ICES/GLOBEC Newsletter

Number 8, December 2001

Editorial

by Keith Brander

Seasons *Greetings* to all our readers and I hope this science-packed issue of the Newsletter stimulates you to renewed intellectual assault on the complexities of marine food chains, once the effects of Christmas over-indulgence have left your digestion and mental capacities in a fit state.

What can we look forward to in 2002?

- A concentrated burst of Cod and Climate Change activity in Denmark during week 16 (Workshop on Transport of Cod Larvae; Cod and Climate Working Group and a joint session with the Recruitment Processes WG - see back page for details)
- The second GLOBEC Open Science Meeting in Qindao, China in October
- Closer co-operation over research funding around the whole North Atlantic
- New national GLOBEC programmes getting underway

What about progress with applying the science from GLOBEC and specifically the CCC programme? In some respects this is now almost taken for granted and the pointless arguments about whether fish stocks are affected by environmental variability have faded away, but we have much work to do in understanding the processes and in establishing and testing procedures for including environmental information into management advice.

This Newsletter contains a lot of material on zooplankton dynamics (particularly *Calanus*), which reflects the continuing activity of the TASC community. Several of the articles set out work in progress to link our improved knowledge of secondary production with fish population dynamics. There are big unresolved questions concerning the role of oceanic plankton populations in driving long term changes observed in all trophic levels in shelf seas. Even the "simple" expectation that more plankton will result in more fish turns out to be less simple than one might hope. What is not in doubt is the vigour of the investigation and the careful, concerted scientific approach being followed.

2002 will see more synthesis and application of results, more cooperation around the North Atlantic and with colleagues from PICES and other organisations

Density-dependent egg mortality in *Calanus finmarchicus*

Mark Ohman (Scripps Inst. of Oceanography) and **Hans-Jürgen Hirche** (Alfred Wegener Institute)

This work, which uses results from the TASC programme, was recently published in Nature. It shows the intensity of density dependent mortality on eggs of *Calanus finmarchicus* in the Norwegian Sea.

We estimated instantaneous rates of egg mortality for *Calanus finmarchicus* from the high frequency time series study conducted at Ocean Sta. M (2º E, 66º N) in the Norwegian Sea from 22 March–9 June 1997 as part of the TASC project. For 80 days Xabier Irigoien, Ulli Klenke, and Robert Head, on rotations, conducted extensive sampling and experimental work with *C. finmarchicus*, spanning the onset-through-termination of the spring phytoplankton bloom. Logistical support by the IMR in Bergen was invaluable.

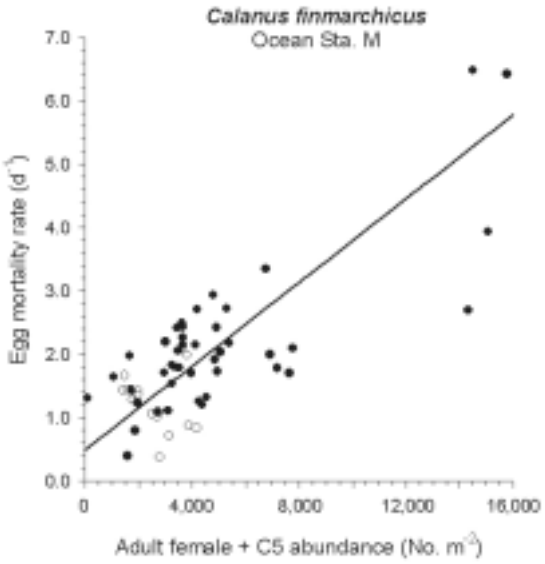


Fig. 1 - Relationship of *C.finmarchicus* egg mortality rate to

We found that egg mortality rates vary appreciably with time and the temporal dynamics of *C.finmarchicus* population growth appear to be closely linked to these variations (Ohman and Hirche. 2001. Nature **412**:638-641). Egg recruitment rates (i.e., per capita egg

production X abundance of adult females) are very high in late winter/early spring, but initially result in no surviving nauplii, apparently because of egg cannibalism by *C.f.* females and C5's in the period before the bloom when alternate prey are scarce. A gradual seasonal decline in abundance of adult females is accompanied by a decrease in egg mortality rates, leading to the density-dependent egg mortality relationship seen in figure 1. This trend is not explainable by variations in egg hatching success.

A consequence of this relationship is that mortality rates of *C. finmarchicus*, which are typically treated as if constant and linear, are instead time-dependent and nonlinear. Nonlinearities of this kind have attracted considerable modeling interest and have been shown in various numerical experiments to alter the temporal dynamics of marine populations and ecosystems. The results also imply that forecasting the long term variability of *C. finmarchicus* populations cannot rely solely upon the influences of external climate forcing, but must also consider the role of internal density-dependent processes. ☙

Theme Session on Growth and Condition in Gadoid Stocks and Implications for Sustainable Management

Co-convenors: **L. Buckley** (United States), **J.-D. Dutil** (Canada) and **T. Marshall** (Norway)

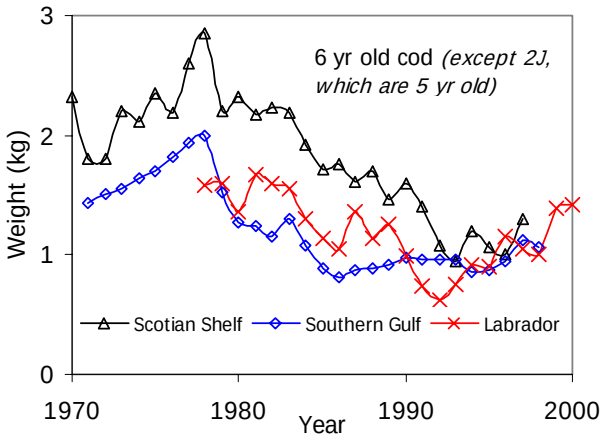
One of the causes of the large changes in biomass (both decreases and increases), which North Atlantic gadoid stocks have undergone over the past decades, has been changes in growth rate. Somatic growth, reproductive output and hence surplus production have been affected, but to date the causes of variability in growth rate are not fully understood or incorporated in our assessments of past and future stock fluctuations.

The ICES/GLOBEC Workshop on the Dynamics of Growth in Cod in May 2000 (CM 2000/C:12) reviewed recent findings on cod growth and condition in contrasting environments and showed linkages between growth, physiological condition, reproductive effort, and production. Not all gadoid stocks or all individuals within a stock exhibit similar growth responses under similar environmental conditions. For instance, fish of different size have different requirements, with larval and juvenile fish growing better at higher temperatures than adult fish.

The aim of the Theme Session during the ICES Annual Science Conference (ASC) in Oslo in September 2001 was to build on the outcome of the Workshop and in particular to (i) explore the use of physiological indicators of condition in juvenile and adult fish in relation to growth dynamics, reproductive effort and production in wild fish (ii) examine stock- and size-specific growth responses to various factors, including climate variability, stock density, and size selective fishing. The Session considered both multivariate analyses at the stock level and field and laboratory studies on growth and condition.

Overview of presentations

27 papers and one poster were presented, the majority of which dealt with cod (*Gadus morhua*). Results came from laboratory, mesocosm, field and modeling studies and presentations were organized by life history stage, spanning all levels of biological organization from molecular to individual and stock levels. Many of the papers cut across the different levels of organization (molecular through to individual through to stock) and provided a good synthesis of ongoing research. Extended abstracts of the papers will be included with the Report of the Workshop on Cod Growth and published as a Cooperative Research Report in 2002. The papers themselves (or abstracts) are also available on the CD-ROM from the ASC and the numbers which appear in italics in the text below refer to specific papers within Theme Session V.



Changes in weight at age for three NW Atlantic cod stocks

Novel approaches

The utility of food web specific lipid biomarkers was demonstated in a study of temporal development of growth and condition of juvenile North Sea haddock (*27).* Molecular techniques, capable of identifying the parental origins of individual fish, were used in a mesocosm study together with RNA-DNA ratios to examine the effects of environmental and parental inheritance on growth and mortality during the first months of life *(8; 28).* Offspring produced by repeat spawners had similar growth, condition and survival to offspring produced by recruit spawners *(28)*, however, repeat and recruit spawners were similar in size. Between mesocosms differences in food concentration generated differential growth and survival and environmental factors gave a larger signal than parental inheritance *(8)*.

Causes of variability

Growth is highly variable at the individual, cohort and stock levels and can have a substantial effect on fish production. Temperature is a dominant factor affecting growth during all life history stages and sets the maximal level of growth potential *(3; 13)*. Other environmental factors including food availability *(3; 11,:22; 31)* and dissolved oxygen *(5; 9; 11)* affect the level of growth actually achieved.

Condition and growth correlate in many feeding experiments. One paper examined whether poor condition had an impact on catch-up growth upon refeeding following a period of food-deprivation, such as occur in some stocks during the winter and spring period. The capacity of poor condition fish to grow rapidly when food is abundant is only restored after several weeks *(11)*.

Three papers *(14; 21; 22)* investigated the relationships between the abundance of juveniles, size-at- age and environmental factors. Growth trends observed at age 1 or age 2 appeared to persist through the next several years.

There was no suggestion that these differences in size-at-age were due to density-dependent growth and depletion of food resources. A fourth paper examined habitat related variability in growth and condition of age 0 walleye pollock in a study of regional and interannual changes in whole body energy content *(7)*.

A multivariate model including temperature, stock abundance and size selective fishing explained a significant proportion of size-at-age in southern Gulf of St. Lawrence cod (ages 5-11) with a marked effect of size-selection *(26)*. Consequently, size-selective fishing has a strong effect on estimates of annual growth. In some years, this would give the impression of apparent faster growth, while in other years apparent slower growth. This could introduce considerable noise into cod growth signals.

Comparison of laboratory, mesocosms and field studies

Larval growth models developed for well-fed, laboratory reared fish were tested using observations from mesocosms and the field and found to be in general agreement *(4, 13)*. Several papers illustrated the value of feeding and behavioural experiments for interpreting interannual variation observed in the field *(5; 9; 15; 22; 25)*. There was considerable discussion related to the observation that the condition of individuals in the field sometimes deviates from laboratory-reared individuals, possibly due to differences in activity levels and/or diets. This may complicate the comparisons between laboratory and field studies.

Several papers addressed variation in the spatial distribution of juvenile cod in the field and laboratory. Survey data from the Barents Sea indicated that the spatial distribution of cod for their first two years corresponded to where they settled *(22)*. In the laboratory juvenile cod exhibit clear preferences for temperature and oxygen *(30)*. However, conditions in Kiel Bay were outside these preferenda at certain points in the seasonal cycle *(30)*.

Bioenergetic models

Bioenergetic models are promising tools for quantifying stock production and reproductive effort *(1, 12: 32)*. Laboratory experiments on growth, condition and environmental factors relevant to bioenergetic modelling *(9: 11 22)* and new analyses of field data were carried out for several stocks and species *(5, 6; 10: 13: 15, 26, 29, 31)*. Planned (GADOLIFE-EU) and current (GADOLIFE-Canada) projects will develop such models using historical data sets and published or unpublished material on cod physiology. North Sea cod, Baltic cod and cod in the southern Gulf of St. Lawrence will be targeted by those studies. Both field observations and additional laboratory studies are required to parameterize these models adequately.

Reproductive output

Relationships among spawner age, size and condition and egg size and quality were considered in several presentations *(8; 18 20; 28)*. Including environmental data (e.g., water temperature) and spawner characteristics gave improved stock/recruitment relationships in Georges Bank cod *(20)* and spatial and temporal variability in reproductive parameters (i.e., proportion mature, fecundity, egg size and viability) was described for Icelandic cod *(18)*. The high degree of spatial, temporal, and inter-stock variability in reproductive parameters suggests that improved sampling programs are required to accurately estimate reproductive potential.

International Symposium on Developmental Ecology of Marine Animals: Industry, Science and Society

Newcastle, UK 2-3 July 2002

Most studies of the responses and adaptations of marine species to environmental change have involved adult life stages. However, the embryonic and larval stages of marine animals are often more vulnerable to environmental challenges than adults.

DEMA science aims to redress this imbalance, and help predict population responses to changes in weather, climate, pollution, species invasions and introductions etc. through understanding developmental (including life history) responses to the environment.

As well as being relevant to ecological questions, DEMA science focuses on commercially important marine species. The first day of the meeting will focus primarily on academic research, while the second day will focus on the relevance of this work to aquaculture and fisheries industries worldwide.

SESSION TOPICS

Nutrition and Growth
Immunology and Environment
Life Histories, Genes, Developmental Plasticity and Modelling
Chemical Ecology - Signalling and Sensitivity Environmental Protection and Conservation
Biodiversity, Genetics and Breeding Programmes
Culture and Rearing Technologies, Growth Factors and Diet
Methods and Applications of Gene Discovery

Oral (20 minutes) and poster presentations are invited for the sessions listed below. The deadline for abstract submission (ca 250) words is 31 December 2001. Selected speakers will be notified in February 2002. Further information from the programme manager **Jan Flint (dema@abdn.ac.uk)** or through the programme website at **www.abdn.ac.uk/dema/**

Conserving reproductive potential is a fundamental goal of fisheries management and biological reference points have been developed for use with medium term projections to formulate catch advice. Several papers examined the effect of growth variation on the use of biological reference points *(2; 17; 20; 24)* and stock projections *(19)*. For the Northeast Arctic cod stock biological reference points should be modified to account for the high degree of uncertainty in the stock/recruit relationship *(2)*. Alternative stock/recruit relationships for this stock have been developed using more sensitive measures of reproductive potential, e.g., total egg production *(17)*. Individual-based models describing energy partitioning can be used to quantify the relative importance of different sources of variation in reproductive potential of stocks *(1; 12)*.

Conclusions and recommendations

Gadoid stocks live in very diverse environments and exhibit a wide spectrum of responses to biotic and abiotic factors. The session illustrated that the full extent of variability in growth, condition and reproductive parameters can only be

recognized by comparisons among stocks. The rapid development and application of novel approaches and the focus on cod in national and international programs are providing new insights into the processes affecting growth, survival, recruitment and production. However, integration of the many different studies will require synthesis of results across life-history stages and stocks. In particular, the diverse data sets should be compiled in common or compatible formats and models linking the different life stages developed. Research survey sampling practices should be modified to provide the basic data (e.g. maturity and fecundity, liver, somatic and gonads weights) needed to set reliable biological reference points and to make improve medium term projections of stock biomass and production. ☙

Secondary Production in the Oceans and the Response to Climate Change

Mike Heath[1], Francois Carlotti[2], Brad de Young[3], Oyvind Fiksen[4] and Cisco Werner[5]

1. Fisheries Research Services, Aberdeen, UK.
2. University of Bordeaux, France
3. Memorial University of Newfoundland, Canada
4. University of Bergen, Norway
5. University of North Carolina, USA

Trends over the past 50 years in the ocean climate of the North Atlantic (convective depth, poleward heat transport, overflow from the Nordic Seas) are now well documented. Some of these are correlated with the North Atlantic Oscillation Index. What is the impact of these large scale, low frequency climatic changes on the living resources of the North Atlantic?

Economically important stocks of many fish species in shelf seas all around the North Atlantic have suffered major declines in abundance over the past half-century. Prime examples are cod in the northwestern Atlantic and in the North Sea. Without doubt, fishing pressure has played the major role in these declines, but some aspects of the changes indicate that concurrent environmental changes are also involved. In the northwestern Atlantic, the cod

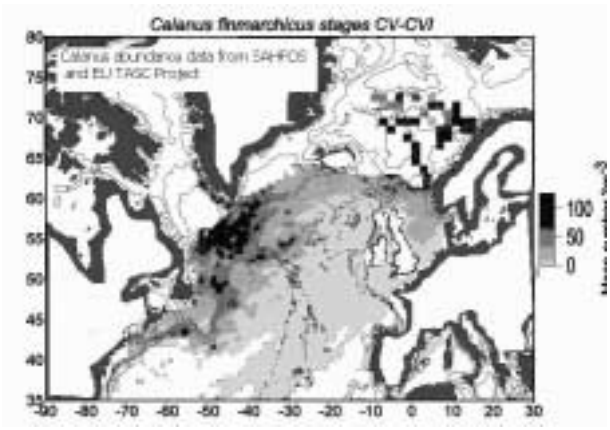


Figure 1. Long-term (1950-1999) mean abundance of adult and late development stages of *Calanus finmarchicus* in the upper 10m of the North Atlantic Ocean. Composite image derived from data supplied by the Continuous Plankton Recorder Survey operated by the Sir Alister Hardy Foundation for Ocean Science, UK, and from the EU-TASC project. The image shows the two main centres of abundance, one in the Irminger/Labrador Sea south of Greenland, and the other in the Norwegian Sea.

stock has failed to recover despite a moratorium on fishing, suggesting that historic productivity characteristics no longer apply. Is this because of some climate-related change in the underlying productivity of the food web as a whole, or some ecological response to the collapse of cod? Northern cod had an historical biomass on the Newfoundland and Labrador shelves of more than 2 million tonnes. The North Atlantic GLOBEC programme aims to discover how the secondary productivity of North Atlantic shelf seas is linked to basin-scale, long-term properties of the ocean circulation and climate system.

It is obvious that, at least at a gross level, there must be some relationship between the amount of primary production in the sea and the amount of fish available for harvesting. However, the details of this relationship are very much less clear. This is partly because the turn-over rates of carbon (roughly the reciprocal of the life-cycle duration) are very much lower at the top of the web compared to the lowest trophic levels. Hence, the production by fish reflects some long-term integral of the primary production. In addition, the connection between primary production by algae and the growth and recruitment of fish involves many predator-prey steps or trophic levels, with varying degrees of energy loss at each stage. Variations in the species composition of each intervening trophic level further weaken the connection between production at the top and bottom of the food web.

At first sight the complexity of the food web makes the task of assessing the sensitivity of secondary production to climate changes seem intractable. However, it turns out that certain key species in the food web, particularly amongst the omnivorous zooplankton (the plankton animals which graze directly on the algae and are in turn eaten by pelagic fish and juvenile demersal fish), exert a particularly strong influence on the proportion of primary production which is passed up the food web towards the fish, or is deposited on the seabed to support the benthos and shellfish. By studying these, we can gain a better understanding of the flux of material to the higher trophic levels.

In the sub-polar North Atlantic and many of the fringing shelf seas, one of the most important of the key species is the copepod *Calanus finmarchicus*. Data from the UK Continuous Plankton Recorder Surveys (Figure 1) show that the contribution of *C. finmarchicus* to the annual average proportion of omnivorous zooplankton biomass in, for example, the northern North Sea has progressively declined from a peak of around 40% in the mid-1960's to around 5% today (Figure 2). At the same time, there has been around a four-fold increase in the abundance of larvae of benthic species, suggesting an increase in the amount of primary production reaching the seabed to feed benthic fauna. These observations indicate dramatic changes over the last 40-50 years in the structure of the food web supporting the North Sea fisheries. The rate at which they have occurred indicates that slow climatic processes are involved.

Analysis of the Continuous Plankton Recorder data set shows that the well documented decline in *C finmarchicus* in the North Sea, has occurred concurrently over a large part of the northeastern Atlantic Ocean, indicating that the events in the North Sea are probably part of a large scale phenomenon and not a local scale event. Similarly, changes in abundance are correlated over a large part of the northwestern Atlantic, but in this case the abundance has

increased since the 1960's. The implication is that whilst year-to-year variability in the shelf seas may be more driven by local conditions, the low-frequency, longer term changes which are important for higher trophic level productivity, are primarily driven by the ocean basin scale dynamics. Over the past 8 years we have gained much insight into interaction between large-scale processes and *C. finmarchicus* population dynamics, from the EU funded ICOS and TASC projects, the US-GLOBEC programme, and

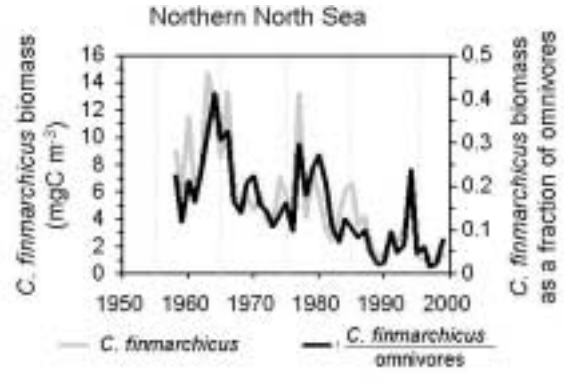


Figure 2. Trends in the abundance of *Calanus finmarchicus* copepodite stages in the northern North Sea derived from Continuous Plankton Recorder Survey data. Annual mean biomass (mg C m^{-3}) in the upper 10m, and as a proportion of the biomass of an assemblage of species representing all omnivorous zooplankton. Data supplied by the Sir Alister Hardy Foundation for Ocean Science, UK.

various nationally funded projects. The details involve particular life-history characteristics of the species, and their interaction with the 3-dimensional basin-scale circulation of the North Atlantic.

The growth and reproduction of *C. finmarchicus* occurs in the upper layers of the ocean (<100m). Under normal circumstances, at surface ocean temperatures, the species has a life cycle of 30-50 days involving a succession of naupliar (larval) and copepodite (juvenile) moult stages. However, the critical life-history trait which couples the species to the ocean circulation, is its overwintering strategy. Late pre-adults have the ability to enter a resting state, equivalent to the diapause in some insects, enabling them to survive without feeding for periods of up to 6-8 months. Typically, late development stages will enter diapause in mid summer, sink out of the surface layer to the seabed or neutral buoyancy depths, forming dense aggregations. The resting copepods remain in this condition until the following spring. We do not know exactly what cues cause emergence from diapause, but in spring the surviving copepods swim back to the surface to mature, mate and spawn a new generation. At the northern extreme of the range, in the Greenland Sea and Davis Strait, the population may only produce a single generation per year, whilst at the southern extreme off the eastern coast of the USA, south of Iceland and in the waters west of the UK, at least two generation per year are more usual.

The conditions defining suitable overwintering habitats for *C. finmarchicus* seem to be accessibility from the loci of summer production in the surface layers, dispersal rate, temperature, and predator abundance. Low temperature is highly advantageous because it further slows down the metabolic rate and increases the endurance of the diapause state. In addition, visual predators are generally less abundant in extremes of low temperature. The appropriate combination of conditions is rarely found in shelf sea waters, and the majority of the overwintering stock resides at depths of 600-2000m in the open ocean, especially in the Norwegian Sea and, it is assumed, in the Labrador/Irminger Sea in the northwest Atlantic. In the Norwegian Sea, these depths correspond to temperatures less than 1EC. Modelling and field observations have shown that most of the productive populations in shelf seas are sustained by annual recolonisation from these oceanic overwintering stocks. This explains why the long-term trends in abundance in, for example, the North Sea appear to be driven by the changes occurring over the wider northeast Atlantic (Figure 3).

So, the issue resolves to what is driving the basin scale changes in *C. finmarchicus* abundance in the ocean? One theory is that changes in the deep circulation of the North Atlantic and the availability of overwintering habitat in deep water masses are playing a large role. Data from the Faroe-Shetland Channel, which lies between the Faroe Islands and the Shetland Islands off northern Scotland, show that between October and March, dense concentrations of overwintering *C. finmarchicus* are found in the deep (>600m) cold overflow of Norwegian Sea Deep Water into the Atlantic. This overflow is part of the thermohaline circulation system which ventilates the global oceans. Norwegian Sea Deep Water is generated by deep convection in the Greenland Sea, and as this process has slowed down in concert with the rise in the NAO since the 1960's, so the volume of Deep Water in the Faroe-Shetland Channel has decreased. In consequence, the abundance of

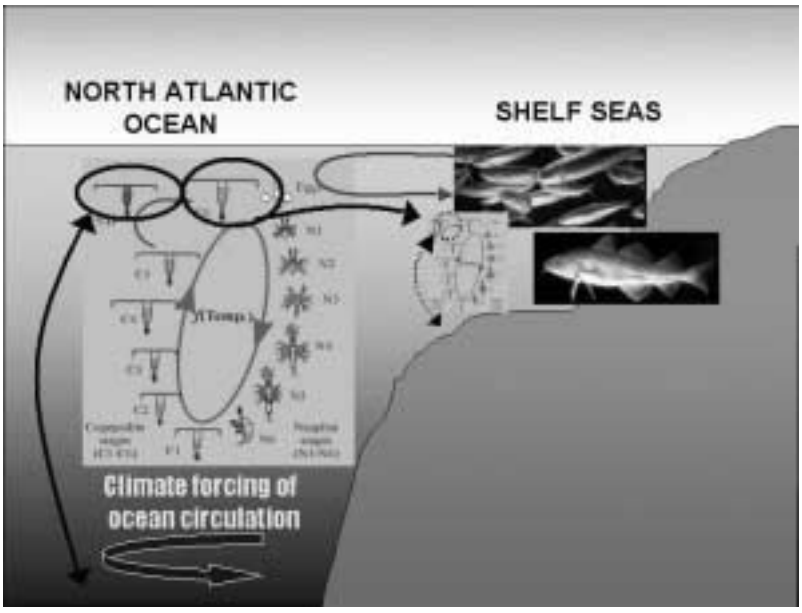


Figure 3. Schematic representation of the role of oceanic population dynamics of *Calanus finmarchicus* in the long-term trends of abundance on the continental shelf. The oceanic circulation system supports a self-sustaining life cycle, with diapause stages surviving through the winter at depth. Late development stages are exported annually to the continental shelves where there is limited scope for year-to-year maintenance of the life cycle. Population production on the shelf supports the fisheries food web.

overwintering stock available to colonise the North Sea each spring has also declined, thus providing a possible explanation for the Continuous Plankton recorder observation in the North Sea. Are similar relationships responsible for the long-term dynamics in the North Atlantic as a whole? A detailed modelling and observation programme in the North Atlantic basin scale will be getting underway in late 2001 to address this question. The work will be a collaboration between the UK-GLOBEC programme and GLOBEC research programmes in Canada, Iceland, Norway and USA. ☋

Unravelling Diversity and Change in the Ocean Plankton.

Bob Dickson, CEFAS, 19 September 2001.

On 7 August, the 70th anniversary and achievements of the Continuous Plankton Recorder (CPR) Survey were celebrated in Edinburgh. When we give Lifetime Achievements Awards to people, it may well be that we celebrate some combination of age and venerability rather than any real continuing usefulness. Not so in science. For any scientific endeavour to persist through seven decades, as the CPR Survey has done, its continued utility can't be in doubt.

The Survey stems from the initiative of Alister Hardy who, in September 1931, began the routine sampling of the free-floating plant and animal life of the ocean---the plankton---using a simple Continuous Plankton Recorder towed at fixed depth behind a commercial vessel. Seventy years and >4 million survey-miles later, the Survey remains unique and the method remains largely unchanged; plankton entering through a hole in the nose-cone become trapped between two strips of silk cloth which unspool at a rate that varies with the tow-speed, and the resulting silk-plankton sandwich is wound onto a third spool bathed in preservative for later analysis in the Laboratory. More than 450 species and entities of the plankton are recorded.

In reviewing its achievements, the first and most basic must surely be the fact that the CPR has formed and shaped our world view of the plankton. Yet even here, it was surprisingly easy to treat this knowledge of the geography, timing, variability and associations of so much of the plankton merely as background to some higher applied task in marine management or policy. It was also something of a retrospective relief to learn, from Sonia Batten's low-key, systematic review that the old machine itself tests well, swimming at a surprisingly constant depth as ship-speeds have increased, drinking $3m^3$ each 10 nmi as we had always supposed, and giving out its own cues (based on phytoplankton colour) as to when and how much to correct for clogging of the silk.

Nonetheless, the thing that staves-off the knacker's yard ---and its been tried!-------is surely a continued value in informing the shifting preoccupations of Governments. Despite star moments in the '60s and 70s when whole fisheries for redfish and blue whiting west of Britain were founded on CPR intelligence [1], support for the fishing industry in Hardy's terms (helping fishermen to find fish) no longer has point. But the issue that arose in the 1970s to take its place, developing agreement on whether particular areas of shelf are actually or potentially eutrophic, still burns as brightly as ever. It is by showing that the changes in the greenness of our seas are coherent on the scale of climate forcing that the CPR has contributed most significantly to this debate.

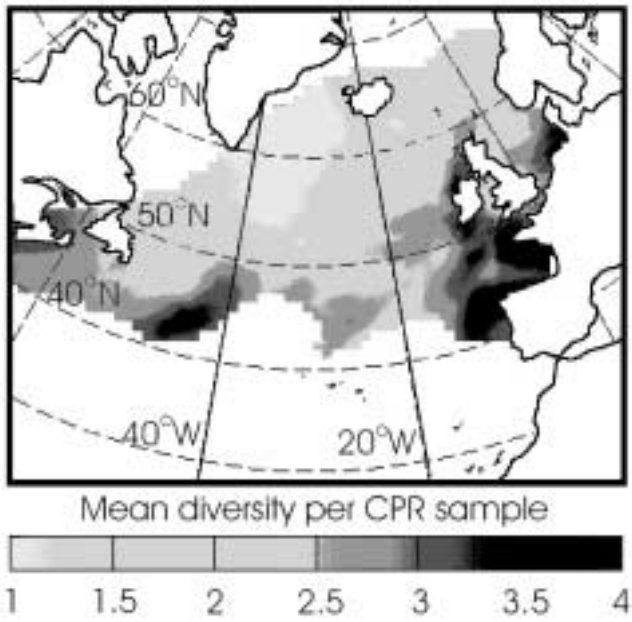


Figure 1 First map of the mean diversity of calanoid copepods in the North Atlantic and North Sea, based on 108 taxa sampled over 40 years by the CPR Survey. The large number of samples (168162) has allowed both the seasonal variation and diel migration of these taxa to be taken into account (see Beaugrand et al, ref 5). Climatic and anthropogenic effects on planktonic biodiversity should be evident in the changes of this pattern with time.

As the issue of eutrophication continues, another asserts itself. Since Rio in 1992, biodiversity has been a priority issue in global ecology, with a growing body of legislation requiring compliance; yet compliance is not going to be easily demonstrated from the 'snapshots' of short-term survey [2]. Teasing-out the natural assemblages in the plankton is, however, a task that has occupied the CPR team for more than half a Century, from the days of Fraser's 'Lusitanian fauna' [3], through Colebrook's landmark application of principal component analysis to the problem in the early '60s [4], to the amazingly coherent pan-Atlantic patterns of zooplankton diversity that are now emerging from the work of Beaugrand. Based on 108 copepod taxa separately counted over 40 years by CPR analysts [5], the mean pattern of copepod diversity (Figure 1) already suggests that present hypotheses (eg of a progressive increase of diversity from the poles to the tropics or of the control of diversity by upper-ocean thermal structure) are insufficient to explain spatial patterns of diversity at a mesoscale level. And the variations with time of this pattern are already informing the key issue of the biodiversity debate ----whether and to what extent climatic or anthropogenic effects are at work.

It is some achievement, and even for something as venerable as the CPR, such utility is the only sure key to survival. ☋

References:

1. Bainbridge, V and G. A. Cooper, 1971. Populations of Sebastes larvae in the North Atlantic. Res. Bull. Int. Commn. North. Atlant. Fish., 8, 27-35.
2. Longhurst, A. 2000. Letter to the Editor. Oceanography, 13.
3. Fraser, J. H. 1962. Nature adrift-the story of marine plankton. Foulis and Co. London, 178pp.

4. Colebrook, J. M., 1964. Continuous Plankton Records: A principal component analysis of the geographical distribution of zooplankton. Bull. Mar. Ecol. 6, 78-100.

5. Beaugrand G., Reid P.C., Ibanez F., Planque B., 2000. Biodiversity of North Atlantic and North Sea calanoid copepods. Marine Ecology Progress Series. 204: 299-303.

Climate and Fish; a GLOBEC related research programme

By Harald Loeng
Programme co-ordinator

The Institute of Marine Research, Bergen, Norway established a new research programme called "Climate and Fish" in 2000. The Programme was partly a continuation of the "Mare Cognitum" programme, but the new programme has more focus on the impact of climate variability on fish population parameters. Some of the questions we had when we started the programme were:

- How does marine climate influence recruitment, growth and migration of fish?
- Can we predict climate variability?
- How can climate/fish relations be included as an assessment tool?
- What is the role of zooplankton in a climate/fish relation?

The first part of the programme will end in 2004, but a second part will last untill the end of 2008. This brief article describes the objectives and gives a summary of some of the involved projects

The main objective of the programme is *to understand and quantify the role of climate variability and its implications for the dynamics of the marine ecosystems*. The sub goals are:

Describe, understand, and quantify the state and variability of marine climate, and develop methods for prediction of regional climate

- Prepare reliable predictions for climate development in Norwegian waters
- Understand relations between global and regional climate change
- Develop numerical models in order to investigate processes controlling the strength of the thermohaline circulation.

Quantify the direct and indirect impact of climate on recruitment, growth and distribution of commercial fish stocks

- Establish quantitative relations between variability in climate and population parameters of fish
- Establish quantitative relations between climate variability and plankton biomass and distribution
- Quantify the role of plankton in relation to growth, recruitment and migration of fish
- Further development of coupled numerical models in order to quantify production and

First Announcement & Call for Papers
3rd International Zooplankton Production Symposium

Sponsored by ICES, PICES and GLOBEC
May 20-23, 2003 Gijón, Spain

The main goal of the Symposium is to define the current 'state of the art' of zooplankton ecology and to determine key research initiatives to be pursued in the 21st century. The sponsorship of the meeting reflects the role of zooplankton in food chain dynamics, biogeochemical cycles, climate variability and global change. Although local, regional and global contributions are solicited, comparative studies between ocean basins are particularly encouraged. Several ongoing research programs within ICES and PICES as well as national and regional GLOBEC and JGOFS research efforts have been running for many years and 'synthesis' papers are especially welcome.

Scientific Programme

Papers are invited on the following topics:

- Physical variability and zooplankton population dynamics
- Role of zooplankton in biogeochemical cycles
- Climate influences - what are long-term zooplankton data sets telling us?
- New approaches to zooplankton modelling
- Progress in molecular biology
- Application of new technologies
- Comparative life histories and life cycles of zooplankton populations within and between the North Pacific and North Atlantic.
- Role of microzooplankton in the sea

Two sessions will run concurrently each day and each session will include one or two keynote speakers followed by contributed papers. For all sessions, poster submissions are encouraged and ample time will be allocated for poster viewing both during the day and during evening social events.

It is expected that the meeting will result in the publication of selected papers in a special issue of an international journal to be announced. The 2nd Zooplankton Production Symposium resulted in the publication of 45 papers in the 1995 ICES Journal of Marine Science 52:1-773.

Convenors

The Symposium has three Convenors representing the three sponsors: Dr. Roger Harris (Chairman, GLOBEC Scientific Steering Committee), Dr. Tsutomu Ikeda (Chairman, PICES Biological Oceanography Committee) and Dr. Luis Valdés (Chairman, ICES Working Group on Zooplankton Ecology). The Organising Committee also includes Dr Peter Wiebe (U.S.A.) Dr William T. Peterson (U.S.A.) and Dr Serge Poulet (France)

Pre-Registration

A Final Announcement with detailed scientific and logistic information will be circulated in February 2002. Please pre-register with us if you are interested in this Symposium and would like to receive the Final Announcement. The on-line Pre-Registration function will be activated on the PICES Home Page http://www.pices.int/ on November 1, 2001.

Information

Current information about the Symposium is available on the websites of all the sponsoring organizations:

PICES **http://www.pices.int/**
GLOBEC **www.globec.org**
ICES **http://www.ices.dk/**

distribution of phyto- and zooplankton in relation to climate variability

Some of these goals may seem a bit ambitious, but that is necessary in order to obtain a understanding of some of the processes and relations that are of importance in this context.

Research projects

The programme has more than 20 projects, but not all of them have relevance to GLOBEC. There are four projects that study climate variability and its causes, and climate processes. All these projects have financial support from EU or the Norwegian Research Council. The impact on fish stocks is studied in several projects. The main impact project within the programme is called *"Variation in space and time of cod and other gadoids: the effects of climate and density dependence on population dynamics"*, which is carried out in collaboration with the University of Oslo. The objective is to increase the understanding of temporal and spatial dynamics of cod and other commercial gadoid species, including the influence of environmental variability on population parameters, and make this knowledge available in assessable form for fisheries management. An other project called *"Linking hydrographic frontal activity to ecosystem dynamics in the North Sea and Skagerrak: Importance to fish stock recruitment"* will investigate seasonal and interannual variability in the frontal regimes of the Skagerrak/North Sea region through the analysis of satellite data and relate these frontal characteristics to the recruitment variability of fish stocks. A third project that should be mentioned is *"Fishery, Earth Observations, Modelling and Prediction"* which focuses on how satellite observations can be used in order to achieve a better understanding of relations between regional climate variability and fish population parameters. There are also a few other climate/fish relevant projects that are not specifically mentioned here.

There is presently only one project that focuses on the role of plankton. The project called *"The role of zooplankton in the Barents Sea food web related to cod"*. The objective is to quantify the role of zooplankton in the diet of cod in relation to the total amount of zooplankton in the Barents Sea. The project also studies the ecological balance between zooplankton, plankton feeders like capelin and herring, and cod. A couple of new projects on the role of zooplankton are planned to start early 2002. If these projects get funded, the programme will be rather complete in order to obtain its objectives. ☙

more information from www.globec.org

Calanus-Cod Interactions

by Ken Drinkwater and Ken Frank

DFO, Bedford Institute of Oceanography, Canada

Calanus finmarchicus has been the main focus of several GLOBEC studies including the Trans-Atlantic Study of *Calanus* (TASC) program. One of the justifications often given for such programs is that *Calanus* is an important food source for Atlantic cod, the assumption being that more *Calanus* results in more and bigger cod. Studies of the relationship between *Calanus* and cod on the Scotian Shelf (Drinkwater et al., 2000) have shown surprising results, however. An exploratory correlation analysis between zooplankton abundance and cod recruitment, survival and growth was carried out. The zooplankton data were collected by the continuous plankton recorder (CPR), which is towed at approximately 7-m depth from commercial ships at regular monthly intervals along fixed routes. Data were averaged over the northeastern and southwestern portions of the Scotian Shelf. They were available from 1961-1975 and 1991 to present, as they were not sampled during 1976-1990. The abundance of *Calanus finmarchicus* (averaged over stages 1-4 and over stages 5-6) were compared to cod abundance in the southwestern (4X) and northeastern (4VsW) Scotian Shelf, obtained from the virtual population analysis estimates. Results indicate a statistically significant negative relationship between the early stages (1-4) of *Calanus finmarchicus* and the recruitment and survival of cod on the northeastern Scotian Shelf. The survival is defined by the number of recruits per unit spawning stock biomass. The correlation coefficients increased when the stage 1-4 *Calanus finmarchicus* were related to the residuals from a Ricker stock and recruitment relationship. The *Calanus* were accounted for over 50% of the variance in the Ricker residuals (Fig. 1).

This negative relationship between zooplankton and fish is surprising but not unique. Cushing (1995) noted that North Sea herring exhibited a negative relationship with *Para/Pseudocalanus* abundance. He suggested the possibility that the herring may have depleted the zooplankton through predation but other possibilities were acknowledged. Although ruling out advective effects on the zooplankton through the data analysis that he performed, he added that the changes in zooplankton occurred simultaneously with large changes in ocean climate, thus the negative relationship with herring recruitment may not have been direct but indirect through another unknown factor. Cushing (1995) also mentioned an inverse relationship between Acto-Norwegian cod recruitment and measured total zooplankton biomass

(mainly *Calanus*) in the region although it was not considered statistically significant (p=0.07 and hence slightly above the generally accepted significance level of 0.05). Gaard (1998) described an apparent inverse relation between *Calanus finmarchicus* abundance and cod recruitment on the Faroe Shelf. *Calanus* dominate the offshore waters around the Faroe Islands in the spring and summer while the a large number of smaller neritic zooplankton species, mainly copepods *Temora longicornis* and *Acartia longiremis*, occur on the shelf. Although *Calanus* form an important prey species, the smaller neritic species appear to be more important to the feeding of cod larvae. During the 1990s, *Calanus finmarchicus* in certain years dominated the shelf communities and the abundance of the neritic species declined. In such years cod recruitment tended to be low. In years when the *Calanus* were less abundant on the shelf, the cod recruitment was higher. The preference for *Calanus* is strongly size dependent and the negative association between recruitment and *Calanus* is driven by the need for other smaller zooplankton at the early larval stages.

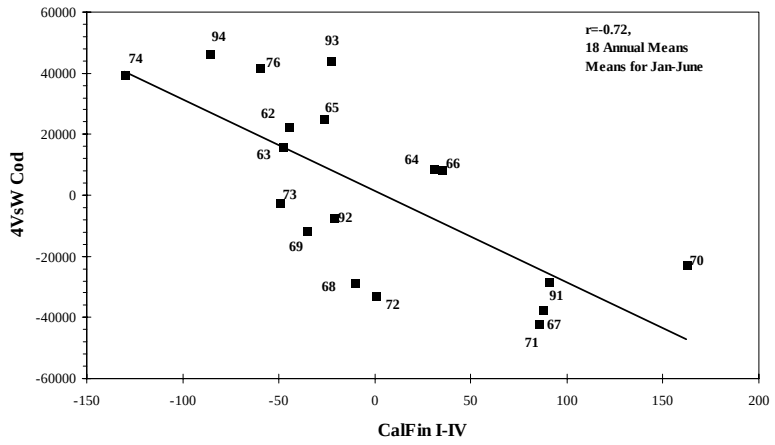


Fig. 1. The relationship between the residuals from the Ricker stock-recruitment relationship for 4VsW cod stock and the abundance of stage (1-IV) of *Calanus finmarchicus* in the northeastern Scotian Shelf.

What does a negative relationship between recruitment and survival and the early stage *Calanus* mean for the Scotian Shelf? One possibility is through predation of the *Calanus* by the cod as suggested by Cushing (1995) for North Sea herring. We believe this to be highly unlikely, however, given that the relative abundance of the fish larvae and *Calanus*. While acknowledging the cod may have an impact locally in some regions, the large-scale impact is expected to be small. Indeed, this conclusion is supported by estimates of food consumption by larvae from field studies on a variety of species that indicate larvae have little impact on the abundance of their prey (see Frank and Leggett, 1994).

Another possibility is that other zooplankton species are more important than *Calanus*, especially at the earlier life stages, and that these species are negatively correlated with *Calanus* as has been suggested for the Faroes. Indeed, recent field studies by MacLaren and Avendaño (1995) and MacLaren et al. (1997) on Western Bank in the autumn indicate that the preferred prey of cod larvae was *Pseudocalanus* spp. and Paracalanus *parvus*. This dependence differs from the expected importance of *Calanus finmarchicus* for cod larvae in the region suggested by the earlier work of Brander and Hurley (1992) and by Runge (1988). To test the possible importance of *Paracalanus* and *Pseudocalanus* we correlated their abundances from the CPR data for the Shelf with the cod and *Calanus* abundances. Correlations between these species were not significant between either the two stage categories of *Calanus finmarchicus*, however. Also, recruitment and survival of the cod stocks were generally negatively correlated with both *Pseudocalanus* and *Paracalanus* abundances but only the relationship between *Pseudocalanus* and 4VsW cod was statistically significant (p=0.05).

At this stage no clear explanation of the negative relationship between *Calanus* stages 1-4 and cod recruitment and survival on the eastern Scotian Shelf can be given. While the time series are short and there is the possibility of coincidence, it is interesting that such results are not unique. The result draws attention to the assumption, which is frequently made, that higher abundance of *Calanus finmarchicus* will result in higher cod recruitment. It cannot be taken for granted and needs to be established, region by region. In the meantime, these results are intended to help researchers to focus their thinking and plan future fieldwork to resolve this apparent paradox.

References

Brander, K. and P.C.F. Hurley. 1992. Distribution of early-stage Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and witch flounder (*Glyptocephalus cynoglossus*) eggs on the Scotian Shelf: a reappraisal of evidence on the coupling of cod spawning and plankton production. Can. J. Fish. Aquat. Sci. 49: 238-251.

Cushing, D.H. 1995. The long-term relationship between zooplankton and fish. ICES J. mar. Sci. 52: 611-626.

Drinkwater, K., K. Frank and B. Petrie. 2000. The effects of *Calanus* on the recruitment, survival and condition of cod and haddock on the Scotian Shelf. ICES C.M. 2000/M:07, 18 p.

Frank, K.T. and W.C. Leggett. 1994. Fisheries ecology in the context of ecological and evolutionary theory. Annu. Rev. Ecol. Syst. 25:401-22.

Gaard, E. 1998. The zooplankton community structure in relation to its biological and physical environment on the Faroe Shelf, 1989-1997. ICES CM 1998:R:7, 21 p.

McLaren, I.A. and P. Avendaño. 1995. Prey field and diet of larval cod on Western Bank, Scotian Shelf. Can. J. Fish. Aquat. Sci. 52: 448-463.

McLaren, I.A., P. Avendaño, C.T. Taggart and S.E. Lochmann. 1997. Fish. Oceanogr. 6: 250-265.

Runge, J.A. 1988. Should we expect a relationship between primary production and fisheries? The role of copepod dynamics as a filter of trophic variability. Hydrobiologia, 167/168: 61-71.

This Newsletter is produced by the ICES/GLOBEC programme coordinator: keith@ices.dk

Remember, backnumbers of this Newsletter are on the website: **http://www.ices.dk/newslet**

The Copenhagen Spring Collection

Not a fashion event, but a week of related Working Groups and Workshops from 14-19 April 2002. The aim was to put three events adjacent to each other, to encourage cross-participation, while minimising the travel costs. It had even been suggested that a further two groups should be included, but the dangers of "meeting fatigue" ruled this out. The meetings in Hillerød take place in a conference centre (http://www.pharmakon.dk), because the ICES HQ facilities are already in full use.

Please contact Keith Brander (keith@ices.dk) for further information about attending these meetings.

Meeting title	Convenors	Location	Dates (2002)
Workshop on the Transport of Cod Larvae	J. Quinlan, USA, B. Aadlandsvik, Norway and M. St. John, Germany	Hillerød, Denmark	14–17 April
Working Group on Cod and Climate Change	K. Drinkwater, Canada	Hillerød, Denmark	17 – 19 April
Working Group on Recruitment Processes	P. Pepin, Canada and R.D.M. Nash, UK	ICES HQ	18–19 April

First off is the **Workshop on the Transport of Cod Larvae** [WKTCL], whose Terms of Reference are to:

- couple circulation models with early life history models to determine the physical and biological processes responsible for the transport or retention of cod larvae;
- develop, if possible, interannual transport indices based on physical variables that reflect the magnitude of the larvae drift or retention;
- attempt to incorporate the interannual transport indices into the cod assessment process;
- collate and synthesize existing direct and indirect observational information about egg and larval transport for all stocks and years (direct information is egg and larvae surveys while indirect information includes unusual distribution and migration in later life, elemental analysis of otoliths, genetic identification, and meristic characters)
- evaluate the effects of variations in transport during early life on subsequent recruitment.

Drift of cod larvae within and across stock boundaries has significant consequences for many stocks. The drift of larvae from Iceland to Greenland and their subsequent return migration to spawn is a classic example. Such transport is also believed to affect recruitment in several other stocks and the workshop was established to explore transport processes and their role in the life histories of these stocks. In particular, we intend to use circulation models to explore the physical processes that lead to the variability in transport of larvae. Comparisons will be made between different regions and stocks.

Rapid advances in circulation models at a variety of scales have improved the prospect of developing scenarios for changes in circulation under different conditions of climate change. There are also improving prospects for operational now-casting and forecasting of circulation. Can larval transport indices derived from model results be used to improve fish stock assessments?

The **ICES/GLOBEC Working Group on Cod and Climate Change** (WGCCC) meets immediately after the Transport Workshop, in a joint session with the **Working Group on Recruitment Processes** (WGRP). The Terms of Reference are to:

- continue with the review and evaluation of work carried out to date on Cod and Climate Change including results and possible follow-up work from the Workshop on Transport of Cod Larvae
- plan and prepare workshops over the next two years in order to:
- coordinate the synthesis work and the preparation of material for the book
- continue the evaluation of studies on Long-Term Climate Change and Prediction;
- foster further cooperation and interaction with the Working Group on Recruitment Processes, the Study Groups on the Incorporation of Process Information into Stock-Recruitment Models and the Study Group on Modelling of Physical/Biological Interactions;
- to explore cooperation and collaboration with the CCCC within PICES regarding climate and shelf fisheries. Examples include, how to determine the effects of climate change on fisheries or the incorporation of environmental information into stock assessments
- determine the Working Group's contribution to the GLOBEC Open Science Meeting in China in October 2002.
- prepare a summary report listing relevant marine bio-ecological variables and indicators suitable for operational use.

The Terms of Reference of the **Working Group on Recruitment Processes** are to:

- review multidisciplinary projects dealing with recruitment research, with attention to providing a synthesis of the projects and highlight unresolved issues which deserve further consideration;
- consider the results of the SGPRISM's examination of the STEREO project, along with concurrent and subsequent investigations;
- evaluate an analysis of simulations exploring the effects of stock structural factors on the parameters of stock-recruitment relationships with a view to preparing a case for a Study Group on evaluating the impact of these factors on stock projections, and in the light of results from the Workshop on the Transport of Cod Larvae held immediately prior to the meeting;
- consider a synthesis of the 2000 Theme Session on "Spatial and Temporal Patterns in Recruitment Processes" to be prepared by the Session's Convenors as well as a synthesis of recruitment issues presented at the SAP symposium held in December 2000;
- identify areas in the study of recruitment processes where sufficient progress has been achieved with the objective of developing a workshop dealing with specific case studies;
- review the development of new approaches or techniques used in the study of factors and processes that influence the development and survival of fish eggs and larvae in relation to recruitment of the formation of year-class strength. ♋