured. The diameter of the eggs (c, Fig. 2) was measured and the volume was calculated using the equation for spheres.

Using the arithmetic mean of the six measured eggs, assuming a random loose packing of spheres (Weitz, 2004), the number of eggs per egg sac was calculated. With the results, we calculated a daily egg production for the area, using the temperature dependent development time for *P. acuspes* eggs (McLaren *et al.*, 1989):

$$D = 1949(T + 12.59)^{-2.05} \quad (2)$$

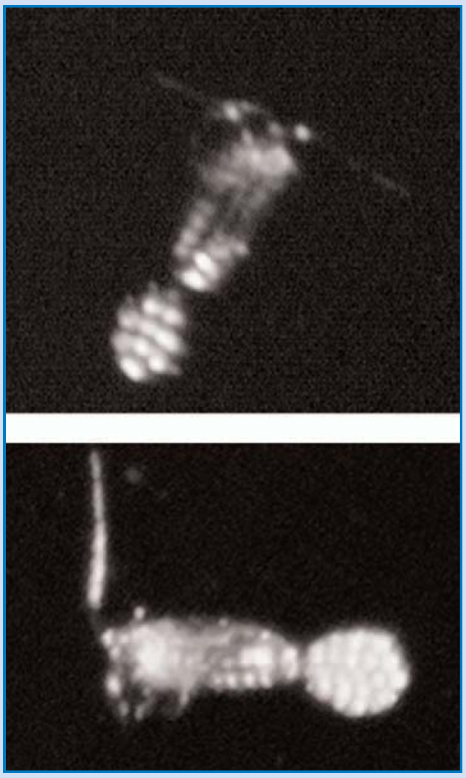

Figure 1. VPR-images of female P. acuspes carrying egg-sacs; a) from 2002 survey; b) from 2003 survey.

The basin wide abundance of female *P. acuspes* was calculated with the objective analysis (Bretherton *et al.*, 1976), using abundances estimates derived from bongo sampling. Temperature was taken from CTD measurements and an average was calculated for the reproduction volume (Schmidt *et al.*, 2003). Foremost, we calculated the ratio of nauplii to female abundance before and after the inflow event in 2003 to get an idea of the production/survival ratio. The nauplii to female ratio was 27.6 in 2002 and 53.1 in 2003 being nearly twice as high. High biomass after an inflow event could be caused by higher production rates, e.g. measurable by egg production experiments, or a reduced mortality.

The measurement of about 30 egg sacs per cruise showed a slight difference in individual egg number per clutch between May 2002 and April 2003. In May 2002 the females carried on average 18.9 eggs and in April 2003 22.3 eggs/female. Contrary to the nauplii to female ratio from field sampling, the daily egg production was slightly higher in 2002 (411.1 × 1012) than in April 2003 (407.4 × 1012) as the temperatures in May 2002 were higher (7°C versus 3°C in April 2003). Therefore, the development time of the eggs was much shorter in May 2002 (4.4 days) compared to April 2003 (7 days).

The methodology used has some shortcomings. The number off eggs per female may be overestimated because the egg sac does not represent a perfect sphere. However, measurements from field samples as well as from laboratory-reared females provide a calibration option, which should improve our results in the future. In addition, we did not include refractory time, i.e. times where the females do not produce a new clutch.

Although this method could only be applied to copepods carrying egg sacs, it offers a great opportunity to obtain additional information from optical gears to understand the dynamics of these species.

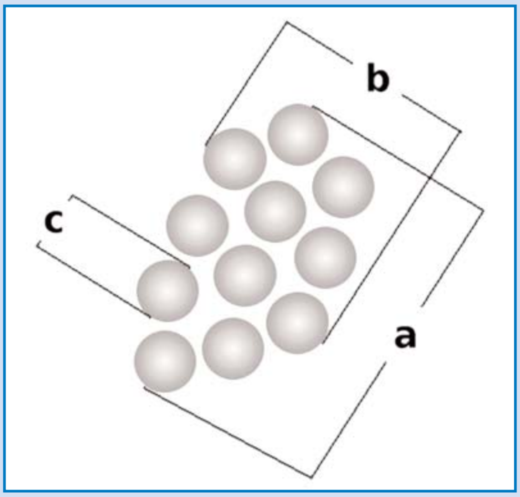

Figure 2. Scheme of an egg clutch of P. acuspes; a) length measurement; b) width measurement; c) egg measurement.

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Indications of bottom-up control of sprat recruitment in the Baltic Sea?

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Marine fish recruitment strength is generally established by processes operating during the first year of life and survivors might emerge from temporally and spatially distinct "windows" that may be determined by a factor (or factors) impacting multiple life stages (e.g. the availability of suitable prey). In Baltic sprat, spawning stock biomass is a poor predictor of recruitment (Köster *et al.*, 2003; MacKenzie and Köster, 2004) suggesting that factors impacting larvae and early juveniles are most important to early survival in this stock (Köster *et al.*, 2003). Unfortunately, mechanisms influencing the survival of Baltic sprat during the larval stage are poorly understood. This is due, in part, to the difficulty of adequately assessing environmental conditions over the course of the protracted spawning period (March to August; Grimm and Herra, 1984). Sprat larvae feed on a variety of copepod species and prey consumption shifts from copepod nauplii at first-feeding to larger copepodite stages in older, larger larvae (Voss *et al.*, 2003). Therefore, food limitation may result from a temporal mismatch of older copepodite stages and larger sprat larvae. Baltic temperatures can also impact larval sprat survival both indirectly, by influencing the timing of plankton production, or directly when lethal, lower thresholds encountered (*ca.* 5°C; Nissling, 2004). The latter can occur during the early portion of the spawning season.

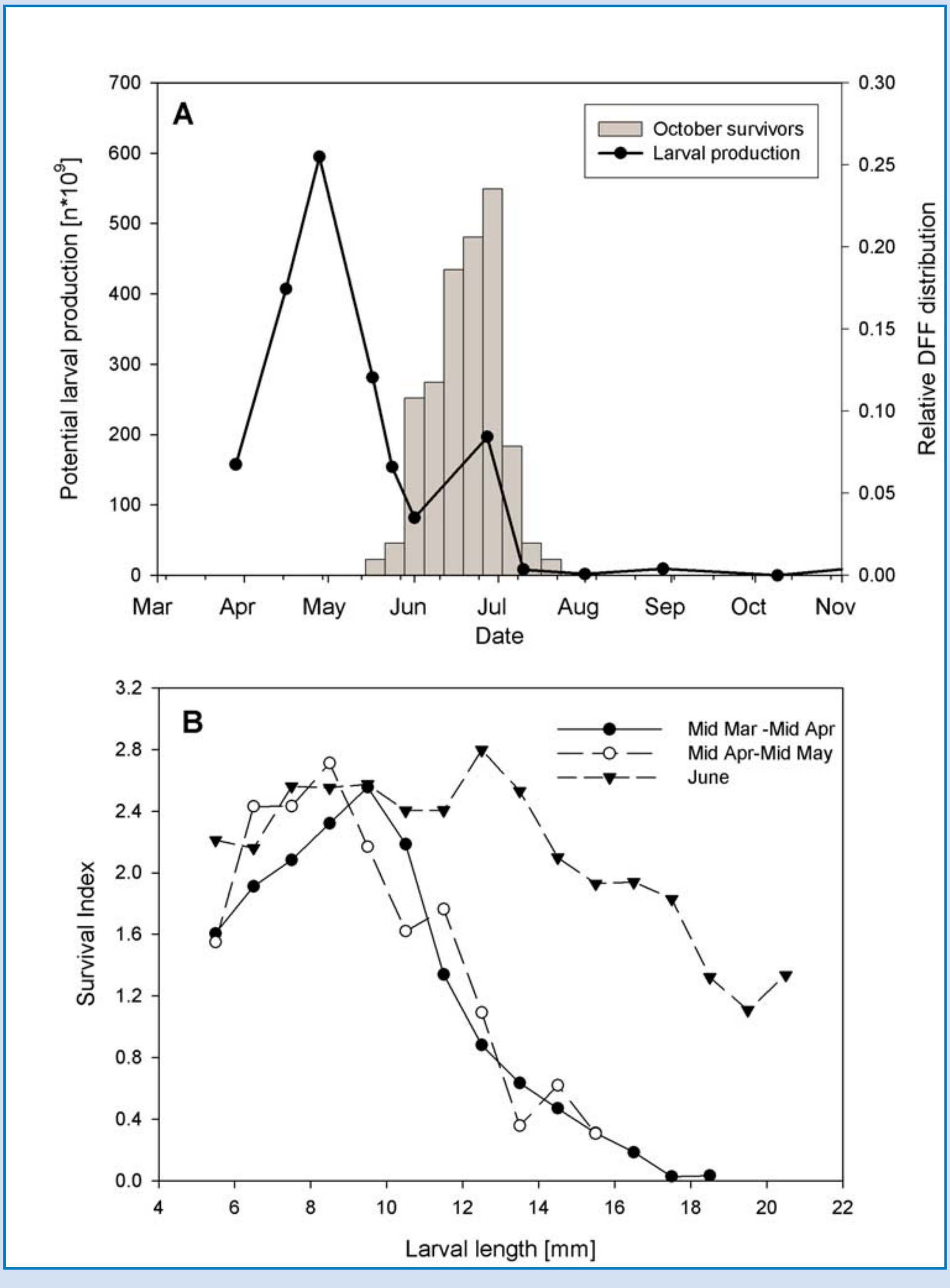
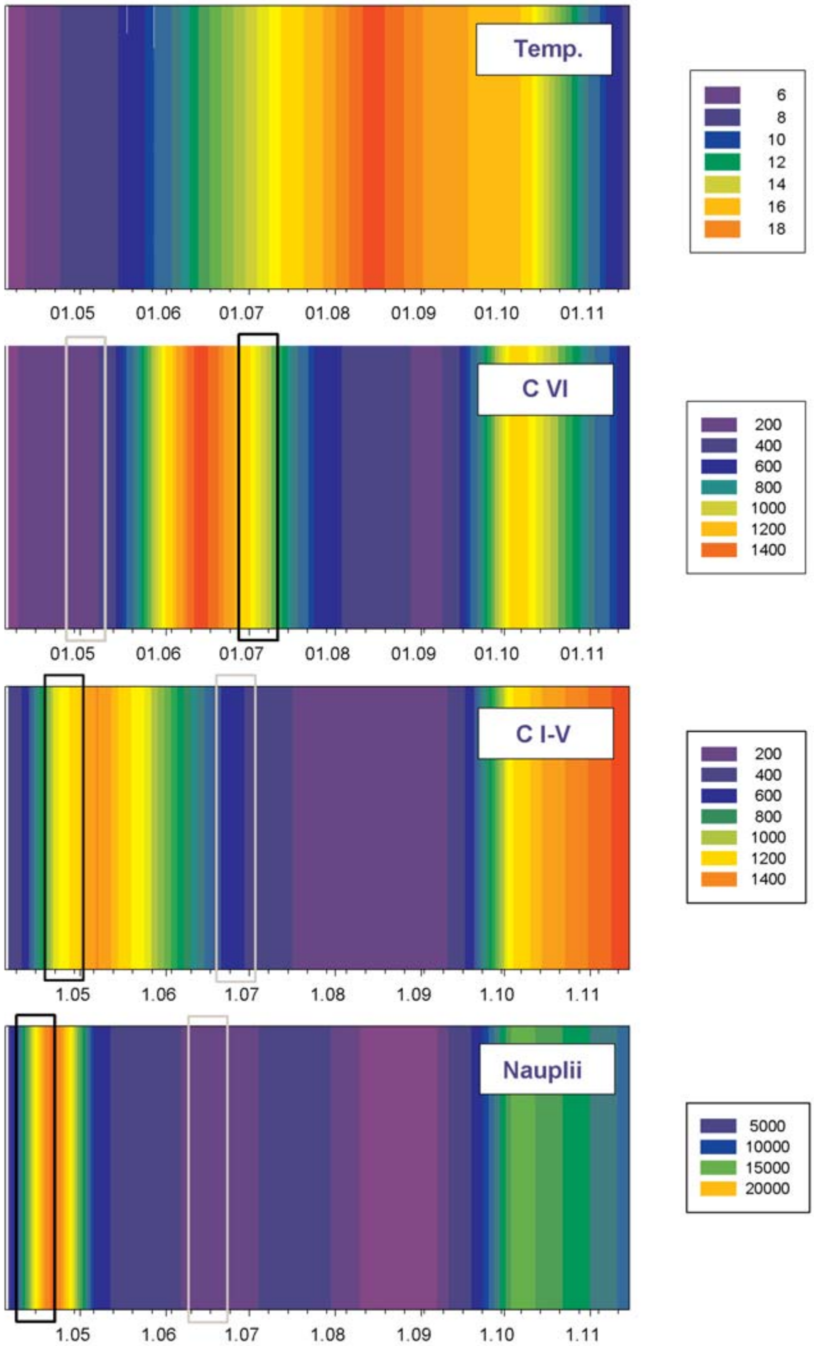


Figure 1. (Panel A) Temporal overlap between larval production and back-calculated distribution of the day of first feeding for YoY sprat caught in October 2002 in the Central Baltic Sea. Larval production was calculated from stage IV egg abundance in the Bornholm Basin adjusted for temperature-dependent duration times from stage IV to hatch. (Panel B) Size-dependent larval survival index for different hatching periods over the 2002 spawning period. Three hatching periods are displayed: mid-March to mid-April, mid-April to mid-May and June. Highs values correspond to highs survival rates up to the specific length.

Figure 2. Seasonal development of ambient temperature (°C) and larval prey fields (n/m³). Larval prey fields are separated into (a) nauplii, (b) copepodite stages I–V and (c) adult copepods. Rectangles display two pseudo-cohorts of sprat larvae originating from peak spawning and the estimated "window of survival".



Within the GLOBEC-Germany programme we have investigated seasonal differences in the relative survival of sprat in different larval size classes. During 2002, sprat eggs and larvae were collected during 14 cruises covering the spawning season in the Bornholm Basin. In October of that year, Young of the Year (YoY) sprat were sampled by pelagic trawl and otolith microstructure analysis was used to back-calculate their hatch-date distribution. Otolith results suggested that the majority of surviving juveniles initiated first-feeding during a confined period between June and July (Fig. 1a). This window of survival did not coincide with the main egg and larval production in April but with a second, smaller peak in June 2002. Similar differences in the relative survival during the spawning season were evident from an early life stage index. The index was calculated by combining field data with hydrodynamic modelling to allow a correction of field-based abundance values (Fig. 1b). The index suggested a much higher survival of sprat born in the summer compared to conspecifics born in the spring with pronounced differences in survival for larvae >11 mm. The two, independent methods clearly suggested a selective survival of sprat that were feeding relatively late in the spawning season.

To link sprat survival to plankton dynamics, we also investigated the size-specific feeding behaviour. Results of gut content analyses indicated copepodite stages were incorporated into the larval diet by ~7 mm, while adult copepods were found in larvae that were ~13 mm onwards (Dickmann *et al.*, submitted). Information on larval hatch dates, growth rates and size-dependant changes in feeding behaviour coupled to *in situ* zooplankton dynamics allow us to follow the fate of virtual larval cohorts through their temporally changing ambient temperature and prey fields. Here, we highlight two such cohorts of larvae: One, less successful cohort originating from the peak spawning time versus a cohort that stemmed from the observed "window of survival" (Fig. 2). On the one hand, first-feeding and medium-sized larvae originating from the peak spawning time (mid-April) developed at high suitable prey abundance. However, temperature conditions at this time were close to the critical threshold and comparably high mortalities would be expected, even within these good feeding conditions. Moreover, after growing for some time, larger larvae in this cohort faced low abundances of adult copepods. The combination of low survival of small larvae due to temperature conditions and low survival of large larvae due to food limitation would explain why relatively few larvae survived during the time of peak spawning. In the second cohort that was produced later in the season, food conditions for younger larval stages were less optimal while the ontogenetic shift to feeding on adult copepods coincided with higher prey abundances. Apparently, lower nauplii abundances later in the season did not result in high mortalities.

Additional information for larval sprat during the spawning season of 2002 as well as comparable information for 2003 will soon be available including RNA/DNA ratios, otolith microstructure analysis, seasonally resolved feeding data and lipid analysis. This information, when combined with detailed analyses of prey field dynamics and larval transport rates (Baumann *et al*., 2005; in press; Hinrichsen *et al*., 2005; Voss *et al*., 2006) offers the opportunity to reach a comprehensive understanding of Baltic sprat recruitment processes, including the question of potential bottom-up control.

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Temperature dependent developmental success of sprat early life stages: comparing Baltic and North Sea sprat

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Temperature plays a central role in early life stage development of fishes due to its importance in controlling physiological processes (Blaxter, 1992; Fuiman, 2002). The exact timing of critical transitions during early life history is essential for larval survival and thus the success of a cohort. The speed of yolk depletion depends on surrounding water temperature and as soon as endogenous reserves have been consumed and morphological changes like a functional visual system, functional jaw formations and mouth gap opening allow successful foraging, prey availability is essential for the larvae. Therefore, knowledge about duration and timing of early life stages is a prerequisite for understanding and interpreting match and mismatch situations (Cushing, 1972) between larval predators and their prey.

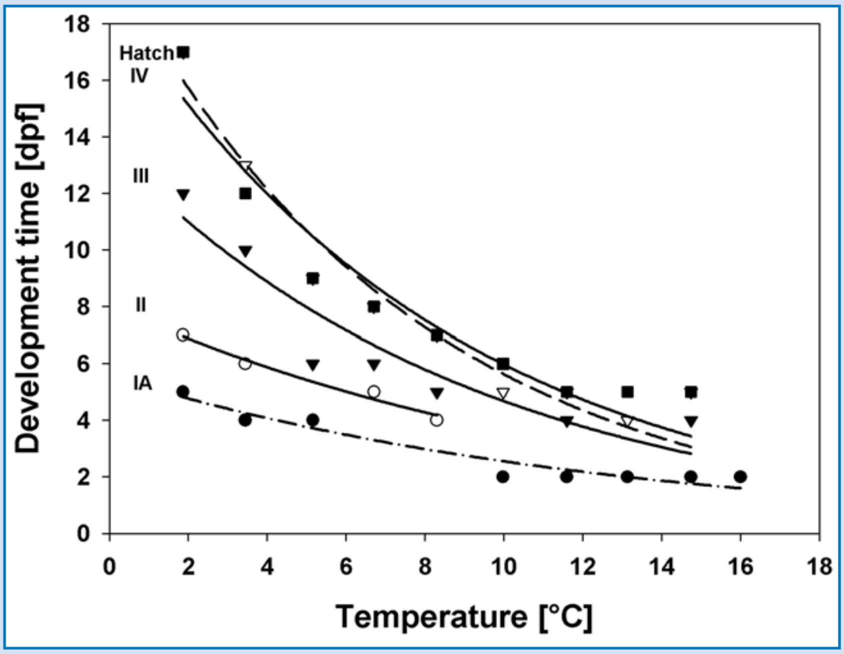

Figure 1. Stage specific egg development times in days post fertilisation [dpf] for Baltic sprat eggs. Shown are time to last observed occurrence of a specific developmental stage and the first occurrence of hatched larvae.

Surprisingly little is known about temperature effects on sprat early life stages (*Sprattus sprattus*) in the Baltic Sea

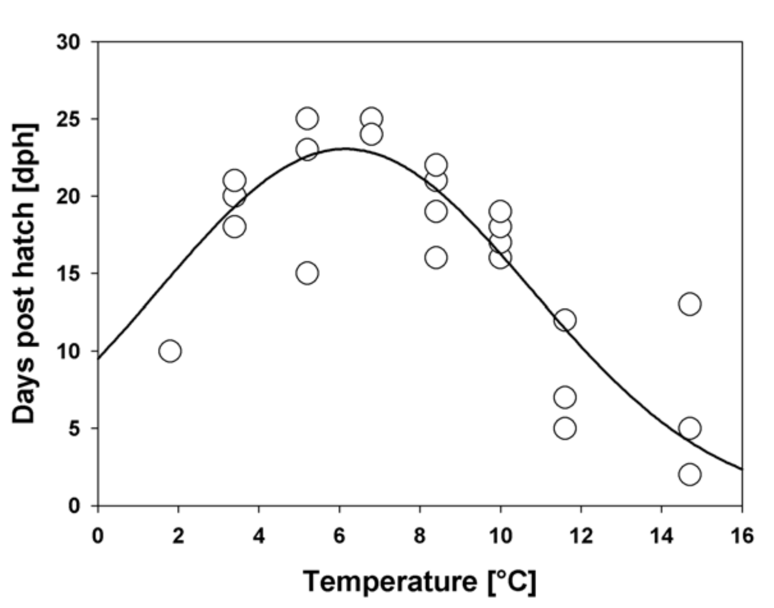

Figure 2. Time to starvation of Baltic sprat larvae in relation to temperature in days post hatch. Each symbol represents an individual observation. The regression line represents a fitted normal distribution curve.

and North Sea. In the frame of the German GLOBEC and National Science Foundation "Aquashift" programme we performed two sets of experiments with Baltic sprat (*Sprattus sprattus balticus*, Schneider) eggs and larvae in spring 2004 and 2005 simulating different temperature scenarios. Egg development and hatching showed exponential temperature dependence (Fig. 1). No hatching was observed above 14.7°C and hatching success was significantly reduced below 3.4°C. Similarly, resilience of yolk sac larvae to starvation was temperature influenced following a dome-shaped curve with the maximum time to starvation of 25 days observed at ~6°C (Fig. 2). Comparing the experimental results on Baltic sprat with existing information on English Channel and North Sea sprat, differences were detected in egg development rate and in yolk sac depletion rate (Figs. 3 and 4). A climate change scenario of a 2°C warming as predicted by the Intergovernmental Panel on Climate Change (IPCC) for the year 2100 would result in favourable hydrographic conditions for the development of Baltic sprat eggs and larvae, whereas North Sea sprat may not be able to take significant advantage of such a scenario. In addition to the direct effects of warming on sprat eggs and pre-feeding larvae, higher temperatures would result in a higher production of *Acartia* nauplii, the main food item of sprat larvae in the Baltic Sea (Möllmann *et al.*, 2000; Dutz *et al.*, 2004), while for North Sea sprat food competition with sardines and anchovies is likely to increase, as the abundance of these species has always been high during warm periods, e.g. the 1950s or the mid 1990s (Aurich, 1953; Beare *et al.*, 2004).

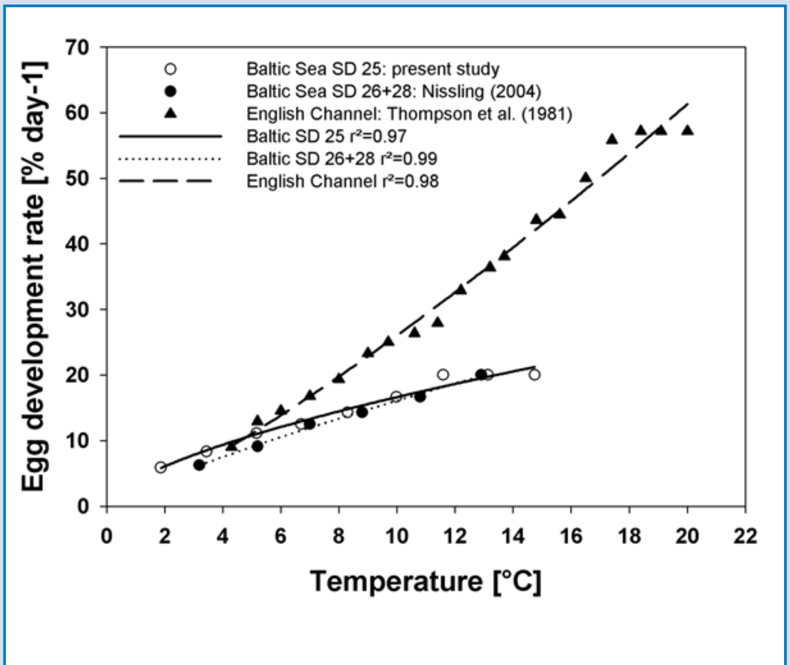

Figure 3. Egg development rates in percent per day versus temperature for egg incubation experiments from different areas with fitted power regressions. Data for the English Channel and Subdivisions (SDs) 26 and 28 of the Baltic Sea are extracted from literature.

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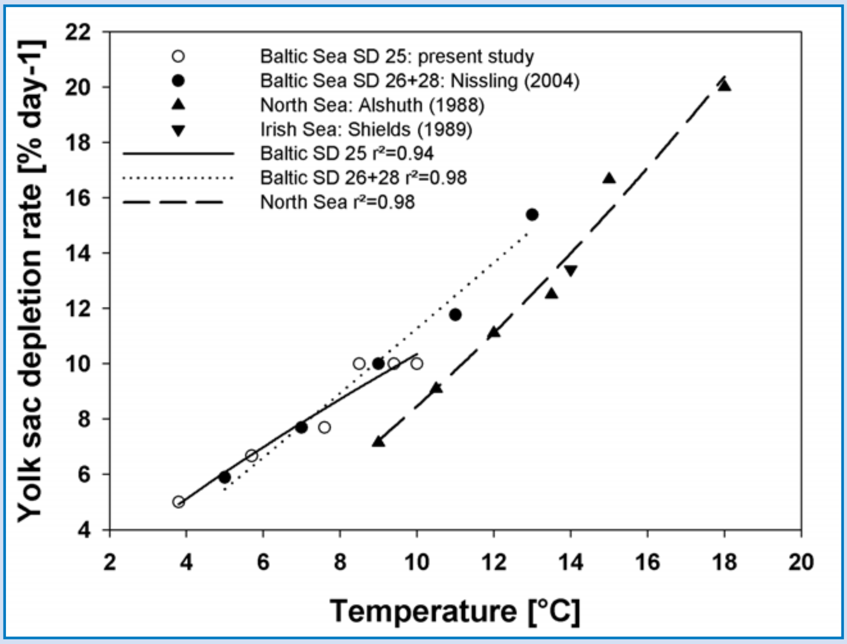

Figure 4. Yolk sac depletion rate for larvae from different areas incubated at different temperatures with fitted power regressions. Data for the North Sea, Irish Sea and Subdivisions (SDs) 26 and 28 of the Baltic Sea are extracted from literature.

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Processes acting during the post-larval/early juvenile stage influence Baltic sprat recruitment

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Differential survival patterns during all pre-recruit developmental stages are potentially able to modify year-class strength in marine fish. Because losses are generally highest during the egg and early larval stages, factors acting during a species' early ontogeny are traditionally considered to be most relevant for recruitment determination. Over the last decade, however, studies have suggested that, in some species, predictable recruitment levels are often established later, i.e. during the late larval and early juvenile stages (Leggett and Deblois, 1994; Wilhelm *et al.*, 2005). This

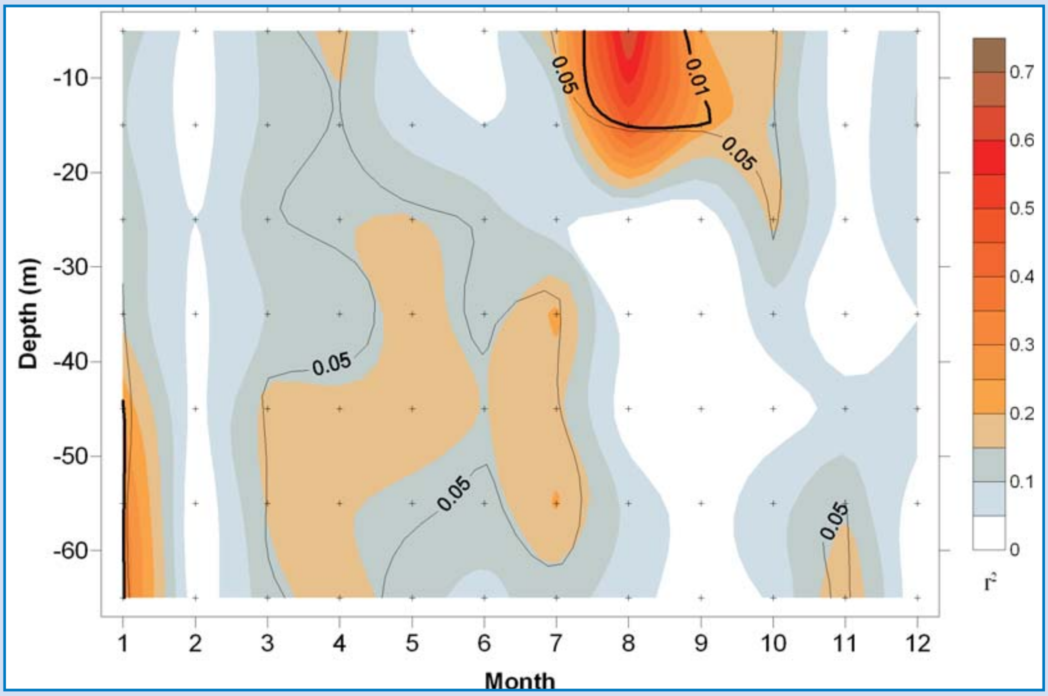

Figure 1. Summarising the results of sprat age 0 recruitment in the Baltic Sea (1974–2003) regressed linearly on ambient temperature for different month and depth strata (10 m). Colour shading and isolines correspond to r^2- and P-values, respectively, while crosses refer to the data grid points used to create the contours (kriging).

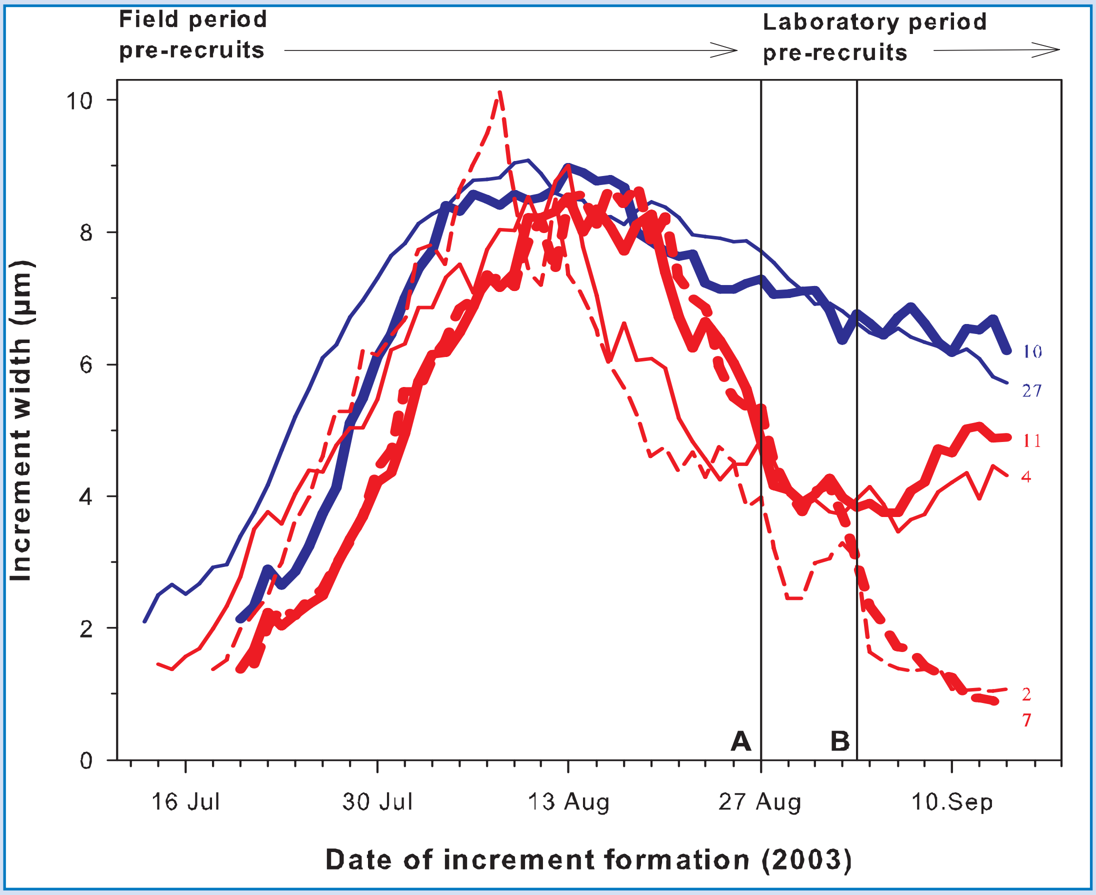

Figure 2. Mean increment widths per date of formation for pre-recruit sprat (red lines) and recruits (blue lines) sampled in August and October 2003 in the Kiel Fjord and the western Baltic, respectively. Thin and thick lines depict the trajectories of 2 different age groups, which formed first feeding increments between 13–19.7.03 and 20–26.7.03, respectively. Solid lines depict pre-recruits re-fed ad libitum rations in the laboratory, while starving groups are shown by dashed lines. Vertical lines A and B denote the day prior to the pre-recruit field collection and the start of the feeding trials, respectively. Means were based on the number of individuals given right next to each trajectory.

conclusion has also emerged for Baltic sprat, a key species of the German GLOBEC project. Two independent sources of evidence point to important processes acting on sprat in the post-larval and early juvenile period.

The first source of evidence stems from long-term temperature-recruitment correlations. Year-, month- and depth-specific temperature means between 1974-2003 were derived from the ICES Oceanographic Database (http://www.ices.dk/ocean/) and linearly correlated to Multispecies Virtual Population Analysis (MSVPA) estimates of age 0 Baltic sprat abundance (ICES, 2005). From this analysis, three spatially (water depth) and temporally (month) distinct "correlation clusters" were recognised (Fig. 1). January temperatures below 40 m were significantly, positively related to Baltic sprat recruitment ($P < 0.01$), suggesting a temperature influence on the pre-spawning stock over-wintering in the warmer waters in or below the halocline. During the prolonged spawning season of Baltic sprat (March–July), significant but loose temperature-recruitment correlations ($P < 0.05$) were observed in mid-water depths (30–60 m), corroborating studies on the temperature-dependent survival of Baltic sprat eggs and yolk-sac larvae (Köster *et al.*, 2003; Nissling, 2004). The third "cluster" was observed between July and September in Baltic surface waters (0–10 m), with August relationships having more than three times the explanatory power ($r^2 = 0.66$) compared to all other temperature correlations. This strongly indicated that temperature-related survival processes acting during the late summer months, when sprat are in the post-larval and early juvenile stages (Peck *et al.*, 2005; Baumann *et al.*, in press), appear to explain most of the inter-annual variability in Baltic sprat recruitment success.

The second source of evidence stems from a comparison of otolith-based somatic growth trajectories of 26–42 mm total length (TL) pre-recruits (sampled in August 2003) and those of 60-95 mm TL age-0 recruits (sampled in October, 2003) in the western Baltic Sea. Within a similar range in ages, pre-recruit growth rates declined very rapidly at the end of August compared to fish that survived until October (Fig. 2). We speculate that this decline most likely resulted from very poor feeding conditions for pre-recruit sprat in nearshore waters since i) pre-recruits and recruits likely experienced similar temperatures, ii) almost all pre-recruits had empty stomachs when caught, but mainly because of iii) the otolith growth patterns (somatic growth) of field-collected pre-recruits exposed to controlled feeding conditions in the laboratory. Pre-recruits responded immediately by increasing growth rates when provided *ad libitum* food rations while fish kept under zero food conditions showed a similarly rapid growth decline as observed prior to sampling (Fig. 2). Starvation of early juvenile fish has rarely been documented in the field but may, at least in the case of Baltic sprat, comprise a density-dependent mechanism operating in coastal nursery areas.

Our results suggest that high temperatures may be necessary but are not always sufficient to fuel high rates of growth and survival in Baltic sprat. Future investigations will target the interaction between temperature and prey availability in Baltic sprat since both factors establish growth rates in fishes (Houde, 1989).

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Seasonality in morphometrics and energy allocation suggest food limitation with increasing size in Baltic sprat in the Bornholm Basin

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During the last two decades, the upper trophic level of the Central Baltic Sea ecosystem has shifted from being dominated by cod (*Gadus morhua*) to being dominated by sprat (*Sprattus sprattus*) (Köster *et al*., 2003; Alheit *et al*., 2005). The cod spawning stock declined to a historical low level (~75 000 t) in 1999 due to successive recruitment failures combined with high fishing intensity (Bagge *et al*., 1994). The corresponding decrease in predation pressure on sprat, combined with low fishing mortality and high reproduction success of this species, resulted in a pronounced increase of the sprat stock (ICES, 2003). Lower salinities and higher temperatures since 1990 have resulted in a significantly reduced biomass of *Pseudocalanus* sp. and an increase in the biomass of *Acartia* spp. (Möllmann *et al*., 2000). Changes in the dominant copepod species in the Baltic appear to have impacted zooplanktivorous fish. For example, dramatic changes have been observed since the 1980s in the weight at age of herring (*Clupea harengus*).

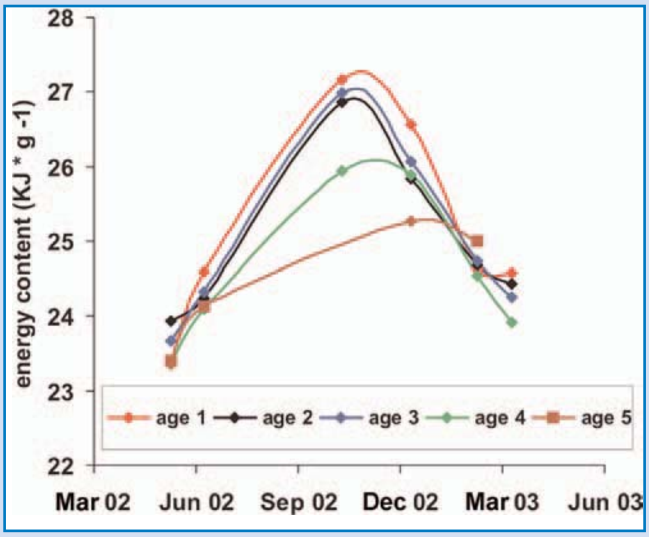

Figure 1. Annual cycle of dry weight-specific energy content (KJ g DW^{-1}) of five age classes of Baltic sprat sampled from May 2002 to April 2003 in the Bornholm Sea.

Within the GLOBEC Germany program, we have been investigating potential top-down and bottom-up processes using sprat as a target species. Large juvenile and adult sprat have been collected during an intensive field sampling program consisting of 15 cruises conducted from April 2002 to November 2003 in the Bornholm Sea. The temporal coverage of these sampling efforts allowed the annual cycle of sprat energy content to be measured as a basis for bioenergetics modelling. Similar seasonal patterns of energy content were found in all sprat age classes (Fig. 1). The lowest energy was observed at the end of the spawning period (May to June) and energy content was highest in November after the summer feeding season. The annual cycles for 1- to 3-year-old sprat were almost identical. Sprat

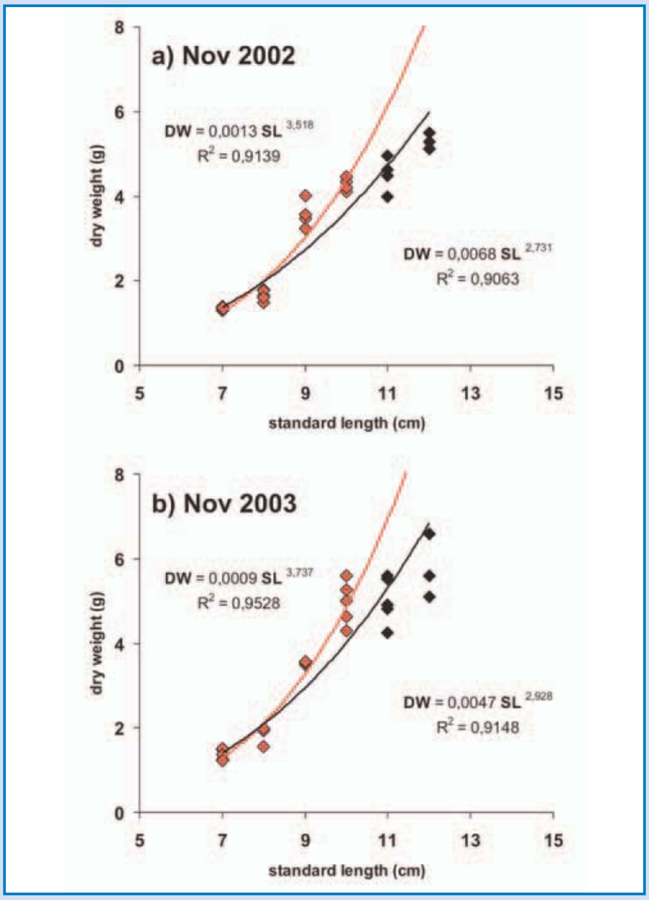

Figure 2. Dry weight (DW, g) versus standard length (SL, cm) for Baltic sprat collected in the Bornholm Sea in a) November 2002 and b) November 2003. Two regression lines are shown: Black = full data set, Red = exclusion of fish >10 cm SL.

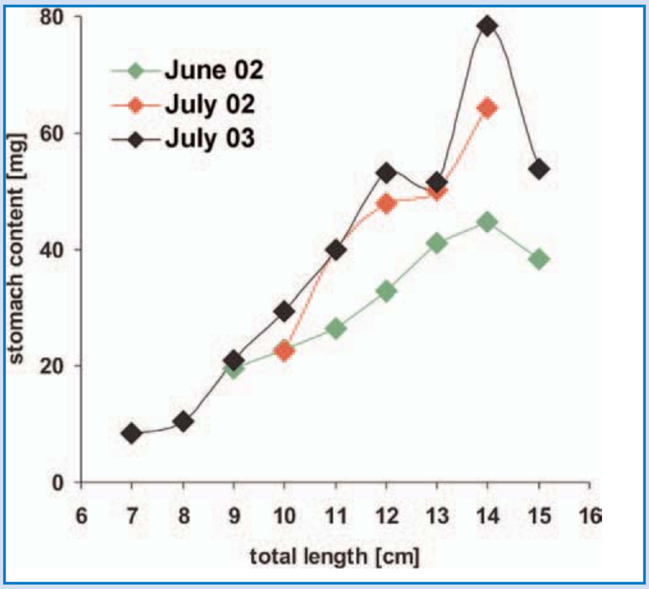

Figure 3. Stomach content (mg) versus total length (cm) for Baltic sprat collected during each of three months within the main feeding period in the Bornholm Sea.

>3 years of age also exhibited the same exhaustion of energy stores than younger conspecifics at the completion of spawning. However, compared to younger fish, the energy contents of these older fish were comparably lower in November. This pattern suggests food limitation in older age classes. Food limitation was also evident from the weight-length relationship of fish in November 2002 and 2003 (Fig. 2a and b). In this case, a lower weight-at-length for sprat larger than 10 cm standard length (SL) is clearly indicated by an increased exponent of the weight-length regression upon exclusion of these larger fish from the data set.

The weight at the end of the growing season is the result of the total food intake over this period. Sprat schools are composed of a mixture of all age classes that feed together on the same prey patches (at the same prey densities). Stomach content data from three months during the main feeding period sampled in the same program also indicated that sprat in all size classes fed on the same diet (prey composition) but that sprat >12 cm total length (TL) did not increase their food intake in comparison to the fish in smaller size classes (Fig. 3). In contrast to herring, sprat have never shown filter feeding behaviour, even at very high food densities, in our facility and rely solely upon snatching behaviours to catch individual prey items. Moreover, unlike herring, stomach content data for sprat indicated that prey size does appear to increase with increasing body size for fish >5 cm TL. We hypothesise that this prey snatching behaviour and lack of prey switching by Baltic sprat becomes disadvantageous with increasing predator size. Larger sprat have higher total energy demands and are less abundant than smaller individuals. These large fish must compete for limited resources with smaller conspecifics that have similar rates of snatching (prey capture) as larger fish. The problems faced by larger sprat are likely exacerbated at high stock sizes where these fish may exhibit top-down control on Baltic food resources (Möllmann *et al.*, 2004). Ongoing and future laboratory and field sample analyses will examine this hypothesis as well as compare and constrast these Baltic data with those collected for North Sea sprat.

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Facing the past – recovering historic echo-data

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Although we were able to contrast two distinct hydrographic regimes in the Baltic Sea within the field phase of the German GLOBEC project, i.e. a stagnation period and a post inflow situation (Mohrholz *et al.*, in press; Kraus *et al.*, 2003), long term ecosystem changes were not in focus until now. However, an important regime shift was observed in the Baltic Sea some fifteen years ago. In the late 1980s the pelagic ecosystem changed from a cod-dominated to a sprat dominated system (Kornilovs *et al.*, 2001; Alheit *et al.*, 2005). A combination of reduced reproduction success and increased fishing pressure led to a rapid decrease of the stock size of Baltic cod (Köster *et al.*, 2003). Simultaneously the sprat stock size increased rapidly. Stabilising effects are assumed for both regime states, due to predatory control. During the cod-dominated phase, cod controlled the sprat stock, while at present, sprat strongly influence cod reproduction success preying upon cod eggs. Therefore, the spatial and temporal overlap of both species is essential to understand the dynamics of the Baltic Sea pelagic fish community.

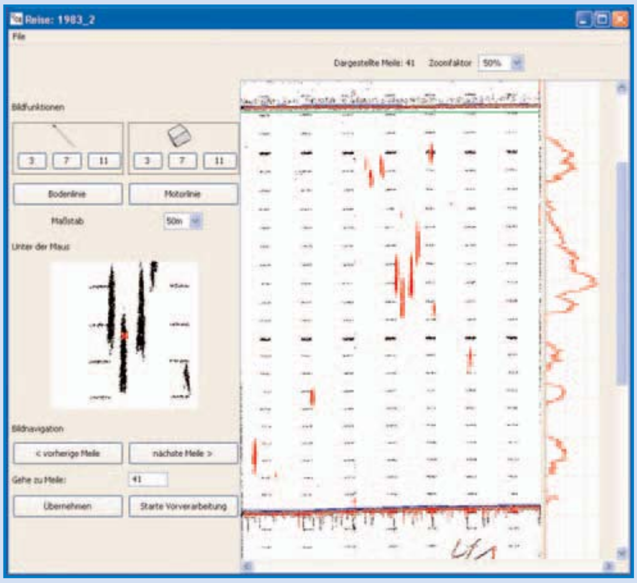

Figure 1. Screenshot of the program-graphical user interface (GUI). This window shows the fine-processing routine for pre-processed echograms. At the right side, the relative vertical echo-distribution is displayed.

Hydroacoustics is an important tool to define preferred habitats and estimate abundances of pelagic fish species. Since 1999, we conducted regular acoustic surveys in the Baltic Sea regularly from spring to autumn. As a result, seasonal changes in abundance and distribution during a phase of high sprat abundance are now well understood. As yet, a comparison to a phase of low sprat and high cod abundance (i.e. before 1990) was restricted by the coarse horizontal resolution of historic acoustic data files. These files do not contain any information on the vertical scale, which is essential for defining habitats and their overlap. Historic raw data are available back to 1979 and stored as printed echograms.

In the frame of the German GLOBEC-project, software was developed for the analyses of scanned echograms at the Fraunhofer Institute for Computer Graphics, Rostock. This software prevents the loss of valuable historic data (Zeller *et al.*, 2005) and offers a high degree of automation. The scanned echograms are automatically prepared for analysis (optimal rotation, detection of ROIs and horizontal markers, i.e. nautical miles, calculation of thresholds and others). Subsequently, for every processed nautical mile bottom detection and identification of fish echoes are displayed and unwanted pixels (e.g. depth markers) are deleted automatically. The software has a high degree of flexibility and offers manual manipulation in case the implemented algorithm delivers unsatisfying results. All configurations for echograms are stored in .xml-format, which supports further software-independent handling of echogram-scans. Finally, the software exports the vertical distribution of black pixel, caused by fish echoes.

With this application, we are now able to compare acoustic sprat abundances and distribution patterns during two contrasting ecosystem regimes in the Baltic Sea, i.e. a cold, cod dominated phase and a warm, sprat dominated phase. This supports Focus 1 of the GLOBEC-Implementation Plan (IGBP, 1999), which is the retrospective analyses of ecosystems to understand variability and changes, which cannot be resolved with single or even multi-annual studies.

We would be happy to share our knowledge with colleagues, who face the same problem of recompiling historic echo-data.

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Ocean Sneaker's Tool: An open code software tool for fast processing, exploring and visualising marine and aquatic data

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Aquatic data often require various processing steps from collection to analysis. This might include the adding of metadata to measured values for mapping software, the conversion of stacked net data to area related or other complex transformations. Although these steps can be accomplished quickly for single parameters it is a time consuming process with increasing numbers.

As a spin-off from GLOBEC-Germany the software package 'Ocean Sneaker's Tool' (OST) was developed (Fig. 1). Its focus is to aid biological researchers with their daily work and to facilitate the initial exploration of datasets. OST includes a basic spreadsheet analysis, provides a universal import filter for ASCII plaintext formats and supports several specific file types generated by different oceanographic gears. Three major modules cover a wide range of processing, converting, exploring and visualising of selected data subsets.

The data mining module can create reports for statistics, calculate percentile proportions, perform various transformations and conversions and provide iterative data scaling. Statistical analyses include basic descriptive statistics (e.g. *mean*, *median*, *sum*, *range*, *variance*, *SD*, *SE* and *VC*). For similarity and dissimilarity based investigations (Clarke and Warwick, 1994) matrices according to *Bray-Curtis*, *Canberra*, *Manhattan-* or *Euclidean distance* can be computed. The Sammon mapping option provides an easy multidimensional scaling technique (Sammon, 1969) that reveals inherent structures in order to explore data sets, like finding possible clusters, correlations or underlying distributions and can be run with raw data. Prior to analyses, data can be automatically *log*, *ln*, *sqrt* or *arcsin* transformed. Functions are available for the conversion of $n \times m^{-3}$ from stacked nets to $n \times m^{-2}$, which can be used to calculate the weighted mean depth (Bollens and Frost, 1989) for several species simultaneously.

The geo-coded export module includes metadata like cruise, station, date, time longitude, latitude and bottom depth to measured values. The output format can be imported directly to Ocean Data View (http://www.awi-bremerhaven.de/GEO/ODV) or other mapping programs for further investigation. Latitude and longitude can be given in various formats and are automatically converted to decimal degree notation as required for computer assisted work.

The visualising module allows data sets to be displayed in various graphical formats, e.g. as line, bar, area, polar, scatter, stacked and surface plots (examples in Fig. 1). All properties can be customised to modify the appearance in 2D or 3D mode. Additional algorithms can create interpolated isolines, allow labelling of charts and adjust to the desired perspective. Charts can be saved in different formats (e.g. emf, eps, gif, jpg, pdf, wmf and several others) and displayed data can be exported as MS Excel, HTML or native ASCII format.

At present OST is in the beta phase of version 2.0 after pervasive modifications during the last year. The project now consists of more than 23,000 lines of source code distributed over 25 units and is written in easy understandable object Pascal (Borland Delphi; http://www.borland.com/de/products/delphi). The source code can be downloaded from the website (http://www.awi-bremerhaven.de/Software/OST) and allows users to inspect algorithms, modify functions as desired and developers to implement new features.

Since the reorganisation of the website in October 2005 (www.awi-bremerhaven.de/Software/OST) the tool has drawn international attention beyond Germany (Fig. 2). It is now referenced by other institutes and projects like CENSOR, IOC Ocean-Teacher and Pangaea. OST runs under Windows 95/98/2k/XP and no problems have been reported so far when used with emulators under Linux and Mac environments. The use of efficient code and the waiving of specific code linked to an operating system results in a stand-alone software of just 2.5 MB. As neither additional libraries nor an installation is required OST can even be run directly out of a zip-archive from an USB stick on machines with different regional preferences.

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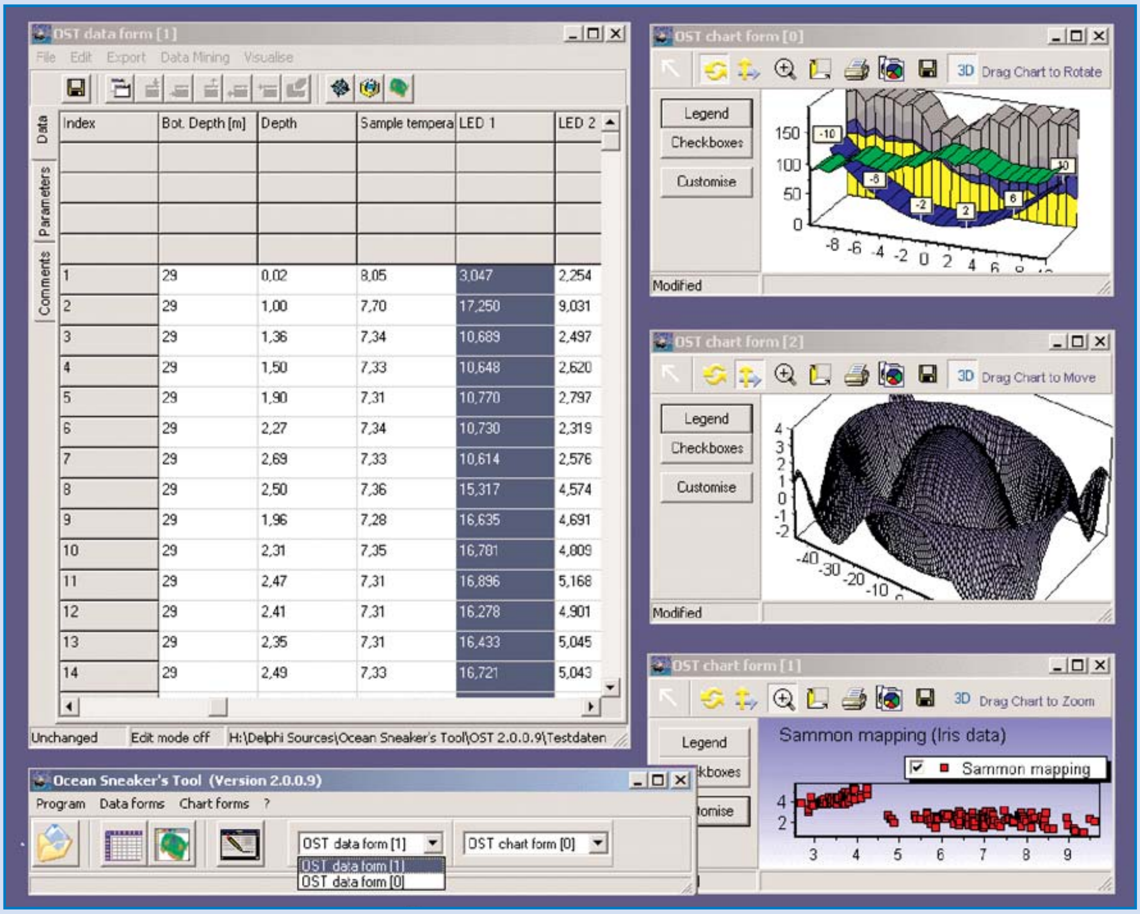

Figure 1. Screen shot of the current Ocean Sneaker's Tool version. The application navigator (lower left) makes it simple to access the different chart (right) and data-windows (upper left). Windows are resizable and can be arbitrarily positioned.

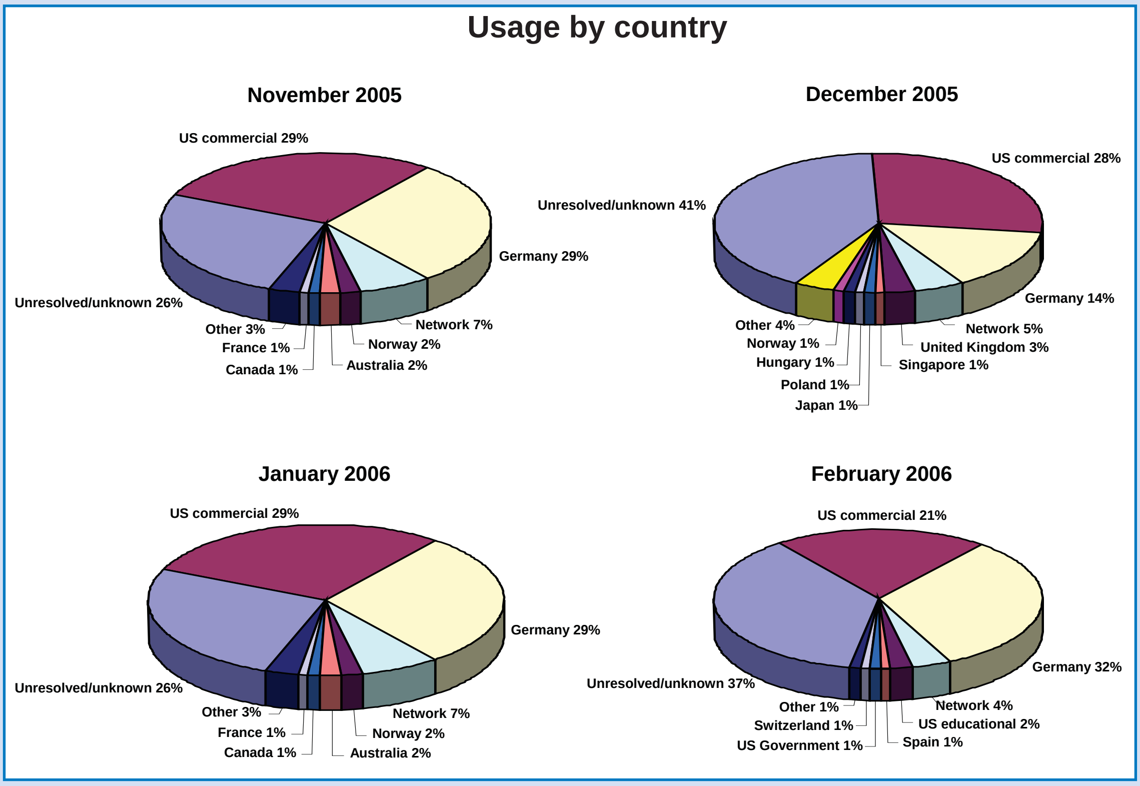

Figure 2. Website usage by country between December 2005 and February 2006 generated from the web logs.

GLOBEC Workshop on "impact of climate variability on marine ecosystems: a comparative approach"

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The Focus 1 Working Group on Retrospective Studies and Time Series Analysis will organise a workshop on the "Impact of Climate Variability on Marine Ecosystems: A Comparative Approach" in the Museum of Natural History of the Humboldt University in Berlin, 4–8 September 2006.

Justification

Marine ecosystems are far from constant. They can undergo dramatic changes in their community structure and dynamics over various time scales, from interannual to decadal and beyond. This includes significant changes in the abundance, diversity and productivity of the plant and animal populations, as well as changes in the dominance patterns within marine communities. Low frequency changes at decadal and longer time scales are sometimes severe and can lead to devastating impacts on those people and nations dependent upon the sea and its resources. Climate is often implicated as the driving force in any of the large scale shifts in marine ecosystems. Recent evidence for climate induced ecosystem changes on the decadal scale has been accumulating and numerous examples have been described, particularly from the North Atlantic, the North Pacific and eastern boundary currents. This evidence was gained largely through retrospective studies, i.e., the analyses of historical atmospheric and marine data. In some instances, paleo-records have allowed us to look much further back in time and, most importantly, at periods when human intervention through fishing was not important. Such studies provide the overall framework to understand the underlying natural modes of ecosystem variability, their characteristic temporal scales and their rates of change. They offer us the opportunity to distinguish the effects of human intervention, such as habitat alteration as well as harvesting, from natural variability in these systems. This is especially important as we attempt to devise better management strategies for present-day fisheries, since understanding the relative roles of climate and humans, as well as their interactions in controlling fish stock variability, is crucial for good management. It is also a prerequisite that will enable us to predict future impacts of anthropogenic global climate change.

The impact of climate variability on marine ecosystems has been an important focus of a number of national and regional GLOBEC programmes which are carried out in local waters through a combination of retrospective investigations, modelling efforts and process studies. The comparative approach has played an important role in these regional studies. However, to date, there has been little opportunity for the national and regional GLOBEC programmes to conduct larger-scale comparisons across marine systems and species types. Such comparisons, however, have the potential to further elucidate the inherent mechanisms controlling large-scale ecosystem changes.

The aim of this proposed workshop is to bring together the representatives of these GLOBEC programmes to discuss these interactions and their ramifications. Strong interdisciplinary participation between physical oceanographers, biological oceanographers and fisheries scientists is already present in these national and regional projects and the proposed workshop would help to continue this. To strengthen interdisciplinarity, we have also invited paleo-oceanographers, climatologists and fisheries historians, as their input will provide a deeper insight into the mechanisms leading from atmospheric signals to reactions of marine populations. Since the overall problem involves many interrelated aspects of different scientific disciplines (marine, terrestrial atmospheric; biological, physical and biogeochemical), the scientific effort to further our knowledge must necessarily be broad and diverse. The proposed workshop will enhance our understanding of the response of marine ecosystems to environmental change and improve our knowledge of the impact of climate variability on marine ecosystems. Through the comparative approach, it will help to elucidate mechanisms controlling the abundance and distributions of marine populations, including commercially important fish species. The improved mechanistic understanding of the coupling between physics and biology will, in turn, improve the reliability of predictions of the future composition of marine communities and provide a new basis for ecosystem and resource management.

Goals

- to provide a survey of large-scale, long-term ecosystem changes throughout the world's oceans;
- to identify apparent synchronies or asynchronies between these changes and to evaluate the ramifications to current understanding of marine ecosystem operation;
- to gain insight into the causes and mechanisms underlying the major ecosystem changes;
- to promote development of new, more powerful methodologies to quantitatively assess large-scale ecosystem changes;
- to better understand how human exploitation modulates the response of marine populations and ecosystems to climate variability;
- to further the assembly of the scientific understanding needed to effectively model the dominant modes of marine ecosystem variability in the world's oceans;
- to determine the potential use of resulting model outputs for better management of present-day fisheries and in predicting possible future marine ecosystem structures under anthropogenic global climate change.

Format

The workshop will follow the format of the Dahlem conferences. Participation is by invitation only. There will be no presentations during the meeting. However, some participants have been asked to provide background papers which will be available to the participants well in advance of the workshop and which will be the basis of the discussions during the workshop. These background papers together with the summaries of the discussions will be published in a special volume of the Journal of Marine Systems after peer-review shortly after the meeting.

Themes

The discussions will be held in four working groups focusing on:

- Climate variability and teleconnection patterns of marine populations
- Impacts of past climate variability on marine ecosystems (over the past two millenia)
- Mechanisms linking climate variability to marine ecosystems
- Sensitivity of marine ecosystems to climate and human exploitation.

The working titles of the background papers are:

- Synchronies in fish population fluctuations within and between ocean basins
- Global comparisons of zooplankton time series
- Climatic teleconnection patterns forcing marine ecosystems
- Paleo evidence for the variability of upwelling and other systems prior to industrialised fishing
- Historical evidence for the variability of fish populations prior to industrialised fishing
- Linking climate to population dynamics: integrative concepts and novel constructs
- Major routes by which climate signals force marine populations
- How does human exploitation alter marine populations and ecosystem sensitivity to climate?

The workshop will be chaired by Jürgen Alheit, Ken Drinkwater and Ian Perry, which is a contribution to GLOBECís Integration and Synthesis. If you would like to be informed of the outcome of the meeting please contact the chairs or the GLOBEC IPO.

GLOBEC Focus 2 Process Studies Working Group meets at Dartington Hall

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The historic Dartington Hall in Devon, UK, parts of which date back to 1388, was the venue for a recent meeting of the Focus 2 Working Group. Full details of the meeting can be found in the report at http://www.globec.org. This short article summarises selected aspects of the WG meeting.

WG members contributed a wide range expertise on geographical regions and ecosystem types as well as providing relevant specialist knowledge of calanoid copepods, euphausiids, gelatinous zooplankton and microzooplankton. Attending the Dartington Hall meeting were (Fig. 1), Uli Bathmann, Ulf Bämstedt, Francois Carlotti, Sanae Chiba, Dian Gifford, Roger Harris, Serge Poulet, Marina Sabatini, Sun Song and Mike St John. They were joined by Manuel Barange and Dawn Ashby from the GLOBEC IPO.

The Process Studies Working Group helps to facilitate international implementation of the research on process studies outlined in the GLOBEC Implementation Plan. The group works with the definition, *"an organised, systematic investigation of a particular process designed to identify all of the state variables involved and to establish the relationships among them. Process studies yield numerical algorithms that connect the state variables and determine their rates of change; such algorithms are essential ingredients of Earth system models".* This working definition illustrates the importance of such studies for GLOBEC and their particular relevance for models and for the Integration and Synthesis phase of the programme. Throughout the Dartington Hall meeting the emphasis was on the role that the group could play in Integration and Synthesis.

The WG reviewed progress on the review article on *"Feeding, growth, reproduction and mortality of copepods: a GLOBEC review".* This project reviews these four processes for a subset of target species studied over a range of physical system types addressed in national and regional GLOBEC programmes. Also the group agreed to begin a new activity considering process studies with a focus on Antarctic krill with the provisional title, "*Euphausia superba* as a key species for small- and mesoscale processes and population dynamics in Antarctic ecosystems: The SO-GLOBEC perspective". Rather

Figure 1. The Working Group members outside the Dartington Great Hall.

than duplicating recent krill reviews, the aim will be to focus on charting new directions for future research on Antarctic krill. Progress on another initiative on GLOBEC process studies of small scale biology-physics interactions (turbulence, mixed layer dynamics, patchiness) was also reviewed. Finally, it was decided to begin new writing activities on gelatinous zooplankton and processes. The database of GLOBEC publications maintained by the IPO as well as the recently published GLOBEC Special Contribution No. 7, "*Update of GLOBEC National, Multinational and Regional Programme Activities, 2004*." formed a valuable basis for these discussions and the associated writing work.

In addition to considering key processes, the concept of key species is critical in attempting to tackle the complexity of marine ecosystem dynamics. Key species are important for the work of the WG and for the Integration and Synthesis effort. To ensure that the group's work is most effectively linked with major national and regional programmes the Focus 2 group tries to assimilate information on target species from these programmes. To aid this it was decided that a small F2WG writing team would draft an article for the GLOBEC Newsletter discussing the key species concept and its application within the GLOBEC I&S effort

Figure 2. Sun Song, Dawn Ashby and Manuel Barange at the wine tasting (top) and Uli Bathmann discusses the finer points of Devon wine (bottom).

A new initiative within IMBER on *"End-to-end food-webs"* was presented and this links with plans for a EUR-OCEANS meeting on *"Parameterization of Ecosystem Models".* Plans for the joint workshop with F3WG on *"Mathematical modelling of zooplankton dynamics*", to be held at CIRM, Luminy, Marseille, France, 2–5 May 2006 were reviewed. Development of major potential programmes in the North Atlantic and North Pacific were also discussed. In the North Atlantic the planned BASIN program would further the capacities necessary to predict the structure and dynamics of the North Atlantic and related shelf ecosystems under the influence of climate variability.

The proposed Oceanic Ecodynamics COmparison in the Subarctic Pacific (OECOS) may develop in parallel to BASIN providing the opportunity for Pacific-Atlantic comparisons and synthesis. OECOS would make "An east-west comparative study of lower trophic level pelagic ecology in the sub-arctic Pacific Ocean".

Detailed plans for a 2006 Roscoff workshop on "*Influence of phytoplankton on herbivore reproductive success – impact of infochemicals and food quality?"* were discussed by the group. Finally advice and input was sought on the session topics for the 2007 4th International Zooplankton Symposium to be held 28 May – 1 June 2007 in Hiroshima sponsored by ICES, PICES and GLOBEC and the Plankton Society of Japan and the Japanese Society of Fisheries Oceanography.

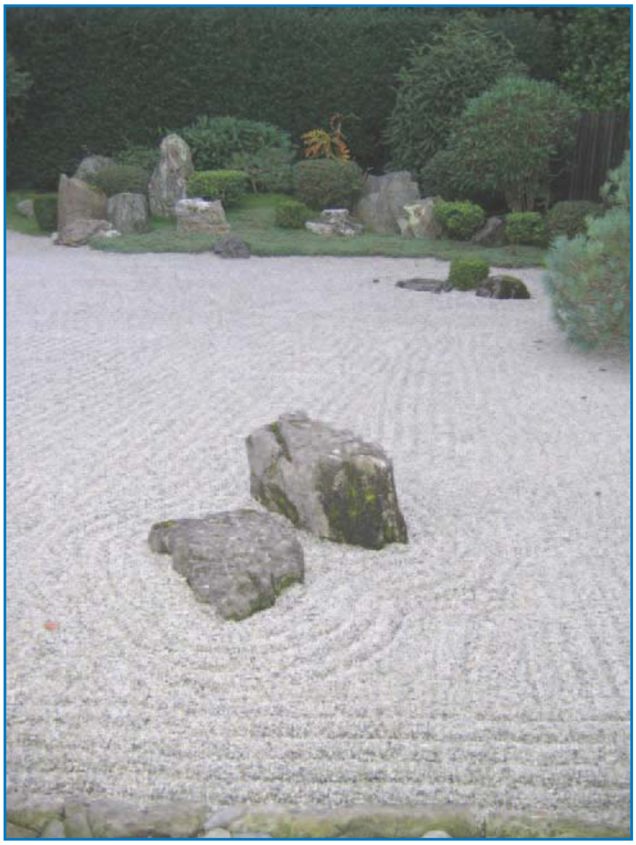

Figure 3 Japanese garden at Dartington Hall.

The Dartington Hall meeting began by revisiting the *GLOBEC International Integration and Synthesis Blueprint* and subsequent discussion throughout the meeting concentrated on how future work on process studies might best contribute to the programme-wide effort. As part of its role the Focus 2 WG will continue to foster comparative studies including both contrasts among key species within regions, between regions, and also across system types and processes. The wide range of writing activities, research proposals, workshop and symposium plans discussed at the meeting should all contribute to the overall Integration and Synthesis. As mentioned previously full details are in the F2WG report on the GLOBEC website.

Dartington Hall provided a beautiful and tranquil environment for what was a productive meeting. In addition to long days of presentations and discussions, time was found for a wine tasting visit to a local Devon vineyard (Fig. 2) and there was also opportunity for reflection in the Japanese garden (Fig. 3).

The Focus 2 Working Group works with and supports the whole GLOBEC community. It is not a closed group and anyone interested in the activities covered at Dartington Hall and who would like to become involved the work on GLOBEC process studies is encouraged to get in touch with one of the WG members. A full membership list with contact details is on the GLOBEC website.

GLOBEC Focus 3 (predictive and modelling) working group meets in Scotland

Brad de Young, Memorial University, St. John's, Canada (bdeyoung@physics.mun.ca)

Our working group met last September in Aberdeen following the ICES Annual Science Conference. This was our first full group meeting since Qingdao in October of 2002 and was an opportunity to review progress on different projects and to plan for the coming years. We reviewed our approach and again endorsed the need to ensure that our meetings are as productive as possible and that we should avoid meeting just to meet and that work subgroups and tasks should all aim to produce papers in the primary literature. Much of the discussion at our meeting would be of interest to the broader GLOBEC community and key aspects are presented here. If you would like to hear more, or contribute to any of our activities, you are encouraged to contact the chair – Brad de Young (bdeyoung@physics.mun.ca).

Mathematical modelling of zooplankton dynamics

Together with Focus 2, we will be holding a workshop early this May (2006) to review and discuss the mathematical modelling of zooplankton dynamics. This effort is led by Francois Carlotti (France) and David Mackas (Canada). The meeting will be held at the International Center for Mathematical Meetings (http://www.cirm.univ-mrs.fr) outside Marseille, France. We will define some key processes for discussion that are central to marine zooplankton and for which progress can be made in a workshop environment. It is expected that about twenty people will attend with interests that cover mathematical modelling, population modelling, spatially explicit modelling, process studies, observational and data collection and evolution and ecology. We propose to review five key issues:

1. Feeding functional responses
2. Metabolism and growth
3. Mortality
4. Predator-prey interactions and
5. Habitat selection.

Publications for the primary literature will be prepared following the meeting. We will report on the meeting in a future newsletter.

Spatial modelling of fish populations

Models of fish population dynamics have a long history in marine science, generally motivated by the needs of stock assessment and advice. Most the models have been spatially aggregated to the scale of management units (e.g. the Norwegian Sea), delivering advice on regional scale integrated abundance and projected changes in species numbers at age under different scenarios of spatially integrated fishing mortality rate. However, as the demand to incorporate a wider range of ecological considerations into fisheries management increases, with the aim of both responding to the effects of climate change and minimising collateral effects of fishing on habitats and other species, so there is a requirement for new models which will explicitly resolve the spatial structure of fish populations.

Models to predict the consequences of spatial management measures on a spatially structured stock will need to represent the physical oceanographic features and fish behaviour patterns that maintain spatial organisation, as well as the spatial patterns of production (recruitment and growth) and mortality (natural and fishing) and how all of these may have changed over time in response to climate fluctuations and human interventions. This type of modelling represents a significant departure from the current modelling approaches as applied to fish stocks.

Population dynamics of any species are fundamentally governed by rates of reproduction, growth and mortality. Protozoan and metazoan populations differ in that for metazoans these rates depend more heavily on demographic factors and individual behaviour, and this dependence is strongly accentuated with increasing body size and functional complexity. Hence, whilst models of phytoplankton and micro-zooplankton based on the accumulation and loss of the elemental mass of the population are generally sufficient to caricature the population dynamics, such principles are unable to capture the key properties of fish or larger zooplankton populations to any acceptable degree. A different modelling approach is required for such species. For this reason, the construction of models incorporating the trophic linkages between for example, fish, their planktonic prey and bird or mammal predators, represents a major challenge, but one which must be overcome to fulfil the demand for spatially resolved models.

Fish exhibit a very wide range of behaviours at the individual and population level, which dictate the population dynamics. Some species form large schools and are migratory at ocean basin scales, spending their entire lives in the upper water column. Others are solitary and territorial at metre-scales associated with sea-bed features. Some species appear to be pan-mictic at large (ocean basin) scales (e.g. anglerfish, *Lophius piscatorius*, in the northeastern Atlantic), whilst others exhibit meta-population structure at relatively small scales (reefs, islands, few 100 km). In many cases, population structures can be related to oceanographic features dictating the extent of passive larval dispersal, although the active behaviours which complement these must represent some evolutionary adaptation to secure the persistence of genetic lineages. Hence, spatial perturbations of habitat, oceanography or foodweb structure can be expected to result in dynamic changes in fish populations.

There have been a number of initiatives to develop spatially resolved closed life cycle models of fish populations, following a number of alternative methodologies. Individual based models offer the prospect of explicitly incorporating behavioural rules and adaptation responses, but carry a heavy computational overhead. Eulerian grid type models may have lower computational demands but face major technical challenges in representing the movement of structured populations. We propose to review the state of knowledge of population structuring processes in fish and the recent developments in representing these in population dynamics models. Mike Heath has agreed to take the lead on this project which is expected to be developed in 2006 with completion in early 2007.

Connections with IMBER

We invited Mike St. John to attend our meeting as he and Coleen Moloney are co-chairs of a task team of IMBER/GLOBEC that is working to define the concept of end-to-end food webs to discuss how we could make headway in the experimental, observational and modelling studies of marine food webs. Our working group addressed a related issue of modelling ocean basin ecosystems in a paper that was published in Science in 2004 (deYoung *et al.)* and so have a direct interest in the problem of how to tackle marine ecosystem structure. We had a lively and interesting discussion on this issue. It was suggested that one approach might be to identify examples from JGOFS and GLOBEC food web/ecosystem research and proposing realistic ways of extending the scope of each. This leads naturally into a discussion of bringing together and building upon these complementary approaches. Our working group agreed to support the work of the joint task team however possible.

An informal meeting of the working group at Dunnottar Castle on the coast of Scotland, famous for its defiance of Oliver Cromwell in 1651. From left to right: Celia Marrase (Spain), Coleen Moloney (South Africa), Francois Carlotti (France), Brad deYoung (Canada), Oyvind Fiksen (Norway) and our host for the meeting Mike Heath (UK). Roger Harris (UK) and Mike St. John (Germany) also attended parts of the meeting but were not present for this historic meeting at Dunnottar. Other members of the group unable to attend the meeting include Lou Botsford (USA), Michio Kishi (Japan), Eugene Murphy (UK), Cisco Werner (USA) and Meng Zhou (USA).

Ecosystems and fisheries management

GLOBEC is one of the leading global science programmes focusing on understanding the functioning of marine ecosystems, with special reference to harvestable resources and the impacts of climate change and fishing. The international investment in GLOBEC should be realised as a major contribution to the task of implementing an ecosystem approach to fisheries management. The societal relevance of GLOBEC science will be one of the measures of its success. Our working group did not develop any specific plans to address this issue but proposed that this activity be viewed as an ongoing, long-term activity of GLOBEC, sustained through GLOBEC involvement and representation in international fora concerned with ecosystem issues. We see this activity as a broad issue that could be addressed by different groups within the GLOBEC program. No particular plans were developed for this activity at this time.

Comparative ecosystem analysis

At a previous meeting, the working group supported the synthesis of generic, simplified conceptual models of marine ecosystem function, with the zooplankton community as a core element. Over the past decade, we have developed new understanding of marine ecosystems, yet that knowledge has not yet reached the broader marine science community nor the public at large. We propose that a small group should write a review of ocean ecosystem function that draws on current theory and also highlights some of the new insights derived from GLOBEC studies. It was suggested to use structure and metabolic indexes to classify the systems and explore if it is possible to describe general key physical and biological factors that drive the structure and function of the system. The exponent of the size-abundance relationship was proposed as a structure index and ratios like respiration/biomass or new production/carbon sequestration as metabolic indexes. The ratio new production/carbon sequestration will give an idea of the relative importance of recycling and therefore the relative importance of certain pathways of carbon and nutrient fluxes. This could be an exciting activity that would be of broad interest to the marine science community. Eugene Murphy has expressed an interest to take the lead for our working group although no specific work plan has yet been developed.

GLOBEC Focus 4 Workshop on the human dimensions of marine ecosystem changes: understanding the linkages through comparative case studies.

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Assessing the human dimensions of, and their interactions with, marine ecosystem changes is a new initiative of GLOBEC, without analog in other Regional or National GLOBEC programs. It has the potential for strong interaction with other global change programs, such as the International Human Dimensions Program (IHDP). Two preparatory meetings of GLOBEC Focus 4, with unofficial membership, were held (in Sidney, Canada, June 2002 and Banff, Canada, June 2003) to scope out the issues and problems related to the linkages between fishing-dependent human communities and marine ecosystem changes, and to establish working relationships among natural and social scientists. Reports of these workshops have been published in previous issues of the GLOBEC Newsletter. The Focus 4 Working Group has now been formally constituted (see the GLOBEC International Newsletter 11(1): 38-39) and its first meeting was held at Dunsmuir Lodge, Sidney, BC, Canada, from 31 August to 2 September 2005.

The objectives of this workshop were to:

1) develop an "appraisal" paper on 'inter-dependent changes in marine ecosystems and fishing-dependent human communities';
2) develop plans for a major symposium on coupled marine ecosystem-human community interactions in the face of global changes; and
3) develop contacts among members of the Focus 4 Working Group, hopefully leading to collaborative proposals and activities.

All of these objectives also serve as important contributions to GLOBEC's Integration and Synthesis activities.

Most of the meeting focused on the first objective; case studies were presented on a number of examples worldwide of inter-related marine ecosystem and human coastal community changes. Two of these examples discussed North Atlantic cold-water ecosystems. Svein Jentoft (University of Tromsø, Norway) described the Barents Sea ecosystem. Its high latitude, large seasonal and inter-annual variability and position near the Arctic Ocean makes it an extreme environment. The marine ecosystem is dominated by a few key species and experiences marked fluctuations of commercially-important species. The economy and human population are connected with the marine ecosystem through three main activities: fishing, oil and gas extraction, and sea transportation – with fishing the most important activity for the northernmost county of Finnmark. Severely reduced Atlantic cod stocks in the 1990s affected this county particularly harshly, hitting coastal communities harder then those in the interior. Consequences included a fishing industry near bankruptcy, unemployment and out-migration of much of the younger population. Those people who remained survived largely on other employment opportunities (such as with the public sector), welfare, fishing "harder" and for other species (such as shrimp) and skills-upgrading through education. Fortunately, this crisis disappeared in the later 1990s with the return of healthy cod stocks, although permanent changes remain. Barbara Neis (Memorial University, St. John's, Canada) and Rosemary Ommer (University of Victoria, Canada) presented a similar example from the other side of the North

Atlantic, off Newfoundland, Canada. This is also a large cold-water ecosystem with strong seasonal and inter-annual variability. Fish biomass now is lower than historically and the region has a relatively low human population density which is declining in most fishing-dependent areas. The early 1990s saw a major shift in species dominance from demersal fish to shellfish, small pelagic species and seals. This collapse of bottom fish caused a decrease of 50% in the fish processing labour force. However, by 2003 the number of fish harvesters had almost recovered to pre-collapse levels; their distributions among boat sectors and species harvested, however, were quite different. Small-scale fisheries of the past were household-based; family connections still matter today but are now less important. Low incomes and overall outmigration of younger families are contributing to aging labour forces in fishing and fish processing and potential future labour shortages. Harvesters have developed a variety of fishing and non-fishing livelihood strategies to deal with variations in their social, economic, political and natural environments. These include fishing "harder", multiple income sources which include other sectors and employment insurance. Industrial and environmental restructuring in Newfoundland interacted with policy changes and outmigration to sustain fishing effort in the short-term, drive up fishing costs and pressure to harvest, thereby contributing to ongoing problems with stock abundance and scientific uncertainty. In addition, rapid environmental and industrial restructuring influenced occupational health risks in fishing and fish processing, including increased search and rescue events, and serious occupational health problems such as asthma and allergy to shellfish.

Ian Perry (Fisheries and Oceans Canada, Nanaimo, Canada) presented an example from the Northeast Pacific, dealing with Pacific salmon. Although not as severe as the North Atlantic, this region also experiences significant natural variability on seasonal, inter-annual and longer time scales. The 1990s were a time of warm sea temperatures and a shift towards warm-water species of more southern origin. These conditions ended abruptly following the large 1997–98 *El Niño* and the 1998/99 *La Niña* events. Warm ocean conditions are generally not favourable for the growth and survival of Pacific salmon which originate from British Columbia and many of these stocks declined significantly over this period so that several major salmon fisheries were closed. These declines and closures caused unemployment and outmigration from coastal communities, leading to stress, family breakdowns and deterioration in individual and community health. Alternative employment in the other major industry in this region - forestry - was reduced because of declining jobs in that sector at the same time. Human responses to these changes were to move into other fisheries and marine-related activities such as aquaculture and tourism, reliance on government support programs, or outmigration.

Focus 4 Working Group members participating in the Sidney workshop. From L to R: top row: Ian Perry, Rosemary Ommer, Barbara Neis, Kevin Stephanus, Renato Quiñones, Kenny Broad; bottom row: Jiehua Lu, Carrie Holcapek, Rashid Sumaila, Svein Jentoft.

A variety of examples were presented focusing on upwelling systems, which inherently experience strong variability on a variety of temporal scales and to which one might expect fishing communities to have adapted at least to seasonal and inter-annual variability. Jiehua Lu (Institute of Population Research, Beijing, People's Republic of China) presented the situation of upwelling areas of China, in which most key fish species such as larger yellow croaker and small yellow croaker are declining and being replaced in catches with small pelagic species characterised by small size, low value, young age and early maturation. In addition, coastal lagoons are facing pressure from water quality, habitat degradation and overfishing issues. The past two decades have seen an almost 10% per year growth in fishing, driven by large increases in fishing effort; however, marine catches still account for only 36% of total Chinese fishery production. The remainder is made up by enormous mariculture production. This latter activity has been a major strategy of fisherfolk to adapt to fluctuations in availability of their key fishery species. Other strategies have included prey switching, migrations to distant fishing grounds and risk-spreading using social security measures. However, the effects of those strategies on the changes in upwelling systems needs to be evaluated and measured taking a long-term perspective. Ian Perry also presented the example of Ghana, West Africa, which is part of a tropical upwelling system with strong seasonal and inter-annual variability. Inter-annual variability appears to be driven at large spatial scales by *El Niño* events which influence sea surface temperatures and subsequent pelagic fish landings off Ghana. At decadal scales, Ghanaian marine waters experienced cool sea temperatures and low fishery landings during the 1960s, rapid warming and increases in fishery landings during the late 1970s and 1980s and variable temperatures and fishery landings during the 1990s. Added to this natural variability is intensive fishing which has reduced the biomass of several important harvested species. As expected, artisanal fishers and fishing communities in Ghana have devised strategies to deal with this natural variability, including exploiting marine and terrestrial resources more intensively, ensuring multiple and diversified income sources; investing in social relationships and communities for support; and undertaking seasonal or permanent migrations.

The more "traditional" major upwelling systems off Africa and South America were examined in three presentations. Rashid Sumaila (University of British Columbia, Vancouver, Canada) and Kevin Stephanus (University of Namibia, Windhoek, Namibia) described the situation of the Southwest African pilchard stock (off Namibia) and the interactions with human communities. The annual catch of Namibian pilchard declined from a peak of about 1.4 million tons in 1968 to the current annual catch of less than 20,000 tons. Two key reasons have been advanced for this decline: overfishing and an adverse environment. They concluded that the pilchard biomass collapses in 1971 and 1977/78 were largely attributable to overfishing. However, the collapse of the 1990s is blamed principally on environmental changes and in particular on the interaction between an unfavourable environment and unsustainable fishing practices. A number of coping strategies were used by both the pilchard harvesting and processing sectors in Namibia to mitigate the sharp declines in catches. These included movement of (largely foreign-owned) vessels to other parts of the world, targeting other species such as horse mackerel and shifting processing of pilchard to higher-valued products such as canning. This latter action both improved the total economic returns to the fishery and, because it is more labour-intensive, also contributed to softening the impact of the declines to workers in the processing sector.

Bringing in the catch in Moree, Ghana. Photo courtesy of FAO Sustainable Fisheries Livelihood Program.

In general, it appears that seasonal workers from the north of Namibia probably paid the highest price for the collapse of pilchard. Kenneth Broad (University of Miami, USA) explored the working hypothesis that vulnerability in Peru to the societal impacts of climate variability could be significantly reduced if strategies for improving socioeconomic development - particularly with respect to health, infrastructure, industrial fleet structure and small scale market exchanges - were strategically coordinated with knowledge of climate variability and change. Strong *El Niño* events cause spatial and temporal changes in ecosystems and also cause increased damage to ports, homes and roads resulting in health problems and increased spoilage of the catch. As there is not a culture of eating 'oily' fish (i.e., anchovy, sardine, mackerel) in Peru, these species, which make up 95% of the total catch, are largely converted to fishmeal for export. Considering the high degree of natural variability in this system, the artisanal fishery is challenged by economic and resource availability issues. They have developed a variety of fishing and non-fishing strategies to deal with variations in their social, economic, political and natural environments, including: use of multiple gears; occasional migration, especially during strong *El Niño* events; and occupational multiplicity (e.g. taxi driving, small household businesses). Renato Quiñones (Universidad de Concepción, Chile) described the jack mackerel crisis in central-southern Chile and the roles of environmental variability and scientific uncertainty as factors which increased the intensity of the resulting social conflicts.

The jack mackerel off Chile is one of the most important world fisheries in terms of landings (up to 4.5 million tons per year). It occurs in the Humboldt Current System, which experiences strong variability in a wide range of temporal and spatial scales. The crisis increased because of scientific and therefore management, uncertainty about changes in fish size: whether the apparent increase in abundance of juveniles and the reduced number of individuals belonging to older classes in the fishing zones represented fishery-induced declines in adult abundance or environmentally-induced (related to *El Niño*) changes in the spatial distributions of adults and juveniles. A management response was required and so the quota was cut drastically, which caused significant unemployment in the fishing industrial sector. Due to the complex web of ecological, oceanographic, economic, social and political factors acting in a system such as this, a major crisis in a key industrial fishery has a high probability of significantly affecting other economic activities (e.g. artisanal fisheries) and industrial associations, especially if they are located in the same geographical area. In this case, the effect was to increase employment in the artisanal sardine/anchovy fleet by 380% (person/trip equivalent units) over the period 1997-2001. Eventually, after much discussion, consensus was reached among government, industry, unions and artisanal fishermen about an appropriate allowable jack mackerel catch and its associated risk levels, which diffused the crisis. Long-term government responses included:

- awareness of the lack of instruments in Chile to confront major fisheries crises;
- the need to stop the "gold-rush" and establish new forms of property rights;
- the need to invest more money in fisheries research; and
- the need to advance towards decentralisation of decision making regarding quota definition and its allocation.

Ultimately, it was recognised that the challenge imposed by climate global change on fisheries management and its social consequences remains far beyond our present capabilities.

Several important concepts can be drawn out of these case studies. Diversity is an inherent feature of marine ecosystems and highly diverse systems are believed to be more resilient. However, human interactions with marine ecosystems tend to reduce their diversity by changing benthic environments, truncating life spans and age structures within populations, contributing to range contraction and to the elimination of subpopulations and species. These changes can decrease the "strategies" or options available to such populations when responding to environmental variability and can increase the risk of threshold shifts at multiple spatial and temporal scales. Longer lived and larger species appear to be particularly vulnerable to collapses which are linked to overfishing. Climatic changes can either exacerbate or mitigate the impacts of fishing, but rapid climatic changes are likely to be detrimental to local populations. Since longer-lived species, species diversity and reasonable levels of abundance of key species give a certain stability to the structure of ecosystems, the result is greater variability and greater scientific and management uncertainty.

On the human side, harvesters tend to respond to ecosystem change in the short term by diversifying their fishing strategies through spatial, temporal and ecological intensification and expansion. Coping strategies that were apparent in the case studies presented included "riding out the storm", "fishing harder", diversifying, innovating, relying on social networks, attempts to even out boom-and-bust cycles and political action. Thus, in the short term, fisheries can become more diverse and variable. In the longer term, however, in the absence of focused and sustained recovery strategies, matters change. The combination of environmental degradation and crisis management associated with large scale collapses has tended to generate responses which can result in the consolidation of fisheries in the hands of fewer, larger enterprises. Globalisation and the rapid spread of new technologies, standardised organisational systems and standardised approaches to fisheries science and management are tending to erode the diversity of technologies, cultural diversity, local social networks and the resilience of local communities.

Consequently, humans are building increasing vulnerability for ourselves, our communities and also the marine ecosystems upon which we depend. The paper that is being prepared from this Focus 4 workshop will consider trends in diversity at the levels of the fish stock and fishery-dependent human communities when confronted with a rapidly-changing marine ecosystem. It will also identify ways in which current developing trends may result in declining diversity in both marine ecosystems and human communities on longer time scales. Implications of these trends for scientific and management uncertainty, social conflict and for our capacity to reverse these trends will also be considered.

The new China GLOBEC III / IMBER I programme takes off

Manuel Barange[1] and Ling Tong[2]
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The third phase of China GLOBEC has been launched as the first combined GLOBEC/IMBER national programme, with the title of "***Key Processes and Mechanisms of Sustainable Food Production of Marine Ecosystems in China***". A kick-off symposium was held at the Equatorial hotel and at the Yellow Sea Fisheries Research Institute in Qingdao, China, 23–25 January 2006. The symposium was attended by Drs Sylvie Roy (Director, IMBER IPO) and Manuel Barange (Director, GLOBEC IPO) to provide international context to the occasion. Programme MOST 973–2, as it is known in China, is headed by Prof Dr Qisheng Tang (Chief Scientist) and Prof Dr Jilan Su (Scientific Consultant) and includes researchers from the Yellow Sea Fisheries Research Institute (YSFRI), the Second Institute of Oceanography (SOA), the East China Normal University, the Ocean University of China and the Institute of Oceanology (CAS). The Symposium built on a number of key stepping stones: the formation of an IGBP GLOBEC-IMBER National Committee in 2004 and the results of the 228th Xiangshan Science Meeting (2004), attended by the chairs of the GLOBEC and IMBER scientific steering committees. By creating the first combined IMBER-GLOBEC national programme China shows its leadership in implementing the wishes of the co-sponsors of GLOBEC and IMBER, to promote combined activities between both programmes (see Editorial). GLOBEC looks forward to the results of programme 973–2 and wishes China great success in its implementation.

Prof Qisheng Tang opening the GLOBEC/IMBER symposium

Main participant list
China-GLOBEC-III, IMBER-I kick off symposium

Total participants: *ca*. 110, including government officials, external experts, main participants of the program and post-graduate students.

1. Relevant government and administrative officials

Name	Affiliation	Title/Profession	Remarks
WANG Chang-rui	Joint Office[1] for 973 Program[2]	Division Director	Representing MOST
LU Ze-wei	Department of Earth Science, NSFC	Deputy Director/Professor	Representing NSFC
CHEN Yi-de	Bureau of Fisheries (BoF), Ministry of Agriculture (MoA)	Deputy Director	Representing MoA
DONG Jin-he	Division of Science and Technology, BoF, MoA	Director	
LI Nai-sheng	Bureau of Science and Technology, Shandong Provincial Government	Deputy Director	Representing Shandong Provincial GOV
ZHOU Qing	Bureau of Science and Technology, Qingdao Municipal Government	Deputy Director	Representing Municipal GOV
LI Jie-ren	Chinese Academy of Fishery Science (CAFS)[3]	Vice President	Representing CAFS
XU Zhu-qing	Division of Science and Technology, CAFS	Director	

[1]Jointly organised by the Ministry of Science and Technology (MOST), the National Natural Science Foundation of China (NSFC) and the Ministry of Finance, China
[2]National Key Basic Research Development Programs
[3]Chinese Academy of Fishery Sciences, Yellow Sea Fisheries Research Institute (YSFRI) is a regional fisheries research institution affiliated to CAFS.

2. Eminent external experts/scholars

Name	Affiliation	Title/Profession	Remarks
SUN Shu	Institute of Geology and Geophysics, Chinese Science (CAS), MoA	Former Vice President of Academy of NSFC/ Academician	Member, High-level Advisor Committee for 973 Program (HLAC)[4]
GUAN Hua-shi	Ocean University of China (Qingdao Ocean University)	Former President/ Academician	Member, HLAC
LI Wen-hua	Institute of Geographical Sciences and Natural Resources Research, CAS	Academician	Expert, Consulting Group for 973 Program (CG)[5]
WU De-lin	South China Institute of Botany, CAS	Principal Scientist	Expert, CG
XU Dong-yu	Institute of Marine Geology, Ministry of Land and Resources	Principal Scientist	Expert, CG

[4]MOST has set up a High-Level Advisor Committee seated by eminent scientists, who not only have profound understanding of the basic research and important national demands, but also can fully reflect the opinions of the scientific and technological society. This committee is responsible for offering consultation advice, assessment and supervision on the stipulation of 973 Program and the organisation and selection of the research projects of the 973 program, so as to fully assure the scientific, democratic and impartial feature when evaluating and putting the 973 projects under the authorised program.
[5]MOST has also set up a consulting group, which appoints senior experts and scholars from relevant fields to conduct follow-up observation and research during the implementation of the projects. These experts in turn put forward their comments and suggestions directly to the Ministry of Science and Technology, so as to help chief scientists and project expert teams to fulfill the preset objectives more effectively.

3. Main program participants

Name	Affiliation	Title/Profession	Remarks
TANG Qi-sheng	Yellow Sea Fisheries Research Institute (YSFRI), Chinese Academy of Fishery Science (CAFS), MoA	Director General/ Academician	Chief Scientist of Program; member of Program Expert Team (PET); Leader, Project 7
SU Ji-lan	Second Institute of Oceanography (SIO)/ State Oceanic Administration (SOA)	Former Director General/Academician	Program Scientific Advisor, Member of PET
ZHANG Jing	East China Normal University / Ocean University of China (OUC)	Professor	Assistant to Chief Scientist, Member of PET; Leader, Project 1
Wang Rong	Institute of Oceanology, CAS	Principal Scientist	Member of PET
ZHANG He-cheng	Chinese Academy of Fishery Science (CAFS), MoA	President	Member of PET
WEI Hao	College of Physical and Environmental Oceanography, OUC	Dean/Professor	Leader, Project 2
HUANG Da-ji	Laboratory of Ocean Dynamic Processes and Satellite Oceanography, SOA, SIO, SOA	Deputy Director/ Principal Scientist	Leader, Project 3
XIAO Tian	Institute of Oceanology, CAS	Principal Scientist	Leader, Project 4
NING Xiu-ren	Second Institute of Oceanography, SOA	Principal Scientist	Leader, Project 5
SUN Song	Second Institute of Oceanography, SOA	Deputy Director/ Principal Scientist	Leader, Project 6
SUN Yao	YSFRI	Principal Scientist	Second Leader, Project 7
JIN Xian-shi	Marine Fishable Resources and Ecosystem Laboratory, YSFRI	Director/ Principal Scientist	Leader, Project 8
FANG Jian-guang	Mariculture Ecology and Carrying Capacity Laboratory, YSFRI	Director/ Principal Scientist	Second Leader, Project 8
ZHUANG Zhi-meng	Division for Scientific Planning and Coordination, YSFRI	Director/ Senior Scientist	Program Secretary
TONG Ling	Division. for Personnel Resources, YSFRI	Director/Senior Scientist	Program Secretary
ZHAO Xianyong	YSFRI	Assistant to the Director General/ Principal Scientist	Program Secretary

CALENDAR

26 March – 2 April 2006: DISsertations initiative for the advancement of Climate-Change ReSearch (DISCCRS) Symposium, Pacific Grove, USA

April 2006: SCOR WG125 on global comparisons of zooplankton time series, Honolulu, USA

3–5 April 2006: Advancements in modelling physical-biological interactions in fish early life history: recommended practices and future directions, Nantes, France

3–7 April 2006: BENEFIT Forum, Swakopmund, Namibia

10–12 April 2006: Modelling ecosystem dynamics based on plankton functional types: recent advances and challenges, Villefranche-sur-mer, France

19–21 April 2006: PICES/GLOBEC symposium on Climate variability and ecosystem impacts on the North Pacific: a basin-scale synthesis, Honolulu, USA

23–25 April 2006: GLOBEC SSC Meeting, Honolulu, USA

26–28 April 2006: Eulerian observatories workshop, Monaco

2–5 May 2006: Focus 2/Focus 3 workshop: Mathematical modelling of zooplankton dynamics, Marseille, France

8–11 May 2006: GLOBEC CCC workshop on the decline and recovery of cod stocks throughout the North Atlantic including tropho-dynamic effects, St John's, Canada

8–12 May 2006: Revisiting the role of zooplankton in pelagic ecosystems; 38th International Liège Colloquium on Ocean Dynamics, Liège, Belgium

19–20 May 2006: SCOR WG 115 on standards for the survey and analysis of plankton, Plymouth, UK

12–14 June 2006: ESSAS/PICES Workshop to compare four sub-Arctic marine ecosystems, St Petersburg, Russia

15–16 June 2006: ESSAS SSC Meeting, St Petersburg, Russia

18–28 June 2006: GLOBEC/EUR-OCEANS Summer School. Towards ecosystem oceanography: identification and modelling of controls in marine ecosystems

12–14 July 2006: Scientific Committee on Antarctic Research (SCAR) Open Science Conference, Hobart, Australia

17–21 July 2006: Living with climate variability and change: understanding the uncertainties and managing the risks, Espoo, Finland

4–8 September 2006: GLOBEC Focus 1 workshop on impact of climate variability on marine ecosystems: a comparative approach, Berlin, Germany

2–6 October 2006: SPACC Synthesis Workshop, Roscoff, France

7–8 November 2006: 2nd International Young Scientistsí Global Change Conference, Beijing, China

9–12 November 2006: Global environmental change: regional challenges. An Earth System Science Partnership Global Environmental Change Open Science Conference, Beijing, China

27 November – 1 December 2006: The Humboldt Current System: Climate, ocean dynamics, ecosystem processes and fisheries, Lima, Peru

6–9 December 2006: IDGEC synthesis conference, Bali, Indonesia

28 May – 1 June 2007: 4th International Zooplankton Symposium, Hiroshima, Japan

GLOBEC INTERNATIONAL

GLOBEC International Newsletter is published biannually by the GLOBEC International Project Office, Plymouth UK. Correspondence may be directed to the IPO at the address below or by e-mail on: globec@pml.ac.uk. Articles, contributions and suggestions are welcome. To subscribe to the GLOBEC International Newsletter, or to change your mailing address, please use the same address. GLOBEC International Project Office, Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, United Kingdom.

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Printed on 100% recycled paper, Revived Matt 130g/m^2

Circulation: 1800

Editor: Manuel Barange and Dawn Ashby (GLOBEC IPO)

Produced by: Latimer Trend & Co Ltd, Plymouth, Devon, UK

A CORE PROJECT OF THE GLOBAL IGBP CHANGE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME

Co-sponsored by: The Scientific Committee for Oceanic Research (SCOR) and The Intergovernmental Oceanographic Commission of UNESCO (IOC)