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CLIOTOP planning meeting, Sète, France, 4-7 November, 2003

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Amongst the top predator species in the vast pelagic ecosystem, tunas and tuna-like fishes, billfishes and sharks have the greatest commercial importance, either in terms of catch (e.g. skipjack tuna is the 4th most productive and fished marine species in the World, after Peruvian anchoveta, Alaska pollock and Atlantic herring) or economic value, e.g. the price of bluefin tuna frequently reaches more than US$100 per kg on the sashimi market. Most pelagic top predators are migratory species that are fished worldwide, from the Equator to temperate regions by multiple national fleets using many different fishing gears (Fig. 1). During recent decades, tuna fisheries have expanded their range worldwide, with a continuous increase of fishing effort and fishing capacity leading to a dramatic increase in catches.

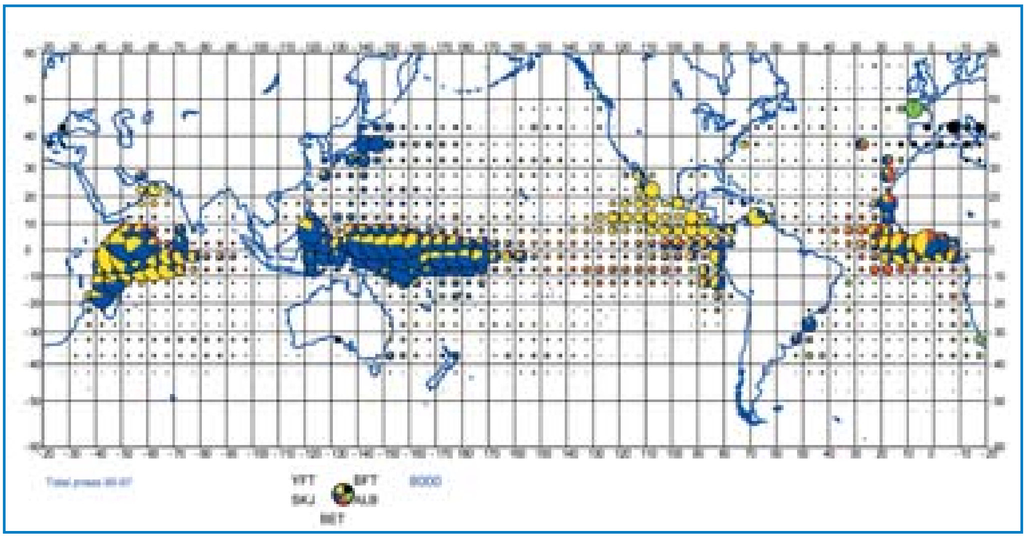

Figure 1. Worldwide distribution of tuna catch cumulated over 1990-1997 (tonnes). Yellow: yellowfin tuna: blue: skipjack tuna: red: bigeye tuna; green: albacore tuna; black: bluefin tuna. Data source: FAO. Figure: courtesy of A. Fonteneau. Picture by P. Lehodey.

Currently, open ocean ecosystems support catches of approximately 6 to 7 million tonnes per year of large pelagics (mostly tunas, billfishes and sharks). Because they mostly comprise the highest trophic levels, there is an increasing concern about the potential top-down cascading effects that fishing may have on the overall ecosystem. At the same time, environmental variability determines phytoplankton abundance and distribution and then leads to important bottom-up effects on forage species and then on top predator abundance and distribution. There is also increasing evidence for the impact of climate variability on tuna stocks and pelagic ecosystems at seasonal, interannual, or decadal time scales, and long-term global changes will modulate this variability and may have unexpected effects on ecosystems dynamics. Simultaneously studying those bottom-up and top-down effects in the context of climate variability requires extensive collaboration and the development of new approaches and appropriate models of the processes occurring within open ocean pelagic ecosystems. In this context, the GLOBEC CLIOTOP initiative has been developed as an international framework of collaboration and exchange with a multi-disciplinary comparative approach for considering these issues.

The first CLIOTOP meeting was held in Sète, France, 4-7 November, 2003, with the support of IFREMER and the French

CLimate Impacts on Oceanic TOp Predators

Institut de Recherche pour le Développement. An enthusiastic group of 40 scientists attended this planning meeting in this historical city of the Mediterannean French coast. The scientists from France, Spain, USA, England, Japan and Australia who attended were well representative of the worldwide interest in this project, and of the multi-disciplinary approach that is encouraged. The objective of the meeting was to write the science plan of this new planned GLOBEC regional activity, based on a preliminary draft that was circulated through the community of fisheries and marine scientists and made available through the GLOBEC web site.

The meeting first discussed the preliminary definition of the working groups and came up with a new simplified structure of five groups (Fig. 2). Through a series of presentations and group discussions, the participants identified several key scientific questions (Box 1) for each working group and started to develop the implementation strategies that will be necessary to tackle these questions.

The comparative approach constitutes the basis of CLIOTOP. Comparing various species, regions and ecosystems by searching for regularities and differences is indeed of fundamental importance because universal patterns would reveal common principles underlying the organization of ecosystems and their response to climate forcing. Therefore, impacts of both fishing and climate variations on marine ecosystems inhabited by open ocean top predators will be evaluated by analyzing and comparing long-term data series, ocean/atmosphere and biogeochemical reanalyses, field observations, *in situ* and laboratory experiments and measurements. Significant emphasis will be also given to modeling and simulation as a comparative framework used to identify key processes, and to deduce and understand the dynamics of the ecosystem and its constituent populations, leading towards the development of 'next-generation' models, which will embody both a high degree of realism and predictive skill.

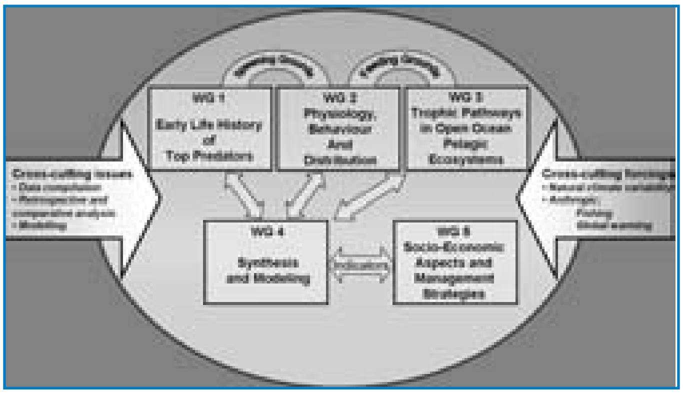

Figure 2. CLIOTOP working groups

Figure 3. The Sète group

These objectives require an approach involving research teams currently working in process-oriented projects which address the mechanisms linking physical forcing, zooplankton production, prey abundance and distribution and top predator behaviour and ecology, and modellers involved in climate, physical and biogeochemical oceanography, and individual, population and ecosystem dynamics. Given the complex nature of its foci, the CLIOTOP project strongly encourages the co-operation and exchanges with other IGBP programs such as IMBER or GAIM as well as WCRP programs such as CLIVAR, and the SCOR affiliated Census of Marine Life (CoML) projects. Being able to make use of the tools and expertise provided by those international programs will be crucial for an effective "open sea" project.

The revised science plan will be submitted to the next GLOBEC Steering Committee and will be available on the GLOBEC website. For more information contact Olivier Maury, IRD, Sète (maury@ird.fr) or Patrick Lehodey, SPC, Noumea, New Caledonia (PatrickL@spc.int)

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Key scientific questions identified for the five CLIOTOP working groups

WG1 - Early life history of top predators

Q1: What environmental characteristics define the spawning areas and timing of top predators?

Q2: What environmental and biological characteristics most influence larval survival of top predators?

WG2 - Physiology, behaviour and distribution of top predators

Q1: To what extent does spatial dynamics result from proximate cues and to what extent is spatial dynamics independent of environmental cues?

Q2: How does school size and fidelity vary in relation to environmental variability and change?

Q3: What determines the time and place of reproductive and feeding-related behaviour?

Q4: How do anthropogenic forces such as fishing interact with environmental impacts on distribution and population structure?

WG3 - Trophic pathways in open ocean pelagic ecosystems

Q1: What are the main trophic pathways of pelagic top predators and how do they differ between and within oceans?

Q2: Is there evidence of change in trophic pathways over time and space consistent with climate variability? Can seasonal and spatial variability be used to explore climate variability?

Q3: Is it possible to identify indicators, such as prey species/size spectra, that would highlight significant changes in trophic pathways?

WG4 - Synthesis and modelling

Q1: What is the relative importance of exploitation and the environment in structuring pelagic ecosystems?

Q2: Does one mechanism (e.g. match/mismatch) explain observed variation across species, trophic pathways, regions, etc.? Do alternative mechanisms have equally good explanatory power? Which mechanism(s) provide the greatest predictive power?

Q3: What alternative states might occur in pelagic ecosystems, how might they be characterized (e.g., can they be described by indicators), how might they be caused, what are their consequences, and are they reversible?

Q4: Does knowledge about environmental forcing and the nature of fisheries (e.g. the species composition of the catch) suggest an optimum allocation?

WG5 - Socio-economic aspects of managing and responding to climate impacts on oceanic top predator species

Q1: What are the socio-economic pressures on, and context of, tuna fisheries ?

Q2: How have fisheries organizations (whether local, national, regional, or international) addressed climate change issues?

Q3: What are the Flows in capital and knowledge among the world's large fisheries and how do they respond to variability?

Q4: How useful are the fisheries management decision support tools developed by WG 5?

Editorial

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I am writing this Editorial shortly after attending the annual meeting of the Scientific Committee of the International Geosphere-Biosphere Programme (IGBP), co-sponsor of GLOBEC. The Chair of GLOBEC, Prof C Werner, was asked to present highlights of recent GLOBEC research worldwide, to provide the IGBP with a broad view of the programme's achievements and development. The presentation, prepared in coordination with many of the leaders of GLOBEC research at national and regional level, was extremely well received. Just like the other GLOBEC sponsors (SCOR and the IOC) the IGBP recognised that GLOBEC is reaching its peak in terms of outputs and relevance, a message that needs to filter through to the community at ground level. The feeling that the pieces are finally "completing the puzzle" is very real, as can be perceived from a recent science update article in Nature (Nature, 4 March 2004), heavily relying on multi-institutional, multi-disciplinary GLOBEC work in the North Atlantic. International science is all about adding value to local research, an effort that does not happen overnight. We need to build upon this platform, and this Newsletter provides some tools to do so. In this issue I would like to highlight a special section on GLOBEC Germany, after their recent phase one review. The work is relevant to many other GLOBEC projects and thus may generate fruitful contacts and add more pieces to our puzzle. In addition, the Newsletter introduces further developments of two new GLOBEC activities at regional level: ESSAS (see GLOBEC Newsletter 9.2: p.30) and CLIOTOP (see GLOBEC Newsletter 9.2: p.3). Science Plans for these activities are in the process of completion, cementing GLOBEC's geographical implementation and scientific relevance.

Meeting Announcement
Joint PICES/CLIVAR workshop
Scale interactions of climate and marine ecosystems, Honolulu, 23-24 October, 2004

Both the physical climate system and the marine ecosystem vary on a wide range of time and space scales. The focus of the workshop will be how the various scales of climate variability impact upon the population of a given species and the ecosystem as a whole, in the North Pacific. The workshop will bring together experts in physical oceanography, climate variability, marine ecosystems, and fisheries. The workshop follows the PICES XIII meeting in Honolulu and is open to all. For more information visit www.pices.int or contact Alexander Bychkov (bychkov@pices.int) or Kelvin Richards (rkelvin@hawaii.edu).

Figures for Marchesiello *et al.* p.5-7

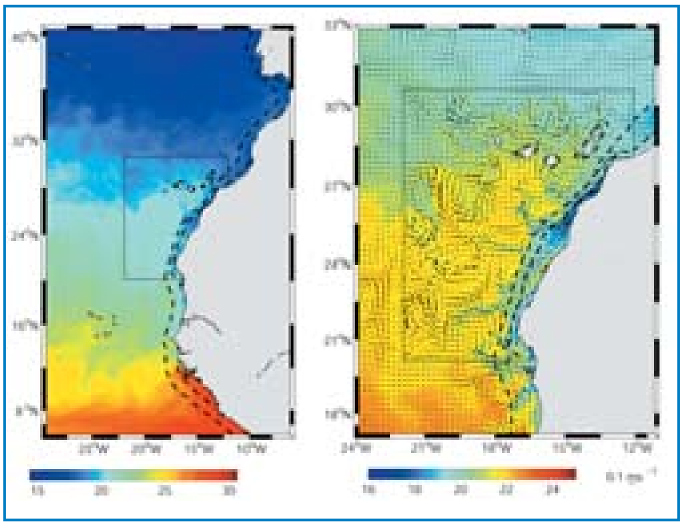

Figure 1. (Marchesiello, p.5-7) Left panel: sea surface temperature in the Canary Current System model; the whole regional domain at 25km resolution is shown with an embedded subdomain at 7km resolution in southern Morocco. Right panel: surface temperature and currents in the southern Morocco region

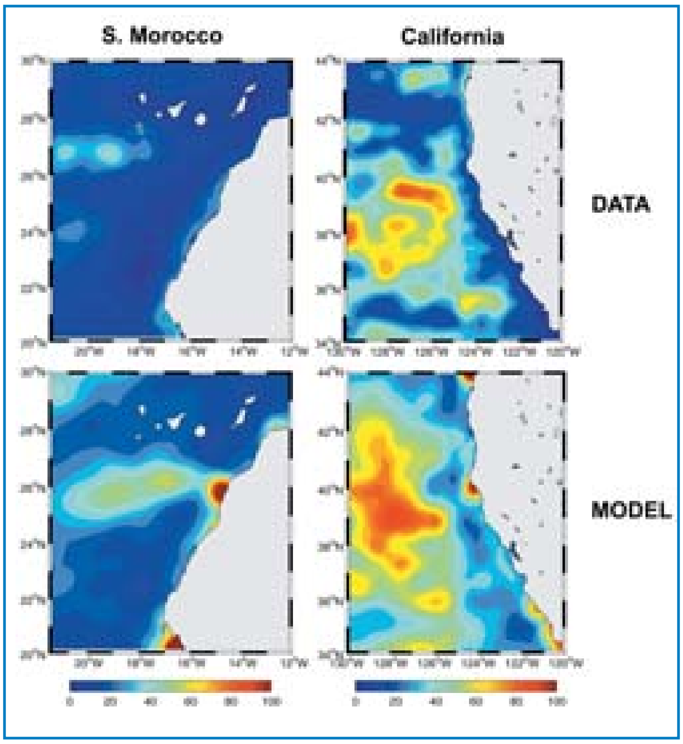

Figure 2. (Marchesiello, p.5-7) Variance of sea level anomalies from the climatological simulation (top panels) and Topex/ERS altimeter data (bottom panels) for the upwelling regions off southern Morocco (left) and California (right). Note that the high coastal values present in the altimeter data can be attributed to synoptic and interannual forcing which is absent in these simulations.

Figure for Robinson p.8

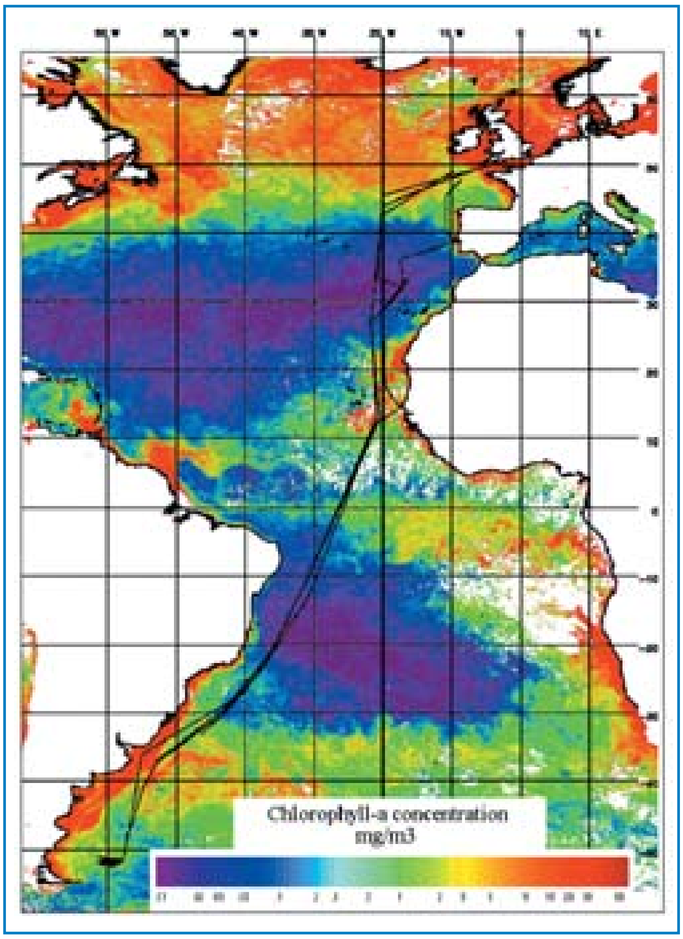

Figure 1. (Robinson, p.8) AMT cruise tracks

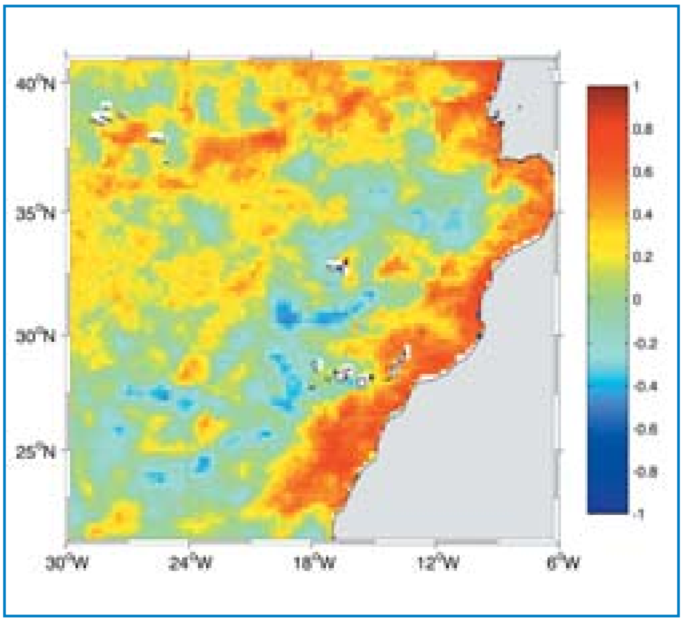

Figure 3. (Marchesiello, p.5-7) Correlation coefficient between time series of observed and modeled SST anomalies for the 25km resolution regional model. It shows high coastal correlation values and relative loss of correlation offshore where eddy dynamics are dominant.

Eddy-driven dispersion processes in the Canary Current upwelling system: comparison with the California system

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Introduction

The Canary Current System is one of the four major upwelling regions of the world. It is poorly studied compared to the other eastern boundary current systems (California, Humboldt, Benguela) even though it sustains large fisheries resources and constitutes a major economical component for the neighbouring African countries: Morocco, Mauritania, and Senegal. The basic coastal upwelling process is well understood: equatorward trade winds along West Africa lead to an offshore transport of surface water and subsequent upwelling of cold, nutrient rich waters in the coastal area. The mesoscale synoptic structure observed in the Coastal Transition Zone (CTZ) is a combination of upwelling fronts, offshore squirts and filaments, and eddies, many of which occur as dipoles. These features are part of a highly non-linear dynamical system associated to the basic upwelling process and their impact on the transport and distribution of coastal properties is still a matter of research (Marchesiello *et al*., 2003). More importantly, the mesoscale and sub-mesoscale activity of the CTZ is expected to be a major contributor to the processes controlling the downscaling of global climate changes to the scale of the regional upwelling systems.

Upwelling ecosystems are characterized by high primary production due to sustained nutrient input by the vertical circulation. Upwelling zones also provide a very dispersive environment where nutrients, phytoplankton, zooplankton and meroplankton can be quickly swept from the coastal area. Usually, sardines and anchovies, essential components of the ecosystem and the local fisheries, tend to avoid the upwelling zones for spawning (Roy *et al.*, 1992), although examples of the opposite can be found off southern Morocco and Senegal. Spawning success may be related to the physical environment through a balance between various processes of enrichment, retention/dispersion and concentration (Bakun, 1998). It is one of the objectives of this study to understand the mechanisms that govern spawning of small pelagic fish and the variability in time and space of these mechanisms.

Modeling Approach

The Regional Oceanic Modeling System (ROMS; Shchepetkin and McWilliams, 2003) was developed to simulate both coastal and oceanic regions and their interactions. ROMS solves the primitive equations in an Earth-centered rotating environment, based on the Boussinesq approximation and hydrostatic vertical momentum balance. The model grid, forcing, initial and boundary conditions are built using the ROMSTOOLS package (Penven, 2003).

Our strategy for managing the large range of scales from regional down to the local scales is a multi-level approach based on the AGRIF package developed by Blayo and Debreu (1999). This is an online (synchronous) nesting procedure which allows a rapid setup of a series of embedded domains with increasing resolution. To encompass the whole Canary Current System, we have designed a parent grid extending from 5°N to 38°N and from 30°W to 5°W (Fig. 1, see p.4) at a resolution of 25km horizontally with 32 vertical levels. Child grids have also been designed, in particular a zoom off Southern Morocco at 7km resolution which will be used to examine mesoscale physical processes. The resolution here is still coarse with regards to convergence experiments performed in Marchesiello *et al.* (2003) and further refinement of the model will be considered.

Our modeling approach is of incremental complexity. It starts by addressing the mean circulation, seasonal cycle and mesoscale physics in the Canary Current System, leaving aside the inter-annual variability. The model is forced by COADS ocean surface monthly climatology (Da Silva *et al*., 1994) for the heat, fresh water fluxes and momentum fluxes. The three lateral open boundaries (Marchesiello *et al.*, 2001) are forced using a climatology derived from Levitus *et al.*, (1994). A parameterization of the Mediterranean outflow is realized by nudging temperature and salinity for depths deeper than 750m to their monthly Levitus means with a time scale of 50 days. In climatological runs, the model is integrated until a statistical equilibrium is obtained (spin-up of 2 years), then integration is continued for several seasonal cycles to study the dynamical equilibrium of the system. A first validation of the seasonal cycle was realized by comparing model output with climatologies from satellite and in-situ data and global models. It shows the skills of the model to reproduce the regional circulation and the seasonal cycle of coastal upwelling in agreement with other studies, (Nykjaer and Van Camp, 1994; Mittelstaedt, 1983).

Eddy-driven Dispersion of Coastal Properties

In a previous study of the California Current System (Marchesiello *et al.*, 2003), we intentionally posed our calculations without synoptic and interannual forcing. The success of the simulations, in approximately matching the observations, suggested that the mesoscale variability of an upwelling system is intrinsic, hence chaotic with limited predictability, while the large-scale structure is substantially a deterministic response to the low-frequency, large-scale atmospheric forcing (whether local or remote) and transmitted through the regional boundaries.

We are following a similar approach for the Canary Current System. Figure 2 (see p.4) shows maps of sea surface height (SSH) variability from the model and from Topex/ERS (gridded by AVISO) for both the Southern Morocco region of the Canary system and the central upwelling region of the California system. Both regions are similar in size and feature comparable upwelling-favourable winds over the year cycle. A comparison of the observed and modeled broad patterns shows that there is a good match in both regions due to realistic model representation of the unstable jet, eddies, offshore squirts and associated filaments (Fig. 1, see p.4). However, the comparison of SSH variability between the two regions reveals a striking quantitative difference where the variability in the California System is more than twice the amount shown for the central Canary system. Since both regions are forced with equal intensity, the reason for such a difference is found in the stratification background.

Mesoscale variability in upwelling systems is produced mainly through baroclinic instability of the coastal upwelling jet (Marchesiello *et al.*, 2003). In terms of energy, the wind drives available potential energy in the coastal area which is transformed into eddy kinetic energy during the baroclinic instability process. The amount of energy conversion varies with the available potential energy, or equivalently with vertical shears of the coastal jet which is largely dependent on stratification (the reduced gravity number **g'** representing the variation of density between surface and subsurface layers, gives a good index of velocity shear in the two-layer upwelling problem). Values of **g'** in the California Current System are more than twice as large as the values in the Canary Current System. The reasons lie in the salinity structure provided by the large-scale circulation. In the North Pacific, a low-salinity signal of subarctic water can penetrate the upwelling system and travel far south while saline equatorial water is transported northward in the subsurface layer. This results in a negative vertical salinity gradient which is unique among large upwelling systems (Huyer *et al.*, 2004). In the North Atlantic, there is a barrier to the subarctic water which cannot affect the subtropical region while equatorial waters have a limited expression due to the intrusion of fresh Antarctic intermediate waters. The resulting difference in vertical gradients of salinity between the two systems leads to a large difference in available potential energy and eventually in mesoscale activity as suggested by our model results.

Analysis of the heat budget in the California Current System permitted a quantification of the impact of mesoscale activity on cross-shore distribution of coastal properties. It showed that the offshore eddy heat fluxes provide the principal balance against near-shore cooling by mean Ekman transport and upwelling. This result can be explained by considering the eddy flux working as eddy diffusion. This eddy diffusion mixes cold near-shore water, originating from upwelling of subsurface water with warm offshore water. This eddy diffusion can be expected to also affect nutrients and plankton concentrations by eroding coastal high values in regions where mesoscale activity is important. Our model results therefore suggest that the Canary Current System has a much less dispersive environment that the California Current System.

Interannual Variability

Interannual variability can be introduced in the model as remote forcing through the lateral boundaries and as local forcing through surface fluxes, particularly wind stress. The former type of forcing requires use of global or basin-scale model outputs while the latter is done using atmospheric models or satellite scatterometer data. Weekly ERS 1-2 wind stress fields (Bentamy, 1996) has been used here to estimate the part of interannual variability which is forced locally in the system. The product gridded at a spatial resolution of 1 degree is interpolated on the 25km model grid (the zoom is not applied here and the mesoscale activity is relatively weak) for the period August 1991 to January 2001. Time-integration starts from an equilibrium solution of the climatological run.

We are presenting only preliminary results from comparisons of the model SST with Pathfinder observations (Vazquez *et al.*, 1998). The inter-annual signal is extracted by subtracting the mean seasonal cycle from the observed or computed SST and then applying a 6 months running average in order to filter intra-seasonal variability. The correlation coefficient between time series of observed and computed SST anomalies is high all along the coast (Fig. 3, see p.4). Both signals clearly follow the North Atlantic Oscillation index for the period 1991-2001. These high correlation values decrease offshore in the coastal transition zone because intrinsic variability which is unpredictable in nature becomes dominant. This is consistent with results obtained in other upwelling regions (Blanke *et al.*, 2002). Interestingly, the coastal high correlation values have a more limited offshore extent in regions of stronger eddy activity such as the lee of the Canary Islands and the Cape Blanc area (Barton *et al.*, 1998). Note that beside the unpredictable nature of the mesoscale response to interannual forcing, the differences between model and data can also be attributed here to the use of coarse resolution which leads to under-resolving the cross-shore exchanges induced by eddies and filaments. A better resolution in the future of the eddy activity should allow a more realistic downscaling of the interannual forcing in the coastal transition zone.

Discussion: Downscaling and Spawning Success

Sinclair *et al.* (1985), analysing El Niño impacts on larval success in decades of CalCOFI data, suggested that despite lower enrichment of coastal waters, El Niño provides a period of low dispersal of fish eggs and larvae for certain species which is favorable to later recruitment. What seemed puzzling to Sinclair *et al.* was the absence of correlation between local wind intensity and El Niño signal in the CCS (consistent with the generally accepted notion that upwelling intensity decreases in the CCS during El Niño essentially because the thermocline deepens, not because the upwelling-favourable winds are reduced). Our results on mesoscale patterns provide an interesting solution to this problem and a clear example on how downscaling may operate in upwelling regions: a deepening of the thermocline leads to reduced upwelling of dense subsurface water hence reduced available energy for mesoscale dispersion. This is consistent with anecdotal evidence from satellite observations that upwelling filaments have a more limited extent during El Niño events. This idea is yet only speculative and a clear demonstration has to be made, but it may provide a pathway to explore the non-linear response of spawning strategies to regime changes and the different strategies adopted in different systems.

If sardines spawn on the innershelf of southern Morocco in the heart of the upwelling regime, it may be because of a less dispersal environment as suggested above. However it may also be due to the presence of a large, shallow innershelf which can provide protection from the dispersive upwelling regime (Roy, 1998). All of these physical mechanisms have to be considered in a fully integrated approach.

Acknowledgments

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The Atlantic Meridional Transect Programme

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The biota of the surface ocean has a profound influence on the global budgets of climatically-active trace constituents in the atmosphere (CO_2, DMS, N_2O, CH_4 and aerosols) and hence climate. Our understanding of how biogeochemical cycling in the oceans affects climate, and of how changes in climate influence the structure and activity of oceanic ecosystems is still incomplete, hindering accurate predictions of the future global environment. Realistic model simulations require new observations of both the spatial and temporal variability of planktonic ecosystem structure, multi-element cycling and exchange processes between ocean and atmosphere.

The Atlantic Meridional Transect Programme (AMT) is a UK National Environment Research Council (NERC) funded project which aims to quantify the nature and causes of ecological and biogeochemical variability in the planktonic ecosystems of the Atlantic Ocean, and the effects of this variability on the biological C pump and on air-sea exchange of radiatively active gases and aerosols. The programme continues a series of 12 bi-annual transect cruises between the UK (50°N) and the Falkland Islands (52°S) which took place between 1995 and 2000 (Aiken *et al.*, 2000) making measurements of hydrographic and bio-optical properties, plankton community structure and primary production. Six further cruises will take place between 2003 and 2005 to provide a unique decadal time series of spatially extensive observations on the structure and biogeochemical properties of planktonic ecosystems (Fig. 1, see p.4). The project will allow 45 investigators from 6 partner UK institutions to test nine inter-related hypotheses (Fig. 2) which fall within the following three scientific objectives:

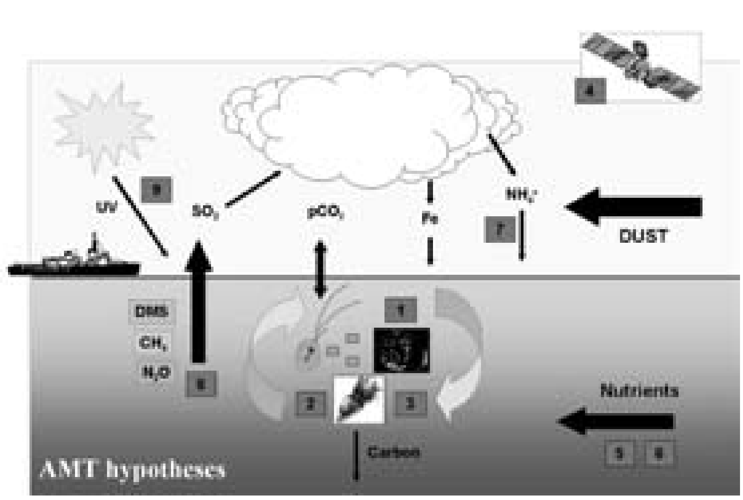

Figure 2. AMT hypotheses

- To determine how the structure, functional properties and trophic status of the major planktonic ecosystems vary in space and time

The first three hypotheses strive to address the question of linking plankton biodiversity with variability in biogeochemical fluxes, in particular the potential for carbon export to the deep sea and ocean / atmosphere exchange of carbon dioxide. A fourth hypothesis will develop and validate models and empirical relationships to enable the use of remote sensing to interpolate in time between the two AMT sampling periods per year and to extrapolate in space from the single track of *in situ* samples to the basin scale.

- To determine the role of physical processes in controlling the rates of nutrient supply, including dissolved organic matter, to the planktonic ecosystem

Hypothesis 5 and 6 deal with the physical supply of nutrients on two space and time scales. The programme will derive an indication of lateral transport of nutrients from upwelling regions into the gyres as well as validating models which predict the impact of atmospheric forcing functions on nutrient supply mechanisms.

- To determine the role of atmosphere-ocean exchange and photo-degradation in the formation and fate of organic matter

Hypothesis 7 assesses the impact of atmospheric input of nutrients such as inorganic nitrogen and iron, and hypothesis 8 will further investigate the link between the production of radiatively important gases and plankton community structure with a view to improving basin scale estimates of the fluxes of CO_2, DMS, N_2O and CH_4. Finally hypothesis 9 will determine the magnitude and variability of the photodegradation products of coloured dissolved organic matter.

The schematic shows how the hypotheses follow a climate feedback loop, with plankton community structure and activity impacting gas emissions which influence cloud formation which in turn influence dust solubility and hence deposition of nutrients and so community structure and activity.

The first cruise of the programme occurred in May/June 2003 and aimed to compare and contrast the functioning of the plankton in the North and South Atlantic Gyres. The second cruise is currently heading south from the UK with a focus on sampling the upwelling regions off the coast of NW Africa and repeating the transect of the South Atlantic Gyre.

The website www.amt-uk.org is the main source of cruise updates, contact information and reports relevant to the project.

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The German GLOBEC Project

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The German GLOBEC contribution (www.globec-germany.de) titled '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 of reproductive success of fishes. The results will form the basis for strategic modelling of the recruitment success of fishes. Over the last several decades, herring and sprat, but also numerous copepod populations, in the Baltic and in the North Sea have experienced high fluctuations in recruitment and biomass. Whereas a substantial decrease of individual weight of herrings and sprats at high biomass was documented in the Baltic Sea, a similar relationship was not observed in the North Sea. It is assumed that this phenomenon is caused by food (mainly copepods) limitation in the Baltic Sea. However, it is not clear whether this is due to direct effects of trophic interactions (internal dynamics) in the rather simple Baltic food web or whether the decrease of some copepod populations is a reaction to physical processes (external forcing). An interdisciplinary team of fisheries biologists, planktologists, physiologists, geneticists, physical oceanographers and modellers are investigating these hypotheses. The influence of physical processes on zooplankton and on the spawn of two planktivorous fish species with different life histories, herring and sprat, and on their trophodynamic interactions is studied in the Baltic and the North Sea, two ecosystems with very different oceanographic characteristics. This is done using a combination of field studies, experimental investigations and modelling. The two seas under investigation exhibit a gradient from marine to almost fresh water conditions. Top-down and bottom-up processes are studied comparatively in both ecosystems. The same suite of species will be investigated in both areas: the planktivorous clupeids, herring and sprat, and their main food basis, the copepods *Pseudocalanus* spp., *Acartia* spp. and *Temora longicornis*. The focus is on an intra-seasonal and regional comparison of the reactions of egg and larval cohorts of herring and sprat produced at different periods over the entire spawning season with respect to their continually changing physical and biological environments. A tight coupling between field research and modelling is required to enhance our understanding of the two ecosystems. We expect that an improved understanding of the mechanisms governing population fluctuations at short time scales will finally give us insight into the causal relationships of major population fluctuations and ecosystem changes on the decadal scale.

The project is funded for three years with 4 million EURO by the Federal Ministry of Education and Research (BMBF). Similar funds are contributed by the 8 participating institutions. The project is run by 80 scientists and technicians from seven different research institutions and started two years ago. The first results from the Baltic Sea studies are presented below.

Variation in nutritional condition of larval sprat *(Sprattus sprattus)* caught during the 2002 spawning season in the Bornholm Basin, Baltic Sea

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In marine fish species, rates of mortality and growth are inversely related during the first year of life. Since the growth and survival of larval fish is affected by the abundance and quality of food, understanding recruitment dynamics requires robust estimates of nutritional condition and growth rates of field-caught fish. Within the German Globec programme (www.globec-germany.de), we performed grid sampling with Bongo nets in the Bornholm Basin (Baltic Sea) in March, April, May, early July and late July 2002 to collect sprat eggs and larvae. Results from the sprat egg surveys indicated that the major peak in spawning activity occurred in mid April, followed by a second smaller peak in mid June. Sprat larvae caught in May and early July were the survivors of these two spawning events. To evaluate the condition and growth rates of field-caught sprat, we 1) measured a biochemical growth indicator (RNA/DNA ratio, Clemmesen 1993) in individual field-caught larvae to track changes in larval condition during the 2002 spawning season, 2) conducted four, 10 day laboratory experiments to evaluate the relationship between RNA/DNA ratios and growth rate in post-larval sprat, and 3) analysed the gut contents of larvae to determine how feeding habits changed during the season.

New larval cohorts were observed during the cruises in April, May and early July but not at the end of July, when no newly-hatched or young sprat larvae were encountered. Median values of RNA/DNA ratios were higher in small (4-12 mm) larvae in May and April compared with those of similar sized larvae in July indicating a better nutritional condition during the former period. Differences in nutritional condition of these small sprat larvae corresponded to seasonal differences in the abundance of copepod nauplii, the dominant food of small sprat larvae (Voss *et al.*, 2003).

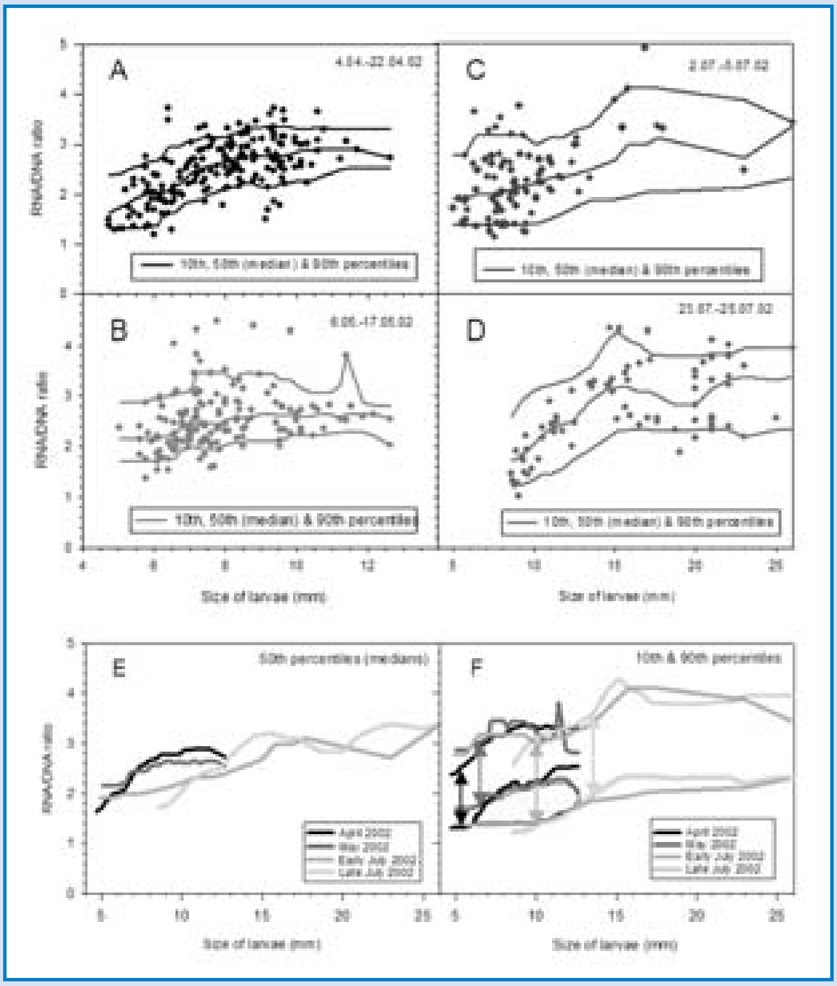

Figure 1. Comparison of the medians, 10th, and 90th percentiles of the probability distribution function of RNA/DNA ratios (Evans, 2000) for each of four months (panel A-D). Arrows indicate the magnitude of difference between the 10th and the 90th percentiles and the shaded area highlights the observed differences between the time periods (panel F). The relative scatter in RNA/DNA ratios versus larval size suggests that slow growing larvae were lost from the population prior to measurements in April and May, but not in July, when poorly nourished larvae persisted.

In contrast to the small larvae, larger larvae (> 12 mm) caught during the July cruises had higher RNA/DNA ratios indicating a good feeding environment for larger larvae and suggesting a higher occurrence of prey eaten exclusively by larger larvae (e.g. larger, later-stage copepods). Gut content analysis of 2002 field-caught larvae supported the RNA/DNA results and revealed that medium sized (8 to 12 mm) larvae fed on a more variable diet and had a lower proportion of nauplii in July (30-50%) compared to March-May (60-90%).

Based on the hypothesis that patterns in RNA/DNA ratios reflect the feeding environment (Pepin *et al.*, 1999; Evans 2000; Clemmesen *et al.*, 2003), different growth and condition scenarios were evident during the 2002 spawning season. Variability patterns in RNA/DNA ratios (differences between 10th and 90th percentiles) were nearly twofold higher for the larvae caught during the cruises in July compared to March and April. The persistence of sprat larvae with lower RNA/DNA ratios in the July population suggests that the environment did not strongly select for fast growing, well nourished individuals. Whereas an increase in RNA/DNA ratio values comprising the 10th percentile with increasing larval size in April and May suggests a loss of the slow growing, less nourished larvae from the population (indicates size- and condition-selected mortality). Highly significant correlations between muscle tissue RNA/DNA ratios and growth rates of post-larval sprat in laboratory calibration experiments were found. None of the analysed field-caught larvae had RNA/DNA ratios below the laboratory-determined threshold for zero growth. Our ongoing approach, coupling field studies and laboratory experiments, will incorporate temperature effects on RNA-DNA ratios, and will include otolith microstructure analyses. All of these techniques will be used to parameterize individual-based models investigating factors affecting early growth and survival of sprat in the Baltic Sea.

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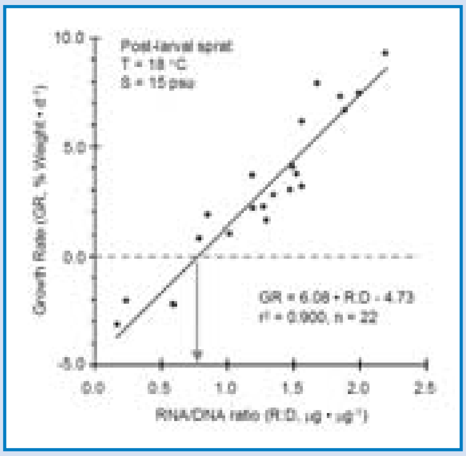

Figure 2. Relation between growth rate and muscle tissue RNA/DNA ratio in post-larval sprat in the laboratory. The dashed line indicates zero growth rate, the arrow indicates the threshold RNA/DNA value for zero growth.

A new retention index for the Central Baltic Sea: long-term hydrodynamic modelling used to improve Baltic sprat recruitment models

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The stocks of small pelagic fish such as Baltic sprat, *Sprattus sprattus*, are known as highly fluctuating in size due to the combined effect of only few age-classes present in the population and a generally very variable recruitment success. This has led to considerable efforts channelled towards a better understanding of processes potentially responsible for recruitment variability as well as to a whole suite of biotic and abiotic variables identified as being correlated with recruitment strength. In the case of Baltic sprat from ICES (International Council for the Exploration of the Sea) Subdivision (SD) 25, Köster *et al.*, (2003) have shown that temperature in the intermediate (winter) water layer (influencing both fecundity and egg-mortality) and spawning stock biomass are significantly correlated with recruitment success, currently explaining about 32% of the overall variability in SD 25. Among other tested variables, the authors considered wind and resulting drift patterns of larval sprat as potentially important factors conducive to recruitment, although a preliminary larval-transport index failed to explain significant proportions in recruitment variability (Köster *et al.*, 2003). The idea of sprat larvae drifting into areas suitable or unsuitable for survival (with respective consequences for recruitment) was followed up within the German GLOBEC project. Results of an enhanced modelling exercise now suggest that physical processes leading to larval retention/dispersion significantly influence the recruitment success of sprat in the Central Baltic Sea.

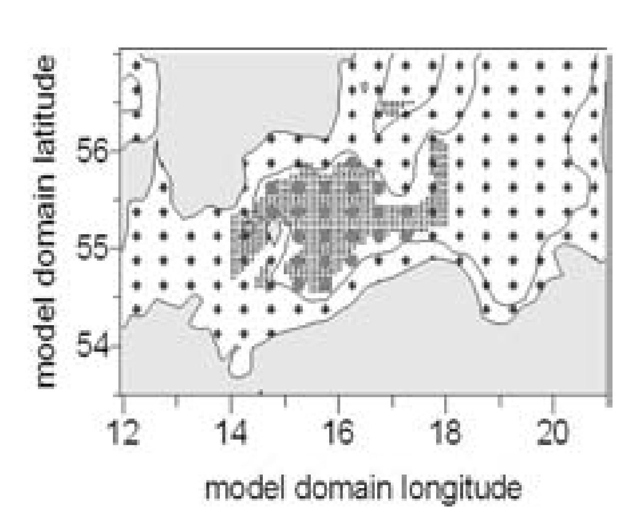

Figure 1. Chart of the model domain showing the Central Baltic Sea with 40m depth contours. Small grey dots show seeding positions of Lagrangian drifters (5-10m depth), big red dots are the midpoints of those 15x15nm rectangles that were defined as retention area; blue diamonds refer to midpoints of rectangles called dispersion area

The goal of this exercise was to study inter-annual differences in modelled drift patterns of sprat larvae stemming from the Bornholm Basin, one important spawning ground for sprat in the Central Baltic Sea. To achieve that, we made use of the 3D, eddy-resolving, baroclinic circulation model for the Baltic Sea as

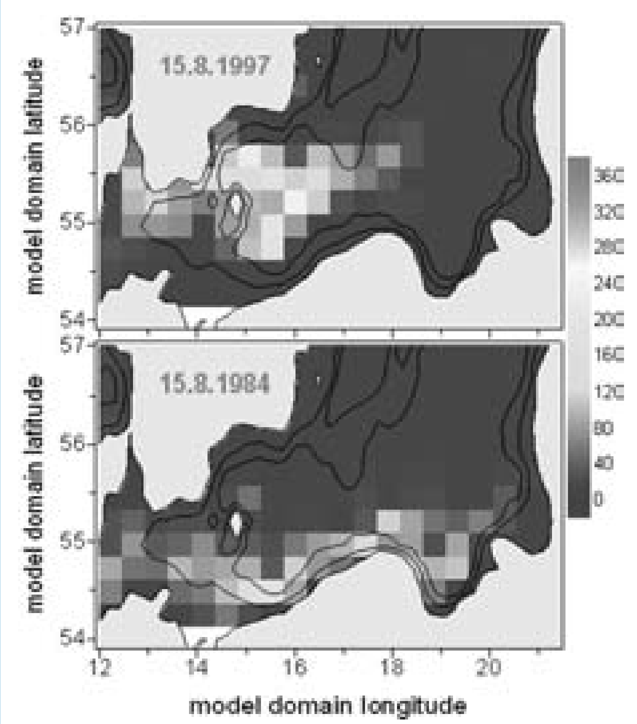

Figure 2. Examples of two contrasting outputs of the hydrodynamic drift model for years 1997 (upper panel) and 1984 (lower panel). Colours illustrate the number of Lagrangian particles collected in each of the 15x15nm rectangles on day 227 (15 August). 20m and 40m isobaths are shown.

described by Lehmann (1995) and Hinrichsen *et al.*, (1997). The model was forced by actual meteorological data that were made available by SMHI, Norrkoeping, Sweden for a time-series of 24 years (1979-2002). Larvae were tracked through the model domain as Lagrangian passive drifters. In each year and at 9 different dates per year (roughly corresponding to an average sprat spawning season) we released 750 particles in a depth layer of 5-10m in all areas of SD 25 deeper than 40m (mainly the Bornholm Basin, Fig. 1). Particles were forced to remain in this layer, because there is no applicable knowledge yet about larval sprat vertical migration patterns. Depending on the seeding day, particles were allowed to drift for a period of 36-116 days until their position was recorded on 15 August (day 227) for each year. We then devised a relatively coarse grid of 15x15nm rectangles (Fig. 1) and counted the number of particles found in

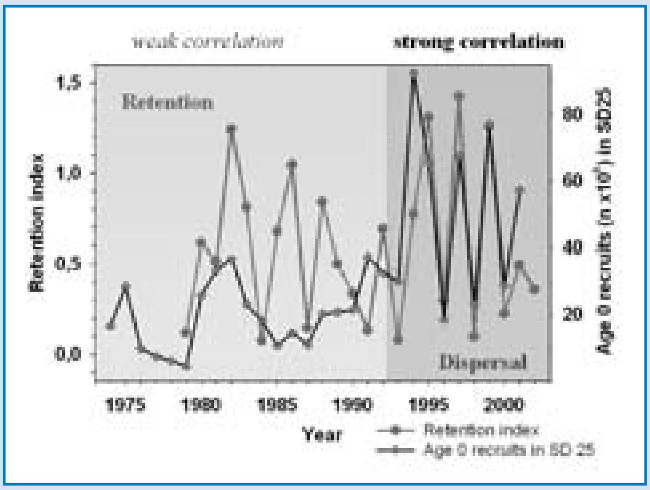

Figure 3. Correspondence between recruitment success of age 0, Baltic sprat in SD 25 (Central Baltic Sea, black line) and a newly developed retention index (green line) for a time series of 23 years (1979-2001).

each rectangle on day 227. All rectangles with midpoints located inside the 40m isobath of the Bornholm Basin were defined as "retention area", whereas all other rectangles outside the basin were referred to as "dispersion area". The new retention index was then defined simply as the ratio of all particles collected within the retention area divided by the sum of all particles collected outside on day 227 (Fig. 1).

Caused by variability in prevailing wind-systems, model outputs were indeed indicative of strong inter-annual differences in the degree of particle retention within the Bornholm Basin (Fig. 2). For example, results for 1997 suggest an almost ideal retention situation (Fig. 2a), whereas the complete opposite is true for other years such as 1984, where almost all particles appear to be pushed southwards towards the Polish coast and stretched out longitudinally (Fig. 2b).

Fluctuations in the new retention index during the last decades correspond well to recruitment at age 0 in SD 25, as derived from area-disaggregated MSVPA runs (Fig. 3). The pattern suggests that in years of strong retention sprat recruitment had been successful, whereas a high level of dispersion, particularly displacement towards the southern coast, appears to be associated with lower recruitment. Figure 3 suggests the existence of two distinctive periods in the relationship between the retention index and recruitment success. During a first period from 1979-1992, the relationship appeared to be relatively weak, whereas throughout the last ten years the relationship is much tighter. Within the latter period, sprat spawning stock biomass was high, while it was considerably lower before (Fig. 4.). This may indicate an interactive effect between environmental effects, e.g. retention vs. transport (this study) and warm vs. cold winters (MacKenzie and Köster, 2004), and reproductive effort by the stock.

Linear regression analyses corroborated this, revealing a significant (P<0.001) linear relationship between the retention index and recruitment strength (1979-2001) explaining 31% of the overall variability. If only the years 1993-2001 are included, the R-square value increases to 0.61. Finally, a multiple linear regression analysis with spawning stock biomass, intermediate water temperature at peak spawning time being as well a proxy for winter temperatures, and the retention index as independent variables is now able to significantly (P<0.001) explain almost 60% of the overall recruitment variability in sprat from SD 25.

As we have seen, the inclusion of our newly derived, simple retention index already led to a considerable improvement of the existing sprat recruitment model. However, there is no way around admitting that the mechanistic reasons for this discovered relationship are clearly not yet understood and will require thorough investigation. Certain preliminary insights, gathered from GLOBEC-Germany´s extensive surveys of the Central Baltic Sea, have already raised our attention and seem to point towards spatio-temporal differences in food-availability and potentially also predation pressure to which larval sprat are exposed. In parallel, there is also a need to refine the current modelling approach in order to minimize assumptions and maybe even increase the explanatory power of the retention index.

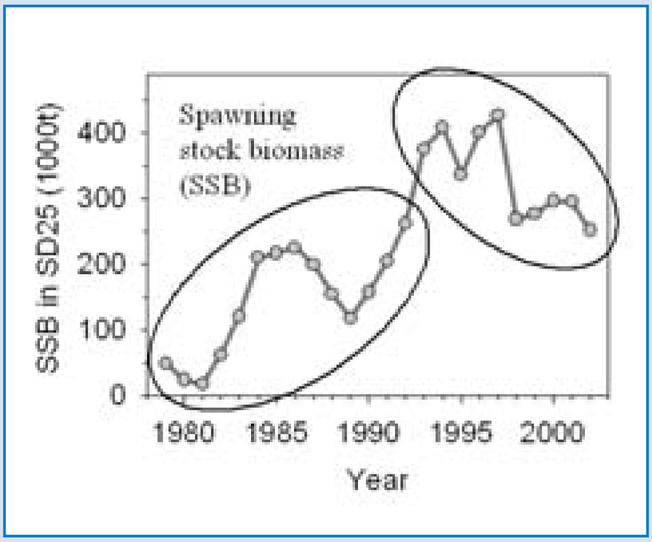

Figure 4. Time-series of Baltic sprat spawning stock biomass (SSB) in SD 25. Circles depict the suggested two periods of predominantly low and high biomass levels.

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A strong impact of winter temperature on spring recruitment of a key copepod species in the Bornholm Basin: potential linkages to climate variability

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Recent analyses of the feeding habits of Baltic sprat demonstrate a strong preference for nauplii and copepodites of *Acartia* spp., particularly by their larvae (Voss *et al*., 2003). These copepod species thus form an important link between phytoplankton production and fish recruitment in the food web of the Baltic Sea. Long-term investigations in the Central Baltic, however, revealed inter-annual fluctuations of the standing stocks of calanoid copepods which have been related to changes in hydrographic conditions (Möllmann *et al.*, 2000; Hänninen *et al.*, 2000). An increasing biomass of *Acartia* spp. in the 1990s contrast with strongly decreasing biomass of another key species, *Pseudocalanus* sp. (Möllmann *et al*., 2000; 2003).

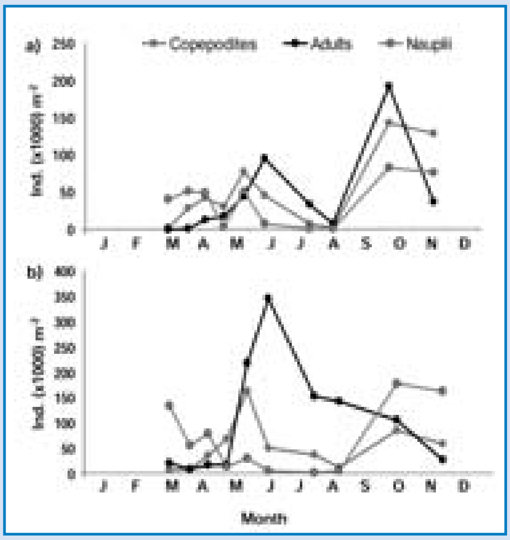

Figure 1. Seasonal abundance of development al stages of Acartia bifilosa (a) and A. longiremis (b) in the Bornholm Sea.

The German Globec Project aims to clarify the trophodynamic interactions between zooplankton and plankivorous fish in relation to reproductive success under the impact of physical forcing. A major goal of the project is the identification of critical life-stages or processes which determine the seasonal population dynamics and, thus, can explain the observed long-term fluctuations in the biomass of *Acartia*. Within this framework, a highly frequent net-sampling programme was carried out in order to investigate the spatio-temporal distribution of *Acartia* spp. in the Bornholm Basin in 2002. Characteristic seasonal patterns in the abundance and stage composition of *Acartia longiremis* and *A. bifilosa* are depicted in Figure 1. In the transition period from winter to spring, a pronounced peak in naupliar abundance generally precedes those of copepodites and adults. During 2003, experiments have therefore been performed to identify the source of the initial naupliar peak and the potential factors controlling the recruitment process.

In these experiments two major mechanisms for the origin of the nauplii have been compared. First, *in-situ* egg production by females and hatching of eggs was determined by incubation experiments on-board research vessels. Second, hatching of nauplii from eggs hibernating in the sediment was studied in the laboratory by the incubation of sediment cores taken by a multicorer in January 2003.

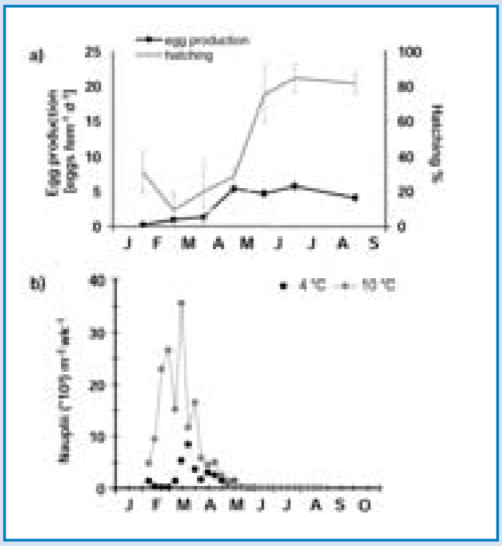

Figure 2. Seasonal variation in egg production and egg hatching of A. longiremis (a) and hatching of nauplii from a sediment core (b).

The results demonstrate that hatching of nauplii from the sediment is by far the most important source for *Acartia* nauplii in spring. As exemplified by the dominant species A. longiremis, egg production by females in the water column is not only poor during the period from January to April, but hatching success of these eggs is also very low (Fig. 2a). In contrast, very high hatching rates of nauplii have been observed from sediment incubated in the laboratory (Fig. 2b). Hatching of hibernating eggs was particularly important during the period when in-situ egg production and egg hatching was low. Roughly calculated between 120,000 and 205,000 nauplii m^{-2} hatched from the sediment in the period January to April, whereas only 8000 nauplii m^{-2} can be derived from in-situ egg production. Thus, hatching of resting eggs explains the early occurrence of nauplii in the water column.

Most important, the laboratory experiments revealed a strong temperature control of egg hatching from the sediment. When sediment cores were incubated at 4°C, hatching rates were on average about a factor of 2 to 5 lower than those observed at 10°C (Fig. 2b). The incubation temperatures represent generally the upper and lower limit of the naturally occurring range above the sediment in the Bornholm Sea. Relatively high temperatures were observed in the winter of

2001/2002 (Fig. 3). At depths below 60m at which peak hatching of nauplii was observed, temperatures above the sea floor were generally above 9°C. In contrast, temperatures in the winter of 2002/2003 dropped to below 5°C in large parts of the Bornholm Sea as a consequence of a major inflow of cold saline water in January.

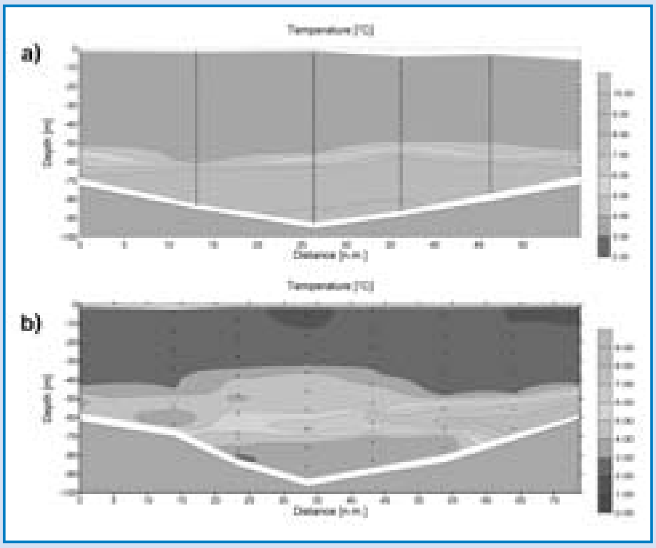

Figure 3. Temperature profiles in the Bornholm Sea during March 2002 (a) and February 2003 (b).

Although our results obtained need further confirmation by analysis of field samples taken during 2003, they suggest that the recruitment through hatching of resting eggs is a critical process in the population dynamics of *Acartia* spp. in the Baltic with regard to physical forcing. First, resting eggs are a major source for the first generation of *Acartia* spp. in the Bornholm Sea as demonstrated for this genus for the northern Baltic (e.g. Katajisto *et al.*, 1998). Second, hatching of resting eggs is restricted to a short time period in winter-spring. And third, hatching depends strongly on the *in-situ* temperature in deep areas of the Bornholm Sea. These characteristic patterns in the early life cycle of *Acartia* spp. potentially relate fluctuations in the biomass of these species to the prevailing hydrographic conditions and, thus, to climate variability. Because the hydrographic conditions in the Baltic Sea are mainly controlled by climatic factors (Hänninen *et al.*, 2000), a lack of deep vertical mixing during cold winters or of major inflows of cold water and consequently high temperatures in the deep water may explain the increasing standing stocks of *Acartia* spp. in the 1990s.

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A new Individual Based Model approach to derive somatic larval growth characteristics from otoliths

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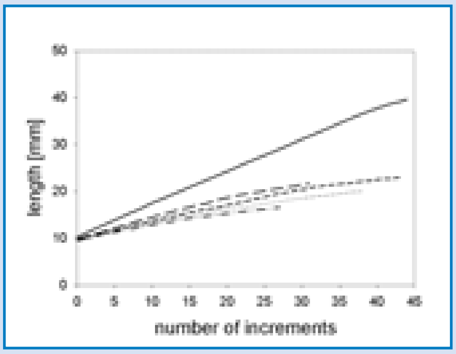

Figure 1. Simulated growth curves of selected herring larvae vs. maximum growth curve

Otolith microstructure analysis of young fish is utilized amongst others to determine age, daily growth rate estimates, mortality, migratory and environmental history, competition, abundance, condition and taxonomy (Campana and Neilson, 1985; Jones, 1986; Re and Goncalves, 1993). Otolith and fish size are highly correlated for a variety of marine and freshwater species (Campana and Neilson, 1985), thus it is possible to estimate growth-rate histories of individual fish by measuring the widths of otolith increments. Otolith increment width and somatic larval fish growth data (length, weight) of North Sea herring were used to develop an Individual Based Model (IBM) in order to describe daily resolved larval growth rates. Firstly, the model utilizes information from sagittal otolith readings as well as measured standard length and weight data of the larvae by solving an overdetermined set of linear system equations for all parameters using the method of least square residuals. The model solving the linear system consists of a matrix that describes the increment width information of more than 140 larvae, a vector containing their length/weight measurements as well as a vector describing the residuals. The solution vector yields age dependent maximum somatic growth rates of herring larvae. Secondly, measured increment width data are used individually to determine daily resolved nutritional growth parameters of single larvae in relation to their potential maximum somatic growth conditions. The model has been utilized for larvae caught during ichthyoplankton

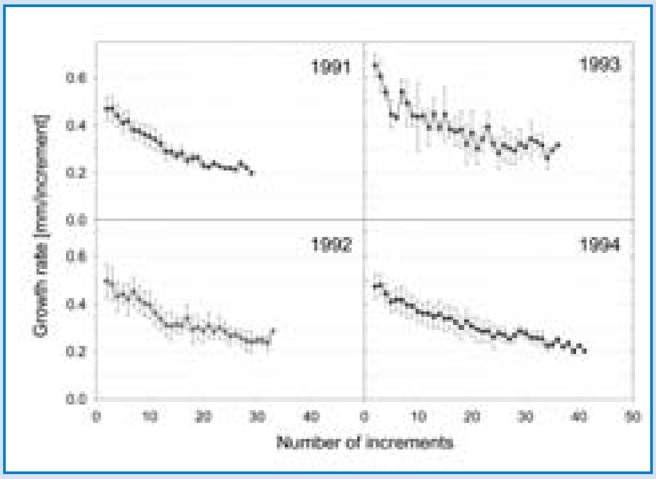

Figure 2. Average growth rates of North Sea herring larvae 1991-94

surveys from 1991 to 1994 to simulate somatic growth curves of selected larvae in comparison to the maximum larval growth curve (Fig. 1) derived from laboratory experiments (Folkvord *et al.*, 2000). The solid line displays the maximum larval length for each of the otolith increments as well as the inner core. All larvae showed similar sizes at formation of the first increment, highest growth rates were observed for the herring larva represented by the long-dashed line. Lowest growth rates were found for the larvae described by the dotted and dash-dotted lines, which also were defined as being in a bad nutritional condition (Fig. 1). Average herring larvae growth rates for the years 1991-1994 are displayed in Fig. 2. Larvae sampled in 1991 showed the worst growth conditions. 1992 had similar mean growth conditions in comparison to 1994. In 1993, larval growth started with extremely high growth rates for the first larval feeding phase and showed the highest variations throughout the feeding period out of all the years. Compared to the low values in 1991 growth rates at around increment 30 were 50% higher. 1994 represents normal or moderate growth conditions and covers the largest larval age spectrum.

The area where the herring larvae have been caught is characterized by low stratification and usually has almost constant late-summer temperature conditions between the years as seen in the data from 1991-1994. Thus, with a high degree of confidence variation in otolith increment widths is not caused by temperature effects, but can be assigned to variability in the abundance of available larval prey. In areas with less homogenous environmental conditions, temperature has to be considered as a driving key factor influencing otolith growth. Once the spatially and temporally resolved environment is known the presented method can be extended to a more complex version including both temperature as well as available food. For this specific purpose, this type of individual-based model can be coupled with local or regional circulation models in order to enable larval environmental reconstruction by backward projection (Hinrichsen *et al.*, 1997).

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Fish predation control of key copepod species in the Bornholm Basin

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Although an established concept in freshwater ecology (Kitchell and Carpenter, 1993), top-down controls of plankton communities by fish predation have been rarely documented in the marine environment (e.g. Shiomoto *et al.*, 1997; Cury *et al.*, 2000; Kaartvedt, 2000). For Central Baltic deep basins (Gotland Basins and Gdansk Deep), seasonal time series investigations demonstrated the importance of predation by sprat (*Sprattus sprattus*) for the interannual dynamics of the copepods *Pseudocalanus* sp. and *Temora longicornis* (Möllmann and Köster, 2002). Within the GLOBEC-Germany programme a highly resolved spatio-temporal investigation on the predatory effect of the main planktivores in the Baltic Sea, i.e. beside sprat also herring (*Clupea harengus*), on the dynamics of the key copepods *Pseudocalanus* sp., *T. longicornis* and *Acartia* spp. was conducted. An almost monthly coverage of the Bornholm Basin between April 2002 and May 2003 included spatially resolved net sampling of copepods, determination of the predator stock size and distribution using combined hydroacoustic and trawl surveys, and an extensive stomach content sampling programme.

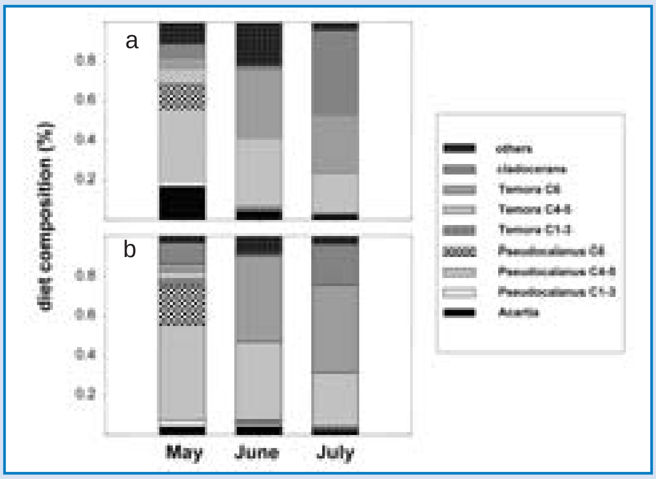

Figure 1. Average monthly stomach content of a) sprat and b) herring.

To date, stomach content data from 738 herring and 883 sprat from surveys in May, June and July 2002 have been analysed. Diet data indicate a switch of both predator species from mainly older copepodite stages (C4-C6) of *Pseudocalanus* sp. in May to *T. longicornis* in June/July (Fig. 1). The pelagic fish community is presently characterized by the dominance of the sprat stock (Köster *et al*., 2003). During May to July 2002, the stock size of herring in the Bornholm Basin increased due to the return of the fish from their coastal spawning area. In contrast, the sprat stock showed an opposite movement from spawning in the deep basins in May to coastal feeding later in the season (Fig. 2).

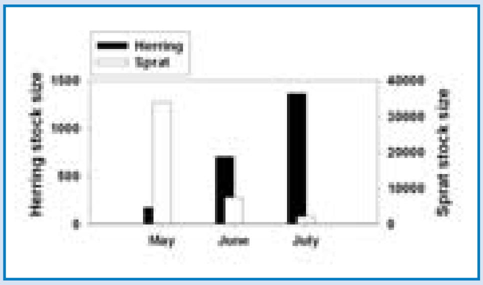

Figure 2. Monthly herring and sprat stock sizes (in millions).

Combining daily food intake estimates for single fish [calculated using average stomach contents in a temperature-dependent model of gastric evacuation (Temming, 1996)] with stock size estimates from hydroacoustic surveys allowed the calculation of the population consumption by herring and sprat stocks. These were confronted with potential secondary production estimates of the target copepod species [using a temperature-dependent model of Huntley and Lopez (1992)]. The resulting consumption to production ratios (C/P) indicate a major predatory impact of the sprat stock on *Pseudocalanus* sp. in May with an average C/P of almost 0.6 for adult copepods (Fig. 3). A considerable, although lower impact is demonstrated from herring C/P (max 0.2) on *Pseudocalanus* sp. in May and *T. longicornis* in July.

Resolving a predatory impact on smaller spatial scales is a relatively seldom investigated feature (Fig. 4). Our results clearly demonstrate the high within-basin variability, with high C/P of sprat on *Pseudocalanus* sp. stages in May, concentrating mainly on the north-eastern parts of the Bornholm Basin. Even though the average C/Ps of herring were low, locally predatory hot spots can be identified in May for *Pseudocalanus* sp. and *T. longicornis* with peak C/P of 1. These areas of high predation pressure are, as for sprat, mainly located on the eastern flanks of the basin.

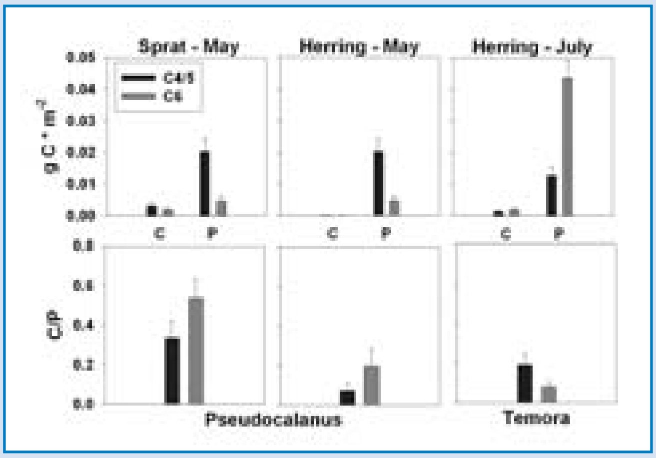

Figure 3. Average predatory impact of planktivorous fish on copepod species; C – population consumption, P – copepod secondary production; error bars indicate the standard error of the mean.

Although these are preliminary results, which will be complemented to a full seasonal scenario by further sample and data analyses, first conclusions with respect to copepod population dynamics can be drawn. (i) *Pseudocalanus* sp. which suffers presently already from unfavourable hydrographic conditions (Möllmann *et al.*, 2003; Schmidt *et al.*, 2003), is under additional stress by the unusual high sprat stock, which feeds heavily on its older developmental stages during the peak reproduction time of the copepod in early spring; (ii) *T. longicornis* is obviously much less affected by fish predation due to the summer migration of sprat out of the basin; (iii) *Acartia* spp., the third target copepod in our study, seems to be unaffected by pelagic fish predation which is mainly due to a lacking vertical predator-prey overlap.

Generally, we stress the importance of spatial variability in the predatory impact on copepods, which will be further evaluated by comparing predation estimates with local copepod population dynamics, i.e. growth and mortality rates.

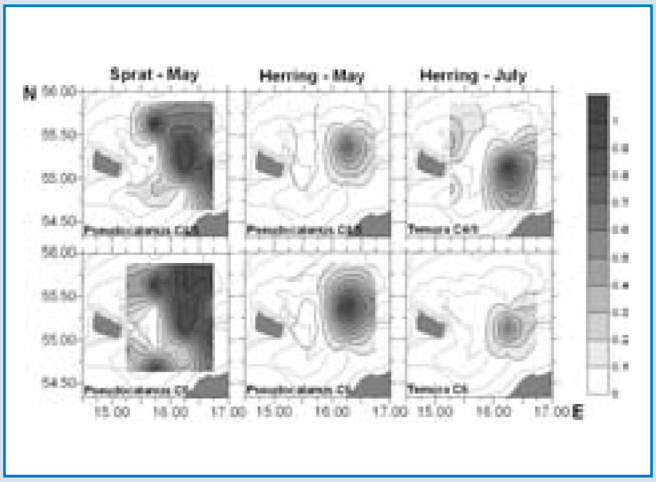

Figure 4. Spatially-resolved predatory impact of planktivorous fish on copepod species: Consumption to production ratios (C/P).

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German GLOBEC Statusseminar: Programme evaluators meet in Hamburg

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Poster session, (left to right) - Francois Carlotti, Roger Harris, Keith Brander, Jürgen Alheit, Axel Temming, Prof. Dr. Udo Schöttler, Dr Peter Seifert and Prof. Dr.Gerd Hubold.

This issue of the GLOBEC Newsletter includes a series of scientific reports on the German GLOBEC programme, which recently held a two day review meeting (Statusseminar) in Hamburg, 27 - 28 January, 2004. Topics covered are spring recruitment of copepod species in the Bornholm Basin (Dutz *et al.*), fish predation on copepods (Möllmann *et al.*), nutritional condition of larval sprat (Clemmesen *et al.*), a new IBM approach to derive somatic larval growth characteristics from otoliths (Hinrichsen) and a new retention index for the Central Baltic (Baumann). These five articles provide a flavour of the meeting selected from the 18 scientific presentations and 28 posters, and in addition Jürgen Alheit provides an overview of the project.

As well as providing the opportunity for a review of the status of the programme the Hamburg meeting also involved a group of international evaluators who were invited to attend and to provide a report on progress to date and future prospects for the programme. In addition to me, the evaluator group (see photo) included Gerd Hubold (Bundesforschungsanstalt für Fischerei, Hamburg), Keith Brander (ICES, Copenhagen), Francois Carlotti (Université de Marseille). We were joined by Udo Schöttler and Peter Seifert (Projektträger, Jülich) representing the funding agency, BMBF. Gus Paffenhöfer (Skidaway Institute of Oceanography) was unable to attend.

The articles elsewhere in this Newsletter provide a selection from the range of topics presented at the meeting, demonstrate the high quality of those contributions, as well as how active and dynamic the German GLOBEC programme is at mid-term. The evaluators enjoyed both the programme of oral presentations and the opportunity to interact with the participants during the evening poster session. The latter was enlivened by one of Jürgen Alheit's "German wine tasting sessions", which are world famous in the GLOBEC community.

More than 60 German GLOBEC scientists from 8 participating institutions were at the Statusseminar. A particularly impressive aspect of the meeting was the strong representation of students, who gave excellent oral presentations, together with the degree to which the participating institutions are collaborating, interacting and communicating to achieve a truly integrated programme. To date most of the focus has been on the Baltic Sea with field-work in the North Sea just starting. Once the latter work is completed this will provide the programme with a unique opportunity to compare and contrast the two systems. Such integration and synthesis, particularly allowing data to be matched with the models, will be presented at a final international symposium of the programme which is in the early planning stages.

At the end of the two days the evaluators met formally with the representatives of the funding agency, the German Federal Ministry for Education and Research (BMBF), to review the progress of the programme so far and to consider plans for future development. Consistent with the impressive body of work presented in Hamburg and the exciting plans for future work the outcome of this review was entirely favourable.

Life-cycles, productivity and biomass of copepods in the Southern Ocean: A new perspective

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Foodwebs in the Southern Ocean: perspectives old and new

Since the early days of scientific exploration in the South Polar seas, the Antarctic krill (*Euphausia superba* Dana) has occupied a pre-eminent position in the study and quantification of Southern Ocean food webs. From the early part of the last century the Discovery Investigations, undertaken in response to overexploitation by the whaling industry, placed krill very much at the centre of the food web. Subsequently, the continuing commercial exploitation of Southern Ocean resources and strong conservation interests for krill-dependent predators have perpetuated this view. The enduring paradigm has been one in which short food chains linking phytoplankton to vertebrate predators via krill has been viewed as the *modus operandi* of the entire system.

Recent research is emphasising the role of alternative pathways of energy flow in the Southern Ocean through the rich protist fauna and the complexity of the mesozooplankton and gelatinous animals that consume both phytoplankton and protists (Longhurst, 1998). In the Atlantic sector, known to be a hotspot for krill, estimates of krill biomass are around 44 x 106 tonnes (Hewitt *et al.*, 2002) but that of copepods is thought to at least be its equal and probably considerably more (Voronina, 1998). Further, because of allometric scaling considerations, rough estimates of annual production by copepods exceed those of krill by up to 12 times (Voronina, 1998). There is now sufficient understanding of the biomass distribution (Ward *et al.* 1995; 1999), growth (Shreeve and Ward 1998; Shreeve *et al.*, 2002) and production, to begin development of life-cycle models of key species (Tarling *et al.*, in press).

Comparing productivity in copepods and krill

One of the main geographic foci of BAS research is the island of South Georgia, a productive region of the Southern Ocean of great importance with respect to fisheries and home to a vast number of land-based planktivores, such as seals, penguins and albatrosses. Over the past 5 years, our research has focussed on the inter-annual variability of biomass and productivity in this ecosystem. Copepod abundance and carbon mass has been found to be strongly related to past feeding conditions, as signified by dissolved silicate concentrations. Spatially, copepod and krill distributions differ, with higher abundances of the former generally being found off the shelf to the north west of the island. It is here that satellite imagery consistently shows extensive phytoplankton blooms developing during spring and summer, and which often persist through to autumn. Conversely, highest krill biomass was located over the shelf, in waters that typically have a lower standing stock of phytoplankton. Although krill can reproduce around South Georgia, recruitment rates appear low and their presence and, ultimately, their flux to higher predators is largely the result of transport into the region by water mass movements. We estimated that the daily production of all copepods around South Georgia was up to 16 times that of krill. The role that copepods play in supporting food webs in such productive areas of the Southern Ocean must therefore be significant.

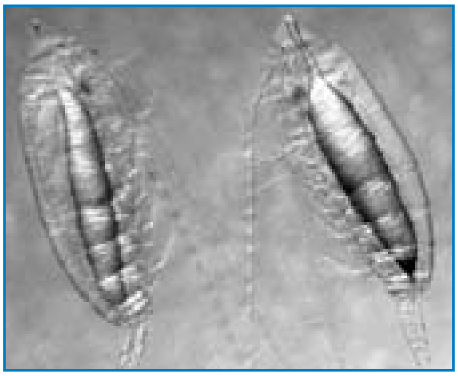

Figure 1. Calanoides acutus CVs, with prominent oil sacs (the darker elongated structures). These will fuel the animal over the extensive overwintering period. Typical body length, 4 mm.

Modelling the life-cycle of a key copepod species

Copepod diversity in the Southern Ocean is low, with biomass dominated by a few key species, such as *Calanoides acutus* (Fig. 1). These alone can account for up to 25% of total copepod biomass. The variety of life-cycle strategies in the calanoid community is also limited, with very few reaching adulthood within the short productive season of any one year. Survival over the extended winter period is accomplished through the animals entering partial or full diapause, where metabolic rates are slowed and movements are limited in order to conserve energy. *C. acutus* exhibits one of the most extreme patterns of diapause, descending to depths of over 1000 m for up to 9 months. It spends most of the winter as a copepodite (either stage IV or stage V), using its oil sac to fuel residual energy demands. It moults into adulthood and mates whilst still at depth. Females re-ascend to the epipelagic to spawn at the start of a new productive season. Males remain at depth and die soon after mating.

Population dynamic studies of *C. acutus* have shown that there must be some variation on this basic life-cycle pattern, with part of the population living through two winters before eventually reaching adulthood. This overlap of generations with different ages, but not necessarily different stages, which are impossible to separate morphologically, makes it difficult to estimate population parameters such as mortality and production, especially during the growing season. We have therefore built a stage and age structured model to determine the most likely proportions of these various life-cycle phenotypes in the Scotia Sea population (Tarling *et al.*, in press; Fig. 2). The model was parameterised with temperature dependent growth and development rates made from empirical observations (Shreeve *et al.*, 2002) and overwintering mortality rates from population dynamic studies (Atkinson *et al.*, 1997). The model varied the proportions of different life-cycle phenotypes and mortality rates in the summer period to predict a population dynamic profile that could be compared with a large set of empirical observations. These observations were a composite of data collected over the last 60 years from the Atlantic sector of the Southern Ocean,

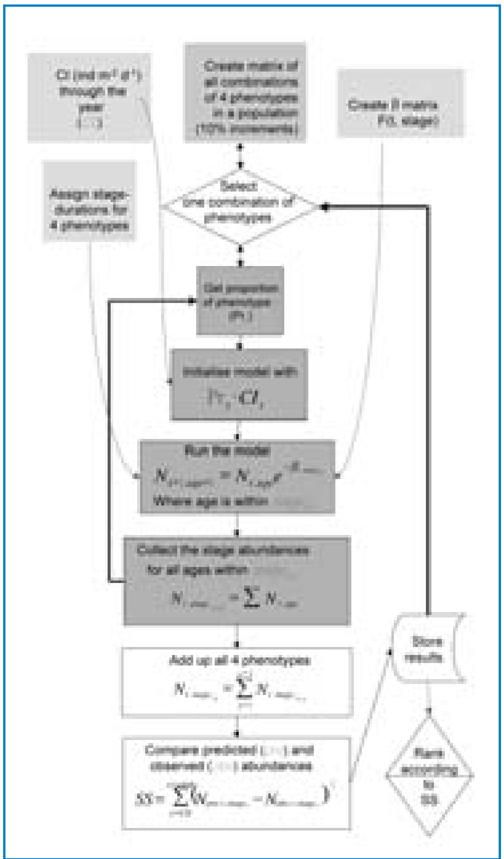

Figure 2: A schematic of the stage and age structured model.

particularly the Scotia Sea.

The model predicted that animals that mature after 1 year dominate *C. acutus* populations in the Scotia Sea. This appears to be the fittest strategy since the model also predicted that an average individual has less than 1% chance of making it into their second year. Further simulations showed that the 2-year phenotype is more common further south, where the growing season is even shorter and less predictable. It is likely that there is a dynamic equilibrium between the 1- and 2-year phenotypes. In years where the primary productivity is good, the number of 1-year phenotypes will increase. However, in bad years, the 1-year phenotype will suffer high mortality and the main survivors will be the 2-year phenotype.

Life-cycle adaptation in an extreme environment

The very limited duration of the productive season in the Southern Ocean makes it a particularly extreme environment in which to survive and persist. Even short delays in the timing of the phytoplankton bloom can cause reproductive failure in adults or starvation in newly hatched larvae. Currents are strong in the Southern Ocean and plankton may be advected over many degrees of latitude (Fig. 3) within their own lifetimes to end up in environments with very different temperature and productivity regimes. For *C. acutus*, the coexistence of several life-cycle phenotypes may allow populations to persist under such challenges.

Status summary

The parameterisation and modelling of life-cycle strategies of key species will be useful in improving biogeochemical and energy flux models by allowing us to pinpoint the timing of peaks in development, productivity and energy demand. The range of conditions experienced throughout a life-cycle will be gauged through utilizing the output of corresponding physical circulation models. From this, the Southern Ocean can be mapped in terms of species distribution and the prevalence of different phenotypes. The approach can also inform on the likely impacts that climate change may have on population dynamics and hence ecosystem function.

Ongoing work on copepod and krill dynamics is being carried out at BAS as part of the DYNAMOE programme, which contributes to Southern Ocean GLOBEC.

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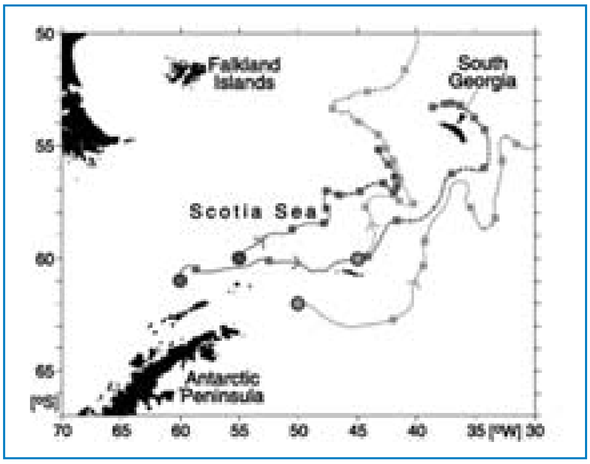

Figure 3: Hypothetical tracks of Calanoides acutus being advected across the Scotia Sea over the course of 1 year. The figure shows tracks for particles starting from 4 different locations (marked by circles) derived from time-varying model velocity fields from the Ocean Circulation and Climate Advanced Modelling project model (OCCAM, run by Southampton Oceanography Centre). The particles were released on 01 October 1994, spend the first four months at the near-surface (15 m) and the subsequent 8 months at depth (approximately 1000 m). Arrows show the direction of transport and squares mark 30 day intervals on each track. The first 4 months are solid lines, the next 8 months dashed lines.

Comparing visual survey and passive acoustic detections for humpback whales, *Megaptera novaeangliae*, during the austral autumn and winter in the Western Antarctic Peninsula

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The use of Acoustic Recording Packages (ARPs) in concert with visual sighting surveys during the IWC collaboration with the US Southern Ocean GLOBEC program in the Western Antarctic Peninsula (WAP) was reviewed in the October 2003 issue of this newsletter. Initial analyses of the ARP data revealed nearly year-round detection of blue whale calls at some sites and marked seasonal pattern to fin whale call detection (Širović *et al.*, 2004). The sighting survey data revealed that the seasonal distribution of humpback and minke whales was influenced by a suite of oceanographic factors including: bathymetric complexity, current velocity and proximity of the marginal ice zone and associated biological activities (Thiele *et al.*, 2004). While these results are exciting, the synergy between visual and acoustic data for enumeration of cetaceans has yet to be fully explored. Thus, recent effort has focused on comparing visual and acoustic detections of one species, humpback whales (*Megaptera novaeangliae*) in the WAP study area, with provisional results summarized here from poster presentations at the American Geophysical Union 12th Ocean Sciences Meeting, January 2004.

Antarctic waters are key seasonal feeding grounds for many baleen whale species, with most thought to depart for lower latitude breeding grounds at the end of the austral summer. Humpback whale migrations are the classic example for these high to low latitude movements, despite evidence that some proportion of populations may not undertake them. Few cetacean sighting surveys have been conducted in the Antarctic autumn and winter, and so the question of influences on the timing of migrations and proportion of populations involved has not been investigated. The collaboration between the IWC-US GLOBEC provided an opportunity to directly test the utility of both visual and acoustic techniques to answer the question about humpback whale migratory timing offshore the Antarctic Peninsula.

Seasonal presence of humpback whales was investigated using acoustic data from four ARP sites in the WAP. Data was compared between years and by month from continental shelf and offshore sites. Call detections were lower than expected given the frequency of visual sightings. Visual surveys were conducted on nine research cruises in the US Southern GLOBEC area between 2001 and 2003. Results from both methods confirm humpback whale presence in the study region, being detected visually from late summer through to late autumn (371 sightings: 850 individuals) and acoustically from early autumn to early winter (days of calling: 98). Specifically, during 2001/02, calls were detected between May to July (days of calling: 37) compared with visual sightings between March to May during 3 cruises (75:152) (Fig. 1). The number of visual sightings increased dramatically in 2002/03 during 5 cruises conducted in February (both years), April to May and August (296:698). One sighting should be noted from mid-winter (August) 2002 near the northern islands (64°53'S: 64°08'W). Calls were detected between April to June (days of calling: 61) (Fig. 2).

Unfortunately, there was very little overlap in visual and call detections within the 30km radius of each ARP site due to limited on-effort survey within these areas. The overall increase in visual sightings in 2002/03 can be explained by increased on-effort searching during cruises and higher numbers of whales within the survey zone due to ice conditions. It should be noted that although the ARP at site S9 in Marguerite Bay had sightings during both years, the ARP was not deployed until

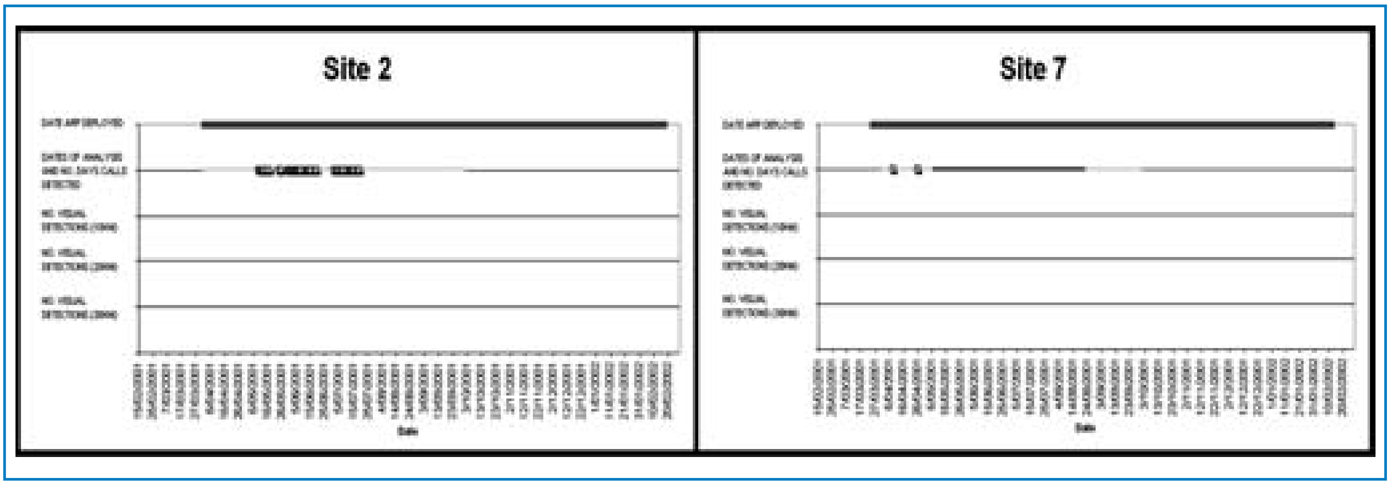

Figure 1. 2001 ARP deployment and analysis duration with dates of call detections and the number of visual detections within 10, 20 and 30km of each ARP. Numbers in brackets indicate sightings:individuals.

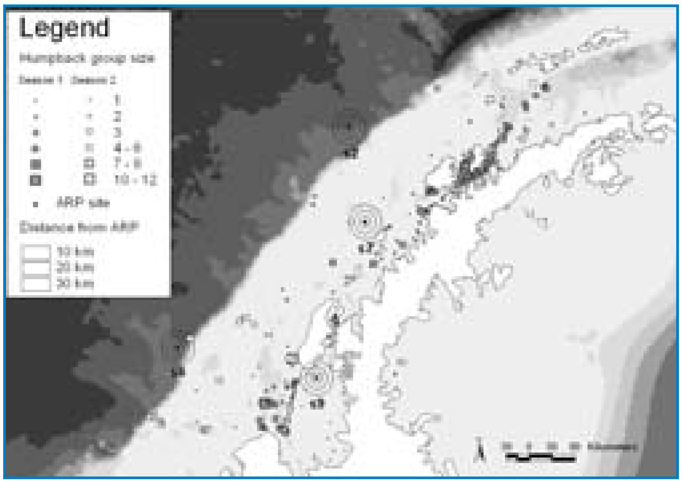

Figure 2. 2002 visual sightings and ARP deployments with 10, 20 and 30km detection radius. Season 1: Sightings outside of ARP analysis time (October - March), Season 2: Sightings during ARP analysis time (April – September).

2002 and was quickly covered by ice within a few weeks. This explains the low number of call detections and visual sightings around this site even though the acoustic data was analysed for the entire year, rather than only April to September. Interpretation of these strong differences between visual and acoustic detections are the result of social and seasonally modulated behaviour in this species and are important to investigate further in the context of improving the potential use of passive acoustic monitoring of cetaceans.

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The SPACC Executive Committee Met in Concepción, Chile 17-18 February 2004

Claude Roy, IRD, Plouzané, France (claude.roy@ird.fr) and Dave Checkley Jr, Scripps, La Jolla, USA (dcheckley@ucsd.edu)

The SPACC Executive Committee took the opportunity to meet after the SPACC workshop and meeting in Concepción. Our first objective was to review SPACC activities since the last Executive meeting, in Dartington, UK in May 2002:

- Theme 1 (Retrospective Analyses) has had a proposal to the IAI, IRD, CICESE and IMARPE accepted for coring off Peru and the organization of a series of workshops on long time series.
- Theme 2 (Comparative Population Dynamics) has included work by the SPACC/IOC Study Group on the use of environmental indices in the management of pelagic fish populations; reports of two workshops (available on the GLOBEC website); and several publications.
- Theme 3 (Reproductive Habitat Dynamics) focused on the Concepción workshop and meeting (reported in this Newsletter).
- Theme 4 (Economic Implications of Climate Change) is new and will conduct a meeting in September 2004 in Portsmouth, UK, announced on the GLOBEC website.

SPACC activities have expanded recently in Europe and Asia in addition to the Americas and Africa.

Our second objective was to plan for the future. With GLOBEC to end in 2009, the question was asked, " What will SPACC's legacy be?" Synthesis and integration were agreed to be the goal during the coming, final five years of SPACC. We decided that this goal would be best attained by maintaining the four SPACC themes and adding two new activities:

- The publication of a book in 2007 consisting of chapters on the major research areas of SPACC. These would include historical and retrospective studies, status and dynamics of present stocks, the assessment and ecosystem role of small, pelagic fish, economics of their fisheries, and modeling. These chapters would be first presented at a workshop in 2006.
- An international symposium in 2008 at which achievements of SPACC would be presented for all themes and regions. Proceedings of the symposium would be published in a major, scientific journal.

These two activities would represent significant and lasting contributions of SPACC to fisheries science and form the basis for future activities.

SPACC Executive 2003

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1st ANNOUNCEMENT International GLOBEC Symposium

Climate Variability and Sub-Arctic Marine Ecosystems

Victoria, B.C., Canada, May 16-20, 2005

Co-sponsors: Fisheries and Oceans Canada, National Science Foundation, U.S.A. North Pacific Marine Science Organization (PICES)

Background and Objectives

Sub-Arctic seas support extraordinarily rich marine resources, which provide food and wealth to local communities. These seas include: the Okhotsk Sea, Oyashio shelf region, Bering Sea, Hudson Bay, Newfoundland/Labrador shelves, Gulf of St. Lawrence, Greenland shelves, Iceland regions, the Nordic Seas and the Barents Sea. These seas share several common features: seasonal ice cover, freshwater from ice-melt and runoff, dramatic seasonality, reduced sunlight and low biodiversity. Recently, changes in species abundance or distribution have been observed within several Sub-Arctic marine ecosystems. A symposium on climate effects on the Sub-Arctic marine ecosystems is timely because these recent changes appear to correlate with fluctuations in the physical environment and because of the growing concern about anthropogenically induced climate change. Also, several new national programs in Sub-Arctic seas have recently been initiated, e.g. Bering Ecosystem Study (BEST), Effects of North Atlantic Climate Variability on the Barents Sea Ecosystem (ECOBE), Ecosystem West Greenland (ECOGREEN), and the Oyashio-pollock project in Japan. Additionally, a new GLOBEC regional program, Ecosystem Studies of Sub-Arctic Seas (ESSAS), is in the planning stage. This symposium offers the opportunity to influence the implementation plans of ESSAS and BEST.

Scientific Program

The symposium's scientific objective is to present current knowledge of the effects of seasonal to multi-decadal climate variability on the structure and function of Sub-Arctic marine ecosystems. We invite papers, particularly interdisciplinary or comparative ones, on the following topics:

- large-scale climate forcing on the physical oceanography of Sub-Arctic seas
- physical and biological factors structuring Sub-Arctic ecosystems (e.g. nutrient availability, sea ice, low temperatures, low species diversity, etc.)
- the transfer of energy and material through subarctic food webs, from primary producers through zooplankton and benthic fauna to fish, seabirds, marine mammals and fisheries
- recent changes in subarctic ecosystems, time scales of variation and possible causes
- inter-comparisons between Sub-Arctic marine ecosystems.

Papers on related topics will also be considered. Scientists are invited to submit titles and abstracts (maximum of 250 words), for oral presentations or posters, through the GLOBEC website, www.globec.org. All abstracts will be reviewed for merit and relevance. The deadline for abstract submission is December 1, 2004.

Symposium Structure

The symposium will have a combination of plenary sessions in the mornings and parallel sessions in the afternoons. Keynote speakers will provide 40-minute introductions and challenges to selected topics. Contributed papers that are accepted will be 20 minutes in length. Posters will be displayed throughout the meeting, and sufficient time will be provided for discussion with authors. Workshops on BEST and ESSAS will be held on the first and last days of the symposium. The official language of the symposium will be English.

Publication

The symposium proceedings will be published in a refereed journal yet to be selected. Papers, including those based on poster presentations, will be considered for publication following peer review. Interested authors will be required to submit an electronic version of their manuscript in standard format at the time of meeting.

Dates and Venue

The symposium will be held May 16-20, 2005, at the Victoria Conference Centre in Victoria, British Columbia, Canada. May 16 will be a workshop for discussion of the Bering Ecosystem Study (BEST) Implementation Plan, and May 21 will be an all-day workshop for developing the Implementation Plan of ESSAS. All symposium participants are welcome to attend and participate in these workshops. Local arrangements will be coordinated by the PICES Secretariat.

Participation

The symposium is open to all scientists and students interested in Sub-Arctic marine ecosystems.

Registration Fees

Those attending are invited to register by **December 1, 2004**. A registration fee of $250 US ($150 for students) will be charged to help cover the costs of the symposium. Late registration is $350 US ($250 for students). Limited support for student participation is expected to be available. Applications for student support must be made by **December 1, 2004**. Registration, abstract submission and student support will be through the GLOBEC website, www.globec.org.

Important Dates

December 1, 2004	Deadline for early registration and abstract submission
December 1, 2004	Deadline for application for Student Support Grants
February 1, 2005	Notification of abstract acceptance
April 1, 2005	Notification of Student Support Grants
May 17, 2005	Submission of electronic versions of papers

Further information about the symposium, including accommodation and registration forms can be found at www.globec.org.

Co-Convenors:

George L. Hunt, Jr. (University of California, Irvine, U.S.A.)

Ken Drinkwater (Institute of Marine Research, Bergen Norway)

Scientific Steering Committee:

- Olafur S Astthorsson (Marine Research Institute, Reykjavik, Iceland)
- Manuel Barange (GLOBEC IPO, Plymouth, UK)
- Mickle Flint (Shirshov Institute of Oceanology, Moscow, Russia)
- Jean-Claude Gascard (Universite Pierre et Marie Curie, Paris, France)
- Jackie Grebmeier (University of Tennessee, Knoxville, U.S.A.)
- Erica Head (Bedford Institute of Oceanography, Dartmouth, Canada)
- Hans-Jurgen Hirche (Alfred Wegner Institute, Bremerhaven, Germany)
- Eileen Hofmann (Old Dominion University, Norfolk, U.S.A.)
- Anne Hollowed (Alaska Fisheries Science Center, Seattle, U.S.A.)
- Michael Kingsley (Greenland Institute of Natural Resources, Nuuk, West Greenland)
- J. Kishi (Hokkaido University, Hakodate, Japan)
- Harald Loeng (Institute of Marine Research, Bergen, Norway)
- Bernard Megrey (Alaska Fisheries Science Center, Seattle, U.S.A.)
- Ian Perry (Pacific Biological Station, Nanaimo, Canada)
- Sei-ichi Saitoh (Hokkaido University, Hakodate, Japan)
- Yasunori Sakurai (Hokkaido University, Hakodate, Japan)
- Kurt Tande (University of Tromsø, Norway)
- Terry Whitledge (University of Alaska, Fairbanks, U.S.A.)

SPACC Workshop on Long-term Dynamics of Small Pelagic Fishes and Zooplankton in Japanese Waters

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SPACC Workshop attendees.

The task of the SPACC Theme Group “Long-term changes in Marine Ecosystems“ is, *inter alia*, to organize regional meetings to compile and analyse inter-decadal scale physical and biological data sets to investigate the impact of climate variability on SPACC ecosystems. Such exercises have been carried out in the past for the Benguela (Cape Town) and the Humboldt (Lima) Current, the results of which are in press. On recommendation of the respective SPACC Theme Group and the GLOBEC Focus 1 Group on Retrospective Studies, Prof. Takashige Sugimoto from Tokyo University organized a symposium on “SPACC in the Kuroshio System” in Tokyo from 9-10 December 2003, which was followed by a GLOBEC-SPACC Workshop at Misaki Marine Biological Station from 10-11 December 2003. The objectives were to present and analyse all relevant long-term data sets on the Kuroshio system and waters surrounding Japan and to compare them with similar data from the Humboldt and Benguela Currents and NE Europe. A particular aim was to encourage and intensify studies on the old Japanese sardine periods which date back to the early 1500s. The Symposium was attended by 25 participants from the fields of paleoceanography, climatology, physical oceanography, biological oceanography and fisheries biology. The two non-Japanese participants were funded by PICES (A. Bakun) and GLOBEC (J. Alheit) which is acknowledged here. Many excellent papers were given on long-term processes in relation to Japanese waters. Prof. T. Kawasaki, who was the first to draw our attention to the synchrony of Pacific sardine stock dynamics (FAO Symposium on Pelagic Fishes in Costa Rica in 1983), gave an impressive presentation on Fisheries Management based on the Regime Shift Theory. Drs. K. Kuroda, T. Sugimoto and M. Tsuboi presented a paper on “cycles of japanese sardine catch and the physical environment from the 16th to the 20th Century.” The famous *iwashi* fishery landed sardines, anchovies and round herring. Dr. K. Hiramoto informed on the “history of the sardine fishery off the coast of the Boso Peninsula.” The sardine fishery there was originally started to provide farmers with fertilizer to grow rice and cotton. Drs. M. Tsuboi, K. Kuroda and T. Sugimoto reported on “historical commercial data on dried sardines and the social background since the early Edo Period.” Fish fertilizer was important as cotton was in high demand to produce fuses (slow match wicks) for ancient guns. Human consumption did not play a major role in the Japanese sardine fishery before 1900, as preservation with salt was too expensive. The meetings, excellently organised by Prof. T. Sugimoto, finished with a traditional tuna party where many old tales and stories were told. The symposium proceedings will be published in a special volume edited by T. Sugimoto.

SAHFOS

The New CPR Atlas: 240 distribution maps

Anthony J. Richardson, SAHFOS, Plymouth, UK
(anr@mail.pml.ac.uk)

The purpose of the SAHFOS column this month is to advertise the recently published CPR Atlas (Continuous Plankton Recorder Survey Team 2004, see Figure 1). It is the culmination of work from the latter half of the 20th century by the CPR survey, the longest-running, large-scale, marine biological monitoring programme in the world. CPRs are virtually unchanged in design since the 1930s and have been towed behind 256 vessels for nearly 5 million nautical miles. The Atlas is based on the 155,000 samples that have been counted by more than 90 plankton analysts from 1958-1999; a period when counting methods have remained unchanged.

This Atlas gives distribution maps in the North Sea and North Atlantic for 240 common plankton taxa. It focuses on diatoms (59 taxa), dinoflagellates (48 taxa) and calanoid copepods (63 taxa), with the majority of taxa identified to species level. The Atlas also includes distribution maps of important groups such as silicoflagellates, coccolithophores, tinntinnids (6 taxa), ostracods, cladocerans (3 taxa), harpacticoid copepods (3 taxa), molluscs (11 taxa), echinoderms, chordates (7 taxa), chaetognaths and many other groups.

Particular phytoplankton taxa of interest include many that form harmful algal blooms (HABs) such as *Noctiluca scintillans, Dinophysis* spp., *Gonyaulax* spp. and the foam alga *Phaeocystis poucheti*. The distribution of the introduced diatom species *Coscinodiscus wailesii*, which was resident in the North Pacific and was first found in the Atlantic in 1977 (Edwards *et al.*, 2001), is also shown. The most complete data for any genus is that for *Ceratium*, with distribution maps of 27 species. The distribution of the diatom *Ephemera planamembranacea*, an occasionally abundant member of the phytoplankton community in the NW Atlantic, is shown; this species was discovered and first described from CPR samples in 1962. Noteworthy zooplantkon taxa in the Atlas include those that may regulate cod recruitment in the North Sea, such as *Calanus finmarchicus, Calanus helgolandicus* and *Pseudocalanus elongatus* (see Beaugrand *et al.*, 2003); warm water indicator species such as *Centropages chierchiae* and *Temora stylifera*; super-abundant small copepods of the genera *Oithona* and *Oncaea*; and predatory gastropods of the genera *Cavolinia, Clio, Diacria, Limacina, Clione* and *Pneumodermopsis*.

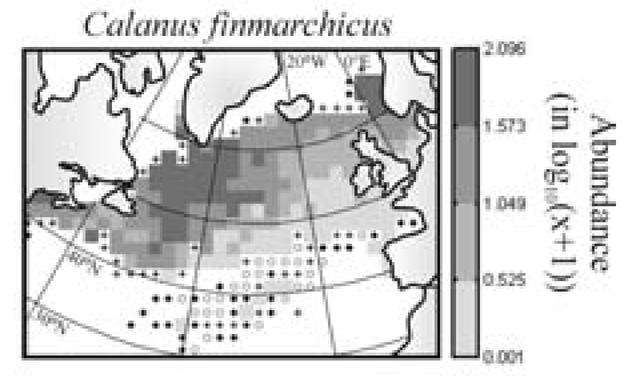

Figure 1. The distribution of Calanus finmarchicus in the North Atlantic. Colours represent abundance. Circles: never recorded. Diamonds: only 1 presence. Plus: >1 presence.

As well as becoming an indispensable taxonomic aid for marine biologists in the North Atlantic, it is hoped that the Atlas will contribute towards current global biodiversity initiatives such as Census of Marine Life (CoML). In terms of the impact of climate change, the Atlas provides a baseline for assessing shifting biogeographical patterns; comparing distribution maps from the present Atlas with those from the inaugural Atlas in 1973, it is apparent that many warm water taxa have shifted northward. The Atlas may also be useful for monitoring the rate of spread of non-indigenous species, which is essential for establishing the effectiveness of any management strategy to limit invasions.

Finally, SAHFOS would like to thank the editors of MEPS for publishing the new CPR Atlas and making it available free of charge to the scientific community. The CPR Atlas can be downloaded from the following web page - http://www.int-res.com/abstracts/meps/CPRatlas/contents.html.

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Call for Abstracts

SPACC Workshop on the economics of small pelagics and climate change

The Boathouse, University of Portsmouth, Portsmouth, UK, 13-15 September 2004

The Small Pelagics and Climate Change Programme (SPACC) announces a workshop on the economic consequences of climate change- driven changes in pelagic fish production.

Climate change is likely to have an impact on the abundance and distribution of fish stocks. This in turn will have positive and negative effects on the livelihood of people who make their living from fishing. In any case, adjustment costs may be expected to result from these changes.

Small pelagic fish species are notorious for their variability in stock abundance, generally caused by fluctuations in environmental conditions (such as El Niño events). For a long time people have had to adjust to changes in the abundance of these types of fish, albeit on highly variable time scales. It therefore seems that studying the economic consequences of these variations and adjustments would be of particular interest for adjustments on a broader scale resulting from global environmental change.

Research on the economic implications of climatic changes on fisheries has been limited and fragmented. The purpose of this workshop is to contribute significantly to such research, focusing on small pelagic fish. While papers need to be well grounded in biological and oceanographic reality we are looking for papers with a significant economic content.

Abstracts of papers to be presented should be sent to the GLOBEC International Project Office through the webpage (www.globec.org, follow signs to "SPACC Economics Workshop") by April 30, 2004. Authors of accepted papers will be invited and sponsored to attend the workshop. Additional, unfunded invitations may be offered subject to space availability. It is expected to publish the papers presented at the conference as a special volume of a relevant journal or as a book of case studies.

Workshop Organising Committee:

- Mahfuzuddin Ahmed, ICLARM, Penang, Malaysia
- Manuel Barange, GLOBEC IPO - Plymouth Marine Laboratory, United Kingdom
- Doug Butterworth, University of Cape Town, South Africa
- Rögnvaldur Hannesson, The Norwegian School of Economics and Business Administration, Bergen, Norway
- Sam Herrick, NMFS, La Jolla, California, USA
- José de Oliveira, CEFAS, Lowestoft, United Kingdom
- Julio Peña Torres, Alberto Hurtado University, Santiago, Chile
- David Sampson, CEMARE, Portsmouth, United Kingdom
- Dale Squires, NMFS, La Jolla, California, USA

Regime Shifts in the North Atlantic Ocean: Coherent or Chaotic?

The ICES Annual Science Meeting in Vigo, Spain (September 22-25, 2004) has a Theme Session on Regime Shifts in the North Atlantic (Session M). For more information please contact Jeremy - jcollie@gso.uri.edu.

http://www.ices.dk/iceswork/asc/2004/themes.asp#SessionM

Co-convenors: Jeremy Collie, Roger Harris and John Steele

The term "regime shift" coined in the North Pacific is now applied to diverse phenomena in the North Atlantic, such as plankton communities and fish stocks, and to different regions of the ocean, shelf seas and upwelling areas:

- Are there any consistent patterns in the North Atlantic cases across trophic levels?
- Is there spatial and/or temporal coherence across geographic areas and ecosystems as is proposed for the North Pacific?
- Are there agreed methods of analysis? In particular, is PCA the most appropriate way to integrate heterogeneous data?
- Is there a generally acceptable explanation? Especially, are the patterns explicable in relatively passive terms as, for example, a low-pass filtering of physical variability? Or do we need basic ecological processes such as switching between different stable equilibria top-down as well as bottom-up regulation.

Answers to these questions are central to our attempts to introduce "ecosystem-based" management of marine resources. The expected outcome of this theme session is some synthesis of observations and clarifications of concepts for the North Atlantic region.

Paper/poster titles and abstracts should be submitted to the ICES Secretariat in Copenhagen, clearly stating the Theme Session to which they are being submitted. The abstracts must be received by no later than Monday 3 May 2004.

Marine environment study by CMODIS/SZ-3 in China

Pan Delu, Laboratory of Ocean Dynamic Processes and Satellite Oceanography of State Oceanic Administration, China (pandelu@mail.hz.zj.cn)

The third Chinese space ship SZ-3 was launched in March, 2002, including the Chinese Moderate Imaging Spectra Radiometer (CMODIS). In this note, the properties and characteristics of CMODIS are briefly introduced. In addition, the data quality and availability, and measurement accuracy are evaluated. Finally, CMODIS ocean color and temperature maps are shown and their applications to marine environmental research discussed. The results show that the CMODIS has capability in marine environment detection, management and protection of marine resources, and protection of national rights and interests.

Introduction of CMODIS

China is one of the most important marine countries in the world. The length of the coastline exceeds 18,000km, in addition to the 14,000km of coastline from the 6,500 coastal islands. The continental shelf and Exclusive Economic Zone around this coastline is about three million kilometers, or about one third of the total area of China. About 40% population of China live along the coast, so the ocean is very important in the economy and defence of China. For marine environment monitoring (Pan Delu *et al*., 2001), one sensor (CMODIS) has been developed by the Shanghai Institute of Physics and Technology (SIPT) and tested on the spaceship Shen Zhou-3 (SZ-3), launched in March 2002. Its orbit is non-sun-synchronous at an altitude of 343km. CMODIS has a total of 34 channels (30 channels of 20nm wavelength in the spectral range of 0.403 -1.043µm, and four infrared channels with 2.15 -2.25µm, 8.4 -8.5µm, 10.3 - 11.3µm and 11.5-12.5µm). Its instant field of view is 1.2m with 1024 pixels per line and a quantification of 12 bits. Since reaching its orbit the CMODIS had been operating normally for 6 months, and about 287 orbits data have been received and archived by the Beijing satellite receive station of the Chinese Academy of Sciences, and analyzed by the Second Institute of Oceanography, in Hangzhou.

Data quality and availability

The data quality and availability (AVA) of a space sensor is very dependent on its characteristics, the orbits of the space ship or satellite, the observation conditions (such as air and ocean water), as well as data processing technique (such as the accuracy of atmospheric correction). It is difficult to evaluate the data quality and availability of whole pass images through a year, but it is possible to evaluate them by simulation under different conditions. Here, a key index of image, the so - called Complex Signal Noise Ratio (CSNR), is employed in the evaluation of data quality and AVA (Pan Delu *et al.*, 1990, 2000a, 2002) with the following results:

1. The CSNR and AVA of CMODIS vary with the no-sun-synchronous orbits critically (Fig. 1a). The CSNR and AVA increase in the morning and decrease in the afternoon. For example, in winter it varies from 16 and 31% at 8:00 am to 38 and 75% at 12:00 noon.

2. The CSNR and AVA also vary with season, being best in autumn (41 and 81%), then spring (39 and 78%), summer (37 and 74%) and worst in winter (27 and 57%) (Fig. 1b).

3. The averages of CSNR and AVA for all conditions through the whole year are 36 and 72.8%.

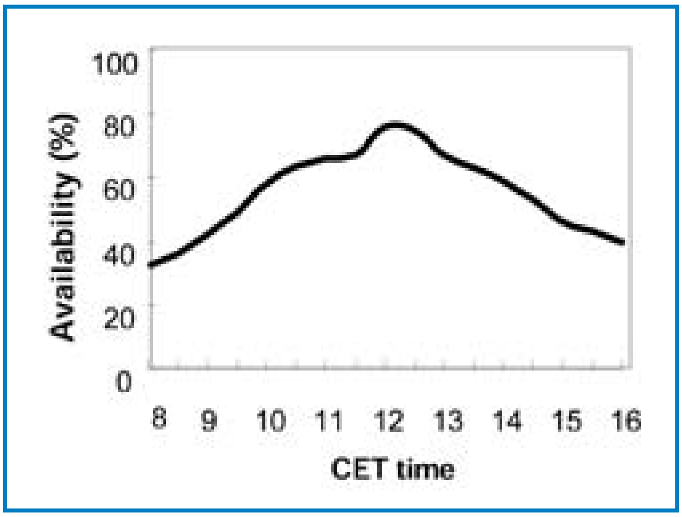

Figure 1a. The availability of CMODIS varies with CET.

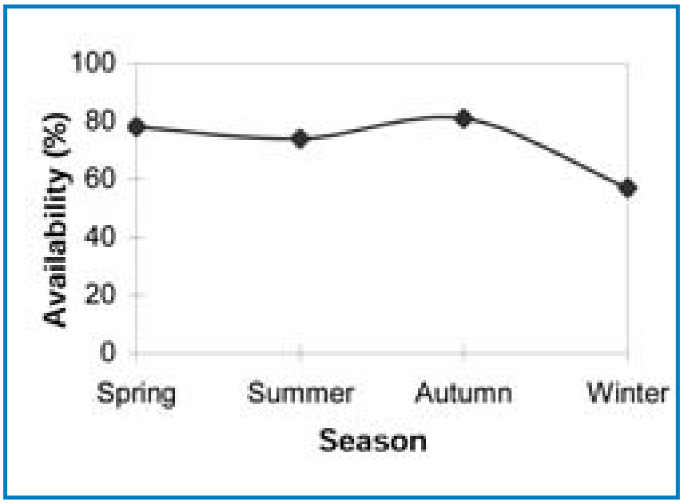

Figure 1b. The availability of CMODIS varies with season, and is worst in winter.

Radiance measurement accuracy

In principle, if two sensors on the different space orbits measure the same target at the same observation condition, the measured radiance of the target should be the same. So, a sensor's radiance measurement accuracy could be evaluated by another sensor with a higher and known accuracy, through comparisons of the radiance measured by the two sensors (Pan Delu *et al.*, 1990, 2000a, 2002). The SeaWiFS accuracy of radiance measurement is higher than 5% (relative error), here CMODIS is evaluated by SeaWiFS, with the following results:

1. In general, the water leaving radiance derived from CMODIS is higher than from SeaWiFS.
2. Long wavelength channels have better radiance measurement accuracy than short wavelength channels.

3. Visible bands have good radiance measurement accuracy, the relative error being less than 10%, except for the band of 413nm. The water leaving radiance of channel 413nm between SeaWiFS and CMODIS is not linearly correlated, the relative error being about 15%.

Marine application potential

The SZ-3 transfers two kinds of CMODIS data to the Beijing receiving station: real time data and delayed data. The latter is stored in the static memory of the spaceship while out of coverage of the Beijing station. Received data are pre-processed by geometric correction, radiation calibration and atmospheric correction. Then the different types of images such as chlorophyll (Fig. 2a), suspended material (Fig. 2b), yellow substance, temperature, plan index and coastal zone classification maps are produced. Comparing to other ocean color satellites, such as SeaWiFS, CMODIS has a much higher spectra and special resolution (34 channels and 500m per pixel) to meet the requirements of Chinese coastal waters, which are very high in suspended material (which co-varies with high chlorophyll), and other pollutants. The different maps could be applied in the following marine applications:

Monitoring of water quality

The quality of Chinese coastal waters has been deteriorating with the development of coastal industries and human activity. The image of suspended material, yellow substance and temperature can be used to extract nitrogen and phosphate pollution maps, eutrophication maps and exceptional plankton blooms maps (such as red tides). A water quality classification can be derived from those maps (Khalid Maskaoui *et al.*, 2003).

Fishery resources protection, development and use

So far the coastal water area has been fished excessively in China. The fishing grounds are shrinking day by day, due to overfishing and pollution. CMODIS data can be used to detect fish leaving the coastal environment, using indices of chlorophyll, suspended material distribution, and temperature. They could be applied to make decisions on fishing restriction policies, such as fishing restriction areas, location and time, as well as to find fishing grounds and save fishing effort. They are also useful for fishery recovery plans and as applications to aquaculture.

Coastal engineering environment

The CMODIS data are used to map the concentration of suspended material and vegetation index. So, CMODIS could be applied to investigate engineering conditions to modify entrance to channels and build ports, and applied to coastal monitoring, management and development of coastal resources (Pan Delu *et al.*, 2000b).

Oceanography

The CMODIS data could be applied to understand oceanography phenomena, such as coastal water dynamics, bio-chemistry and water optics (Su Fenzhen *et al.*, 2002). It is useful to apply it to joint international global change programmes, such as GOOS, and to joint international data bases and information sharing systems.

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SPACC Workshop and Meeting on spawning habitat and assessment of small pelagic fish, Concepción, Chile, 12th - 16th January 2004

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[1] Marine and Coastal Management, Cape Town, South Africa

[2] Universidad de Concepción, Concepción, Chile

Small pelagic fish support large fisheries in many parts of the world's oceans, and together comprise over a third of annual global landings made by marine fisheries. Small pelagic fish characteristically exhibit large fluctuations in population size that arise from high recruitment variability, this variability being considered to be primarily environmentally mediated. These fluctuations in population size vary on interannual, decadal and centennial time-scales, and synchronies in abundance of small pelagic fish populations at an ocean-basin scale suggest that this environmental forcing operates at an ocean scale. Many hypotheses have been proposed to explain these population fluctuations, one of which being that changes in the productivity of small pelagic fish populations may be caused by changes in ocean climate that affect the extent, or spatial and temporal location of, suitable spawning habitat.

In order to further understanding of the linkages between fish population dynamics and ocean climate variability, a SPACC Workshop and Meeting were held to present current methods and results of analysing spawning habitat dynamics of small pelagic fish. Additionally, the meeting reviewed data obtained from application of the daily egg production method (DEPM), since this methodology was considered to provide valuable information on the mechanisms by which environmental changes could modulate the reproductive biology and survival of early life history stages of small pelagic fish around the world. These events were held under the auspices of SPACC Theme 3: Reproductive Habitat Dynamics. The Workshop on "Characterizing and Comparing the Spawning Habitats of Small Pelagic Fish" was held from 12th-13th January 2004, with the Meeting on "Small Pelagic Fish Spawning Habitat Dynamics and the Daily Egg Production Method (DEPM)" being held over the following three days (14th-16th January). The Workshop and Meeting were sponsored by the Universidad de Concepción, GLOBEC, IRD, IDYLE, IAI, SCOR, Gobierno de Chile Subsecretaría de Pesca, Sociedad Chilena de Ciencias del Mar, and Lota Protein Ltd.

The objectives of the workshop were to characterize in terms of environmental parameters the spawning habitats of small pelagic fish (principally anchovy and sardine) from a variety of ecosystems using standardized analysis methods. The results of these analyses would be used to conduct inter ecosystem comparisons of anchovy and sardine spawning habitats, and to infer the likely responses of these species to changes in ocean climate and also population size. Spawning habitat was characterized using temperature/salinity plots and single parameter quotient analysis performed on data comprising egg abundance data and concurrently-measured environmental parameters (primarily temperature and salinity) brought by participants. The application of standardized analyses follows the SPACC approach of using a common set of core measurements and analyses to infer cause-and-effect linkages between fish, zooplankton and ocean physics from comparisons of the many diverse ecosystems dominated by small pelagic fish.

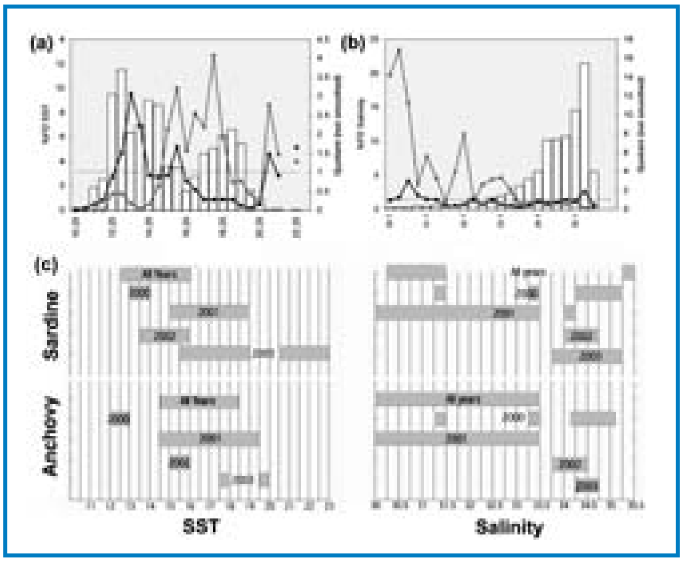

Figure 1. Aggregated egg abundance/sea surface temperature (a), and egg abundance/salinity (b), quotient curves for Bay of Biscay anchovy (Engraulis encrasicolus; grey line) and sardine (Sardina pilchardus; black line) from annual cruises conducted over the period 2000-2003 (the frequency distributions of environmental parameters are shown as bars), and (c) schematic showing the ranges of quotient values that were >1 (and hence indicative of positive selection) for each year and each species; note that positively selected habitat in individual years does not always fall within the range indicated by the aggregated analysis. Figure from B. Planque, IFREMER, France.

The workshop was attended by 21 participants from 12 countries, and the spawning habitats of anchovy (*Engraulis encrasicolus, E. mordax* and *E. ringens*), sardine (*Sardinops sagax* and *Sardina pilchardus*), mackerel (*Scomber australasicus* and *Trachurus symmetricus*) and round herring (*Etrumeus whiteheadi*) from the Benguela, Canary, California, and Humboldt Current systems, the Iberian Peninsula, the Bay of Biscay, the Mediterranean Sea, and eastern Australia, were examined. Workshop participants considered the characterizations of spawning habitat made using the standard analyses to be useful, but emphasized that comprehensive coverage (both spatial and temporal) of egg distributions and a sufficiently large range of environmental variability is required in order to fully assess spawning habitat selection. Substantial inter-annual variability in the selection of spawning habitat by small pelagic fish was observed (Fig. 1), and whereas analyses of aggregated data may be useful in determining average patterns, such inter-annual variability indicates that data need to be interpreted within the oceanographic context observed at the time of the survey. Moreover, variation in the spawning habitat selected by different reproductive groups within the same population may also be observed (Fig. 2, p.29). Environmental parameters chosen for analyses may be proxies and may show co-variance, hence identification of the mechanisms by which fish select spawning habitat based on such analyses should be made cautiously. Additionally, the use of other indices,

Figures for Van der Lingen, p.28-31

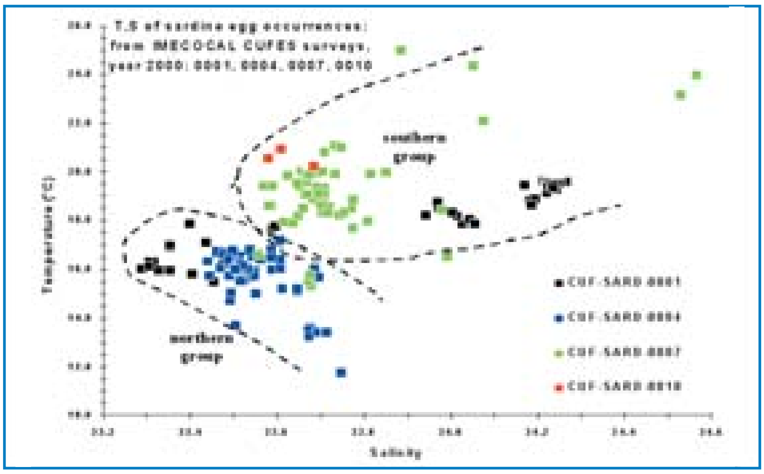

Figure 2. Temperature/salinity plot for eggs of sardine (Sardinops sagax) collected during 4 surveys (January, April, July and October) conducted off Baja California in 2000. The selection of different spawning habitats (as indexed by temperature and salinity characteristics) by northern and southern groups is apparent. Figure from T. Baumgartner, IMECOCAL, Mexico.

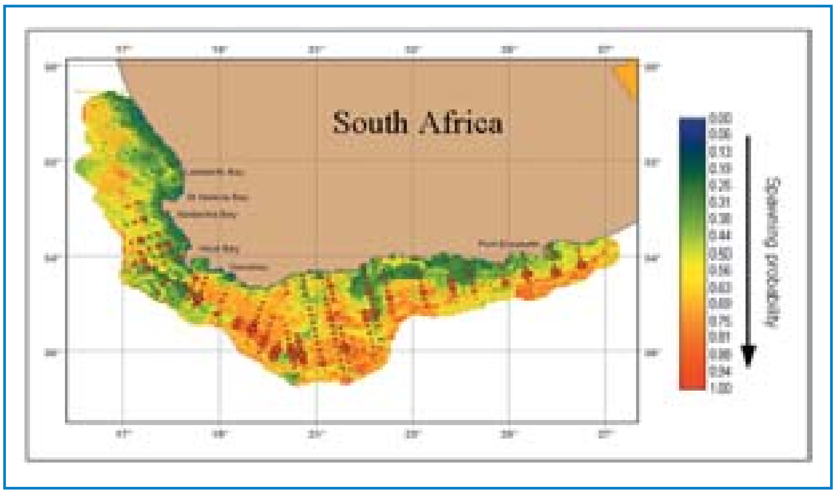

Figure 3. Comparison of predicted suitable spawning habitat (coloured contour map with scale bar on right; blue/green indicates minimum suitability for spawning and orange/red indicates maximum suitability for spawning) and observed egg distribution (filled circles with size proportional to egg abundance) for Southern Benguela anchovy (Engraulis encrasicolus) surveyed in summer 2001. Predicted spawning habitat was computed from aggregated quotient curves for egg abundance and bathymetry, SST, wind speed and chlorophyll a collected over the period 1984-1999 and applied using satellite-derived data for the appropriate period. Observations of anchovy egg distributions were derived from CalVET net hauls. Figure from L. Drapeau et al., IDYLE, South Africa.

Figures for Delu, p.26-27

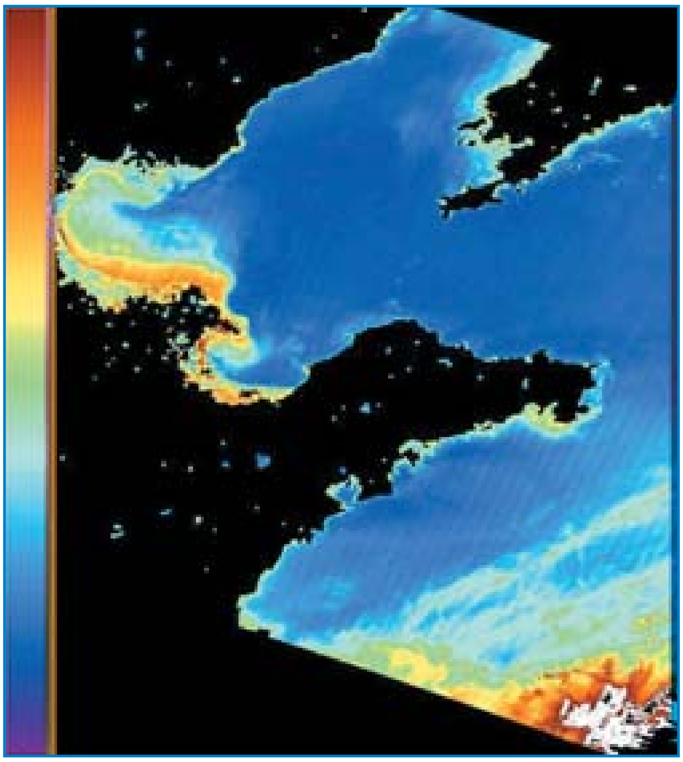

Figure 2a. (Delu, p.26-27) Chorophyll concentration mapping by CMODIS on April 18, 2002

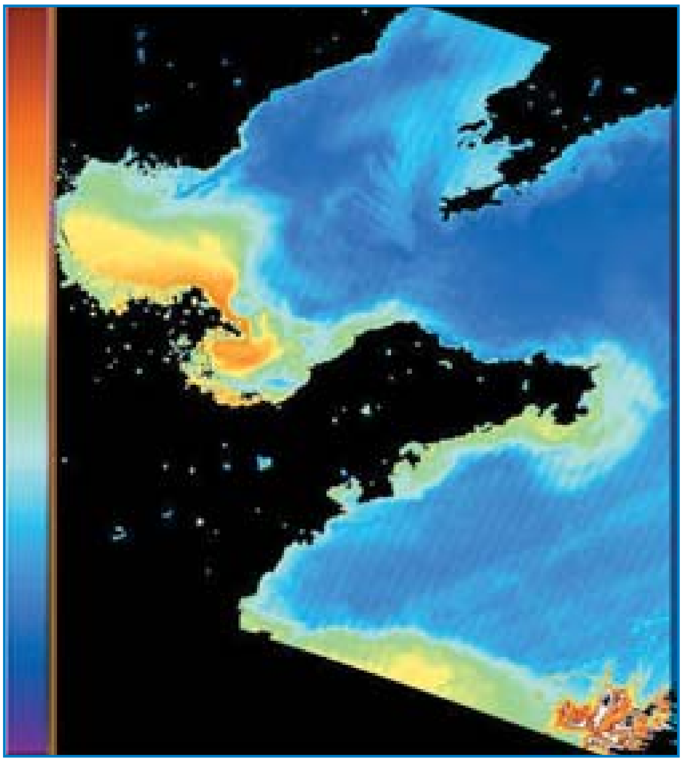

Figure 2b. (Delu, p.26-27) Suspended material concentration mapping by CMODIS on April 18, 2002.

particularly those related to biological productivity, may be more effective in delineating spawning habitat than physical parameters such as temperature and salinity.

There was insufficient time at the Workshop for extensive discussion of the methodologies used and for species and ecosystem comparisons, but some interesting points emerged. For example, whereas small pelagic fish show relatively strong selection of spawning habitat (as inferred from quotient curves) in some systems (e.g. anchovy in the southern Benguela, anchovy and sardine in the Bay of Biscay), they do not in other systems (e.g. sardine off the Iberian Peninsula; anchovy in the Humboldt system off Chile). Environmental characteristics of spawning habitats of anchovy and sardine from the same system may show marked differences (e.g. the Mediterranean Sea) or they may be similar (e.g. the Humboldt system off Peru). Spawning habitat may be selected on the basis of hydrographic or biological parameters and/or spatial location, and the relative importance of these is likely to vary between ecosystems and also between species. In non-upwelling ecosystems such as the Bay of Biscay and the Mediterranean Sea, anchovy and sardine appear to select spawning habitat in geographically fixed locations that correspond to the location of river outflows.

The objectives of the meeting were to analyze and compare the biological and oceanographic information obtained in DEPM and other studies around the world to assess the effect of environmental variability on spawning habitats of small pelagic fish populations. More specifically, the meeting was organized around three major topics that included the relationship between the early life history of small pelagic fish and their spawning habitat quality and dynamics, the reproductive biology of small pelagic fish and their spawning habitat, and new methodological approaches and spatial analyses in relation to use of the DEPM. The Meeting was attended by 76 participants from 15 countries, and was divided into two days of presentations and one day of parallel discussion sessions.

A total of 39 oral presentations were made at the meeting, these being grouped into four sessions:

- Spawning Habitat – presentations described methods for characterizing spawning habitat; the potential use of such characterizations to model the dynamics of spawning habitat via 3D hydrodynamic models and to predict spawning habitat from satellite-derived information (Fig. 3, p.29); and provided descriptions of spawning habitats of small pelagic fish from a variety of systems.
- Reproduction and Egg Development – presentations described reproductive parameters such as spawning fraction, gonad atresia, and batch fecundity; and temperature-dependent egg development models for a variety of small pelagic fish. One presentation in this session described the relationship between daily spawning fraction (DSF) and female weight for several stocks of *Engraulis*, and showed that with the exception of Peruvian anchovy stocks, DSF was dependent on average female weight (Fig. 4a, p.32). Another presentation compared daily egg production with estimates of daily specific fecundity for several *Engraulis* stocks (Fig. 4b, p.32). This showed that whereas a significant isometric relationship that was indicative of density-dependent usage of spawning habitat was observed for anchovy in non-upwelling systems (the Bay of Biscay and the Mediterranean Sea), no relationship could be discerned for anchovy in upwelling systems (the Benguela, California and Canary Current systems) where daily egg production estimates were high (and more variable) over a narrow range of low daily specific fecundities.
- Reproductive Strategies – presentations described observations and models of horizontal and vertical distribution patterns of anchovy and sardine eggs; inter-population variability in early life history traits of anchovy along latitudinal gradients; egg mortality via euphausiid predation estimated using immunological techniques, and field studies on larval growth and mortality of anchovy and jack mackerel.
- Methods – presentations described the use of the continuous underway fish egg sampler (CUFES) in assessing distribution patterns of pelagic fish eggs and compared estimates of egg abundance from this sampler with other ichthyoplankton samplers; reviewed the use of the DEPM in estimating pelagic fish biomass; and described the application of new statistical tools such as generalized additive models (GAMs) to improve DEPM-based estimates. This approach allows a spatially explicit estimation of fish reproductive parameters such as daily egg production (Fig. 5, p.32) and daily fecundity, and hence represents an important new advance in this methodology.

Parallel discussion sessions that focused on (1) Habitat characterization, reproductive strategies, development, and early life history, and (2) the DEPM, reproductive aspects, sampling methods and data analyses, were held during the morning of Friday 16th January. In the afternoon rapporteurs from each session provided summaries of those discussions. Points arising from the *Habitat Characterization Discussion Session* included several definitions of spawning habitat; namely "Potential spawning habitat", defined as habitat where the hydrological conditions are suitable for spawning; "Realized spawning habitat", defined as habitat where spawning actually occurs, and "Successful spawning habitat", defined as habitat where fish have spawned and from where successful recruitment has resulted. It was noted that the relative importance of environmental parameters that fish select spawning habitat may vary over their distributional range, and that realized spawning habitat may well differ for stocks/populations at the mid-point of their distributions compared to those at the extremes of their distributions. Additionally, realized spawning habitats should be compared for different population levels and for different age classes within a population, in particular for refuge areas during periods of low biomass since biomass effects (density dependence) on the selection of spawning habitat may be important. Suggestions for future research regarding spawning habitat selection included assessing relationships between spawning area (as indexed by egg distribution and abundance data) and biomass for a variety of small pelagic stocks, and comparing the slope values of such relationships; assuming that significant relationships exist, species that show a steep slope may be less subject to environmental variability than those that show a reduced slope, and biomass effects may dominate in the former whereas environmental effects could dominate the latter. Finally, metadata analyses of realized spawning habitats for a variety of small pelagic stocks should be conducted to test for generalities regarding regions, species, environmental characteristics (upwelling versus non-upwelling systems) and biomass effects.

Discussions in the *DEPM Discussion Session* focused on the advantages derived from and considerations required for the use of the continuous underway fish egg sampler (CUFES) to provide qualitative and quantitative data on spawning habitat. Whereas CUFES was considered a good tool for mapping spawning habitats, possible biases in the consistency of egg catches could occur depending on the spawning behavior of the species (i.e. spawning depth), egg characteristics (size, hardness of the chorion) and the hydrodynamics of the environment. CUFES was considered particularly useful for some species as a tool for identifying areas for adaptive sampling using the CalVET net. The applicability of CUFES for incorporation into the DEPM requires further analysis, especially regarding its limitations for sampling the vertical domain. In this respect, recent efforts to model the vertical distribution of eggs and the development of multiple covariate analyses seem very promising. Another major point considered in the discussion session was the improvement in estimations of daily egg production (Po) within the DEPM. Particularly relevant were the recent development of GAMs to produce spatially explicit estimates of Po, which also allows for a spatial separation of mortality (Z), an aspect particularly important in the context of spawning habitat analyses. Additionally, adult parameters can also be modeled by GAM and thus biomass estimates can be visualized in space. Improvement of the precision of Po estimates made by including yolk sac larvae in abundance-at-age plots and by developing a temperature dependent model of yolk sac larval growth from experimental studies was also discussed. The influence of temperature on Po estimates was also considered; in particular, different methods to carry out egg development experiments and model temperature dependent development were considered, as well as Bayesian methods to minimize possible errors in the assignation of the final age to eggs. The last point raised in the DEPM discussion session was related to reproductive parameters and the potential effects of temperature on these. Some studies suggest an effect of temperature on gonad atresia, a process that may affect spawning frequency and batch fecundity. Temperature may also have an effect on the rates of degeneration of post ovulatory follicles and hence have an effect on the total reproductive output and population dynamics of some species. From the SPACC point of view, the examples here mentioned are key issues to assess in the near future in order to improve our understanding of the effect of potential changes in spawning habitat on the reproductive biology and survival of early life stages of small pelagic fish.

Outputs from the Workshop and Meeting will be published in the GLOBEC Report series. The Workshop Report will comprise an overview of the Workshop, descriptions of the two standard methodologies used to characterize spawning habitat, and extended abstracts submitted by participants in which their data sources are briefly described and their results presented. The Meeting Report will comprise an overview, extended abstracts submitted by participants who made presentations at the Meeting arranged by Session, and sections summarizing the discussions on Spawning Habitat Dynamics, and the Daily Egg Production Method, respectively.

GLOBEC CALENDAR

2004

10-11 March 2004: Meeting of ICES Working group on Modelling Physical-Biological Interactions (WGMPBI). Barcelona, Spain.

31 March - 3 April 2004: IOC-SCOR Symposium on 'Quantitative Ecosystem Indicators for Fisheries Management'. Paris, France

16-19 April 2004: GLOBEC SSC Meeting. Swakopmund, Namibia

19-23 April 2004: BENEFIT Forum. Swakopmund, Namibia

2-6 May 2004: 4th World Fisheries Congress. Vancouver, Canada

9-10 May 2004: ICES-GLOBEC CCC Working Group meeting. Bergen, Norway

9-10 May 2004: GLOBEC Focus 3 Working Group Meeting. Bergen, Norway

11-14 May 2004: ICES-GLOBEC Symposium on 'The Influence of Climate Change on North Atlantic Fish Stocks'. Bergen, Norway

20-25 June 2004: ECSA 37 - ERF 2004 Conference Estuaries and Change'. Ballina, Australia

21-25 June 2004: CLIVAR 2004: 1st International CLIVAR Science Conference. Baltimore, USA

15-31 July 2004: SCAR Open Science Conference: Antarctica and the Southern Ocean in the global system. Bremen, Germany

18-20 July 2004: GLOBEC Focus 2 Working Group Meeting. Rhode Island, USA

1-3 September 2004: Bjerknes Centenary 'Climate change in high latitudes'. Bergen, Norway

4-9 September 2004: 8th International Global Atmospheric Chemistry Conference. Christchurch, New Zealand

13-15 September 2004: SPACC workshop on the economics of small pelagics and climate change. Portsmouth, UK

22-25 September 2004: ICES Annual Meeting: Theme Session on Regime Shifts in the North Atlantic. Vigo, Spain

27-30 September 2004: SCOR General Committee Meeting. Venice, Italy

11-14 October 2004: SOLAS Open Science Meeting. Halifax, Canada

Figures for Van der Lingen p.28-31

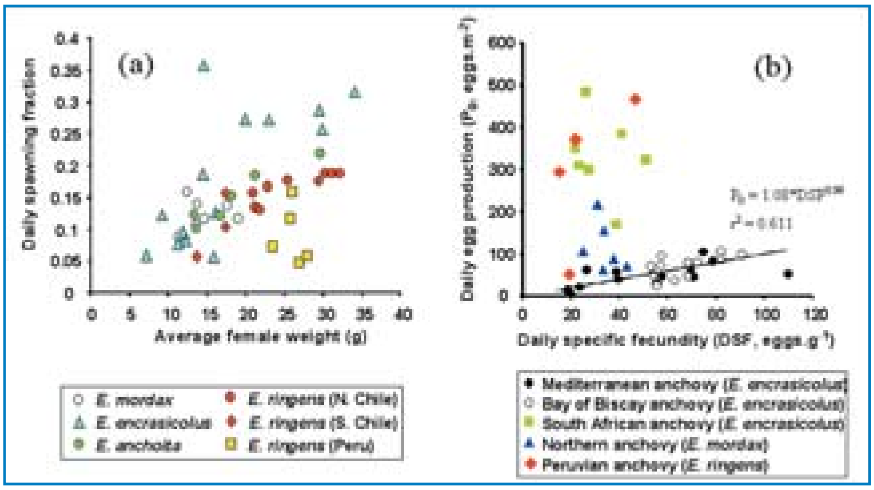

Figure 4. (Van der Lingen, p.28-31) Relationships between daily spawning fraction and average female weight (a), and daily egg production and daily specific fecundity (b), for several Engraulis stocks. Figure (a) from G. Claramunt et al., Universidad Arturo Prat, Chile, and Figure (b) from S. Somarakis et al., University of Patras, GREECE).

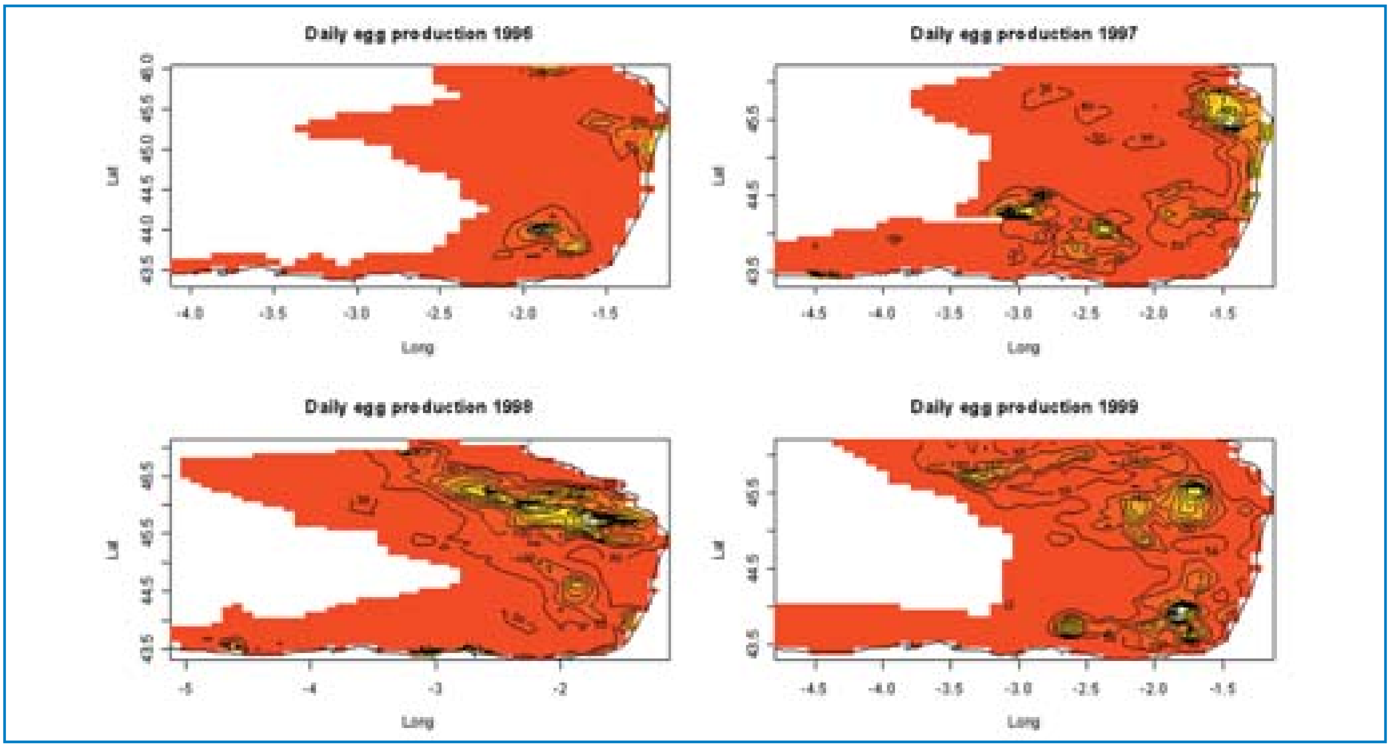

Figure 5. (Van der Lingen, p.28-31) Map of predicted daily egg production by Bay of Biscay anchovy (E. encrasicolus) during annual surveys conducted in 1996-1999 and derived from the application of generalized additive models (GAMs) to the DEPM for this species. Figure from L. Ibaibarriaga et al., AZTI, Spain.

GLOBEC INTERNATIONAL

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