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EDITORIAL

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It is always gratifying to see a Newsletter growing in stature, and even more so for its Editor. Now that GLOBEC International is in full implementation we want to use the Newsletter more and more as a vehicle to communicate scientific results, and I am pleased to see that many of you see it the same way. In this edition we have a substantial amount of scientific articles, mostly coming from the SPACC and PICES communities. This year the Southern Ocean GLOBEC regional programme commenced its field programme, and we look forward to reading their preliminary results in future editions of the Newsletter as well. If you were in the GLOBEC mailing list you would have received this Newsletter with our latest Report (GLOBEC Special Contribution 4), which describes all national, multi-national and regional GLOBEC activities. We see this report as a living document, and expect to update it regularly as some of the activities mature and others see the light. The feedback of the community will be essential to ensure that the document continues to be relevant on the ground. There is no better way to appreciate the broad coverage and

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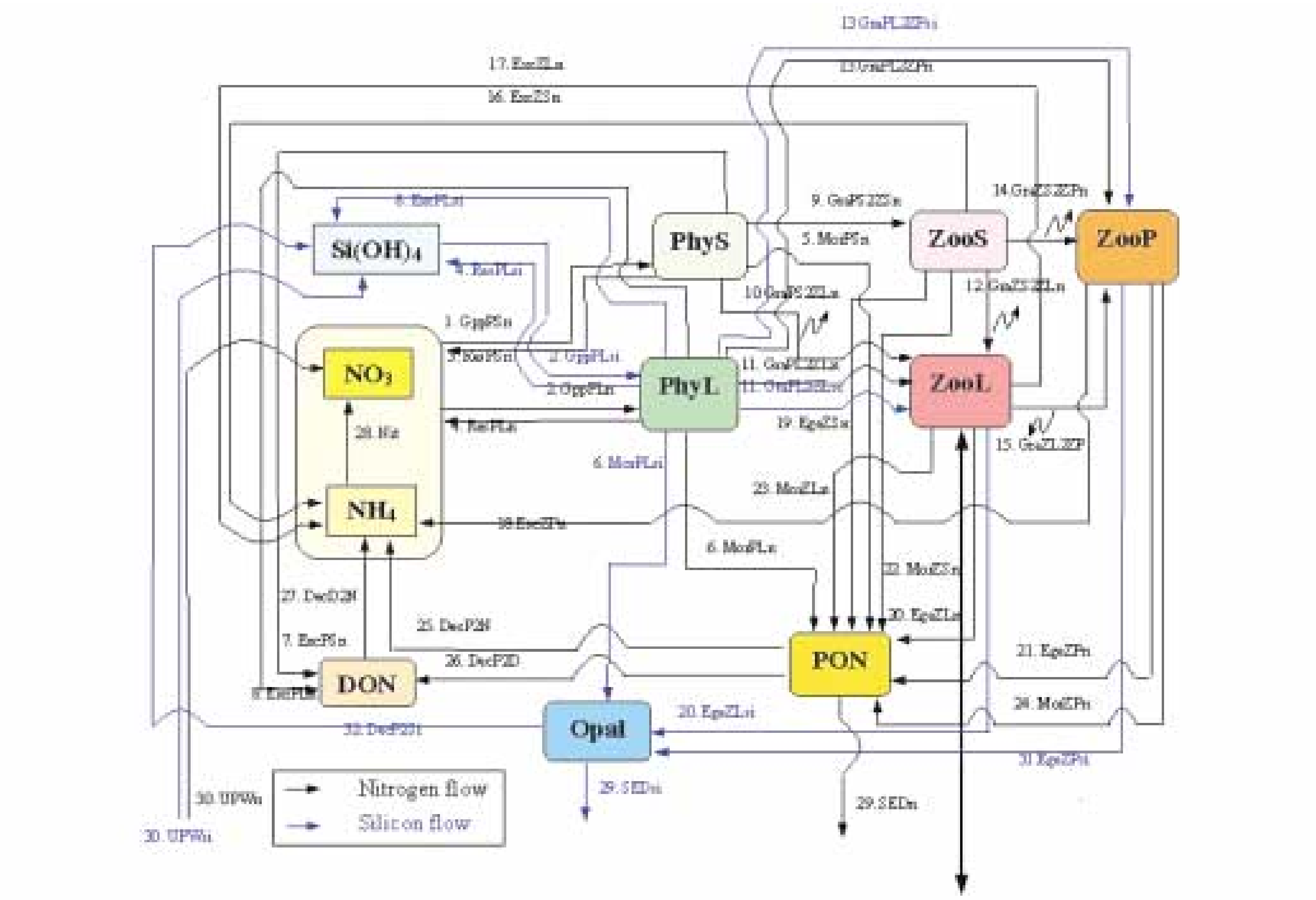

Kishi *et al.* - Figure 1. Trophic structure and biological relationships between essential marine ecosystem components in the North Pacific. NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography), is a conceptual model developed within the GLOBEC/PICES CCCC consisting of two phytoplankton function groups and three zooplankton functional groups. Flows are described in units of nitrogen and silicon. Dark (thick) arrow indicates diel vertical migration by ZooL (large zooplankton). See full article on p.3-6

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scientific support that GLOBEC enjoys than through this Report. 15 countries have full-fledged GLOBEC national activities, an additional 6 participate in multi-national programmes, and an even larger number contribute to the regional programmes. Co-ordinating the synthesis of all these activities is a considerable but rewarding challenge. It is our intention to initiate this co-ordination at the Second GLOBEC Open Science Meeting, which will take place 15-18 October 2002 in Qingdao, People's Republic of China. Again, members of the GLOBEC mailing list would have received a brochure with the first announcement for this meeting. The 2OSM will follow on the successful 1st GLOBEC OSM held in Paris in 1998, attended by over 200 scientists from all over the world. The venue and dates have been negotiated with PICES, as they will host their XI Annual Meeting following our GLOBEC OSM. I suggest that those interested follow the preparations through the GLOBEC website, or contact the IPO in months to come. Happy reading, and thank you very much to all of the contributors to this Newsletter.

New members of the GLOBEC SSC

Roger Harris, GLOBEC Chair, Plymouth Marine Laboratory, UK (R.Harris@pml.ac.uk)

Rosemary Ommer, Steve Nicol and Takashige Sugimoto, new members of the GLOBEC SSC

Three new members have joined the GLOBEC Scientific Steering Committee in 2001. These appointments will bring additional expertise, particularly in relation to the human dimensions of changes in marine ecosystem structure (Focus 4), one of the major regional programmes (Southern Ocean GLOBEC), and linkage with one of the major national GLOBEC programmes (Japan-GLOBEC).

Rosemary E. Ommer
is the Director of the Calgary Institute for the Humanities, and holds a joint appointment as Professor to the University of Calgary Departments of Geography and History. She is also an Adjunct Professor with the Faculty of Humanities, University of Calgary, the History Department, University of Victoria, Fisheries Centre UBC and Department of History, Memorial University of Newfoundland. She obtained her PhD in economic historical geography from McGill University, and researched and taught economic history at Memorial University of Newfoundland from 1982 until 1999. During the 1990s, she served on the SSHRC Council and the Executive of the (Canadian) Vanier Institute for the Family; she also served on the Steering Committee for the International Human Dimensions of Global Change (IHDP) Program and created and co-chaired the Canadian Global Change Program's International Human Dimensions of Global Change committee. During that time she was also involved in two major interdisciplinary research projects, "Sustainability in a Cold-Ocean Coastal Environment" and "Ethics as a basis for policy decision-making in fisheries management". In 2000 she

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became P.I. of the SSHRCC-NSERC funded "Coasts Under Stress: the Impact of Social and Environmental Restructuring on Environmental and Human Health in Canada" project - a joint initiative of The University of Calgary, Memorial University and The University of Victoria. Rosemary Ommer is the author and/or editor of several books including, most recently, *Fishing Places, Fishing People: issues in Canadian small-scale fisheries,* University of Toronto Press,1999, an interdisciplinary look at fisheries in Canada which she co-edited with Dianne Newell of UBC, and *Just Fish: Ethics and Canadian Marine Fisheries,* ISER, 2000, which she co-edited with Harold Coward and Tony Pitcher.

Stephen Nicol
was born in Dublin, Ireland, and attended schools in Ireland, England, the U.S.A. and Scotland. He obtained his BSc. (Hons.) in Zoology, from the University of Aberdeen, U.K., 1977, an MSc. in Oceanography, from Southampton University, U.K., 1978, and a PhD. from Dalhousie University, Canada, 1984. His PhD Thesis was on surface swarming behaviour of North Atlantic krill. Steve Nicol has continued to work on krill ever since with post doctoral work in Canada and Cape Town, South Africa. He joined the Australian Antarctic Division in 1987 to lead the krill research team. Since 1999 he has been the Program Leader for the Antarctic Marine Living Resources Program at the Australian Antarctic Division. Research interests include all aspects of the biology and ecology of krill, Antarctic fisheries, and the dynamics of Southern Ocean ecosystems. Stephen Nicol has been a member of Australia's delegation to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) since 1987 and is currently vice chair of CCAMLR's Scientific Committee. He has been involved in Southern Ocean GLOBEC since its inception in 1993 and is a member of the Southern Ocean Planning Group as well as being a member of the GLOBEC Focus 2 Working Group.

Takashige Sugimoto
is currently Professor at the Ocean Research Institute, University of Tokyo, and Director of the Department of Marine Living Resources. He obtained B.S., M.S., and D.S. degrees in Geophysics from the University of Kyoto. His research interests include multi-scale spatial structures and their temporal variations in relation to low trophic level biological production, larval transport and recruitment, fish school migration and fishing ground formation, as well as conservation and restoration of coastal marine environment, focusing on physical biological interaction. He has combined field observation, laboratory experiment, numerical simulation and historical data analyses as the main tools in his research. Professor Sugimoto has been a Guest Investigator in the Department of Oceanography, Texas A & M University, and at Woods Hole Oceanographic Institution. In 1976 he was awarded the Okada Memorial Prize of the Oceanographical Society of Japan. He has served as President of the Japanese Society of Fisheries Oceanography, as a member of the Biology Committee of the Science Board of PICES, and as a member of the Fisheries Scientific Committee of the Science Council of Japan. Professor Sugimoto has had a long association with, and interest in GLOBEC. He was a member of the SCOR International GLOBEC Committee from 1995-97. He is currently Chairman of the Japan-GLOBEC subcommittee of the Science Council of Japan.

Report of the 2001 PICES Model Task Team Workshop on Strategies for Coupling Higher and Lower Trophic Level Marine Ecosystem Models: Status of the LTL Model

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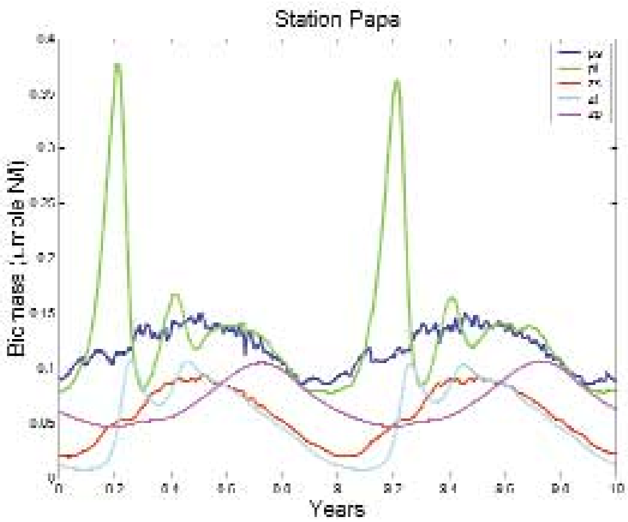
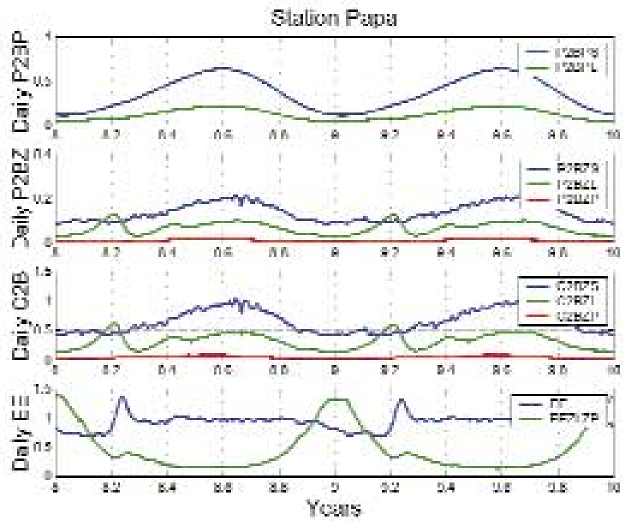
A variety of models have been used to describe lower trophic level (LTL) and higher trophic level (HTL) components of North Pacific ecosystems. In order to facilitate comparisons of model results between areas, the goal of the MODEL Task Team for the next few years is to adapt a prototype LTL model developed at the Nemuro Workshop in 2000 and apply it to basin and regional scale ecosystems in the North Pacific. The MODEL Workshop, held in Nemuro, Japan, in January 2000, focused on the development and parameterization of a LTL model to PICES regional ecosystems, and began discussions about ways to link HTL models to LTL models. The Hakodate workshop, co-convened by Drs. Michio J. Kishi and Bernard A. Megrey, was intended to extend the initial discussions which begun in Nemuro, to develop viable strategies for developing this important linkage. The workshop was held at Hakodate Future University in Hakodate Hokkaido Japan during the annual PICES science meeting in October 2000. The PICES webpage http://pices.ios.bc.ca contains additional information.

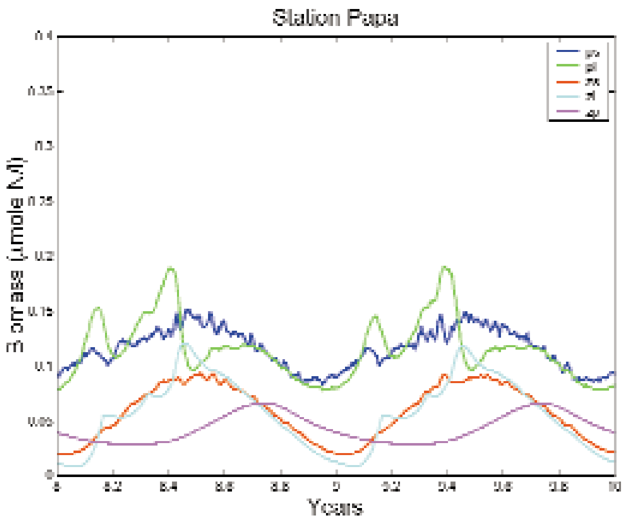
At the Hakodate meeting, the MODEL task team discussed some of the processes that need to be considered for representing LTL coupled to HTL



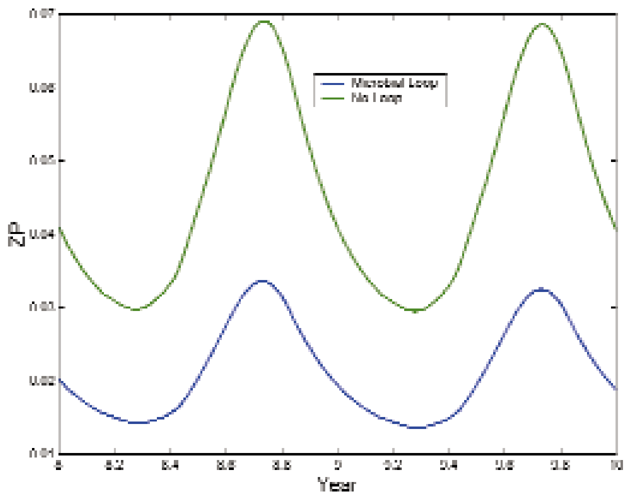
Kishi *et al*. (p.3) Figure 2. Nemuro model base-case solution at Station P.



Kishi *et al* (p.3) - Figure 3. Production/ Biomass), (Consumption/ Biomass), Production/ Consumption) ratios and Ecotrophic Efficiency.



Kishi *et al*. (p.3) - Figure 4: Sensitivity at Station P to migration of large zooplankton (ZP). Without migration of ZP (figure 2) diatom bloom is close to twice as large as in the presence of ZP migration (figure 4).



Kishi *et al* (p. 3) - Figure 5. Predatory zooplankton biomass (in mM N/m^3) for two years with (blue line) and without (green line) the inclusion of a microbial loop.

trophodynamics in marine ecosystems. The task team noted that significant advances in modeling the dynamics of LTL in aquatic systems (i.e. the microbial food web, and large phytoplankton and zooplankton) have occurred in the last decade. Progress has also been made in linking the production of HTL organisms (e.g. squid, fish, seabirds, and marine mammals) to LTL production models. Since LTL and HTL organisms function on different time and spatial scales within the ecosystem, successful coupling requires getting a number of things right -- or just about right. In this context, information about the diet, the functional response, growth efficiencies, large-scale seasonal movements of migratory species, and the impact of climate variability on these processes are required. For some marine ecosystems in the PICES area, enough biological, ecological, and stock assessment knowledge exists to begin using coupled models as primitive diagnostic tools to assess the current productivity and impacts of climate change on the ecosystem, and the effects on the dynamics of the key organisms within it. The development of a successful prognostic capability is a more challenging, longer-term problem, which requires additional information on recruitment dynamics, dispersal and migratory behavior, and behavioral changes in predator-prey interactions.

The goals of the workshop included:

- To develop strategies for integrating different time/space scales and size spectra from different models.
- To find areas of mutual interest where MODEL could interact with other PICES CCCC Task teams, especially the REX (Regional Experiments) and BASS (Basin Scale Studies) Task teams.
- To achieve broad synthesis through modelling which will lead to global understanding of the response of marine ecosystems to global climate change.
- To discuss strategies for simulating variability in populations of fish and zooplankton, to evaluate the cause of this variability, and to identify approaches that will ultimately permit the development of a predictive capability.
- To discuss how to best link LTL and HTL marine ecosystem models, regional circulation models, and how to best incorporate these unified models into JGOFS models and the PICES CCCC program.

Status of the LTL Model. As a result of the Nemuro workshop an ecosystem model with eleven compartments was developed in order to describe primary and secondary production in the Northern Pacific Ocean (see Figure 1- front cover). This model was made by the request of the PICES/GLOBEC CCCC program and is described, together with base case and sensitivity studies in Eslinger *et al*. (2000) and Megrey *et al*. (2000). Formulations in box-model form as well as coupled to a one-dimensional physical mixed layer model are presented. Model equations describe the interactions of nitrate, ammonium, silicate, two phytoplankton size fractions (tentatively, these are diatoms and flagellates), three zooplankton size fractions (tentatively, microzooplankton, copepods, and predatory zooplankton), as well as nutrient kinetics. Formulations for the biological processes are based primarily upon process equations presented in (Kawamiya *et al*. 1995). Discussion and extensions to the NEMURO box model at the Hakodate meeting and the months that followed included three main components: development of diagnostics and comparison to observed and literature values, effect of vertical migration by large zooplankton, and the inclusion of an approximation to a microbial loop formulation. Some of the results of these experiments, which are highlighted below, are presented for the Ocean Station P location.

Diagnostics. Simulation results (Figure 2, p4) show that there is a small spring bloom of large phytoplankton (PL) (which peaked at a level of about 3x the average biomass around time Year 8.2 (or day 73 or March 13).

This bloom is an artifact of the "box" nature of the model – although see below extensions to the box model and also Kishi *et al*. (2001) for a more realistic implementation. Figure 3 shows the P/B, C/B, and P/C ratios and are reasonable when compared to literature values (see details in the PICES Scientific Report on the 2001 Model Task Team Workshop, in preparation).

Briefly, the above base case results are encouraging in that: (a) the annual primary production in the model (128 gC/m^2/yr) is only 8% lower than the best current estimate (140 gC/m^2/yr), (b) the average chlorophyll concentration at Station P in the model (0.36 mg/m^3 is only 10% lower than the long-term value (0.4 mg/m^3) measured by Wong *et al*. (1995), and (c) an approximate f-ratio estimated from the annual productivity of (PL / Total primary production) yields an "f-ratio"= 29.5/128 = 0.23, which is close to the value of 0.25 estimated by Wong *et al*. (1995).

Vertical migration by large zooplankton: sensitivity studies. At Station P, during spring, the large zooplankton component (ZP) should be dominated by *Calanus*/*Neocalanus spp*. These species exhibit a strong ontogenetic migration: they arrive in the upper layers in early spring at C1 (and older) copepodites and feed for about 60 days until descending from the surface layer as C5's. Therefore, the model population should increase in biomass in the early spring independently of food availability/grazing. Later in the year, the population should decrease by some amount to simulate the descent of the C5's. To explore this effect, we modified the model as follows. Over a certain time (between days-of-the-year 30 and 60), we increased the large zooplankton population five-fold. The increased population would be available to graze the diatoms. Other dynamics occur as normal. After 60 more days, we begin decreasing the large zooplankton population by one half over 30 days (between days 120 and 150). Again, other dynamics are unchanged. Figure 4 shows the effects of including migration in the base case (see Figure 2). In the case of migration (Figure 4), the diatom (PL-large phytoplankton) bloom is much reduced. The estimates of Ecotrophic Efficiency (not shown) are not significantly affected.

Inclusion of microbial loop: sensitivity studies to climate change. Under certain scenarios, it is possible that changes in climate could lead to differences in the amount of primary production passing through the microbial loop. For example, an increase in stratification – due to increased freshwater inputs or higher temperatures – may reduce the nutrient entrainment to the euphotic zone, shifting the pelagic foodweb toward smaller species. We have modified the NEMURO Box model to include an approximation to a microbial loop as described in Megrey *et al*. 2000 and its possible effects on higher trophic levels. We found (Figure 5) that the inclusion of a microbial loop has only a small impact on the standing stocks of small and large zooplankton, but reduces predatory zooplankton standing stocks by about one half. These differences are due to the decreased net trophic efficiency of the system when a large portion of the primary production passes through a microbial community before entering the zooplankton community. With the decreased predatory zooplankton biomass, there is only half as much biomass potentially available for fisheries production.

Future Directions. These results are encouraging and provide a framework within which to continue work of the LTL and its explicit links with physical forcing by the PICES MODEL Task Team. Additional work must also begin on links with Higher Trophic Level Models (HTL), and in establishing strategies for regional and basin scale studies with the PICES REX and BASS Teams and the GLOBEC community in general.

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Marine Ecosystem and Climate Interactions in the Past, Present, and Future: Report of a workshop between GLOBEC, PAGES and CLIVAR

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Understanding the variability of the coupled atmosphere – ocean system and its interactions with marine ecosystems is a complex problem which requires information at large spatial and long temporal scales. Addressing this problem requires collaboration amongst diverse communities such as climatology, paleosciences, and ocean sciences. One of the activities of the GLOBEC Focus 1 Working Group on Retrospective Analyses and Time Series Studies is to develop these collaborations and to understand marine ecosystem and climate interactions in the past, present, and future (see GLOBEC International Newsletter 6(2), October 2000, for a report on the activities of the Focus 1 Working Group). A workshop was held 25-27 September 2000 in Sidney, B.C., Canada, with participation from the IGBP core projects of GLOBEC and Past Global Changes (PAGES), and the World Climate Research Program on Climate Variability and Predictability (CLIVAR). The objective of this workshop was to identify information that each project might need from each other project, and to discuss the formation of an inter-project working group to identify the role and consequences of climate as a forcing mechanism for changes in marine ecosystems, making use of the tools and expertise provided by CLIVAR, PAGES, and GLOBEC. Participants at this workshop are listed in Table 1. The full report of the workshop is available on the GLOBEC web site (www.globec.org) – follow the links under Publications/Research Foci Publications/Focus 1 Working Group.

Cross-cutting scientific issues among GLOBEC, PAGES, and CLIVAR

GLOBEC is focused on understanding the dynamics of marine ecosystems and on predicting their feedbacks with and responses to global changes. There is a need to reconstruct the variations of marine ecosystem components beyond periods of intensive human harvesting in order to determine "natural" variability of the system and to understand the magnitude of human perturbations. Detailed, high resolution analyses obtained from paleoceanographic records provide information on historical fluctuations of fish populations, but they also provide information on temperature, salinity, nutrient concentrations, and trophic relationships (e.g. from stable isotopes). GLOBEC also conducts comparative analyses of the responses of similar marine ecosystems in different areas to global changes (climate forcing in particular). Populations of some fish species appear to undergo synchronous fluctuations even though they inhabit separate oceanic regions (such as the coasts of California, Peru, and southern Africa). Could these populations be synchronised by similar responses to climatic teleconnections? The answers to these scientific problems may lie in collaborative research by GLOBEC, PAGES, and CLIVAR.

The general goal of PAGES is to understand the processes involved in environmental and climate change as manifested in the paleo-environmental record. PAGES (largely through its daughter program IMAGES – International Marine Global Changes: http://images.pclab.ifg.uni-kiel.de/) seeks to improve and broaden its analyses and interpretation of marine sedimentary records. Three aspects are of particular interest to GLOBEC and CLIVAR: improved technical capabilities to analyse samples; expanded interpretation of proxy indicators of past climates to understand processes leading to their formation in sedimentary records; and application of this information to elucidate ecosystem characteristics and human actions and impacts. Technical issues concern improved control over dating of marine sediment cores, inter-calibration of proxy records of marine conditions and climate states, and improved understanding and interpretation of new proxy indices now being developed (e.g. $\delta^{13}C$ and $\delta^{15}N$, alkenones). When analysing and interpreting multi-proxy paleo-records, there is a need to understand the processes that lead to these indicators being preserved in the sediments. Such understanding can be assisted by the studies of modern marine systems that are being conducted by GLOBEC.

There is also interest in applying the understanding of present marine ecosystem dynamics obtained, for example, through modern process studies and modelling, to data from the paleoceanographic record, i.e. comparing our understanding of how marine ecosystems work today with data from the past. A significant problem is the relatively poor temporal and spatial resolution of many of the paleoceanographic records compared to instrumental data. GLOBEC modelling efforts may be able to provide a framework to interpolate these sparse paleo data more broadly through time and space. An example of the problem "Is past marine ecosystem variability equivalent to present variability?" is the indication from PAGES research that the variability of El Niño events has changed, from about decadal in the late 19th Century to periods about 4 years in the late 20th Century (Urban *et al.*, 2000, Influence of mean climate change on climate variability from a 155-year tropical Pacific coral record. Nature 407: 989-993). Multi-centennial records of fish population fluctuations collected by collaborative GLOBEC-PAGES efforts may provide information to refine understanding of such questions.

The general goal of CLIVAR is to understand and to be able to predict climate variability over a wide range of time scales (see: www.clivar.org). Two scales are of particular interest: seasonal to interannual, and decadal to centennial. On the longer time scale there is interest in the role of biological feedback mechanisms on climate variations and the impact that such mechanisms might have on projections of future climate change. At the shorter time scales, there is interest in the potential impacts of variability and the circumstances under which this variability might be predictable. Understanding the important features of marine ecosystems and how they may be connected to the climate system should help to estimate the extent of predictability of marine systems.

A central goal of CLIVAR is to identify how different processes, often acting on different time scales, interact to produce the observed climate. Fundamental modes of variability must be identified. For example, which of the Arctic or North Atlantic oscillations is likely to be the fundamental mode? Variability in other, non-climate, data (e.g. long biological records such as for sardines in the California Current) may provide information to distinguish among competing representations of climate oscillations and how they interact. Marine biological processes, and significant changes in biological features, respond to and integrate many underlying processes occurring in the physical oceanographic and climate systems. Therefore, changes in biological characteristics, e.g. obvious changes in species composition of fishes, may be used as indictors of changes in physical or climate conditions that might not be immediately recognised by observation of these physical or climate variables directly. One example is the collapse of the anchoveta stocks off Peru in the early 1970's that helped point the way to the significance of El Niño variability.

Proposed Terms of Reference for a GLOBEC-PAGES-CLIVAR Working Group

Given these overlapping scientific interests, a Working Group would be useful for discussions and to develop collaborative approaches to investigate these issues. The following terms of reference were proposed:

1. Provide a mechanism for communication amongst these programs on issues and studies of common interest. In particular to promote adequate description and documentation of data and techniques so as to be understood across disciplines.
2. Formulate and promote improved recovery and analyses of information concerning past climate conditions and marine ecosystem dynamics from marine paleoceanographic records. This involves using marine paleo data and understanding of modern marine ecosystem dynamics to reconstruct past climate and hydrographic conditions, and to improve insight into the human impacts of past climate variability and the human roles in present marine ecosystem variability.
3. Develop and promote understanding of climate teleconnections and their impacts to, and potential feedbacks from, marine systems on seasonal to interannual, decadal, and centennial time scales, by the use of spatial and temporal reconstructions and modelling.
4. Foster collaboration and co-ordination among marine paleoceanographic, modern marine system studies, and climate analyses.

Recommended Activities

Three specific activities were recommended to move this initiative forward.

1) *Develop understanding of marine ecosystem controls on, and marine ecosystem impacts of, climate variability.*

GLOBEC activities can provide CLIVAR with models of ocean productivity and climate interactions on both long and short time scales. At long time scales, information from GLOBEC on critical controls on marine productivity and the fate of carbon removed from the atmosphere can provide inputs to global climate models. At short time scales, the CLIVAR Working Group on seasonal to interannual predictability is interested in what variables and locations may be useful to assess the relationships between climate variability and predictability on these time scales and their impacts. Discussions with this CLIVAR working group are underway to examine the outputs of climate models for variability at time scales that may be important to small pelagic fish, assuming that critical habitat for these species is determined in part by air temperature, humidity, sea surface temperature, surface wind stress, and mixed layer depth.

2) *Promote multi-disciplinary collaborations to derive more complete information from marine sedimentary records, and to identify new locations for collaborative PAGES, GLOBEC, and CLIVAR studies.*

There is a need for all projects to contribute towards a better understanding of the information derived from marine sediment cores, for example, improved "dating/chronological control"; improved calibration and integration of multiple proxy indices of past conditions; and improved understanding of new proxy indices. Such collaborations are most useful where both PAGES and GLOBEC have on-going field activities, such as the western coast of North America, and the Humboldt, Canary and Benguela upwelling regions. In addition, there is a need to identify new sites globally which preserve long records of marine systems, so as to expand the spatial scales over which these comparisons can be made. There is also a need to identify likely mechanisms underlying large-scale coherent fluctuations in fish abundance that might have a climate-driven component. A small workshop was proposed to co-ordinate and compare approaches and techniques in the analyses of paleoceanographic sites in Eastern Boundary Current regions. What are or have been the linkages amongst climate variability, ecosystem productivity, and dynamical ocean processes during the present and recent past? Relevant projects are or soon will be underway along the western margin of North America, in the Benguela Current region, and in the Canary Current, Humboldt, Current, and Equatorial Current regions.

3) *Identification of modes of multi-decadal scale variability, their global climate teleconnections, and their impacts.*

Variability at multiple time scales has been identified in marine ecosystem, paleoceanographic, and climate data, but it is unclear which are the "most important" or how they are connected. For example, variability in marine systems occurs at seasonal, ENSO, 22, and 50-70 year periods, but the processes driving variability at many of these scales are unclear. Further, can biological variability feed back to the climate system on time scales as short as 50-70 years? Since this latter scale is long relative to most monitoring and process-oriented studies, there is a need to identify the appropriate variables and timescales and to measure these at the appropriate locations to produce data to answer these questions in the future (if they cannot be answered now). Modelling and observational studies of CLIVAR are important to identify the relevant space and time scales of the physical climate system. GLOBEC should consider promoting additional physical and biological oceanographic sensors in CLIVAR ocean observing programs such as the TAO array. Studies have begun to identify 50-70 year variability in physical oceanographic data from the Pacific Ocean, and variability at these scales has also been identified in biological data. However, to date no physical oceanographic mechanism has been proposed that would explain variability at these time scales. Are these related to climate variability and if so, might they be predictable? Does variability in physical and biological conditions at these time scales also occur in the Atlantic, and could it be related (and through what mechanisms) to the variability at these time scales in the Pacific? A theme session or workshop, possibly held as part of the next GLOBEC Open Science Meeting (scheduled for October 2002) has been proposed to discuss these issues. As a start, a small workshop will be held in April 2001 at the Scripps Institution of Oceanography on the topic "Climate forcing of oceanic ecosystems: Are significant biological feedbacks possible on interdecadal timescales" hosted by Art Miller and Niklas Schneider.

The continuation of this GLOBEC, PAGES, CLIVAR working group will be a topic for discussion at the meetings of each project. But the activities proposed here are of significant interest to the objectives of each project that they are likely to continue regardless of the formation of a "formal" working group. We welcome your comments on the contributions and interactions among GLOBEC, PAGES, and CLIVAR.

Table 1. Workshop Participants

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Keith Alverson, PAGES, PAGES International Project Office, Switzerland
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The Southern Benguela Anchovy population reached an unpredicted record level of abundance in 2000: another failure for fisheries oceanography?

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3-OceanSpace cc and University of Cape Town, South Africa
4-University of Cape Town, South Africa.

The annual pelagic recruitment survey carried out during the austral winter (May/June) of 2000 by Marine and Coastal Management (M&CM) recorded an extremely high abundance of young anchovy off the West Coast of South Africa (Fig. 1 - back page), which is the main anchovy nursery ground in the Southern Benguela. Although a survey in this region in March 2000 (M&CM pre-recruit survey) had detected high densities of pelagic targets over a substantial portion of the continental shelf, their identity was not established, and the recruitment survey was the first concrete indication that anchovy reproduction had been particularly successful during the spring-summer 1999-2000 spawning season. This was confirmed a few months later by the results of the spawner biomass survey carried out in early summer (November/December) of 2000. During this cruise, anchovies were found to be widespread in relatively high densities over the Western Agulhas Bank (Fig. 1 - back page), and their distribution was also found to be less patchy than during previous years. The proportion of older fish in the population was relatively small, and the very strong year class spawned at the end of 1999 dominated the anchovy biomass. The estimated anchovy abundance early in summer 2000 was 4.03MT, which is more than 2 times the previous highest level observed since the start of the time-series in 1984.

Previous investigations had shown that anchovy recruitment is inversely related to the intensity of the Southeast, upwelling-favourable wind recorded during the spawning season (Boyd *et al.*, 1998). Increased south-easterly wind, and consequently intensified upwelling, appear to be detrimental to anchovy recruitment because of increased offshore advection and losses of eggs and larvae, whilst weak upwelling would favour successful transport of the reproductive products from the Agulhas Bank spawning ground to the nursery ground off the West Coast.

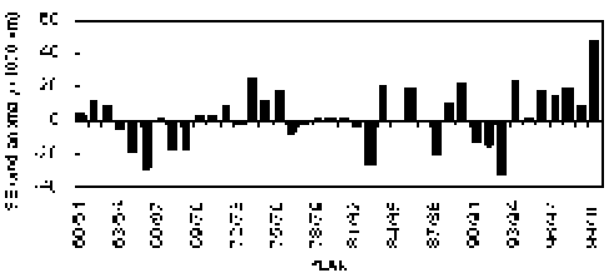

Figure 2: Cumulative October-to March Southeast wind anomaly (compared to the 1960-1991 long-term mean) measured at Cape Point, 1960-2000 (updated from Boyd et al. 1998).

The summer of 1999-2000 had the strongest positive Southeast wind anomaly over the past 40 years (Fig. 2), indicating that upwelling intensity along the West Coast during this period was stronger than usual. Surprisingly, and in contradiction with previous findings, the rather intense 1999-2000 upwelling season appears to have favoured anchovy recruitment in 2000.

Does this apparently contradictory result represent yet another failure of recruitment vs. environment relationships, or can we reconcile the 1999-2000 events with previous knowledge that underlined our understanding of the detrimental effect of enhanced upwelling on recruitment ?

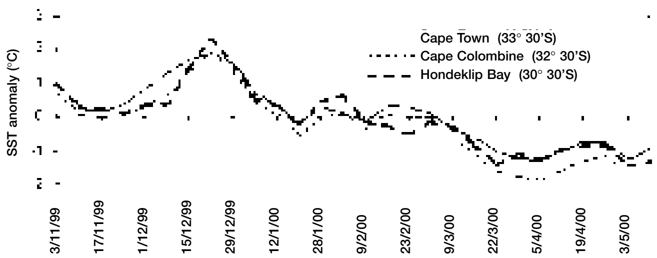

Figure 3: Weekly SST anomalies at three locations off the West Coast of South Africa from November 1999 to mid-May 2000. Source OI-SST (Reynolds and Smith,1994), available at: http://ingrid.ldeo.columbia.edu/SOURCES/.IGOSS/.nmc/.weekly/ .

Using weekly SST anomalies data recorded from three locations off the West Coast, it appears that short-term environmental variability was important during the 1999-2000 upwelling season (Fig. 3). During the last two weeks of December, a pronounced positive SST anomaly (+2.0°C) resulting from a cessation of the upwelling-favourable wind was recorded. As a result, holidaymakers on Cape Town beaches enjoyed coastal water as warm as 20°C,when they are usually greeted with icy waters as low as 10°C. In early January, the upwelling-favourable Southeast wind intensified and the SST dropped to more normal values. Later in the season, upwelling increased still further and SST anomalies dropped to values as low as -2.0°C from early March to May (Fig. 3).

When placed within the long term climatic context, it appears that the mean SST recorded in December 1999 is the second highest warm anomaly over the last 30 years, while the SST anomaly from March to April 2000 is the strongest negative anomaly recorded since 1970 (Fig. 4). Moreover, a 30-year time series of the standard deviation of monthly SST anomalies from November to April shows that the SST standard deviation during the 1999-2000 upwelling season reached the highest value yet recorded, which is 50% higher than the previous maximum (Fig. 5). This standard deviation of SST anomalies can be used as an index of the within-season variability of the upwelling.

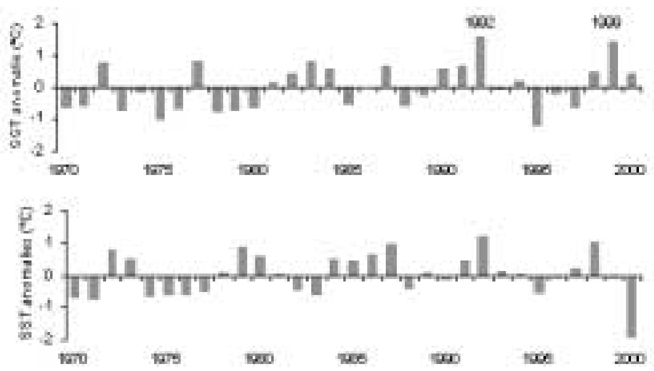

Figure 4: 1970 to 2000 time series of the averaged SST anomalies in December (top) and of averaged SST anomalies from March through April (bottom). Source: COADS data set for the period 1970-1995 (Woodruff *et al*, 1987; Mendelssohn and Roy, 1996) and from NMC real-time marine data set for the period 1996-2000 (http://www.cdc.noaa.gov/).

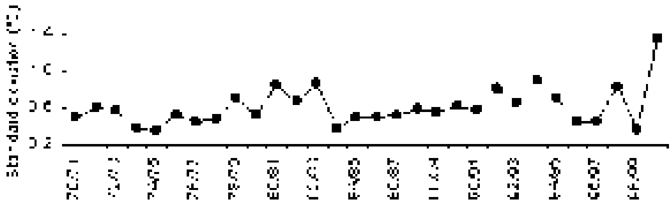

Figure 5: Time series of the standard deviation of monthly SST anomalies during the austral summer season (November to April) from 1970 to 2000. Source: see Fig. 4.

From these observations we conclude that, rather than being characterised by constant and sustained upwelling as indicated by the seasonally averaged wind index, extreme oceanographic events of opposite sign and magnitude reaching the highest recorded values over the last 30 years were observed during the 1999-2000 upwelling season. By taking into account this unusual environmental variability and by putting the timing of the major events observed into the context of the anchovy reproductive strategy (Hutchings *et al*., 1998), we suggest that it is possible to reconcile previous findings regarding the effect of upwelling on anchovy recruitment with the exceptional recruitment recorded in 2000. In so doing, several facts need to be considered:

- Anchovy spawning peaks in late spring and early austral summer (October-December) over the Agulhas Bank. Eggs and larvae are then transported by a coastal jet from the spawning ground to the West Coast nursery ground, and it is during this transport phase than enhanced upwelling is thought to affect dispersal of eggs and larvae (Hutchings *et al*., 1998). In late summer and autumn (January-April) larvae and juveniles are found over the West Coast continental shelf. During this stage, one can expect that enhanced upwelling would lead to increased food availability that would favour growth and decrease mortality. Recent modelling experiments have also indicated that intensified upwelling off the West Coast would favour retention within the coastal domain (Penven *et al*., 2000).
- In 1999, cessation of the upwelling-favourable wind during the last two weeks of December is likely to have reduced advective loss and hence substantially increased the number of larvae reaching the West Coast. Additionally, the elevated water temperature during this period would have resulted in more rapid larval growth, which is likely to have reduced mortality rates during these early life history stages.
- The intensification of upwelling off the West Coast during January 2000 could have favoured the development of a plume downwind of Cape Columbine and of the associated eddy which is thought to enhance transport to the coast and retention. During the same period, SeaWiFS data suggest that elevated chlorophyll levels were present within the West Coast nursery ground. This enhanced primary productivity could also have provided the necessary food for anchovy larvae and early juveniles.
- Later in the season (February-May), the persistence of upwelling and the development of secondary production could also have enhanced food availability for late larvae and juveniles.

In summary, we are proposing that this succession of weak and strong upwelling periods and the suitable timing of these events within the anchovy life cycle, represent an ideal situation for maximising anchovy recruitment success. These hypotheses will be used to further investigate what happened to the Southern Benguela anchovy population in 2000. Research in progress involves a detailed investigation of the meteorological and oceanographic characteristics of the summer of 1999-2000, a determination of the birthdate distribution of the anchovy 2000 year class, and retrospective analysis of the link between recruitment and the environment which will take into account intra-seasonal variability of upwelling.

Acknowledgements

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International SPACC cruise with RV METEOR in Namibian waters

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28 scientists from Namibia, South Africa, the UK and Germany co-operated in the international cruise of the German *RV METEOR* in Namibian waters from 13-31 October 2000. Little is known of plankton and fish production processes in the northern Benguela Current off the Namibian coast. Consequently, the objective of METEOR cruise 48-5 was to better understand the impact of meso-scale physical structures and processes on zooplankton production with reference to fish recruitment. Studies were carried out within the SPACC and the regional BENEFIT programmes and focused on four main questions:

SPACC scientists on board the *RV Meteor*, surrounding the author.

1. What is the impact of the nutrients generated by the Lüderitz upwelling cell on primary production and the development of pelagic food webs up to the level of ichthyoplankton in regions north of Lüderitz?

The impact of the nutrients generated by the Lüderitz upwelling cell is not clear. It is hardly known which production processes are initiated further offshore and north by the Lüderitz cell, where these processes are taking place, which final products are generated and what proportion of plankton production finally ends up as fish production. The context of the study will be to see where (how far offshore and north) the Lüderitz nutrients generate the food chain link from phyto- to zooplankton and whether there is any direct impact on the spawning grounds farther north. The focus will be on:

- temporal and spatial shifts of phytoplankton concentration as dependent on the strength of upwelling off Lüderitz
- temporal and spatial development of the pelagic food web (maturation of food web)
- quantification of the spatially decoupled transfer of organic carbon into the spawning areas.

In summary, the aim will be to examine to what extent the Lüderitz upwelling acts as a "fertilizer factory" for pelagic fish production in distant regions.

2. What is the role of the two-cell cross-shelf circulation in the northern Benguela for zooplankton production and survival of fish larvae?

The main spawning centers of anchovy and sardine are outside the upwelling cells off Lüderitz and Cape Frio. It will be examined why these regions offer good survival conditions for fish larvae. Possible reasons include: (i) avoidance of advection into the open sea by the complex cross-shelf circulation (retention), (ii) improved feeding conditions due to the stabilized water column (low turbulence) or (iii) high density of food particles due to concentrations of zooplankton accumulating in the region of the coastal cell.

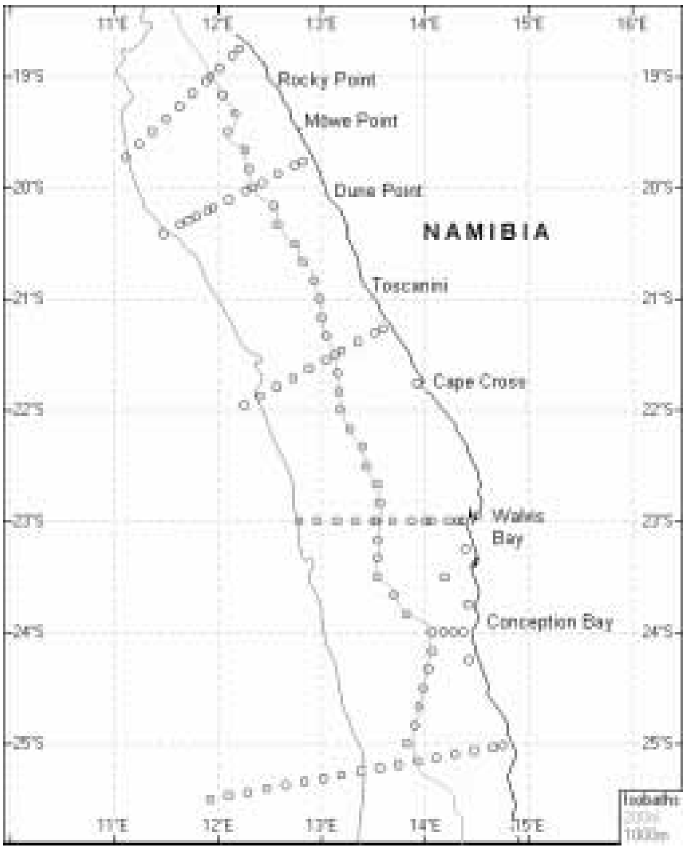


Figure 1: Map of study area and transects

3. To what effect do physically contrasting environments in the Benguela Current influence plankton production?

The waters off Namibia encompass a wide range of different physical regimes: upwelled, non-upwelled and oceanic waters. Upwelled waters range from newly upwelled to mature upwelled environments. Different water masses are separated by fronts and clines which themselves represent different environments. All these contrasting environments will affect growth rates and production of plankton in different ways. Special attention was given to determine species composition, distribution, abundance and biomass of zooplankton and to estimate daily production rates of copepods in contrasting environments and to assess the hatching success of copepod eggs produced under contrasting feeding conditions.

4. What is the variability of the bio-optical properties of water masses in the Benguela ecosystem and the impact on ocean colour?

A series of bio-optical measurements was carried out to (i) examine the validity of existing methods to determine chlorophyll *a* from ocean colour sensors including SeaWiFS and MERIS, (ii) validate novel bio-optical models to determine phytoplankton absorption characteristics from ocean colour, (iii) examine the role of photosynthetic and photoprotective pigments in phytoplankton absorption and (iv) assess the logistical feasibility of determining photosynthetic rates from *in situ* Fast Repetition Rate Fluorometry in order to estimate perimary production.

Intensive biological measurements and sampling were carried out on 5 transects perpendicular to the Namibian coast (Fig. 1) to sample in a range of contrasting environments from newly upwelled to oceanic waters. At present, all samples are processed in the respective institutions in Namibia, South Africa, the UK and Germany. One of the many objectives of the zooplankton studies of the cruise was to assess the hatching success of copepod eggs produced under contrasting feeding conditions (diatom-dominated vs non-diatom food assemblages), and test the hypothesis that diatoms have a deleterious effect (e.g. toxicity of biochemical compounds or nutritional inadequacy) on hatching success rate. During the cruise, egg production incubation experiments were performed (by Hans Verheye, Cape Town, and Xabier Irigoien, Southampton) with females of dominant copepod species including *Calanoides carinatus, Rhincalanus nasutus, Metridia lucens, Centropages brachiatus, Nannocalanus minor,* *Eucalanus elongatus/ hyalinus, Pleuromamma sp.* In total, 104 hatching success experiments were conducted with 7 879 eggs from these copepod species hatching into nauplii within 48 hours of being produced. Generally, the hatching success rate (HSR) varied between as much as 80 and 100%, irrespective of species and the marked inshore-offshore differences observed in the abundance and species composition (diatom *vs* non-diatom) of the phytoplankton assemblages on which the copepods were supposedly feeding (Fig. 2). There was no evidence of any negative effect on hatching rates in this study, which covers an appreciably broad range of phytoplankton concentrations (between 0 and *ca* 30 mg chl.m^{-3}) and was collected from waters characteristic of different phases of the upwelling cycle (H. Verheye and X. Irigoien, pers. comm.).

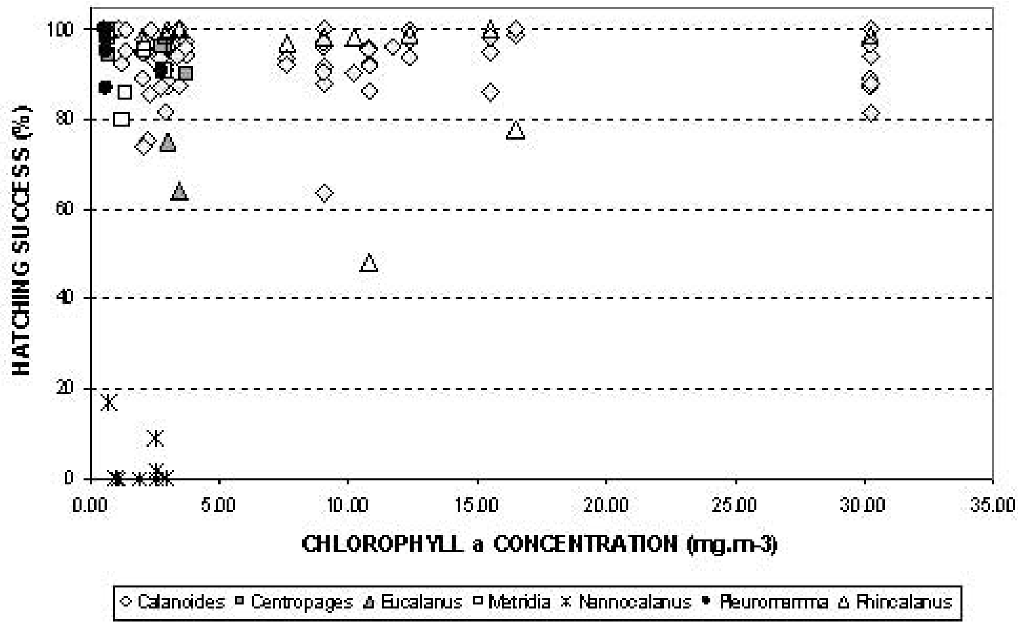


Figure 2: Results of hatching success (HS, in %) of eggs produced by different copepod species under ambient (surface) chl a concentrations.

The cruise also served for training of young scientists and technicians from Namibia, South Africa and Germany in modern methodologies. The cruise was followed by a workshop in Swakopmund for a first analysis of the newly acquired data. The workshop was co-hosted by GTZ and BENEFIT and their funding contributions are acknowledged. Thanks are due to the "Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie" and the "Deutsche Forschungsgemeinschaft" for funding the *RV METEOR*. We are indebted to GTZ, BENEFIT and the World Bank for funding the travels of the workshop and cruise participants.

1st Meeting of the GLOBEC Focus 2 Working Group on Process studies

Serge Poulet, CNRS-Station Biologique, Roscoff, France (poulet@sb-roscoff.fr)

Members of the Focus 2 WG in Roscoff, France.First row: Gerhard KATTNER, Stephen NICOL, David MACKAS, Gary KLEPPEL, Atsushi TSUDA. Second row: Claude ROY, Uli BATHMANN, Michael St. JOHN, Manuel BARANGE*, Richard GOWEN, Serge POULET, Debora THIELE*, Dian GIFFORD, Ulf BAAMSTED. * Invited

The first meeting of the GLOBEC Focus 2 Working Group (F2WG) was held at the Roscoff Marine Station, Roscoff, France, from 10 to 13 September 2000.The following is a summary of the discussions and results of the Roscoff meeting. The full report of the meeting is available on the GLOBEC web site.

The GLOBEC Implementation Plan (GLOBEC Report N° 13) identifies four research foci common to GLOBEC programs. Focus 2 is: Process Studies. The characteristics and objectives of this focus are detailed in the Implementation Plan. By definition, the Process Studies defined in Focus 2 contain conceptual, experimental and field approaches to investigate specific zooplankton processes, which are thought to link ecosystem responses and environmental variability in the context of Global Change. In order to address the complex structural and functional factors linking environment-zooplankton-higher trophic levels, the specific scope of our discussions during the meeting was related to activities :

1. Research on life histories and trophodynamics and their modelling in ecosystems, through the assessment of the population dynamics of zooplankton.
2. Identification and understanding of multiscale physical-biological interactions.

In this context, our intent was to identify climatically modulated key processes acting to influence key species and then to resolve the key mechanisms by which they affect population dynamics of zooplankton and higher trophic levels (Fish are taken as the primary example of higher trophic level linked to zooplankton due to their key position as an economically sustainable resource). In order to achieve this goal, a series of conceptual analyses, tasks and issues must be addressed, prior to producing a comprehensive package of activities for the GLOBEC community.

Basic Needs

In response to the intrinsic complexity of zooplankton (in term of species, behaviour, processes and interactions among the organisms) and of the multiple structural and functional links between environment-zooplankton-fish, it is imperative to reduce this complexity to a level where we are able to capture the essential features which impact on zooplankton at the physiological and population levels, and still provide material that modellers can utilise. SPACC (GLOBEC Reports N° 8 and 11/12) and ICES (ICES C.M. 1993/L:9) are highly concerned with this problem.

The F2WG listed an inventory of basic needs, relevant to identification of data and processes acting to influence population dynamics:

1- Resolution of key zooplankton species in specific ecosystems.

2- Identification of the climatic, physical and biological processes influencing zooplankton key physiological functions (growth, feeding, reproduction, survival).

3- Identification of key inter-specific interactions (predation, competition).

4- Identification of key life history stages.

5- Identification of critical spatial and temporal scales affecting physical-chemical-biological interactions in the context of variations in population dynamics.

6- Identification of zooplankton physiological and population processes which require development of new approaches and techniques to address F2WG objectives.

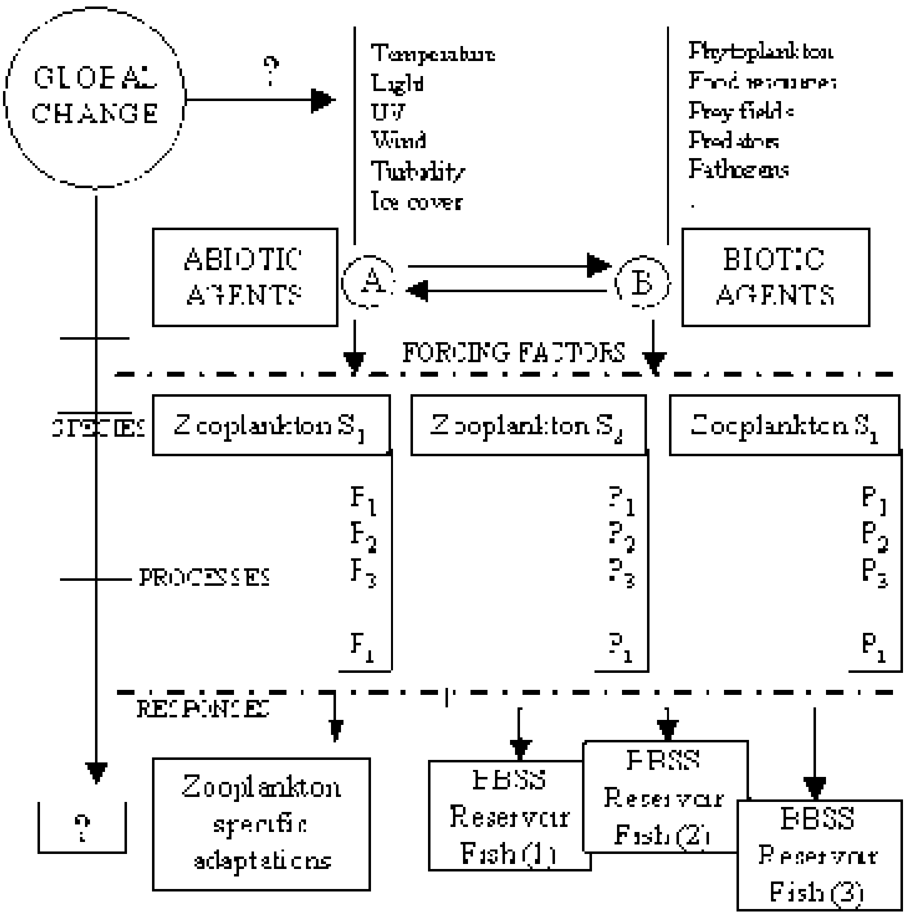
7- Definition of core measurements, standards for core measurements, and inter-calibration criteria for core measurements for zooplankton behaviour, physiological rates and processes.

8- Development of a conceptual framework to investigate links between zooplankton and fish.

9- Development of a plan to resolve the key physical, chemical and biological processes that affect zooplankton population dynamics.

Major Issues

One of F2WG's charges is to identify problems and then find and propose alternative synthetic approaches to solve them. The fact is that we cannot simultaneously measure biological variables and rates at levels of the organism, the population, the community, the ecosystem, and more global scales is a consequence of the complexity of ecosystems. Progress in the study of environment-zooplankton-fish interactions can be made only if we are able to define clearly the basic structural and dynamic properties of zooplankton, their predators, and their prey (e.g., taxonomic and life history structure, production processes and rates). It is well known that correlation between zooplankton and their prey, or zooplankton and their predators, are often statistically non-significant. An average property, like zooplankton biomass, cannot explain the population dynamics of higher trophic levels in general, and fish recruitment in particular. At this level, an alternative approach is to define the characteristics of survivors, a tactic which should identify the processes creating bottlenecks to survival, and should hence allow us to elucidate population dynamics. This approach is intended to simplify, rather than increase, complexity.



Response of zooplankton to Climate Change. Definitive conclusions are not possible due to the complex and unpredictable interactions that occur between abiotic and biotic forcing, which are expected to exert different stresses and impacts on the physiological ecology and population dynamics of co-occurring species. Such responses by the zooplankton are the subject of GLOBEC specific issues related to the fate of the zooplankton BBSS reservoirs affecting population dynamics at higher trophic levels, including fish. Depending on the particular zooplankton species and on the REIP criteria of their processes and responses (SOR), several resource reservoirs can result in time and space. These may exhibit different properties, including shifts in zooplankton species composition, and thus, might favour, or not, the same and/or different species of fish.

In this context, the F2WG has identified four major issues, concerning:

1. The production processes in zooplankton.
2. The development of new concepts and tools to identify structures and functions of zooplankton in ecosystems.
3. The physiological adaptive capacity and population dynamics of zooplankton.
4. The role of biochemistry of zooplankton organisms over their life history stages and events.

Concepts in zooplankton related to GLOBEC Process Studies

Several conventional characteristics (e.g., size, age, biomass, occurrence, distribution, patchiness) in zooplankton have been extensively used in oceanographic research. Recent development in oceanographic instrumentation should make data collection more efficient and closer to modellers's needs. Even though accumulation of such data might be useful to a better structural representation of zooplankton in their ecosystems, it may not be so profitable to GLOBEC Implementation if it is restricted to descriptive approaches, disconnected from a new conceptual framework basically concerned with process studies. The F2WG has examined four concepts, which seem to be particularly important when one tries to estimate and predict zooplankton population dynamics and physical-biological interactions in the ecosystems.

1. The grain size concept. The spatial and temporal scale of environmental variability has important consequences for how that variability affects biological populations, and in particular for whether populations respond and adapt to 'average' environmental conditions or to some subset of the range. It is hypothesised that animals can and should respond differently to "fine grain" versus "coarse grain" patchiness of their environments. A "fine grain" environment is one in which an organism does not or cannot maintain itself within any selected portion of the environmental continuum. Instead, it moves indiscriminately among all environmental patches, and therefore over time experiences and exploits the full local range of conditions. In a "coarse grain" environment, the organism is able to identify, select, and maintain itself within a patch that represents only a portion of the range of environmental conditions. In the extreme, it may spend its entire life within a single environmental patch. Over time it therefore integrates a selective subset of environmental conditions which can be very different from the non-selective overall average. The concept applies more generally to the temporal auto-correlation of environmental conditions experienced by the organism. Roughly, "fine grain" equates to "next encounter uncontrolled and unpredictable based on recent past experience", while "coarse grain" equates to "next encounter conditional on recent past experience". There can be both environmental and behavioural components: lack of predictability can arise either from a rapid de-correlation of the environmental field, or inability of the individual to detect and respond to auto correlated structure present in the field. For example, studies of patchiness indicate that zooplankton to some degree experience their environment as coarse-grained at spatial scales larger than a few meters in the vertical, and a few hundreds of meters in the horizontal.

2. The BBSS reservoir concept. The F2WG recommends to focus on few basic zooplankton criteria (BBSS = Biomass, Biomarkers, Size and Species), which are both taxon- and habitat-dependent (i.e., oligotrophic, eutrophic, upwelling, fronts, warm, cold, offshore, inshore, stratified, unstratified waters, etc). During their ontogenetic development, fish feed on a number of key zooplankton species which are basically the same within a given ecosystem, but vary in time and space. From a GLOBEC perspective, the BBSS concept provides criteria for identifying key zooplankton, which can be linked to the prey requirements of fish during their ontogenetic development (e.g., in spawning, transition, reproduction and nursery areas). Hence, we argue that applying the BBSS concept to the identification of target zooplankton species offers a new conceptual frame-work of food reservoir for higher trophic levels.

3. The SOR concept. The variations of zooplankton criteria (biomass, biomarkers, size and species), in relation to the effects of the various environmental factors, can be described by mathematical equations representing a particular biological response (e.g., seasonal occurrence, number and biomass variations, fatty acid contents) of the individuals, or population belonging to each species occurring in an ecosystem, characterising their Specific Optimum Responses (SOR). Examples illustrating these relationships are given for copepod growth as a function of temperature ranges, or for copepod biomass as a function of field salinity and temperature regimes, or wind patterns. Using the SOR criteria as standards for biological responses, low frequency changes (global, decadal) characteristic of a given population's biotic and abiotic milieu could then be determined. Factors that can be estimated at the level of an individual organism (such as the specific patterns for occurrence, biomass, growth and reproduction) are then compared in time and space.

4. The REIP concept. Implication of a time factor with any biological responses is a cornerstone of all Process Studies in GLOBEC. Therefore, new criteria must be considered to improve our characterisation of the time-dependent zooplankton processes. The basic criteria are given by rates (r_i) , efficiencies (k_i), inertia (e_i) and persistence (p_i) (the REIP criteria) related to physiological, behavioural or biochemical responses, which reflect the acclimatization of zooplankton to their variable environments and which may affect higher trophic levels. The same environmental factors may trigger different biological responses, with different amplitudes, among the co-occurring species; simply because REIP of any biological processes mediated by the forcing factors are likely to differ at all levels of biological organisation, from cells, to individuals to populations. It is recommended to give stronger emphasis to these criteria in future GLOBEC ecosystem studies.

Inter-comparison and synthesis among ecosystems could not be achieved from the particular individual organisms and species to population dynamics, without clarification and standardisation of several basic zooplanktonic criteria. The F2WG discussed the main criteria which should be integrated into the resolution of the ecosystem models.

Criteria for identification of target species

There are many ways to identify zooplankton. The important criteria fitting GLOBEC objectives should consider: (a) their function as buffer/integrator organisms between the physical environment and their predators; (b) their abundance and patchiness in the ecosystem; (c) their ability, described by the REIP criteria; (d) the adequacy of our descriptions of their prey-fields and; (e) their spatial-temporal match/mismatch with higher trophic levels during "critical periods" of their life history (see: the concept of "no-return"; "match-mismatch", "ontogenetic food requirements", "fitness" of key development stages in fish). One way to identify target zooplankton species is to reply to the following key questions: In a given environment, do the SOR criteria in the multiple zooplankton co-occuring species coincide with fish OEW (Optimum Environmental Window)? Which ones are involved in zooplankton-fish weak to strong-interactions? How do they mediate fish recruitment? In the GLOBEC context, the links between zooplankton and fish should not be restricted only to the trophodynamic approach. In addition to the BBSS, SOR and REIP criteria, further pertinent zooplankton characteristics relevant to higher trophic levels should be considered, including predators, pathogens and toxin transfer potential. Such items will be addressed in a future F2WG meeting.

Criteria for identification of key processes

Physiological and population processes are numerous and complex during zooplankton life cycles. The working Group defined key processes (P_i) as biological functions related to feeding (including ingestion, starvation, assimilation), growth, respiration, behaviour, migration, predation, reproduction, genetic adaptation, mortality, etc... These processes are influenced by key abiotic (A) and biotic (B) forcing factors. The interactions between these factors at the individual and species levels are most clearly evaluated through laboratory and mesocosm studies, but are much more difficult to examine *in situ* at the population level. Thus, we suggest that the characteristics of survivor approach be used in order to reduce the number of processes considered to those which actually affect population dynamics.

Although we can imagine which forcing agents might be modified by climate change, predicting the consequent responses of zooplankton species (S_i) and the fate of higher trophic levels is more speculative. One general conclusion that emerged from F2WG is that all processes combined will produce three general consequences: (1) positive or negative adaptation of zooplankton species to the change, or exclusion of the species; (2) the accumulation of BBSS resource reservoirs for fish, i.e., habitats that provide the right food at the right time; and (3) the retention of zooplankton rate, inertia, efficiency and persistence of processes, in phase or not, with physiological requirements during fish ontogenetic development and subsequent development of the population.

Criteria for identifying ecosystem variables

We suspect that all abiotic and biotic environmental factors exert significant effects at different levels of biological organisation, from the cell to community levels. Critical factors must be monitored in the habitats where fish feed in order to fuel locomotion, growth and reproduction. We hypothesise that during the enrichment, concentration and retention processes (three processes known as Bakun's triad) linked to specific hydrographic patterns in the ecosystem, successful fish recruitment relies entirely on zooplankton, which must match fish requirements for food, in term of BBSS, SOR and REIP criteria, suitable to the physiological requirements of fish presenting weak to strong-dependent interactions with zooplankton. The physical factors which promote upwelling, fronts, water column stability, stratification and convergence create hydrographic regimes coinciding, at times, with favourable fish habitats. Identifying which predators and species of zooplankton are affected by the variability of the habitats remains a major issue.

Criteria for identifying key ecosystems or sub-systems

The F2WG recommends that favourable physical habitats, where fish occur during their critical periods of life and recruitment be classified as key ecosystems by GLOBEC. Studies of zooplankton target species, BBSS, SOR and REIP criteria in relation to key processes should be arranged in order of priority within these habitats. Globally, most fish habitats are located in estuarine, coastal or continental-shelf zones. These environments are those GLOBEC community should examine in priority in order to evaluate the potential changes and shifts in marine living resources in relation to Climate Change.

Inter-comparison and Synthesis

The ideas that have emerged from the first F2WG meeting recognised that the biological processes related to both reproduction and genetic adaptation are pivotal, and their elucidation should be a common objective in the study of target zooplankton species. At the cellular and individual levels, processes are widely influenced by both abiotic and biotic agents. In zooplankton, vital rate processes such as feeding, growth, reproduction, and mortality constitute basic events during the life cycle, contributing to the re-establishment of the population in each generation or in subsequent years. The degree of interaction among these processes is believed to determine secondary production thresholds.

Although we posses good background information for few copepod species, and somewhat less for krill; the vital rate processes, interactions and responses to environmental agents, as well as BBSS, REIP and SOR criteria and fate of production are lacking for other zooplankton taxa, including microzooplankton, merozooplankton and gelatinous zooplankton. Priority should be given to studies of these taxa. More specifically, we suggest that the design of future field studies should incorporate new conceptual framework regarding zooplankton biology.

There is a need for the inter-comparison, in particular, of fish habitats and of the apparent large scale synchrony of marine ecosystems to climatic variability. The development and success of the integration of zooplankton rely on the information demand by the GLOBEC community and other groups working on similar problems. Future steps toward zooplankton data assimilation rely on the F2WG intersection capacity, to link with F3WG in order to calibrate models and to define biological coefficients, rates and assumptions more realistically. Promotion of international cooperation in GLOBEC-related studies (i.e. IWC-SO GLOBEC, SPACC, etc..), in conjunction with the development of F1WG data bases, should serve as a catalyst for the incorporation of concrete, essential biological criteria in the various ongoing GLOBEC and future programmes based on zooplankton processes.

Different levels of interactions are considered:

1. To disseminate specific recommendations and propose key actions, from which several workshops and study sessions on target zooplankton processes will emerge in the coming years.
2. To prepare specific review papers, to be published in 2001 in the GLOBEC News Letters, or other media, related to important topics discussed during the first meeting at Roscoff, including (a) Key species and Process, (b) Physical-Biological Interactions and (c) Population dynamics and Biochemical markers.

Closing remarks

The essence of the F2WG's activities is, first, to identify hypotheses, concepts and key criteria, patterns and processes in zooplankton, second, to select target species co-occurring in key habitats, and third, to integrate these components into ecosystem studies, in order to estimate the resulting effects of the environmental variability at the level of population dynamics. Our challenge is, therefore, to propose realistic approaches bridging this extreme complexity and our objectives to estimate how will marine ecosystems respond to Climate Change, without twisting the biological reality by an over-simplification of the entire system. Achieving these time-consuming objectives will not be simple, and its success will obviously rely on the discussions and collaborations with the scientific community, inside and outside GLOBEC.

SPACC/IDYLE/ENVIFISH WORKING GROUP ANNOUNCEMENT:

SPATIAL APPROACHES OF THE DYNAMICS OF COASTAL PELAGIC RESOURCES AND THEIR ENVIRONMENT IN UPWELLING AREAS

Date: 6-8 September 2001
Venue: M&CM Aquarium, Beach Drive, Sea Point, Cape Town, South Africa

Convenors:
M. Barange (GLOBEC, UK)
L. Nykjaer (JRC, Italy)
F. Gerlotto (IRD, France)
C. Van der Lingen (M&CM, South Africa)
M. Guttierez (IMARPE, Peru)
P. Fréon (IRD/M&CM, South Africa)
C. Roy (IRD/UCT, South Africa)
F. Shillington (UCT, South Africa)
L. Castro (University of Concepcion, Chile)

Aim: This symposium is aimed at providing a synthesis of the state of the art on recent theoretical achievements, on analysis techniques and on modelling tools used for the integration of spatial structures to study marine populations dynamics and the environment. To narrow the focus of the symposium, presentations will be restricted to small pelagic resources with particular emphasis on the four major upwelling ecosystems of the world. There will be three major scientific themes:

1- Spatial dynamics of the environment: quantification and modelling.

2- Spatial dynamics of marine resources and the interaction with the environment

3- Characterisation of the spatial dynamic of spawning and nursery grounds and interaction with the environment.

Calendar: This is the first call for registration and submission of communication. Registration is free, but the number of seats in the venue is limited.

Contact: Manuel Barange (m.barange@pml.ac.uk), Pierre Fréon (pfreon@sfri.wcape.gov.za), Leo Nykjaer (leo.nykjaer@jrc.it) or Claude Roy (D6UR9C@mail.uct.ac.za).

Report on the IRI Training Workshop on the Climate variability and Pelagic Fisheries

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The IRI Training Workshop on Climate variability and Pelagic Fisheries took place 6-24 November 2000 in Nouméa, New Caledonia. The Workshop was co-organised and hosted by the French Institute of Research for Development (IRD) and co-sponsored by the Secretariat of the Pacific Community (SPC), GLOBEC, IOC, NASA. The Workshop was animated by Yves Tourre, Neil Ward and Amy Clement from the International Research Institute for Climate Prediction (IRI/LDEO Palisades, NY, USA). The local organising committee included Christian Colin, Thierry Delcroix and Jacqueline Thomas from the IRD, and Patrick Lehodey and Tony Lewis from the SPC.

The focus of the workshop was on the climate and pelagic fish stocks variations, links between them and possibilities to use climate information in the assessment and management of the pelagic fisheries around the world. The workshop was attended by 45 participants including 22 recognised experts in climate and fisheries sciences invited as lecturers and 21 fisheries scientists working with different regional fisheries. The geographical range covered the most important fisheries systems of the ocean. The workshop included series of lectures on current research and methodologies in the field, and practical work on the fisheries ecosystems of interest for participants, as well as on global and regional influences and comparisons. The participants were informed and trained to work with global databases for climate and satellite information and to perform statistical data analyses using the IRI software package CLIMLAB 2000. Participants co-operating in small groups with lecturers worked out synthesis projects targeted on regional or other research topics of common interest. In the last day the results of the projects were presented to all participants and collected by the organisers to be

published in the workshop report. Apart from the specific research results, all projects had to consider the recommendations and perspectives of performing climate and fisheries analyses in the different regions so that the participants' home institutions can benefit from the workshop.

The results of the data analyses performed during workshop indicated globally overspread interannual-to-multidecadal climate variations (see Fig 1 - back page) interacting with marine ecosystems and regional fisheries. On regional scale, specific relationships between climate, marine environment and fish were reported. The participants reviewed the state of the art in observing and modelling the climate and fisheries systems and attempted to provide methodologies for using climate information in fish stock assessment and management. Different methodological approaches were presented and some of them used in data analyses including production and age-structured population models, spatial modelling, non-parametric methods (GAM, loess, neural networks), individual based modelling, food-web simulation, etc. However, many problems are still remaining and much effort is needed until results can be used in the fisheries management practices. While today we have explanations for some of the major processes of climate formation and their large-scale effects on ecosystems, we still lack suitable climate and environmental indicators that can be operationally implemented into stock assessment models and used for prediction of individual fisheries. The need for long-term ecosystem and environmentally oriented fisheries management was discussed.

The main benefit and perspective from the workshop is the establishment of a viable interdisciplinary network supporting future communication, training and research co-operation between participants and other scientists and institutions involved in climate and fisheries. It is expected that future projects based on this co-operation will provide practical results of incorporating climate information into fisheries management to all interested users.

More information about the workshop, participants and their presentations will appear in the workshop report on the IRI website http://iri.ldeo.columbia.edu

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A personal report on the IRI Training Workshop on the Climate Variability and Pelagic Fisheries

Soukaina Zizah, Institut National de Recherche Halieutique, Morocco, hilmi@inrh.org.ma

The IRI workshop held between 6th to 24th November 2000 in Noumea (New Caledonia) was aimed at scientists dealing with climate and fisheries. Personally, I was interested in learning more about the connections between climate and fisheries in different regions in the ocean, which is of great concern for my laboratory.

The main point of the workshop is to provide the trainees with a solid theoretical background through a week of lectures, followed by individual practical assignments under the guidance of the invited experts. For that purpose all trainees were asked to bring their own data, and work them out during the practical part of the workshop. Participants were also introduced to the IRI software package CLIMLAB2000.

The project I performed was entitled "North Atlantic Oscillation and its impact on Primary Productivity in the coastal Moroccan upwelling". The North Atlantic Oscillation (NAO) is a climate signal affecting the regional SSTs through the upwelling activity. The focus on primary production is justified because phytoplankton is the bottom of the food chain, and its importance is quite known in the pelagic fisheries.

One of the successes of the workshop was the communication links established between practitioners. My project has already benefited from these links. At the workshop we started to correlate *in-situ* oceanographic data from my institute with SeaWiFS satellite data from the University of Maryland. We also extended concept of productivity in my project to include secondary production, and a comparison between Canary and Benguela Currents will follow soon. I thank GLOBEC and IRI for supporting my participation at the meeting.

Workshop of the Decadal Changes WG of SPACC on "Major Turning Points in the Structure and Functioning of the Benguela Ecosystem"

Jürgen Alheit, Baltic Sea Research Institute, Germany, (juergen.alheit@io-warnemuende.de), Lynne Shannon (Lshannon@sfri.wcape.gov.za) and Robert Crawford (crawford@sfri.wcape.gov.za), Marine and Coastal Management, Cape Town, South Africa

It was at the famous "FAO Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources" in Costa Rica, in April 1983, when Prof. Tsuyoshi (Ken) Kawasaki from Japan suggested that the large sardine populations in the Pacific fluctuate in synchrony with each other (Kawasaki 1983). Back then, we thought that was an interesting idea, but we were not really convinced. However, about 10 years later, after the Pacific sardine populations had taken a downturn in the late 1980s and the anchovy population in Peru had come back to almost the same catch levels as in the 1960s, fishery scientists began to think that Prof. Kawasaki might have a point. A series of papers were published in the 1990s on the "regime shift" between anchovies and sardines and possible global teleconnection patterns of fish stock dynamics (e.g. Lluch-Belda *et al*. 1992, Schwartzlose *et al*. 1999).

Worldwide, regimes of high and low abundance of sardine and anchovy have been sustained over long periods, but substantial shifts in the relative abundance of these two species have occurred over relatively short time periods. Factors causing the large changes in the structure and functioning of sardine-anchovy systems remain uncertain, but may be elucidated if the times of major change in the ecosystems could be defined more precisely. Working Group 98 of the Scientific Committee on Oceanic Research (SCOR) on Worldwide Large-scale Fluctuations of Sardine and Anchovy Populations concluded that "... targeted studies making the best use of available data and rescuing data still held in manuscript form, may allow some of the major turning points in marine ecosystems this century to be studied in more detail" (Schwartzlose *et al*. 1999). In 1997, the SCOR WG 98 was continued by the new SPACC WG to study "Decadal Changes in Marine Ecosystems" (Hunter and Alheit 1997).

Based on the recommendation of SCOR WG 98, this SPACC WG had its second meeting from 12-16 February 2001 in Cape Town, South Africa, on the "Major Turning Points in the Structure and Functioning of the Benguela Ecosystem" chaired by Rob Crawford (South Africa) and Jürgen Alheit (Germany). Twenty three scientists from Namibia, South Africa, France, Germany and USA, physical oceanographers, statisticians, modellers, planktologists and fisheries biologists, gathered to have a closer look at the turning points in the Benguela system. Amongst them were four veterans from the Costa Rica conference in 1983.

In the latter part of the 20th century, there were large changes in the structure and functioning of the Benguela ecosystem (including the western Agulhas ecosystem). These included long-term fluctuations in the biomass of some fish stocks, persistent changes in the abundance of some mammals and birds, and long-term changes in the distributions of both prey and predator populations. The very large changes in the biomass of especially sardine (pilchard) and anchovy had major repercussions for the functioning of both the northern and southern components of the Benguela ecosystem. The major objective of the workshop was a more precise determination of major turning points in the structure and functioning of the northern and southern components of the Benguela ecosystem through analysis of long-term data series.

The workshop participants at the M&CM research aquarium.

It was decided to investigate as many data series as possible that would enable major turning points in the Benguela ecosystem in the 20th century to be defined more precisely. In this system in most years, there are relatively discrete populations of sardine (*Sardinops sagax*) and anchovy (*Engraulis capensis*) off Namibia and off South Africa that respectively may be referred to as the Namibian and South African populations. The Namibian populations sometimes extend into southern Angola, the South African populations sometimes extend into southern Namibia, and there may occasionally be mixing of the two populations. A collapse of the South African population of sardine in the mid-1960s was followed by a collapse of the Namibian population in the early 1970s (Crawford *et al.* 1987). Off South Africa, anchovy replaced sardine in the purse-seine catches and as the major forage of predators (Crawford and Dyer 1995). A recovery of the South African sardine was initiated in the 1980s (Barange *et al.* 1999). Attention was given to investigating these periods of major change, as well as the late 1980s in Namibia, when the sardine population initiated an increase that was not sustained. Additionally, harvests of seabird guano indicated that over much of the Benguela ecosystem production of forage fish was enhanced in the 1920s (Crawford and Jahncke 1999). This period was also investigated.

A first analysis of catch records showed that the southern Benguela changed in the mid-1960s from a sardine-dominated system to an anchovy-dominated system, whereas in the northern Benguela, this change took place during the first half of the 1970s. In the late 1980s, both systems seem to have reversed again to a sardine-dominated state. As similar regime shifts were recorded in the Pacific around the same periods, it is assumed that there is a linkage of fish fluctuations by global teleconnection patterns and that the regime shifts were caused by climate variability. Certainly, fishing pressure plays an important role in modulating natural swings of anchovy and sardine populations and the relatively early decrease of the sardines in the mid-1960s in the southern Benguela seems to indicate that fishing played an important role. Also, it is assumed that a combination of strong fishing pressure and adverse environmental conditions has kept the northern sardine stock at a low level since the late 1980s. Naturally, it is difficult to separate the effects of fishing and climate fluctuations on fish stocks.

It was suggested that regime shifts are linked to long-term tropho-dynamic changes in ecosystems and that

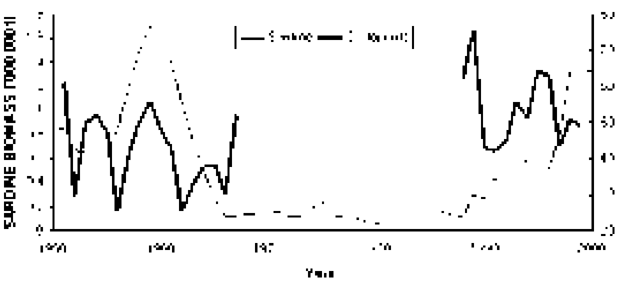

Figure 1: Long-term dynamics of sardine biomass and cyclopoid copepods in southern Beguela (Verheye 2000)

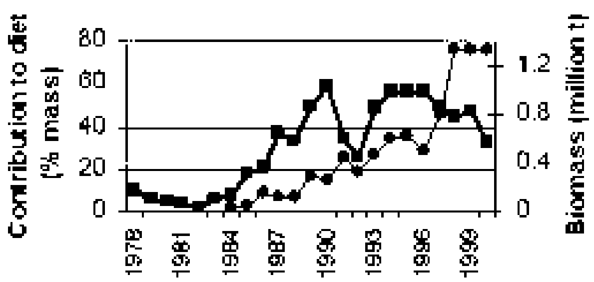

Figure 2: Long-term dynamics of sardine biomass (circles) and %contribution of sardines to Cape Gannet diet (squares) (Crawford and Dyer 1995)

changes in predator-prey interactions might indicate turning points. E.g., for the southern Benguela, Verheye (2000, and references therein) provided convincing evidence that changes in crustacean zooplankton community structure coincided with a regime shift from sardine to anchovy. During sardine dominance, cyclopoid copepods comprised 25-61% (mean = 42%) of the copepod community, considerably less than when anchovies were dominant (42-75%; mean = 54%) (Fig. 1). Long-term data on marine birds also give important evidence on regime shifts. Sardine began to increase off South Africa about 1983 and rapidly became an important contributor to the diet of Cape Gannets (Crawford & Dyer 1995, updated) (Fig. 2). Acoustic surveys indicate that the biomass is now well over 1 million metric tonnes (Barange *et al.* 1999, updated).

At present, the workshop participants are engaged in drafting a joint paper on long-term fluctuations of the Benguela ecosystem for publication in an international journal. The workshop forms part of the activities of the decadal change WG of SPACC. It is the first of a series of similar workshops that will investigate turning points in other regions of the world that support large populations of sardine and anchovy. We gratefully acknowledge the financial support for organising the workshop received from Marine and Coastal Management, Cape Town, and the contributions from BENEFIT, IDYLE, ENVIFISH and GTZ for funding the travel of some workshop participants.

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The Future of Global Ocean Marine Biogeochemistry

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

The International Geosphere Biosphere Programme (IGBP) co-sponsors three marine programmes conducting research on global change and marine ecosystems: the Joint Global Ocean Flux Study (JGOFS), the Land Ocean Interactions in the Coastal Zone programme (LOICZ) and the Global Ocean Ecosystem Dynamics programme (GLOBEC). The three have overlapping questions that required extensive interaction and co-ordination to be answered. However, due to the nature of international science and science funding procedures the three programmes were not activated in synchrony. Both JGOFS and LOICZ have entered their integration and synthesis phase, while GLOBEC is still in full implementation. It is therefore likely that GLOBEC will outlive their two sister programmes, at least in their present form. JGOFS and LOICZ have made very substantial advances in our understanding of ocean biogeochemical cycles and on the dynamic nature of the interactions between land and ocean, respectively. Without pre-empting their own synthesis it is likely that some of their original questions will remain unanswered, while some new ones are likely to emerge. In the case of JGOFS these questions will need new structures to tackle them, as they will complete their activities in the next couple of years. In addition, SCOR and IGBP have recently approved a new programme entitled SOLAS, or Surface Ocean-Lower Atmosphere Study, which will require substantial interaction with the existing JGOFS, LOICZ and GLOBEC.

For these reasons SCOR and the IGBP organized a workshop in Plymouth, UK (September 23-26, 2000) to define key scientific questions concerning ocean biogeochemistry that are central to the goals of the existing global change research programs. The meeting brought together over 40 scientists, under the chairmanship of John Field (South Africa) and Patrick Buat-Menard (France). The meeting defined a number of major questions facing ocean research in the future. It is likely that GLOBEC will play a pivotal role in addressing some of these questions. To ensure that we are ready to adapt to this changing scenario it is important to keep the GLOBEC community informed of developments regarding this initiative.

As a result of the Plymouth meeting an interim planning committee was set up to develop a report during two meetings in 2001 in Baltimore, USA (1-3 March) and Dartington, UK (24-26 June). The committee is chaired by Prof. Peter Burkill (UK), and includes B Constanza (USA), P Falkowski (USA), J Hall (New Zealand), B Jenkins (UK), KK Kiu (China-Taiwan), C Marrase (Spain), P Matrai (USA), P Montfray (France), B Opdyke (Australia), S Sathyendranath (Canada), J Steele (USA) and D Wallace (Germany). Their mandate includes:

• To develop the key scientific questions needed to guide research on marine processes and structure in the context of Earth System Science and global change.

• To identify and prioritise gaps in knowledge of marine research in relation to Earth System Science, and describe an integrative research Framework that will fill gaps and build on existing efforts (e.g. GLOBEC, LOICZ and SOLAS).

• To outline how the proposed Framework would fit into the evolving IGBP Phase II structure, to commence in January 2003.

Following the Baltimore meeting three major issues were identified as requiring further research in the context of global environmental change:

Issue 1 – How will the accumulation of carbon within the ocean system respond to global environmental change?

1. Fate of anthropogenic CO_2 in the context of changing ocean circulation?

2. Fate of terrigenous Carbon in the marine environment.

3. How does the cycling of marine organic carbon (and respired carbon) respond to ocean climate variability?

4. What is the effect of reduced pH on carbonate dissolution and the inhibition of calcium carbonate precipitation in the Global Ocean?

5. What are the consequences of deliberate CO_2 sequestration?

6. What are the details of the physical processes that lead to methane clathrate formation and release?

Issue 2 – What controls the time-varying biogeochemical state of the ocean system and how will it change in response to global change?

1. Ocean interfaces: the first impact zones

2. What will be the first order changes in the biogeochemical state due to climate-induced changes in circulation, ventilation and stratification?

3. What is the role of remineralisation of biogeochemicals within, and reflux from the Twilight Zone in controlling primary production on global change timescales.

4. Hotspots (areas of upwelling and deep mixing)

5. How are biogeochemical processes affected by and affect ecological structure and function?

Issue 3 – How do marine food webs respond to global change?

1. What is the role of physical and chemical forcing in determining the marine food web?

2. Are marine food web dynamics in steady state?

3. What are the biological controls on food web structure in the ocean?

4. What is the relationship between elemental cycling in the ocean and the structure of the food web?

Because the outcome of this debate will have profound implications for GLOBEC, we will report on further developments from the planning group in future newsletters.

Climate changes and variability of small pelagic fish productivity in the Portuguese coast: The PO-SPACC project

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The "Portuguese small pelagic fishes and climate change program: comparative retrospective analysis (PO-SPACC)" (FCT/PRAXIS/P/CTE/11281/1998) intends to be one of the contributions at the Portuguese national level for the GLOBEC-SPACC Programme. The main objective of the project is to build time series of atmospheric, oceanographic and fisheries data and use them to make a comparative analysis to investigate the interrelationships between small pelagic fish (SPF) and its environment (for more details see GLOBEC International Newsletter, Vol. 6 No.1, 15-17).

Sardine (*Sardina pilchardus*) is the main SPF species off Portugal, being of great socio-economical importance for the Portuguese fishing community and industry. Thus, the fluctuations in its productivity place important problems for fisheries' sustainability in the scope of fishery management and policies. For those reason that species is the main target of PO-SPACC Project.

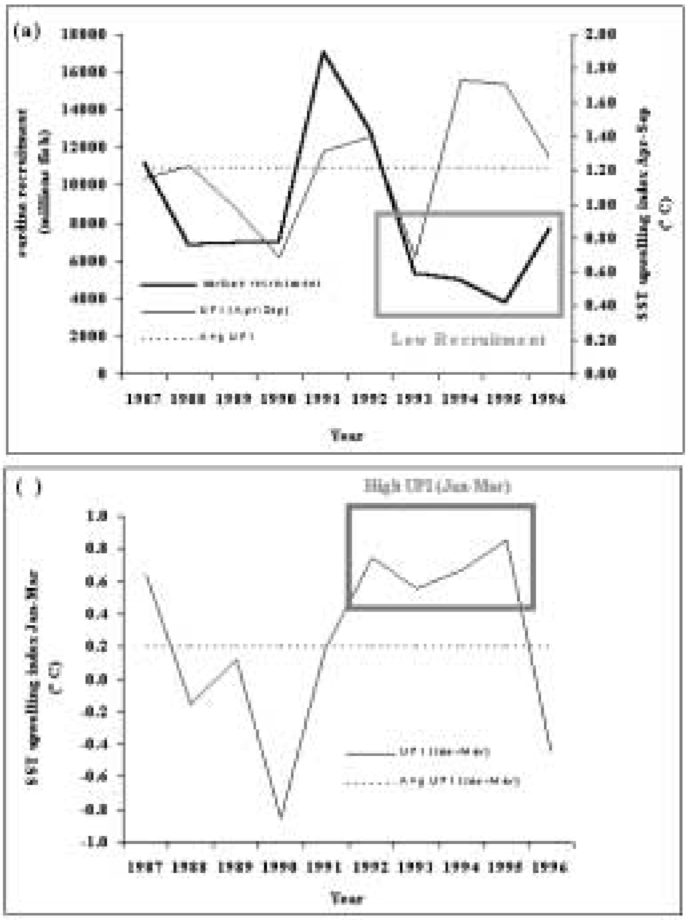

Figure 1: Annual upwelling indexes (UPI) for the typical upwelling season of the west coast of Portugal (April-September), produced from satellite-derived sea surface temperature (SST) anomalies between coastal and offshore areas, and sardine recruitment for the period 1987-1996 (a) and UPI during winter (January-March), the spawning season of these fish species (b). The long-term mean of the upwelling index series are indicated by the horizontal dot line (adapted from Santos *et al.*, 2001).

Until now the project have built the following time series:

- annual catch of sardine, 1896-1999
- sardine recruitment, 1976-1998
- annual catch of horse mackerel (*Trachurus trachurus*), 1915-1997
- horse mackerel recruitment, 1985-1998
- tuna catch, 1808-1835
- NAO index (Jan-Mar), 1864-1999
- Northerly wind frequency (Jan-Mar) from NCAR database, 1946-1991
- Mean northerly wind index (Jan-Mar) from NCAR database, 1946-1991
- Upwelling index from satellite-derived SST, 1987-1997

We (Santos *et al.*, 2001) showed that the decreasing trends in recruitment of sardine and horse mackerel off Portugal observed in the 1990's were caused by the increase of upwelling events during the spawning season (winter) of these SPF species (Fig. 1). We hypothesise that the increasing upwelling events in winter have had a negative impact on fish recruitment due to increasing larvae mortality, possibly through enhanced offshore transport to unfavourable feeding areas. Therefore these upwelling events during the spawning season of SPF off Portugal limit the success of spawning, contrary to the beneficial influence of upwelling events that occur later during summer.

We (Borges *et al.*, 2000) also observed decadal changes in the annual catch of sardine with a period of about 15 years (Fig. 2), as well as long-term periods of about 10-20 years and short-term ones of about 2-3 years of favourable winter upwelling conditions derived from the wind time series (Fig. 3). Furthermore, we detected two cycles in the annual catch of sardine: one high catch cycle in the period before the late 1960's and a low catch cycle from then on. These catch cycles coincide with a shift in the wind conditions which occurred in the beginning of the seventies which are in phase with the NAO index trends (data not shown).

The future work under PO-SPACC will be the continuation of the time series analysis on the effect of the environment on pelagic fish species (sardine, horse mackerel, tuna, anchovy, spinefish), and the investigation of how can we use environmental indices in the management of pelagic fish stocks.

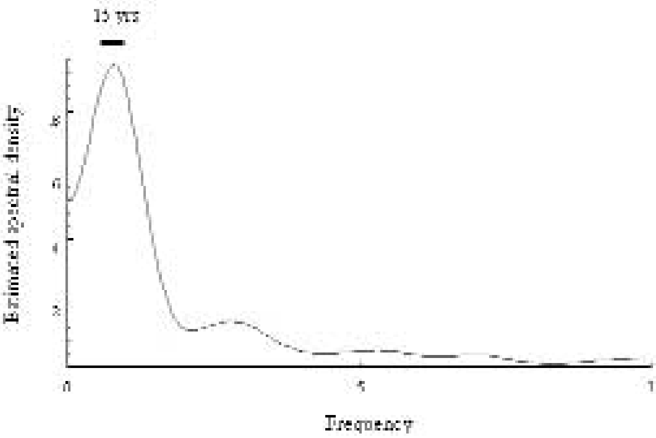

Figure 2: Smoothed periodogram of sardine catches obtained with a Parzen window (m = 25) (adapted from Borges *et al.*, 2000).

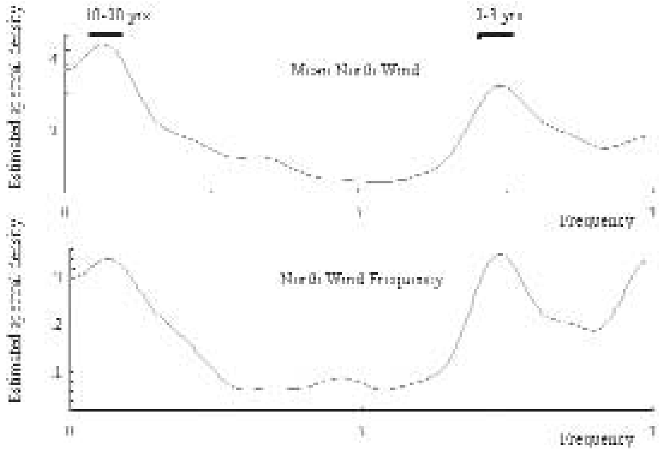

Fig. 3: Smoothed periodogram obtained with a Parzen window (m = 25) for the winter (January-March) wind conditions from 1947 to 1991: (a) mean northern wind (Mean_nw) index, and (b) northern wind frequency (Freq_nw) (adapted from Borges *et al.*, 2000).

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Update on GLOBEC's Data Management strategies

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Data is an investment. We spend considerable amounts of time, money and energy collecting it and, like any investment, we have to take steps to insure that it doesn't lose value. When we receive our salary, we put it in the bank account, we keep records of where it is, what it's been spent on, we convert it to goods, savings, pensions – and we keep a record of all these things. To make the most of our money we must manage it actively and we must do the same for our data investments. Publishing our results is like banking the money – but what do we do with the data then?

The GLOBEC IPO is committed to helping GLOBEC scientists make the most of their data. It is our job to set up easy to use methods of recording and archiving GLOBEC data collected as part of the GLOBEC programme. In December, Hester Willson, the GLOBEC IPO Data Manager visited the Global Change Master Directory in Greenbelt, MD to discuss setting up a GLOBEC Metadata Inventory.

NASA's Global Change Master Directory (GCMD) is a comprehensive directory of descriptions of data sets of relevance to global change research. The GCMD database includes descriptions of data sets (DIFs) covering climate change, agriculture, the atmosphere, biosphere, hydrosphere & oceans, geology, geography, and human dimensions of global change. The user may search the GCMD database and the resulting metadata records provide information on the nature of the data (e.g., parameters measured, geographic location, time range) and where the data are stored.

The funding for the GCMD is long term, therefore storing metadata here is a secure way of preserving a record of the results and achievements of the GLOBEC programme. This will continue into the future when GLOBEC is completed and finished. To distinguish GLOBEC collected data, GLOBEC will have a specially set up portal into the GCMD. This will highlight the GLOBEC data available. The portal can be searched in two ways, by a simple free text search and by a detailed Keyword Search. Experts at the GCMD have proven that this is a more effective and efficient way of finding the data you are looking for. The keyword search also shows the number of records containing that particular keyword, which are available in the portal. The portal will be accessible via the GLOBEC International web pages. GLOBEC scientists will also have access to the GCMD, so that they can expand their searches beyond GLOBEC data if they so wish.

The GCMD uses a data format called a DIF (Directory Interchange Format), a de-facto standard used to create directory entries which describe a group of data. The DIF allows users of data to understand the contents of a data set. The DIF contains those fields that are necessary for users to decide whether a particular data set would be useful for their needs. Six fields are required in the DIF; the others expand upon and clarify the information. Some of the fields are text fields, others require the use of valid values. The 6 required fields are:

1. Entry identifier – must be unique
2. Entry Title
3. Parameters – include categories, topics, terms, variables and detailed variables (these latter two are optional). The parameters must be selected from the valid parameters specified by the GCMD. This list is extremely extensive.
4. Data Centre – Who holds the data (required), data centre URL, data set ID (optional), Data Centre Contact (required), their email, phone and fax (optional)
5. Summary - approx. 30 lines
6. Document Author – person submitting DIF to GCMD

Skinny DIF is a DIF that consists of only the required DIF fields. Skinny DIFs are put into a directory to record the existence of a particular data set, and may be modified at a later time to provide additional information. For more information on DIFs and the other available optional fields, please see the GCMD website http://gcmd.nasa.gov/difguide/difman.html

We encourage GLOBEC members to submit DIFs on their datasets to the GCMD. This can be done easily by clicking on the Metadata Authoring Tool available on the GCMD homepage (in the right hand menu bar). Please ensure that you fill in the PROJECT field with the word GLOBEC or the DIF may not be visible in the GLOBEC portal. **Alternatively, please send your information to the IPO in whatever format it is available and we will write the DIFs for you.**

Some GLOBEC members have mentioned concerns that submitting DIFs to an open access database will lead to them being inundated with requests for their data. The IPO has contacted several experienced Data Managers who have assured us that this is simply not the case in their experience. Rather, the increased visibility of the data sets frequently leads to important, valuable and publishable collaborations. IGBP and GLOBEC are fully committed to achieving progress in the field of environmental science through the synthesis of disparate datasets.

First announcement: SECOND GLOBEC OPEN SCIENCE MEETING

Qingdao, P. R. of China
15-18 October 2002

For further information please contact Ms Charlotte Ireland, GLOBEC International Project Office, Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK. Tel. (44) (1752) 633401. Fax. (44) (1752) 633101. E-mail: cji@wpo.nerc.ac.uk or globec@pml.ac.uk.

New GLOBEC Report Available from the IPO

Willson, H (ed). 2001. Report on the GLOBEC National, Multi-national and Regional Programme Activities, 2001

GLOBEC Special Contribution No.4

IAPSO/IABO Symposium at 2001: An Ocean Odysssey Mar de Plata, Argentina, 21-28 October 2001

The 2001 Joint Assembly of the International Association for the Physical Sciences of the Oceans and the International Association for Biological Oceanography will include a special session sponsored by GLOBEC, together with IAPSO and IABO.

Ecosystem Dynamics: Integrating Biology and Physics

Convened by Dr. Ramiro Sanchez (rsanchez@inidep.edu.ar) and Dr. Nadia Pinardi (N.Pinardi@isao.bo.cnr.it)

GLOBEC research on the coupling between physics and biology of zooplankton and ichthyoplankton is active in the North Atlantic, North Pacific, and Southern Oceans and within the upwelling systems which form the habitat for the majority of the world's small pelagic fish populations. These internationally co-ordinated studies are providing new insights into the coupled biological-physical processes that control animal distribution and abundance and how these might respond to global change.
This session is intended to provide the opportunity for scientists working on physical-biological coupling to present papers that cover the following topics:

1. ocean physics and basic biological processes of individual organisms
2. modelling and observations of mesoscale physical processes (e.g., upwelling, tidal mixing fronts, topographically trapped gyres) which may affect biological processes;
3. data assimilation in coupled biological-physical models
4. the relations between population dynamics and physical processes including linkages to climate change or climate variability;
5. large-scale biological-physical interactions: linking regional physical and biological phenomena to larger scales;
6. connections between ocean physics and fish recruitment.
7. Interdisciplinary modelling and observational studies that integrate biological and physical processes are particularly welcomed.

GLOBEC researchers are encouraged to submit papers for this session. The Abstract Submission deadline is 6th April 2001. Registration packs for the meeting will be issued in July 2001.

Other sessions of particular interest include:

Decadal Variability and Predictability
Sea Ice and Biology
Census of Marine Life
Mesoscale and Smaller Scale Variability and Related Biological Processes

For further information, abstract submission, and registration, contact:

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e-mail: iado@criba.edu.ar
http://www.retina.ar/2001_ocean/

International GLOBEC Optical Plankton Counter Workshop

Meng Zhou, University of Minnesota, USA (mzhou@d.umn.edu) and
Kurt S. Tande, University of Tromsø, Norway (ktande@nfh.uit.no)

An International GLOBEC Optical Plankton Counter (OPC; Focal Technologies) Workshop will be held in June 17-20, Tromsø, Norway, aiming to assist aquatic biologists facing the challenge to study the spatio-temporal variability of zooplankton population processes associated with physical features. The development of acoustic devices provides fast survey tools to assess spatio-temporal distributions of zooplankton biomass. In the last decade the development of the OPC, its application technologies and the mathematical models needed to understand size-structured zooplankton population dynamics, have provided us with a suite of tools to assess zooplankton population processes in aquatic ecosystems.

The OPC was developed by Alex Herman at the Bedford Institution of Oceanography (Herman, 1992), and is commercially produced by Focal Technologies Inc. (Nova Scotia, Canada) since 1992. OPC counts plankton from approximately 200 μm to 16 mm at a maximum rate of 100 individuals·s^{-1}. The lab OPC can be used for counting zooplankton net-tow samples by sizes in both laboratories and fields. Specially, it becomes an efficient tool for retrospective analysis of samples. The towed unit can be mounted on different towed vehicles. It becomes a central piece integrating measurements from other sensors such as CTD, fluorometer and Global Positioning System (GPS). Measurements from these sensors can be transmitted to OPC deck units at real time through conducting wires in the towing cable. There are approximately 100 OPCs collecting data worldwide, of which approximately 60 are towed underwater units.

This workshop is sponsored by the International GLOBEC following the discussions of zooplankton samplers and models in the ICES Zooplankton Ecology Working Group Meeting (Honolulu, April 2000) and the GLOBEC Focus 3 Numerical Modeling Group Meeting (Chapel Hill, July 2000). Current ecosystem studies require zooplankton observations to resolve both spatial and temporal variability, and the assessment of zooplankton population dynamics processes from observable variables. The Focus 3 group indicates a need to integrate observations and models of zooplankton. One such integrated approach is to use size-structured zooplankton models and observations made by OPC. The use of OPC has brought us new insight into zooplankton spatial and temporal variability and population dynamics processes (Heath, 1995; Sprules and Stockwell, 1995; Zhou and Huntley, 1997).

The goals of this OPC workshop are 1) for OPC users to exchange and share new methods and ideas in using OPC, 2) for experts to demonstrate how to use OPC and how to deal with data, 3) for users to discuss some common problems in using OPC, and 4) for users to organize an OPC user help hotline to assist our communities.

The workshop maximizes the hands-on lesson by starting with a 1-day cruise onboard *RV Jan Mayan* in Balsfjorden on day 1 of the workshop. Balsfjorden, near Tromsø, is one of the highly productive fjords in northern Norway. In Balsfjorden, zooplankton are dominated by *Calanus finmarchicus*. *R/V Jan Mayan*, which belongs to the University of Tromsø, is a 64 m long ice-breaker. It has ample wet and dry lab spaces for our workshop. The Scanfish team from the Norwegian College of Fishery Science, University of Tromsø will be onboard to demonstrate instrument integration, deployment and data acquisition. Participants will bring their own data processing software to demonstrate how to integrate and interpret OPC data.

Talks on OPC-related studies will be given on day 2 including several invited speeches given by M. Heath, A. Herman, G. Sprules, R. Hopcroft, and A. Edvardsen. Talks will address important issues such as deployments, calibration, quality control, integration with other sensors, data processing and interpretation.

Day 3 will be devoted to discussions on related issues, posters and further demonstration. And day 4 we will conclude this workshop by making specific recommendation on current and future development of deployment techniques, data processing-quality control, mathematical theories and instrument improvement. The workshop is expected to produce a GLOBEC report.

The University of Tromsø plays a major role in supporting this workshop. The university provides funds for the ship time, the Scanfish-OPC technical team, local transportation, and workshop miscellanies. This workshop is also kindly supported by Focal Technologies, Inc. and US GLOBEC.

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ENVIFISH - the PML contribution*

Nick Hardman-Mountford, Plymouth Marine Laboratory, UK (nhmo@pml.ac.uk)

Envifish (Environmental Conditions and Fluctuations in Recruitment and Distribution of Small Pelagic Fish Stocks)[1] is a project funded by the INCO-DC (International Collaboration - Developing Countries) programme of the European Commission (EC), which focuses on the south-west coast of Africa, from the Equator to the Agulhas shelf. It is formally affiliated to GLOBEC-SPACC. The project is in its third and final year and will culminate with a large open scientific meeting in Cape Town this September (see page 18).

The aim of *Envifish* has been to develop appropriate methodologies for improving the sustainable management of small pelagic fish stocks in the Benguela and Angola systems. Work is based around the identification and quantification of key environmental conditions that influence fluctuations in recruitment and distribution. To this end, satellite, meteorological, oceanographic and fisheries data, over an eighteen-year time series, have been retrospectively analysed. There are ten partners[2] in *Envifish*, from Europe and southern Africa, of which Plymouth Marine Laboratory (PML) is one and this article aims to give a taste of the work we have been doing. Further details about the *Envifish* project as a whole were given in *GLOBEC International Newsletter* 6.1.

One of the roles of PML has been to undertake analysis of large-scale environmental data sets, looking at the whole *Envifish* area, with the aim of trying to understand large scale forcing of the region. This has been done through a number of work packages: multivariate statistical analysis, empirical orthogonal function (EOF) analysis, time series analysis and inter-decadal indices. The main data sets used have been AVHRR SST data[3], TOPEX/Poseidon and ERS I and II altimeter data[4] and ECMWF wind data (east-west and north-south components)[5] .

Correlation analysis between the different large-scale data sets was used to identify relationships between different parameters. EOF analysis was then carried out with a view to simplifying the large-scale spatio-temporal variability of the region. A number of interesting results were obtained through the application of this technique, including identification of the main upwelling cells and oceanic currents, boundaries between subsystems and putative oceanic wave structures. EOF analysis also provides an indication of the variability of these features through time. The next step is to use rotated EOF analysis to refine the results of these analyses.

Work in the time series work package has involved the use of classical time series analysis methods and spectral methods to describe both seasonal and interannual variability throughout the region. Identification of years of major changes and the direction along the coast in which these changes have propagated provide insight into possible forcing mechanisms. Work by other partners in the project (IOW) has suggested that known climate features (e.g. SOI, NAO) are not major forcing functions in the *Envifish* region, therefore, we have begun to look at other potential modes of climate forcing in this region.

Another work package for which PML is responsible involves examining the relationship between long and short time scales. This is currently being investigated using a neural network technique.

Finally, using video analysis of the full time series of spatial oceanographic data, we have been able to identify a range of macro- and meso-scale oceanographic spatial features and, from these, potential structures of biological importance.

This work relates strongly to other areas of investigation in *Envifish* and currently these results are being compared with those of other partners with a view to describing how the environmental dynamics so far described may influence small pelagic fish stocks in the region.

* see figures on page 29.

[1]Envifish contract no.: ERB IC18-CT98-0329.

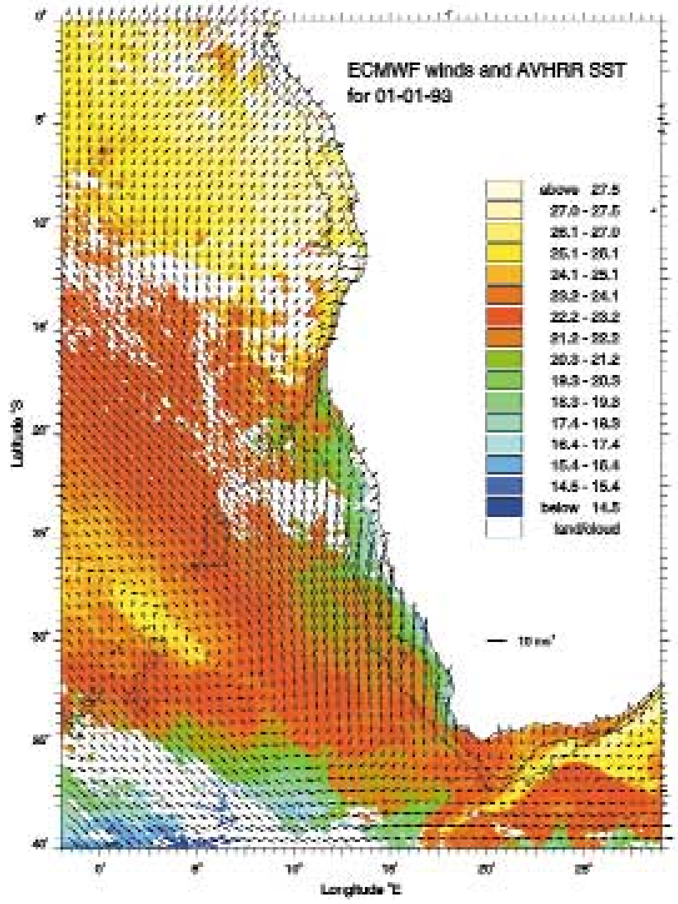
[2]Envifish partners are:

- Joint Research Centre (JRC) of the EC, Italy;
- Institute of Fisheries Research (IIP), Angola;
- National Marine Research and Information Centre (NatMIRC), Namibia;
- Marine and Coastal Management (MCM), South Africa;
- University of Cape Town (UCT), South Africa;
- Institute for Baltic Sea Research (IOW), Germany;
- Institute for Marine Research (IMR), Norway;
- Plymouth Marine Laboratory (PML), UK;
- Food and Agriculture Organisation (FAO) of the United Nations, Italy;
- Instituto de Investigação das Pescas e do Mar (IPIMAR), Portugal.

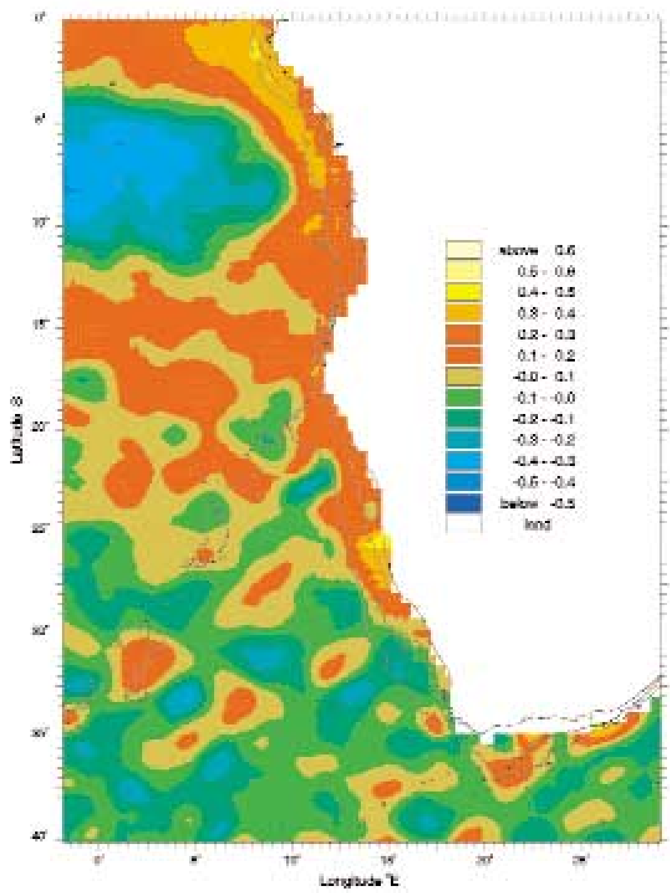
[3]AVHRR SST data was provided by the Space Application Institute, Joint Research Centre (JRC) of the European Commission, as a development of a scientific collaboration agreement between NASA and JRC named "NASA-JRC AVHRR remote sensing collaboration".

[4]TOPEX/Poseidon, ERS I and ERS II altimeter data and products have been made available from AVISO, CLS and the European Space Agency through the ENVISAT project (grant: AO2.UK121).

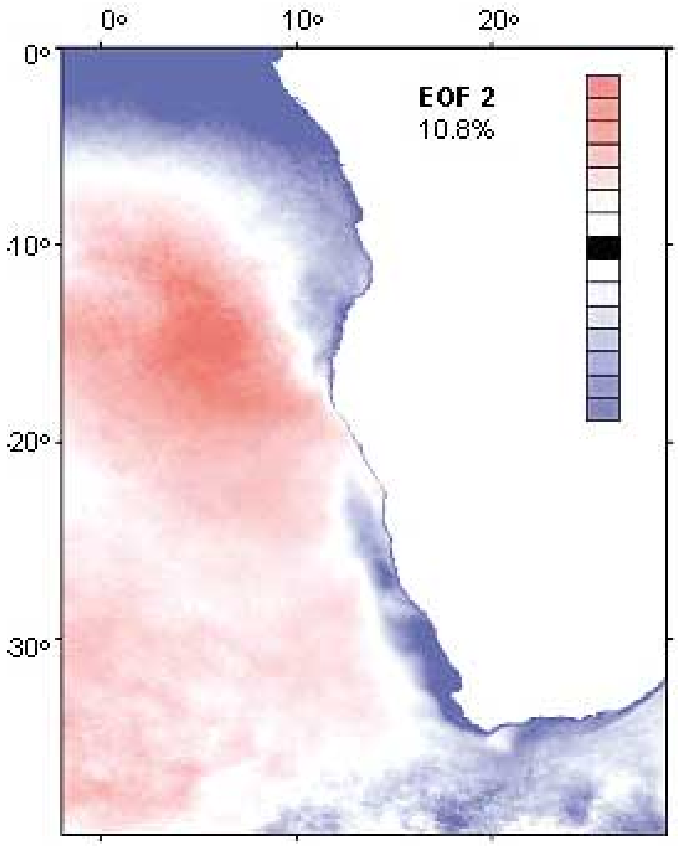
[5]ECMWF wind data were provided the European Centre for Medium Range Weather Forecasting (ECMWF) in Reading, UK.

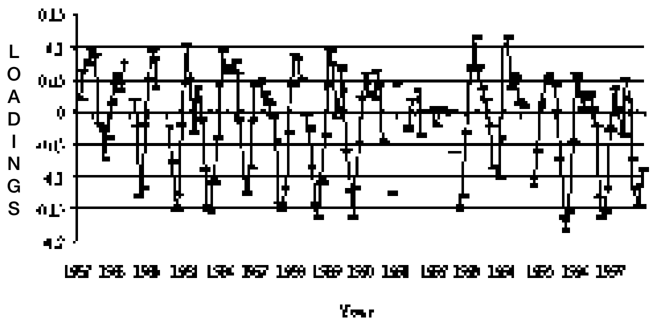


Hardman (p.28) Figure 1. Weekly composite of AVHRR SST (colour scale) and ECMWF wind vectors (arrows) for the first week in January, 1993.



Hardman (p.28) Figure 2. Correlation between the east-west (u) component of wind speed from ECMWF data and SLA from TOPEX/ Poseidon data.





Hardman (p.28) Figure 3. EOF mode 2 of monthly AVHRR SST anomalies (image) and its loadings (time series).

GLOBEC SCIENCE

A column for scientific notes of relevance to the GLOBEC community

At the first meeting of the GLOBEC Focus 1 working group, it was agreed that the GLOBEC community would appreciate some advice on specific techniques relevant to our research objectives. The creation of a scientific column in the GLOBEC Newsletter, the official source of communication between GLOBEC researchers, was suggested. Any reader of this Newsletter is invited to submit a contribution to this column, including responses to previously published columns. Contributions will not be formally reviewed but they may be circulated to the chairpersons of our Foci working groups prior to publication to ensure consistency and relevance to the activities of GLOBEC's working groups. Contributions on any technical, analytical, statistical or modelling aspects of GLOBEC relevance should be sent to Dr Manuel Barange, editor of the Newsletter. There will be no specific calls for submission, so just send them when they are ready. Remember that the column can be a perfect sounding board for new ideas, or a platform for early publication, so use it to your benefit as well as the benefit of the GLOBEC community. We all look forward to your contributions.
The Editor

Models, global change and adaptive behaviour

Geir Huse (geir@ifm.uib.no) and Øyvind Fiksen (Oyvind.Fiksen@ifm.uib.no), University of Bergen, Norway

Our ability to model ocean physics has improved greatly with the advent of modern computers. The biological and ecological models improve at a slower rate, since innovation in such models are more a matter of understanding than of resolution and computing power. Here we point at some methods that may be useful in order to model the response or biological impact, in terms of evolutionary adaptation, of higher animals to persistent climatic changes.

Modelling higher trophic levels like zooplankton and fish is much more challenging than modelling particles and phytoplankton (Aksnes *et al*. 1995). In higher trophic levels, growth, fecundity, mortality and generation time is not easily described by simple functions of density. In contrast to particles, fish and to some degree zooplankton mobility is dominated by individual behaviour rather than by water movements. To a large extent, higher organisms are characterised by flexible behaviour (phenotypic plasticity), i.e. they possess the ability to modify their behaviour or location on short time scales.

To understand how organisms will respond to new environmental situations is of major importance to GLOBEC. Spatial distribution, migrations and phenology (life history) of organisms will be among the first biological parameters that are affected by changes in e.g. currents, productivity and temperature (Murawski 1993), since these traits can often be modified without any genetic modifications. If we can predict changes in behavioural traits as a result of environmental forcing, we will be in a better position to make sensible forecasts of the impact of global change. In addition to these behavioural plasticities, environmental change may also lead to changes in the gene pool caused by natural selection. Ideally, modelling approaches should be able to deal with all these kinds of adaptive responses.

How can we model behaviour? Giske *et al.* (1998) pointed at some tools for modelling behaviour and dynamically interacting individuals. Individual-based models (IBMs) have become popular in ecological modelling (DeAngelis & Gross 1992). IBMs have rarely addressed behavioural issues, but there exist modelling techniques for doing this (Huse *et al*. 1999). One approach is through the use of artificial neural networks (ANNs) and genetic algorithms (GAs), two computational methods, inspired by biology, that are particularly popular outside the biological sciences. ANNs apply neurobiological principles of synaptic brain-activity to perform actions (or simulate behaviour) by differential weighting of input information (Rummelhart *et al*. 1986). In the genetic algorithm (GA) Darwin's principle of evolution by natural selection is applied to search for optimal solutions to complex problems (Holland 1975).

In IBMs it is common to use an attribute vector A_i (Chambers 1993) to specify the states of an individual i such as age, weight, sex, fitness and hormone levels (Fig. 1). In addition to possessing states, real individuals have adaptive traits such as size at maturity or migration strategies, which can be modelled by use of a strategy vector S_i (Fig. 1). The strategy vector may be considered as analogous to a biological chromosome as in the GA (Holland 1975), but it may also be updated during the individual's life as a way to simulate learning (Ackley & Littman 1992). The combination of attribute vectors and strategy vectors thus enables all relevant characteristics of individuals to be specified and modelled using IBMs. Fig. 1 illustrates the ING (Individual based Neural network Genetic algorithm) framework for simulating behaviour using ANNs, strategy, and attribute vectors. Individuals interact with their environment according to their behavioural strategies specified on the strategy vector, and the actions and behavioural forcing lead to changes in the attribute vector. After simulating the part of the life cycle that is targeted (can be the whole life cycle), a new population of S_i's is created from the old one. When comparing the profitability of different strategies (or individuals), a specific measure of fitness such as the net reproductive rate (R_O), can be used.

Individuals with the high fitness score have a greater probability of passing on their "genes" to the next generation than poorer individuals. Variability in the new strategy vectors is provided through recombination among parents (S_{mum} and S_{dad}, Fig. 1), and mutations (Holland 1975). After many generations this process allows individuals to produce increasingly more favourable behaviours as they adapt to their environment. An alternative approach for evolving behaviour in models is to use so-called endogenous fitness, which means that individuals with strategy vectors live and reproduce in an evolving population. Thus rather than maximising a specific fitness measure, those individuals who manage to pass on their own strategies by fulfilling criteria set for reproduction with other individuals in the population, will be the most fit.

The strength of this adaptive approach is that it is robust to most ecological processes and can handle stochasticity, which is often a problem in optimisation models. In general behaviours can be explained both by proximate how and ultimate why causation. ANN based models can link these views on behaviour by including both the proximate stimuli that cause the behaviour as well as providing the ultimate consequence of the behavioural response. Another factor that can be included in such genetically inspired models is the effect of global climate changes on the genotype frequencies of populations through differential selective forcing under different climate states.

We encourage the continued exploration of such methods, particularly in studies where the biological impact of climatic change is being investigated. They may provide useful insights into the dynamics of environmentally driven ecological and evolutionary change. For applications of adaptive models see e.g. Huse & Giske (1998), Huse *et al.* (1999) and Fiksen (2000).

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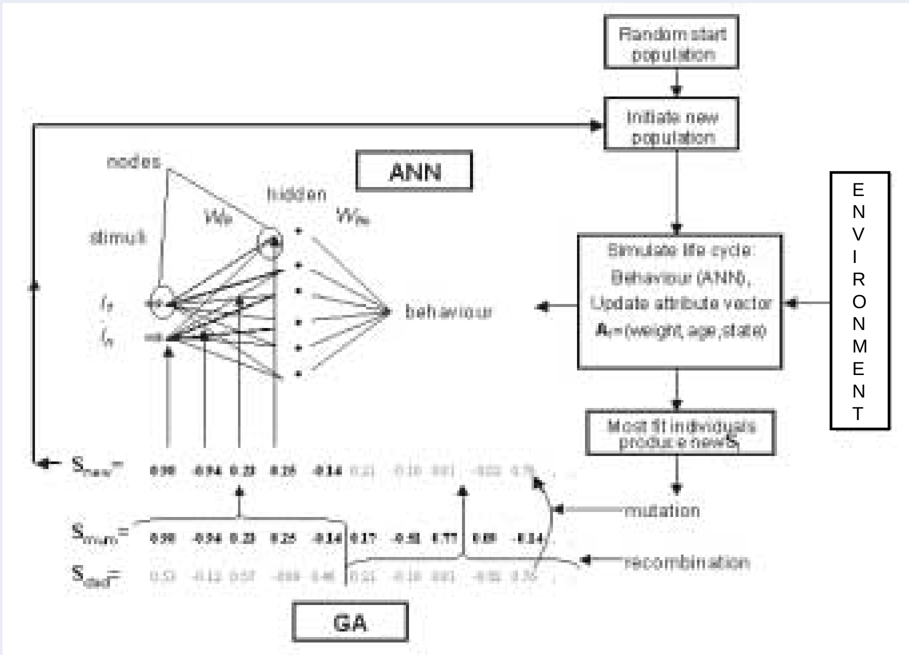

Figure 1. The ING modelling concept with ANN based behaviour and GA based evolution in an individual-based setting. Individuals with randomly set "genetic" S_i that code for the weighting of the ANN, are initiated in the first time step. Individual states are kept track of by the attribute vector. New individuals are produced through recombinations and mutations. Differences between the "genetic" strings are expressed through differences in weights of the ANN, which can lead to behavioural differences. Modified from Huse *et al.* (1999).

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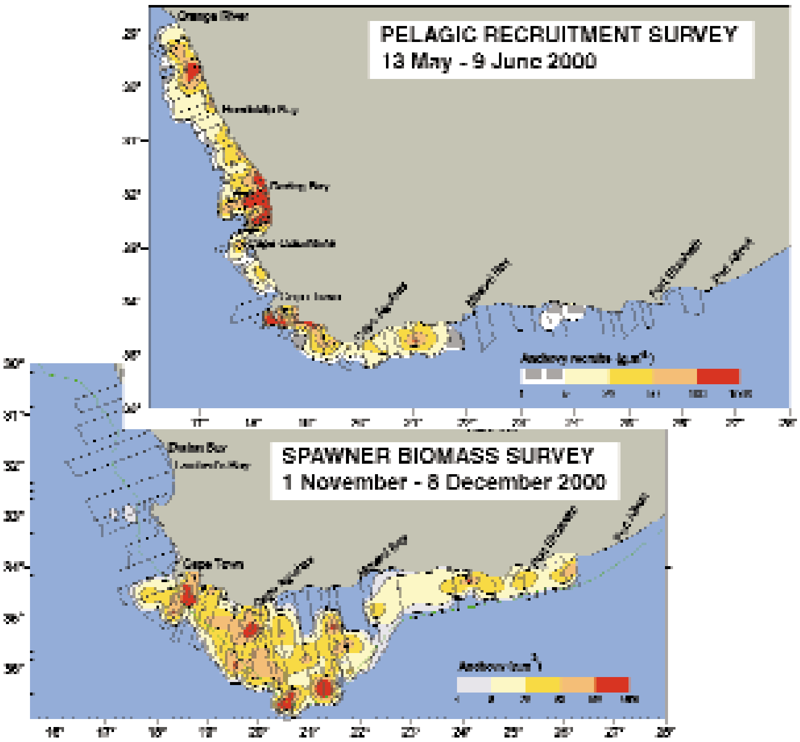
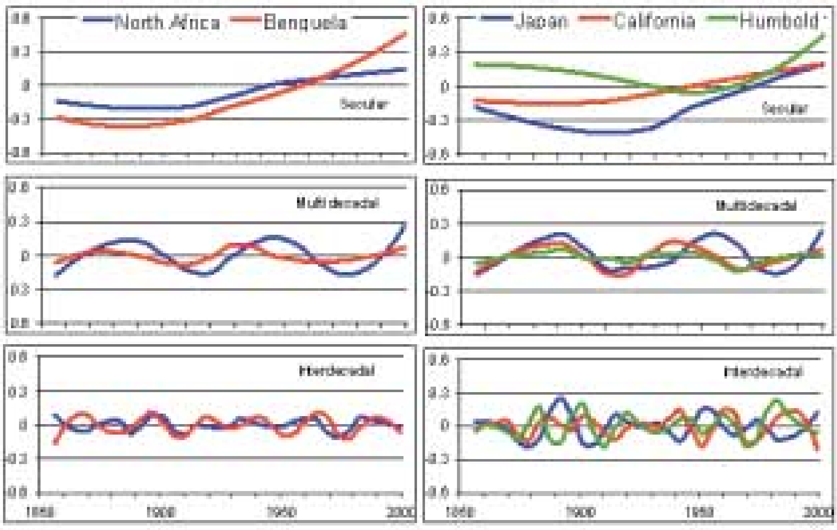


Roy (p.9) – Figure 1. Distribution and abundance of anchovy recruits (May/ June) and adults (Nov/ Dec) of anchovy off South Africa. Unpredicted abundance records were observed in 2000.



Daskalov (p.18) – Figure 1. Low-frequency components of the SST anomaly for the major upwelling systems extracted using loess (Cleveland 1993) from the Kaplan et al. (1997) data-set.

GLOBEC CALENDAR

2-6 April 2001: Benefit Annual Forum, Swakopmund, Namibia

23-25 April 2001: Final planning meeting of the IGBP-IHDP-WCRP Global Environmental Change and Food Systems Programme, Washington DC, USA

23-26 May 2001: GLOBEC SSC Meeting, Lima, Peru

27-28 May 2001: Focus 1 WG Meeting, Lima, Peru

29 May - 1 June 2001: SPACC - Retrospective data analysis in the Americas, Lima, Peru

17-20 June 2001: Optical Plankton Counter Workshop, Tromsø, Norway

10-13 July 2001: IGBP Open Science Conference and Focus 3 WG Meeting, Amsterdam, The Netherlands

3-5 September 2001: IOC/SPACC Study Group on the Use of environmental indices in the management of pelagic fish, Cape Town, South Africa

6-8 September 2001: SPACC - Spatial approaches of the dynamics of coastal pelagic resources and their environment in upwelling areas, Cape Town, South Africa

6-8 October 2001: Open Meeting of the Human Dimension of Global Environmental Change, Rio de Janiero, Brazil

5-13 October 2001: PICES X Annual Meeting, Victoria, Canada

21-28 October 2001: IAPSO/IABO/GLOBEC Symposium, Mar del Plata, Argentina

28 - 30 November 2001: 1st Symposium GLOBEC-Spain, Cadiz, Spain

3-7 December 2001: Oceans and Coasts at Rio+10, UNESCO, Paris

GLOBEC INTERNATIONAL

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