

Fol. 41C

Oceanography Committee

Fiskeridirektoratet
Biblioteket

ICES CM 1998/C:10

REPORT OF THE
ICES/GLOBEC WORKING GROUP ON COD AND CLIMATE
CHANGE

Woods Hole, USA
7-8 May 1998

This report is not to be quoted without prior consultation with the General Secretary. The document is a report of an expert group under the auspices of the International Council for the Exploration of the Sea and does not necessarily represent the views of the Council.

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Palægade 2-4 DK-1261 Copenhagen K Denmark

3108/ b 5015

TABLE OF CONTENTS

Section	Page
1 INTRODUCTION AND TERMS OF REFERENCE	1
2 REVIEW OF 1997/98 ACTIVITIES	1
2.1 The ICES/GLOBEC Programme Office.....	1
2.2 Report on the Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic.....	2
2.3 Workshop on Applications of Environmental Data in Stock Assessment	2
2.4 International GLOBEC Meeting.....	3
2.4.1 Discussion arising from the report on the International GLOBEC meeting	3
2.5 Backward Facing III Workshop	4
2.6 Review of Regional GLOBEC Programmes	4
3 THE WGCCC 5-YEAR PLAN	5
3.1 Background	5
3.2 Where have we come from since 1993?.....	6
3.3 The Major Components of the CCC 5-Year Plan.....	8
4 OTHER BUSINESS AND DISCUSSIONS	11
4.1 ICES involvement within GOOS.....	11
4.2 AMAP	11
4.3 Other Issues.....	12
5 RECOMMENDATIONS AND TERMS OF REFERENCE FOR FUTURE MEETINGS	12
APPENDIX 1 – PARTICIPANTS.....	15
APPENDIX 2 – ICES REPORTS AND PUBLICATIONS RELATED TO GLOBEC	16
APPENDIX 3 – REQUEST FOR THEORETICAL ECOLOGISTS (BY STIG SKRESLET).....	18
APPENDIX 4 – RESEARCH RESULTS (BY STIG SKRESLET)	19

1 INTRODUCTION AND TERMS OF REFERENCE

The Working Group on Cod and Climate Change (WGCCC) met at the Woods Hole Oceanographic Institution, Woods Hole, Mass., 7–8 May, 1998, under the chairmanship of Ken Drinkwater (Bedford Institute of Oceanography, Dartmouth, Canada). There were 14 participants from 6 countries (Canada, Denmark, Germany, Norway, UK and USA) and the ICES/GLOBEC Coordinator. Apologies were received from L. Valdes (Spain), J. Boje (Denmark) and B. de Young (Canada). A list of participants is provided in Appendix I.

Immediately prior to the working group meeting, the ICES Backward Facing III Workshop (4–6 May) was held and on May 9 the ICES/GLOBEC North Atlantic Regional Coordination Group met. Several participants of the working group took part in one or both of these other meetings.

The terms of the reference (C.Res.1997/2:7) for the meeting were:

- a) review and evaluate work carried out to date on Cod and Climate Change and to produce a detailed implementation plan for 1998/99, and an outline for the following three years, including
 - (i) methods for applying environmental data in stock assessments using specific examples where possible and developing a dialogue with the Working Groups on Comprehensive Fishery Evaluation, Zooplankton Ecology and Shelf Seas Oceanography on the kind of data required;
 - (ii) methods for longer term stock predictions, which make use of results from the 1997 ICES/GLOBEC Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic (WKPDOC);
 - (iii) new results on biological processes and coupled physical/biological models from the 1997 ICES 'Recruitment' Symposium, the 1997 ICES/GLOBEC Theme Session on the Trans Atlantic Study of *Calanus* and regional and national GLOBEC programmes;
- b) develop plans for ICES/GLOBEC Backward-Facing IV Workshop in 1999;
- c) Consider the future work programme in relation to the remit of the Oceanography Committee and the ICES 5-year Plan, including co-operation with other Working Groups.

WGCCC will report to the Oceanography Committee at the 1998 Annual Science Conference.

2 REVIEW OF 1997/98 ACTIVITIES

The working group began by reviewing related activities over the past year.

2.1 The ICES/GLOBEC Programme Office

K. Brander informed the working group that funding for his position as GLOBEC/ICES Coordinator is confirmed through to July 1998, but that he expects to sign a new contract soon for an additional year beginning 1 August 1998. Funding for next year will come from Canada, US, UK, Iceland and TASC through the EU. The GLOBEC position is well integrated into the ICES Secretariat and falls under their Science and Processes section. Due to management problems and staff shortages caused by retirements and illness, the Coordinator has spent well over 25% of his time during the past two years on ICES business unrelated to GLOBEC or CCC issues. In recognition of this, ICES provided a 3-month term position that was used to assemble literature for the review of cod life histories. In addition, ICES waived the overhead fees which were in the planned budget. The rest of the Coordinator's time has been spent preparing for the workshops, assisting chairmen and convenors, producing reports and Newsletters (three for TASC and two for ICES/GLOBEC), numerous meetings, making links between programmes.

The Coordinator pointed out that data management and accessibility for ICES/GLOBEC activities is an integral part of the ICES database development. This is progressing more rapidly in some areas than in others. The oceanographic database is comprehensive and accessible while the environmental (pollution) and fisheries databases are not yet as complete and easy to use. Improvements are being worked on, but there are many difficult, interrelated problems to deal with.

The Coordinator's other commitments have meant that the GLOBEC information and data are not as up to date as they could be. Technical support would facilitate a more rapid response time. Discussions following the presentation centered upon three specific databases. Ram Myers from Canada has assembled a large worldwide database on recruitment and stock abundance. M. Fogarty inquired if there had been any discussion regarding ICES taking over this database. Keith said there was none to his knowledge. One problem associated with such a move would be the amount of time required to update it regularly. In response to questions about a database containing information from all standard fisheries surveys around the North Atlantic, Keith indicated that there was no such database within ICES at present. While ICES does have some of the European survey data, it has none from North America. One possibility would be to have a distributed database by identifying links on the web. A tagging database, which had been recommended at a past CCC meeting (ICES CM 1996/A:10), was also discussed. Keith felt that development of such a database was not feasible given his present workload, unless he was provided technical support. The strategy for database development, set out in the report of the Cod and Climate Database workshop, stressed that it should be driven by user needs. To date there have been a number of individual enquiries, which have been dealt with by either supplying the necessary information, or providing a link to a known source. Other data sets have been assembled and disseminated for use by workshop participants.

2.2 Report on the Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic

K. Drinkwater reported on the Workshop held in Copenhagen in September 1997. A brief summary appeared last year (ICES CM 1997/A:13), however, a full report has not yet been submitted. [The full report has now appeared and can be downloaded from the ICES web site (www.ices.dk/committe/occ/wkpdoc98.doc)]. The terms of reference were:

- a) study the decadal-scale ocean climate fluctuations of the North Atlantic, particularly:
 - (i) consider the role of the large-scale pressure anomalies (e.g., the North Atlantic Oscillation),
 - (ii) study the causal relationship between temperature and other physical processes,
 - (iii) evaluate the scientific basis for long-term (decadal-scale) ocean climate predictions,
 - (iv) study the links between decadal-scale climate fluctuations and growth and recruitment in cod stocks of the North Atlantic.

There were 17 participants from 9 ICES countries. The participation of two meteorologists, Dr Peter Lamb (USA) and Dr Mojib Latif (Germany) was noteworthy as inclusion of meteorologists and oceanographers together to tackle the problems of climate variability and prediction has been all too rare in the past. There were three sessions, the first on observations of and mechanisms behind decadal-scale variations of ocean climate. The second was on predicting ocean climate and the third on ecosystem responses to climate fluctuations. Many of the presentations focused upon the large-scale atmospheric changes as reflected in the North Atlantic Oscillation or NAO. The NAO index is expressed as the wintertime sea level pressure difference between the Azores and Iceland or more recently Lisbon and Greenland.

K. Drinkwater made three main points. First, although variability in air and sea temperatures, winds, and ice cover have all been related to changes in the NAO with especially strong relationships in the Labrador Sea and the Barents Sea, presentations indicated that the pathway linking the NAO to climate variables appears to occur through both air-sea heat exchanges and advection of water masses. Their relative importance varies spatially and in most areas further studies are required to determine the dominant process. Second, several ecosystem changes had been related to changes in the NAO index with examples from the open ocean, on the shelves and in the very near shore coastal communities, however, the underlying mechanisms generally remained elusive. Third, prediction using persistence and present modelling efforts was not encouraging.

H. Loeng noted apparent differences in the atmospheric response to the same NAO index over time. This was acknowledged by others and felt to be an important avenue for future work.

2.3 Workshop on Applications of Environmental Data in Stock Assessment

K. Brander reported on the Workshop held in Bergen in March 1998. The report is near completion but has not yet been submitted. [The full report has now appeared and can be downloaded from the ICES web site (www.ices.dk/committe/occ/wkedsa98.doc)]. The terms of reference were:

- a) explore growth, mortality and distribution of juvenile and adult fish in relation to feeding conditions and the physical environment, particularly in relation to the influence of temperature and food abundance on stock assessment parameters as:
 - (i) natural mortality
 - (ii) spawning stock biomass,
 - (iii) fecundity,
 - (iv) VPA;
- b) evaluate the sensitivity of stock assessment models to environmental data;
- c) consider the role of statistical techniques, including exploring autocorrelations.

While the attendance outside of Norway was disappointing (2 from Canada, 1 from Denmark and 1 from Spain) the workshop did produce some useful material. They first identified ways in which improvements can be made in applying environmental data to stock assessments. These included providing appropriate meteorological, oceanographic and biological datasets; developing tools for applying environmental information to actual current stock assessments; evaluating sensitivity of stock assessments to environmental data; identifying promising examples for further study; considering the consequences of environmental factors on strategic management and long-term changes in the fisheries and the ecosystem; and developing "environmental indices" and showing how these can be applied. Discussions on how environmental data can be applied in fisheries assessments included both direct and indirect effects on stock assessments and catch forecast as well as effects on strategic management. It was felt that assembling and maintaining zooplankton datasets would be useful and communications with the Working Group on Zooplankton Ecology in these matters was encouraged. References and examples of where environmental information is being used in stock assessments or where the stocks are sensitive to environmental factors were assembled. Emphasis was on cod and included the Northeast Arctic, Baltic and Greenland stocks but examples from other stocks in waters outside of the ICES area were also discussed. Finally, statistical techniques, in particular those dealing with autocorrelation and prediction were explored. Incorporation of environmental information into fisheries assessments can result in better understanding of past variability and can lead to necessary improvements in future management, but a considerable amount of work is still needed to bring this about.

2.4 International GLOBEC Meeting

K. Brander reported on the Open Science Meeting for International GLOBEC held in Paris during March 1998. Over 200 scientists from 35 countries attended the meeting. There were discussions sessions on the international implementation plan and on regional perspectives, with one session concentrated on the ICES/GLOBEC programme. A number of suggestions were made about Cod and Climate Change including incorporating benthos into marine ecosystem studies with emphasis upon interactions between plankton and the benthos. Also, it was felt that more work was needed on the links between fish and zooplankton. The implementation plan for International GLOBEC will be published in the near future and will include the proposed Cod and Climate Change five year plan as the regional implementation plan for the North Atlantic.

It was generally felt that a synthesis of our present understanding of cod variability and the gaps in our knowledge is needed. Recruitment is sensitive to very small changes in mortality at the larval stage. Reliable methods of early detection of such small changes in mortality are required. Recruitment is also a very dynamic, non-linear process and linear regression models that have traditionally been used to relate recruitment variability to environmental factors, while useful, are not adequate.

2.4.1 Discussion arising from the report on the International GLOBEC meeting

The possibility of prescribing key measurements and a common framework amongst GLOBEC programmes, in order to facilitate intercomparisons between regions, was discussed. With regard to zooplankton, the Zooplankton Ecology Working Group has been working in this direction through their publication of a zooplankton manual. Intercalibration between equipment is needed so that results are comparable. For example it would be useful to know the relative fishing power of the Continuous Plankton Recorder and bongo nets. Opinion was divided on how far it was feasible go with such intercalibration and to what extent it should be user-driven, i.e., carried out when researchers needed to make comparisons. It would be useful to have the results of the ICES plankton intercalibration workshops fully written up.

On the fisheries side the opinion was expressed that there are too many different gear types to adopt standard measurements. While recommendations could be made for standard fishing gear, this may impede the development and use of new technology and gear development..

Concern was expressed on the possible discontinuation of long-term zooplankton time series, especially those collected by Russian scientists. The WGCCC generally supports the continuation of these time series, but it felt that it could best help by encouraging their use and showing their worth. It was suggested that a future workshop in Murmansk, which focused on long-term zooplankton time series would be timely and could bring attention to this issue. In several countries, the high cost of labour has resulted in some zooplankton time series not being maintained, even when the actual samples are collected. Development of methods to speed up processing and analysis would help and this is an area which the International GLOBEC programme should be encouraged to develop.

2.5 Backward Facing III Workshop

The Backward Facing III Workshop: Ocean Climate of the NW Atlantic during the 1960s and 1970s and Consequences for Gadoid Populations was held immediately prior to the WGCCC meeting at Woods Hole and attended by 25–30 participants representing Canada, Denmark, Germany, Norway, the UK, the USA. All present at the CCC meeting attended the workshop. C. Werner, one of the co-convenors noted that details of the workshop will appear in an initial draft report, which should be ready by the end of June 1998. The terms of reference for the meeting were:

- a) analyse the 1960s and the 1970s ocean climate in the Georges Bank, Scotian Shelf and Gulf of Maine;
- b) determine the conditions that may have contributed to the formation of outstanding gadoid year-classes during the 1960s and 1970s including
 - (i) differences in 3-D circulation fields of “cold” and “warm” years,
 - (ii) effect of temperature differences on the distribution of predators,
 - (iii) effect of temperature on larval growth rates,
 - (iv) temporal and spatial distribution and abundance of eggs, larvae, juveniles and spawners;
- c) compare the processes that appear to govern interannual variability in gadoid recruitment on Georges Bank and in other areas of the North Atlantic.

Follow-up work is planned and it will be presented at the Backward Facing IV workshop.

2.6 Review of Regional GLOBEC Programmes

Brief reviews were provided on the status of many of the regional GLOBEC programmes.

A new phase of US GLOBEC has started in the Pacific on the Alaska and California Current systems with modelling and retrospective analyses. Process studies are to begin in 1999 with an announcement of opportunities to be made in the near future. The US will participate in the International GLOBEC initiative in the Southern Ocean with a multiship field study during 2001. Notification of funding for phase 3 of the east coast US GLOBEC is underway and the programme is scheduled to be on the water next year. The groundwork is being laid for phase 4, which will focus on synthesis of the information gathered during the earlier studies. Funding has been holding steady.

A poster summarising some of the results from the East Coast Canadian GLOBEC Programme was on display during the meeting. A national Canadian GLOBEC meeting was held in January 1998 with results presented from both the Pacific and Atlantic components. The programme has largely emphasised retrospective analyses and modelling with only a small field study due to limited funding. Available funding is for 4 years and appears to be holding steady. Planning for the next phase of Canadian GLOBEC is beginning.

The TASC (Trans Atlantic Study of *Calanus*) has a very active programme and held two meetings in the last year with over 50 participants attending each. There was a TASC session at the ICES Symposium on Recruitment held in Baltimore in September 1997 with several papers presented. An ICES Symposium on TASC is scheduled for Tromsø, Norway, in August 1999. K. Brander has been encouraging TASC to invite papers on applications to fisheries for this symposium, especially since this was one of the justifications for undertaking the study in the first place. The Chairman will write the organisers of the symposium to reinforce this request and express the CCC interest. Scientists involved in TASC will play a leading part in the CCC Backward Facing IV Workshop on the "Gadoid Outburst in the North Sea" scheduled for 1999.

MARE COGNITUM, the Norwegian GLOBEC programme, is at the end of phase I and a summary of the results is in preparation. There is a request for further funds to look at historical data. Norway is involved in an EU project to study inflow into the Nordic Seas (VEINS). A decision on the continuation of MARE COGNITUM will be made before the end of 1998.

The EU funded a meeting in Germany in October 1997 to write the science plan for European GLOBEC. This science plan is presently being printed. It is hoped that the programme will start in 1999.

Germany is involved in several GLOBEC programmes, including the studies of the Southern Ocean, CORE, TASC and European GLOBEC. They are also involved in SPACC, a study that includes both retrospective and comparative analyses from the Baltic to the Benguela Current. There is an initiative to form a German GLOBEC programme. The first meeting was in November 1997 with approximately 50 participants. Three target areas were discussed; the Baltic Sea, the North Sea and the shelf break area of the eastern North Atlantic. The North Sea will be included in the eventual proposal but only one of the other two areas will be selected. In the Baltic and North Sea areas the likely focus is on cod, sprat and zooplankton. It is hoped to undertake these studies within an international context. Federal financial support for this programme is at present unknown but it is hoped that they will support a 2 to 3 year programme. Continuation of the CORE programme in the Baltic will be funded, although the nature of the future studies is not known at this time. Another related programme that has received funding is STORE (Stock and Recruitment) whose objectives include, determination of the stock and recruitment for Baltic cod and sprat in relation to hydrographic conditions, development of predictive recruitment models for central Baltic cod and sprat stocks and estimation of the minimum biological acceptable level of spawning stock biomass for central Baltic cod, taking into account the variable environment and existing stock structure.

The UK GLOBEC programme has been resurrected under the title "Marine Productivity" and will be funded. The initial phase, which will be for 2 years, will include data mining, model building, retrospective analyses and hypothesis testing. If this phase is deemed promising, further funding is likely for another 3 years. Any major field component in the second phase would likely focus on the Irish Sea. At present no target species has been identified. A new steering committee is presently being formed whose duties will include the writing of the implementation plan. One consequence of the decision to fund the UK GLOBEC programme is that the future of the Plymouth office for the International GLOBEC programme has been secured.

Denmark is involved within GLOBEC initiatives such as CORE and STORE. While scientists within the country have discussed the possibility of developing a Danish GLOBEC, their relatively small numbers make it logistically difficult to undertake another major initiative at this time.

A discussion of a possible Baltic Sea GLOBEC study focusing upon retrospective analyses will be held in Warnemuende, Germany, in November 1998. A Spanish GLOBEC study has been funded and the French GLOBEC is underway. Iceland has contributed to the ICES/GLOBEC office and while they are extremely interested in GLOBEC, their small number of scientists and prior commitments prevent a major GLOBEC study being undertaken at the present time.

3 THE WGCCC 5-YEAR PLAN

3.1 Background

Dr H. Loeng, chairman of the Oceanography Committee, provided the working group with information on the recent changes in ICES and background on the 5-year plan. With the establishment of the new ICES framework in November 1997, the Science Committees were requested to develop a scientific strategy and plan of action in order to improve the way in which the Committees function. The WGCCC falls under the Oceanography Committee whose area of responsibility is

the physical, chemical and pelagic biological oceanography, especially processes relevant to living marine resources and environmental quality. They include such issues as impacts of climate variability and the physical, chemical and biological fluxes in coastal areas, shelf seas and the open ocean. The ICES Consultative Committee requested the Science Committees to develop a 5-year plan, clearly identifying long-term goals. The Oceanography Committee subsequently asked its associated working groups to develop their own 5-year plan. Specifically to: (i) identify critical knowledge gaps and scientific priorities; (ii) identify priorities to address issues that require the attention of other scientific committees; (iii) take into account the long term needs of the advisory function of ICES; (iv) be sensitive to the emergence of new marine science issues; and (v) develop an interdisciplinary programme of work to address the science of marine ecosystems.

3.2 Where have we come from since 1993?

- K. Brander summarised the progress and achievements within the CCC programme since 1993. The presentation was based on the talk he gave at the Open Science Meeting for International GLOBEC (see section 2.4).
- Present fisheries management practices are not working as well as they should. One improvement would be to account for environmental changes. This would be somewhere between the old view of single stock assessments and total ecosystem management. The time-scale for providing advice to management will vary depending upon the particular species or even stock. Within the ICES/GLOBEC programmes in the North Atlantic, attempts are being made to raise the issue of climate effects on fisheries and relate the marine ecosystem and environmental concerns to fisheries management. In particular, coupled physical/biological models are being developed to determine the causes of observed changes in the plankton ecosystem and predict possible consequences of long-term climate change on fisheries and other marine life. It is recognised that application of the scientific results of GLOBEC to policy and management is, and will continue to be, difficult.
- Much of the ICES/GLOBEC programme comes under the banner of Cod and Climate Change, (CCC) which is recognised as the ICES regional contribution to the international GLOBEC programme. Cod are one of the best-studied fish. Their dynamics and interactions are very complex and we may not be able to completely understand the causes of their variability, but comparative analyses, new technologies and carefully thought out experimental designs will help to increase our knowledge and ultimately result in better advice on how to manage the fishery. The CCC Working Group generally meets every second year and sets up a number of workshops to report on specific issues in the interim. These workshops have included retrospective studies of climate and fisheries (the Backward Facing workshops), the role of intermediate-scale physical processes in cod early life and the establishment of a data exchange system. During the last year a workshop on Predicting Decadal Scale Ocean Climate Fluctuations of the North Atlantic took place in September 1997 and one on the Application of Environmental Data to Fisheries Assessments in Bergen in March 1998. The third Backward Facing workshop, looking at coupled changes in the physics and biology of the NW Atlantic during the 1960s and 70s, was held in Woods Hole in May 1998.

An Implementation Plan for Cod and Climate Change was set out by the Working Group in 1993 and has been followed through since then. The plan identified seven areas of work:

- identifying and addressing common “core science”
- exchange of models for development, testing and validation
- coordinated sampling and observation
- coordinated retrospective data analysis
- databases
- special workshops
- theme sessions for meetings
- addressing specific questions to scientists in other disciplines

These have been tackled in a variety of different ways which are outlined in the following table:

Area of Work	Activity or Recommendation	Action taken (within ICES)
Large-scale Models and Boundary Conditions	Development and application of regional-scale, coupled biological/physical models. Strengthen liaison between these regional scale efforts and existing large-scale (basin or global) endeavours.	Theme Sessions in 1994 and 1997. Workshop on Decadal Scale Climate Fluctuations in 1997
	Comparison strengths and weaknesses of existing regional-scale models. Assess several models at a single site, against a single data set.	
Intermediate scale processes	Establish workshop to consider whether and how intermediate scale processes are important in governing cod stock fluctuations in all regions of the North Atlantic.	The AGGREGATION workshop took place in 1994
	Continue development of intermediate scale hydrodynamic models and incorporate key physical and biological processes.	Theme Sessions in 1995 and 1998
	Analysis of commercial fishing effort distribution to infer large-scale long term variations in spawning concentrations related to oceanographic structure under the influence of climatic variation	
Small scale processes	Coordinated research on stratification and turbulence	
Retrospective analysis	Review a) large scale studies of relationships between cod, copepods and climate variables; b) appropriate methods for time series analysis and geostatistics; c) need for and establishment of a centralised database	Database workshop took place in 1995
	Specific question relating to particular past events such as a) 1880's migration of cod from Labrador to New England during the tilefish kill	Backward Facing workshop in 1994
	b) Effects of cold and warm periods in the Barents Sea in the 19th and 20th centuries	Backward Facing workshop in 1996
	c) Climate at West Greenland 1820–1840; d) Large scale, long term evidence of inter-stock exchange in the NW Atlantic; e) CPR records of redfish in the Irminger Sea; catch history of cod at Northern Labrador and Baffin Island as evidence of inter-stock exchange; long term history of the cold intermediate layer on the Canadian banks and their relation to large-scale climate; f) Evidence of historic shifts in cod spawning.	
Analysis of CPR data	a) CPR survey should be expanded to reoccupy North Atlantic routes. New instrumentation should be added; b) design future process studies around the survey to improve interpretation and intercalibrate with other plankton population estimates; c) address specific questions about regional and interannual variability, timing and extent of ontogenetic migrations etc.	Considerable ongoing work within the TASC programme and elsewhere
Sampling and Observation Systems		
Regional Surveys	Coordinated ichthyoplankton surveys of the North Sea	Unsuccessful bid for EU funding (NSIS)
Cod population dynamics	Theme session on variations in growth at all life history stages	Theme session held in 1995

GLOBEC related reports, which ICES have produced, are listed in Appendix II. In addition to these, a number of other working groups (e.g., Shelf Seas Hydrography) also address GLOBEC related issues. Numerous papers by individual scientists also relate to the ICES/GLOBEC programme, but it is difficult to catalogue these. ICES does not fund research and is therefore rarely acknowledged in publications, even when these are intended as a contribution to an ICES programme. The Symposia on Cod and Climate Change and on Zooplankton Production included many papers relevant to GLOBEC and a session during the latter symposium was devoted to GLOBEC. For the past few years a Theme Session at the ICES Annual Science Conference has been devoted to a GLOBEC related subject. Summaries of the discussions and a list of the papers are included in the ICES Annual Reports.

J. Alheit felt that incorporating GLOBEC results into fisheries management is not so difficult, citing examples of pelagic stocks from Peru and Namibia and CORE results used in the assessment of cod in the Baltic. He mentioned that the success of securing research funds in Germany hinges upon making progress in fisheries management issues. K. Brander stated that we must be very careful and honest in terms of what results we promise funding agencies. One problem might be the existence of unpredictable "regime shifts" as is suggested for the North Pacific where there are believed to be rapid shifts from one regime to another within a relative short time period. The nature of the ecosystem appears to change between regimes so that knowledge and understanding gained during one regime may not apply under a different regime.

K. Frank noted the increase in retrospective analyses within GLOBEC and other climate change programmes. He felt this was an adaptation to reduced funding. While much can be gained from mining historical data, it was felt that continuing field studies should remain an essential component of future programmes.

3.3 The Major Components of the CCC 5-Year Plan

Following lengthy discussions, the WGCCC identified 7 major components of scientific research within a new 5-year plan based upon perceived scientific needs and likelihood of success. The word environment in the following text refers to the biological (e.g., plankton, food and predators), as well as the physical and chemical characteristics of the water.

(1) Fisheries Management

Objective: To incorporate environmental information in a quantitative manner into fisheries management strategies and planning.

Justification: Traditional stock assessments which implicitly assume that environmental and ecological conditions are unchanging, are by themselves not sufficient to ensure sustainable fisheries. Incorporation of environmental and ecological variability offers potential of providing additional explanatory power of changes in fish stocks. Fisheries management was considered by the Working Group to include annual stock assessment, risk analyses and long-term management plans.

Specific Activities: Building upon the discussion and recommendations of the Workshop on Applications of Environmental Data in Stock Assessments held in Bergen during March 1998, a follow-up workshop that focuses upon a specific case study is proposed. Using the West Greenland/Iceland Cod example, models of the circulation will be used to develop transport indices for incorporation into fisheries management models. This workshop is planned during the year 2000 or 2001. A workshop on cod growth (see discussion below) will also address some aspects of the inclusion of environmental information into fisheries management.

(2) Retrospective Analyses

Objective: To examine past events or periods as a means of better understanding the links between changes in the environment and fisheries.

Justification: Insights into the response of fish stocks to environmental variability have the greatest chance of success when examining periods of minimal fishing pressure, large climate variability and/or large changes in fish stock characteristics such as growth, recruitment, abundance etc. Acknowledging the usefulness of past retrospective workshops (i.e., Backward Facing I, II and III), the CCCWG decided to continue these types of activities.

Specific Activities: A workshop on the Gadoid Outbreak in the North Sea (Backward Facing IV) is proposed for March 1999. This will explore the increased abundance of gadoid fishes in the North Sea during the 1960s and 1970s and, in particular, the possible role of environmental changes as a causal mechanism. Investigations undertaken as a follow-on to Backward Facing III will also be presented.

(3) Zooplankton-Cod Linkages

Objective: To understand the relative importance of zooplankton in determining the variability in cod abundance and production.

Justification: During recent years many regional and national GLOBEC programmes have focused upon zooplankton dynamics. Efforts are required to establish quantitative links between zooplankton and fish in order to make full use from the fisheries perspective of the information gathered within these GLOBEC programmes. Equally important are establishment of the diet of cod larvae, including the main zooplankton species eaten and the relationship between larval condition and survival, with possible physically induced changes in diet.

Specific Activities: The CCCWG will strongly encourage examination of zooplankton-cod linkages during the Trans-Atlantic Studies of *Calanus* Symposium scheduled for Tromsø, Norway, in August 1999. The Chairman will write a letter to this effect to the convenors of the symposium. In addition a Theme Session at the ICES Annual Science Conference in September 2000 on the linkages between zooplankton and cod will be proposed.

(4) Comparative Analyses

Objective: To undertake comparative studies of life history strategies and interannual variability in growth, distribution, and abundance between cod stocks around the North Atlantic.

Justification: Research in recent years has expanded our understanding of the dynamics of individual cod stocks and some of the causes of interannual variability. Comparative studies between stocks, such as those on growth and recently on recruitment, have provided knowledge that was unattainable from stock-specific investigations. More such studies offer good potential of providing additional significant insights. Areas where such studies were considered beneficial include further examination of growth and recruitment and investigations into distribution and migration. Application of similar analytical methods for different stocks will be encouraged.

Specific Activities: A Workshop on the Dynamics of Growth in Cod is proposed for autumn 1999 or winter 2000. The aim of the workshop will be develop a single growth model for cod that will allow interpretation of information from all parts the geographic range of cod. Incorporation of this information into fisheries management practices will be attempted.

(5) Climate and Atmosphere-Ocean Interactions

Objective: To understand and predict climate variability and its associated ecosystem response.

Justification: Fisheries managers are demanding increased knowledge of climate-induced ecosystem changes and asking for predictions of future climate conditions. Although predictive success is unlikely in the immediate future, improvements in prediction over the long-term are expected and worth the effort. Both short and long-term (decadal) predictions are of interest to fisheries management. Several large international programmes such as CLIVAR are being developed to gain understanding of the climate of the North Atlantic and the role of the North Atlantic Oscillation (NAO). The CCCWG will communicate its needs and establish links to the CLIVAR community and to other such climate programmes.

Specific Activities: A Workshop on Long-term Climate Change and Prediction is planned for the year 2000, the purpose of which is to explore long-term and short-term predictions in ocean climate, the possible existence of "regime shifts" of climate and the relationship between climate change and their associated ecosystem responses. The mechanisms linking the large-scale atmospheric circulation such as the North Atlantic Oscillation (NAO) to ecosystem changes will be sought as a follow-on from the Workshop on Decadal-Scale Ocean Climate Fluctuations of the North Atlantic.

(6) Data Availability and Management

Objective: To ensure that environmental and fisheries data are easily and widely available.

Justification: Data are critical for research and as such it is important that they be easily accessible to a wide scientific audience. This will encourage and ease activities such as comparative analyses.

Specific Activities: Working relationships with other groups will be established to ensure data accessibility and, where possible, standardise formats. Primary data sources and information required for the proposed workshops will be made available, as much as possible, on the web. The ICES website will be kept up to date. Data sets will be assembled for specific predetermined types of analyses such as undertaken for the various workshops.

(7) Synthesis

Objective: To provide a synthesis of the research information obtained on cod stocks.

Justification: Much material has been published on many of the cod stocks around the North Atlantic. The CCCWG recognises the requirement to synthesise this information into a general framework of cod dynamics.

Specific Activities: While an overall synthesis is the long-term aim, the initial work will proceed in a modular manner. Thus, ongoing synthesis of the workshops and theme sessions is identified as a critical aspect.

Tentative Time Table of Workshops and Activities

March 1999	Workshop on the Gadoid Outburst in the North Sea
August 1999	TASC Symposium
Fall 1999/Winter 2000	Workshop on the Dynamics of Growth in Cod
September 2000	ICES Theme Session on Zooplankton-Cod Linkages
2000/2001	Workshop on Incorporating Environmental Information into Fisheries Management. The West Greenland/Iceland Cod Example
2001	Workshop on Long-term Climate Change and Prediction

Potential Joint Work other Working Groups and Committees

As part of the 5-Year Plan, potential joint work with other ICES Working Groups and Committees and international programmes were identified as follows. This list does not exclude possible links to other groups and committees.

CCCWG Component	Associated Group
Fisheries Management	Resource Management Committee
Zooplankton-Cod Interactions	TASC, Zooplankton Ecology WG
Climate and Atmosphere-Ocean Interactions	Oceanic Hydrography WG, Shelf Seas Oceanography WG, CLIVAR
Data Availability and Management	Marine Data Management

Additional discussion

Much discussion was centered upon modelling and the possibility of including it as a separate component of the 5-year plan. However, it was agreed that modelling should be an integral part of most, if not all, of the above components. The WGCCC therefore decided to encourage the use of modelling within the activities identified above rather than to identify modelling as a separate component.

S. Skreslet contended that biologists need improved conceptual models. Human intervention, whether through fishing, pollution or freshwater regulation can produce large-scale, irrevocable changes in the ecosystem. To model and predict these possible changes requires expertise in theoretical ecosystem analysis, expertise that is not generally available within CCC but could be requested through the GLOBEC Steering Committee (see Appendix 3).

Several participants requested a quantifiable definition for the phrase “regime shift”. While this phrase may apply to the Pacific, observations from the North Atlantic suggest the emphasis should be on decadal and longer time-scale variability rather than on regime shifts. There may have been events in the North Atlantic to which the term “regime shift” can justifiably be applied, e.g., the rapid warming in the north during the 1920s. The WGCCC is interested in the ecosystem response at a wide range of time and space scales. Observations within the past year suggest the possible generation of a

new Great Salinity Anomaly (GSA). It was suggested that GLOBEC programmes should be looking for the ecosystem responses to this GSA.

Major changes have occurred in cod stocks since the mid-1980s with the most dramatic being the collapse of several of the eastern North American stocks. It was suggested that a workshop be held, under the comparative analyses component, which focused on events throughout the North Atlantic during the years since 1985, but the majority of the working group felt that the topic was too broad.

Work has begun on an EU funded project on "Sustainable fisheries. How can the scientific basis for stock assessment and predictions be improved?". The topics being addressed include how to incorporate environmental information into stock assessments. Several CCC Working Group members are participating and will ensure that our activities are coordinated, where possible.

It was agreed that the work begun within the Backward Facing III workshop should be explored further. This will be undertaken during the upcoming year and presented at the Backward Facing IV workshop scheduled for 1999.

Analysis of MARMAP data, which is given in the Backward Facing III workshop report, indicated that year class strength in cod is largely determined by the time the larvae reach 6 mm in length (i.e., shortly after hatching). This result could be tested by analysis of data from other years, because a further ten years of MARMAP sampling has not been analysed. If it continues to hold then it has far reaching implications for studies of the causes of recruitment variability in all areas.

S. Skreslet briefly summarised results from his studies within MARE COGNITUM on linkages between zooplankton and cod (see Appendix 4). It is essential that modelling plays a major role in any synthesis of cod stocks that is undertaken. Identification of the types of modelling activities that should be carried out would be useful, although how the WGCCC should promote this is uncertain. There has been some recent innovative and insightful modelling of trophodynamics using coupled physical/biological models. This is a modular approach to synthesis.

The WGCCC needs to specify their data needs to working groups such as Oceanic Hydrography and Marine Data Management. An open policy on data accessibility should be encouraged.

US GLOBEC is interested in the NAO index and its relationship to climate variability and ecosystem changes, especially within eastern US waters. They have sold themselves to funding agencies as a programme which would make predictions on the effects of climate change. This will be achieved through nested models from the fine scales to population levels out to broader and longer scales. Their interest in the NAO is, among others reasons, to ensure that they are taking the correct measurements. They do not want to be in the synthesis stage of their study to find that they have missed critical measurements. They are considering a workshop to examine the NAO and its influence in western Atlantic waters.

4 OTHER BUSINESS AND DISCUSSIONS

4.1 ICES involvement within GOOS

A letter from R. Sætre requesting views on ICES involvement within the Global Ocean Observing System (GOOS) was distributed to the participants. The WGCCC generally supported ICES involvement in GOOS. Of the four alternatives proposed on the level of involvement, the working group supported that which included the establishment of an operational fisheries oceanography centre working on time scales of weeks to months for the North Atlantic or at least parts of it (e.g., the North Sea). The centre would coordinate national and international data collection, and the processing of such data into numerical and statistical models to produce climate predictions, regular environmental status reports and time series for identifying trends and changes. The working group saw prediction as a very important component of GOOS.

4.2 AMAP

A letter from the Arctic Monitoring and Assessment Programme (AMAP), requesting help from ICES, to put together their work programme to monitor and assess contaminant levels and their effects in the Arctic was brought to the

attention of the working group by H. Loeng. AMAP has been asked by the ministers of the eight Arctic countries to monitor effects on the Arctic environment and its ecosystems due to climate change and changes in the UV/ozone levels. Aware that ICES is presently conducting climate change studies in the North Atlantic, AMAP was interested in establishing close cooperation to avoid duplication. A draft policy paper on climate change should be ready by early summer of 1998. Harald Loeng informed the WGCCC that AMAP will use information on hydrographic variability from the ICES Oceanic Hydrography Working Group. The WGCCC agreed to help them in their planning process, where possible, with H. Loeng being the contact person.

4.3 Other Issues

Given the common interests between the WGCCC and the PICES Working Group on Climate Change and Carrying Capacity (CCCC), including climate variability, regime shifts, water column stability, and the response of fish stocks to environmental change, K. Brander agreed to explore the possibility of more formal relationships between the two working groups.

K. Brander encouraged participants to write or solicit articles and contributions for the GLOBEC Newsletter. He also asked for feedback from readers. The Newsletter provides a vehicle to make points of view known to a wider audience and to generate debate on issues such as the five year plan.

5 RECOMMENDATIONS AND TERMS OF REFERENCE FOR FUTURE MEETINGS

The following recommendations emerged from the meeting. Recommendation I addresses the activities of the Working Group in 1998/99. Recommendations II and III address activities of upcoming Cod and Climate Workshops.

Recommendation I

The **ICES/GLOBEC Working Group on Cod and Climate Change** (Chairman: Dr K. Drinkwater, Canada) will work by correspondence over the next year to:

- a) continue with the review and evaluation of work carried out to date on Cod and Climate Change in order to develop and support further work on:
 - (i) Methods for applying environmental data in stock assessments using specific examples where possible and developing a dialogue with the Working Groups on Comprehensive Fishery Evaluation, Zooplankton Ecology, and Shelf Seas Oceanography on the kind of data required.
 - (ii) Methods for longer term stock predictions, which make use of results from the 1997 ICES/GLOBEC Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic.
 - (iii) Application of new information on biological processes and coupled physical/biological models from recent ICES Symposia, Theme Sessions and regional and national GLOBEC programmes.
- b) prepare for the proposed workshop on the Dynamics of Growth in Cod.
- c) plan and initiate intercomparisons among cod stocks and the synthesis of work to date on Cod and Climate Change.

The Workshop will report to the Oceanography Committee at the 1998 Annual Science Conference.

Justification:

At its meeting in 1998 the WG produced a draft 5 year plan for the Oceanography Committee and for the Implementation Plan of the International GLOBEC programme (The ICES/GLOBEC Cod and Climate Change programme is the North Atlantic regional component of the International GLOBEC programme). The plan will require further development over the coming year and preparations are needed for the activities identified in it. These can be carried out effectively by correspondence.

a (i - iii) Knowledge gained during recent years on the influence of environmental effects on recruitment, growth and distribution of cod, particularly the effects of variable transport, temperature and zooplankton abundance, is not utilized in stock assessment. This is because the tools for applying additional explanatory variables in stock assessments have yet to be developed. The CCC Workshop on Application of Environmental Data in Stock Assessment (ICES CM 1998/C:1), the Fisheries Oceanography Committee of DFO, Canada and the Workshop on Changing Oceans and Changing Fisheries (NOAA, USA) have made progress, but further work is needed to produce operational tools. Plans for workshops in 2000/01 on Long Term Climate Change and Prediction and on Incorporating Environmental Information into Fisheries Management-the West Greenland/Iceland Cod Example will be developed. Working relationships with other groups will be established to ensure data accessibility and, where possible, standardise formats. Primary data sources and information required for the proposed workshops will be made available, as much as possible, using the ICES website.

b) It is proposed that a Workshop on the Dynamics of Growth in Cod be held during the autumn/winter of 1999/2000. The aim of the workshop will be develop a single growth model for cod that will allow interpretation of information from all parts the geographic range of cod. Incorporation of this information into fisheries management practices will be attempted.

c) Research in recent years has expanded our understanding of the dynamics of individual cod stocks and some of the causes of interannual variability. Comparative studies between stocks, such as those on growth and recently on recruitment, have provided knowledge that was unattainable from stock-specific investigations. More such studies offer good potential of providing additional significant insights. Areas where such studies were considered beneficial include further examination of growth and recruitment and investigations into distribution and migration. Application of similar analytical methods for different stocks will be encouraged.

Recommendation II

A Workshop on **The gadoid stocks in the North Sea during the 1960s and 70s, the fourth ICES/GLOBEC Backward-Facing Workshop** will be held in Aberdeen, Scotland from ? to ? March 1999 under the chairmanship of Dr M. Heath (UK), Dr J. Alheit (Germany) and Dr M. St John (Denmark) to:

- a) identify and contrast the components of the physical environment (atmospheric and oceanic) which may have contributed to observed high levels of gadoid recruitment in the North Sea and adjacent sea areas during the 1960s and the 1970s
- b) determine the processes which may have governed the observed high levels of gadoid recruitment, in particular
 - (i) variations in transport
 - (ii) match mismatch in the occurrence of larvae and their prey
 - (iii) growth and condition of larvae, juveniles and adults
 - (iv) predation on early life history stages
 - (v) variations in optimal environments
 - (vi) contributions from several stock components
- c) Synthesise information on factors influencing gadoid recruitment in the NW Atlantic based on information presented at BF-3

The Workshop will report to the Cod and Climate Change Working Group and to the Oceanography Committee at the 1999 Annual Science Conference.

Justification:

This is the fourth in a series of workshops which have used a combination of retrospective analysis and new process studies and modelling in order to interpret the causes of past population events, such as the tilefish kill during 1881/82 and the changes brought about by cold periods in the Barents Sea and the NW Atlantic Shelf. The workshop philosophy, of reanalysing and reconstructing the physical conditions related to a specific fisheries population event or period, has proved to be successful and plans to apply it to the "gadoid outburst" in the North Sea have been underway for some time. In addition to looking at the North Sea, the workshop will also follow up some of the results from NW Atlantic, which emerged during the 1998 Backward Facing meeting and will look at comparisons between stocks and how to synthesise the new knowledge of physical and biological coupling.

Other possible sources of information (e.g., analysis of the long term sedimentary record) about factors influencing gadoid dynamics should be considered prior to the workshop and included at the discretion of the chairmen.

Recommendation III

A Workshop on **The Dynamics of Growth in Cod** (WKDGC) will be held under the chairmanship of H. Gislason (Sweden), G. Ottersen (Norway), and D. Swain (Canada) during the autumn of 1999 or winter of 2000 to:

- a. develop models of growth (post settlement to adult) in order to improve the quality of stock forecasting;
- b. describe major sources of uncertainty in further improving the prediction of growth rate and advise on further studies to reduce the uncertainty;
- c. assess the contribution of growth rate variability to the observed variability in stock biomass and stock forecasts; and
- d. recommend standard methods for comparing growth rates.

The WKDCG will report to the Oceanography Committee at the 2000 Annual Science Conference.

Justification:

Recent widespread changes in growth rates for many cod stocks have considerable consequences for stock biomass estimation and forecasting. A number of studies have related growth changes to temperature, food availability (per capita), maturation and other factors. These are in turn a consequence of shifts in the distribution and abundance of cod and their prey and possibly also to selection due to fishing. As part of the eventual aim to synthesise our knowledge of cod, a single growth model that attempted to bring together and interpret our information on cod growth from all parts of the range would be a valuable component.

Procedures for estimating ambient temperature have improved recently, with the development of data storage tags, isotropic analysis of otoliths and more sophisticated interpretation of the seasonal distribution of fish in relation to temperature fields.

APPENDIX 1 – PARTICIPANTS

Dr J. Alheit
Baltic Sea Research
18119 Warnemuende
Germany
alheit@io-warnemuende.de

Dr K. Brander
ICES/GLOBEC Secretary
Palaegade 2–4
1261 Copenhagen K
Denmark
Keith@ices.dk

K. Drinkwater
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2 Canada
drinkwaterk@mar.dfo-mpo.gc.ca

Dr M. Fogarty
Chesapeake Biological Laboratory
University of Maryland Centre of Environmental
Science
P.O. Box 38
Solomons, Maryland 20688
USA
fogarty@cbl.umces.edu

Dr K. Frank
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2 Canada
frankk@mar.dfo-mpo.gc.ca

Mr Harald Loeng
Institute of Marine Research
P.O. Box 1870 Nordnes
5024 Bergen,
Norway
harald.loeng@iMrno

Dr S. Murawski
National Marine Fisheries Service
Woods Hole, Massachusetts 02543
USA
steve.murawski@noaa.gov

Dr Benjamin Planque
Centre for Environment, Fisheries and Aquaculture
Sciences
Pakefield Road
Lowestoft, Suffolk
NR33 0HT UK
b.planque@cefas.co.uk

Prof. B. Rothschild
Director, Center for Marine Science and Technology
University of Massachusetts Dartmouth
706 South Rodney Rench Boulevard
New Bedford, Mass. 02744–1221
USA
brothschild@umassd.edu

Mr S. Skreslet
Bodø College
Faculty of Fisheries and Natural Sciences
N-8001 Bodø,
Norway
stig.skreslet@hibo.no

Dr M. St. John
DIFMAR
DK-2920 Charlottenlund
Denmark
msj@dfu.min.dk

Dr J. Steele
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts
USA

Dr Chris Weidman
Dept. of Marine Geology and Geophysics
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts
USA
cdw@ams245.whoi.edu

Dr F. Werner
Dept. of Marine Sciences
University of North Carolina
Chapel Hill, N.C.
27599–3300 USA

APPENDIX 2 – ICES REPORTS AND PUBLICATIONS RELATED TO GLOBEC

- ICES 1990. Report of the ICES Study Group on Cod Stock Fluctuations. Cod and Climate Change (CCC), Framework for the Study of Global Ocean Ecosystem Dynamics. ICES CM 1990/G:50 Ref C+L. 29 pp.
- ICES 1991. Report of the ICES Study Group on Cod Stock Fluctuations. Towards an implementation plan for the programme on Cod and Climate Change (CCC). ICES C.M. 1991/G:78. 35 pp.
- ICES 1992. Report of Steering Group on Cod and Climate Change. CCC. Cod, Copepods and Climate. ICES; CM. 1992/G:17. Ref C+L. 7 pp.
- ICES 1993b. Report of the ICES/GLOBEC Working Group on Cod and Climate Change. ICES C.M. 1993/G:3, 67 pp.
- ICES 1994a. Report of the ICES/GLOBEC Working Group on Cod and Climate Change. ICES C.M. 1994/A:7.
- ICES 1994b. Report of ICES/GLOBEC Cod and Climate AGGREGATION Workshop, Charlottenlund 22–24 August 1994. ICES C.M. 1994/A:10.
- ICES 1994c. Report of the Workshop on the Trans-Latitudinal Study of *Calanus finmarchicus* in the North Atlantic, Oslo 6–8 April 1994. ICES C.M. 1994/L:10, 30 pp.
- Brander, K. (ed.) 1994. Spawning and Life History Information for North Atlantic Cod Stocks. ICES Coop. Res. Rep. No. 205, 150 pp.
- Jakobsson, J. (ed.) 1994. Proceeding of the ICES Symposium on Cod and Climate Change, Reykjavik, 23 - 27 August 1993. ICES mar. Sci. Symp. 198: 693 pp.
- ICES 1995a. Report of the ICES Working Group on Cod and Climate Change. ICES C.M. 1995/A:8, 25 pp.
- ICES 1995b. Report of the Cod and Climate Backward-Facing Workshop, Bedford Institute of Oceanography, Dartmouth, Canada, 8–10 March 1995. ICES CM 1995/A:7. 23 pp.
- Harris, R. (ed.) 1995. Zooplankton Production. Proceedings of a Symposium held in Plymouth, England 15–19 August 1994. ICES Journal of Marine Science Vol. 52 (3&4): 773 pp.
- ICES 1996a. Report of the ICES/GLOBEC Cod and Climate Database Workshop. 14–16 November 1995, Woods Hole, MA, USA. ICES CM 1996/A:7, 67 pp.
- ICES 1996b. Report of the Cod and Climate Backward-Facing Workshop, Institute of Marine Research, Bergen, Norway, 21–23 March 1996. ICES CM 1996/A:9. 25 pp.
- ICES 1996c. Report of the ICES Working Group on Cod and Climate Change. Institute of Marine Research, Bergen, Norway 25–27 March 1996 ICES CM 1996/A:10.
- ICES 1996d. Report of the ICES/GLOBEC North Atlantic Regional Co-ordination Group. ICES Headquarters, Copenhagen, Denmark 6–7 June 1996 ICES CM 1996/A:12, 11pp.
- ICES 1997a. Second Report of the ICES/GLOBEC North Atlantic Regional Co-ordination Group. Reykjavik, Iceland, 28–29 September 1996 ICES CM 1997/A:7, 18pp
- ICES 1997b. Report of the ICES/GLOBEC North Atlantic Regional Co-ordination Group. ICES Headquarters, 16–17 June 1997 ICES CM 1997/A:8, 13pp
- ICES 1997c. Report of the Working Group on Zooplankton Ecology. Kiel, Germany, 16–18 March 1997 ICES CM 1997/L:4, 29pp
- ICES 1997d. Report of the Working Group on Shelf Seas Oceanography. March 1997 ICES CM 1997/C:1, 29pp
- ICES 1997. Report of the Working Group on Cod and Climate Change (by correspondence) ICES CM 1997/A:9, 4pp

- ICES 1997 Preliminary Report of the ICES/GLOBEC Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic. ICES CM 1997/A:13, 2pp
- ICES 1997 Theme Session on the North Atlantic Components of Global Programmes: Lessons to ICES/GLOBEC from WOCE and JGOFS. Convenors Prof. B Zeitschel and Dr W J Gould. 21 papers presented. Summary in 1996 ICES Annual Report January 1997.
- ICES 1998. Report of the ICES/GLOBEC North Atlantic Regional Co-ordination Group. Baltimore, USA, 26 and 29 September 1997 ICES CM 1998/C:11, 10pp
- ICES 1998 Theme Session on GLOBEC: Results from Interdisciplinary Programmes in the North Atlantic. Convenors Dr P H Wiebe and Mr S Sundby. 53 papers presented. Summary in 1996/97 ICES Annual Report January 1998.

APPENDIX 3 – REQUEST FOR THEORETICAL ECOLOGISTS (BY STIG SKRESLET)

Stable ecosystems tend to be established when K-selective species have been given the opportunity to reach the system's carrying capacity for their populations. Such populations, like cod stocks, are usually the resource base for fishing. By controlled management, the fishing mortality may be kept on a level that allows the population to exploit the carrying capacity of the ecosystem. By over-fishing, surplus capacity becomes available for opportunistic, more r-selective species. In an over-fished system, where various opportunistic species compete, food webs tend to become unstable and direct the energy flow in unexpected directions. More or less stochastic perturbations possibly force changes of this kind and create checks that appear to be regime shifts.

Human impacts on ecosystems, like pollution, regulation of river flow, etc., that may chronically change the carrying capacities for K-selective populations, may cause the ecosystems to become more vulnerable to instabilities caused by fishing, and fish stocks to display changes at an increasing frequency.

The ICES Working Group on Cod and Climate Change considers that experts in theoretical ecosystems analysis should address the problem. The mandate of the WG does not comprise this kind of expertise and therefore addresses the GLOBEC Steering Committee for due consideration and contact with the relevant instances. The WG needs feedback from ecosystems analysts to better understand and solve the addressed problem.

APPENDIX 4 – RESEARCH RESULTS (BY STIG SKRESLET)

A Norwegian research proposal in the Cod and Climate Change Implementation Plan (ICES C.M. 1993/G: 3) has been addressed in the MARE COGNITUM study on food chain coupling between effects of climate and year-class strength in Norwegian waters.

The project has identified that the Norwegian Coastal Current front on the inner mid-Norwegian shelf serves as a spawning habitat for *Calanus finmarchicus* during summer. The peak spawning occurs in July during the main run-off period for meltwater from high altitudes in Norway. The phytoplankton biomass needed for reproduction is associated with dynamic processes that occur below the pycnocline between the mixed surface layer and the shelf water. The generation produced in this system probably recruits members to the copepod SSB that in the following year produces nauplii being prey for first-feeding cod larvae. Thus, the research has established the existence of a major ecological link between freshwater outflow as a variable of climatic origin, and the food web that supports year-class formation in cod.

This frontal system associated with the coastal current needs further investigation. Cyclonic and anticyclonic eddies may form on different size scales resembling a fractal geometry system. The eddies may be important in a variety of ecological processes such as:

- i) the flux of plant nutrients to the primary production layer,
- ii) concentrations of microalgae,
- iii) recruitment of adolescent copepods to maturing habitats,
- iv) recruitment of males and females to mating habitats,
- v) advection of females to spawning habitats,
- vi) accumulation of nauplii in feasible feeding habitats,
- vii) microturbulence that influences the rate of encounter with particulate food.

On a larger spatial scale, there is still very little understanding of how the copepod SSB is recruited to the coastal current front and how their offspring is dispersed.

Frontal systems that are not characterised by pronounced salinity gradients develop along shelf breaks and associated with slopes between banks and troughs. Such fronts should be identified and studied to establish whether or not they provide conditions that create particular life history habitat for zooplankton.

Information from the MARMAP time series (Morse 1994) indicate that the year-class size of cod may be established at a very early stage, before the larvae reach a length of 6 mm. Thus the abundance of copepod nauplii may be a dominating factor that forces the year-class strength in cod. We hypothesize that important physiological changes may occur in this mixed life stage when three food components may combine to form the necessary diet for an adequate somatic development:

- i) yolk remains,
- ii) green food remains from feeding on micro-algae,
- iii) nauplii as a base for protein synthesis.

The first feeding event is rapidly followed by the formation of a swim bladder. It is possible that the swim-bladder formation in cod larvae represents a shift from a retention mode to a dispersal mode. This feature may be necessary for the larval stock to avoid high density-dependent mortality in the first feeding process, and exploit larger feeding habitats in the following life stage.

Morse, W. W. 1994. Atlantic cod, *Gadus morhua*, Larvae: An analysis of the MARMAP time series, 1977–1987. Northeast Fisheries Science Center Reference Document 94–08. 44 pp.

