

ICES/GLOBEC Cod and Climate Change Program

Revised Strategic and new Action Plan for 2005-2009



**ICES/GLOBEC
Cod and Climate Change Program**

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Action Plan for 2005-2009**

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Contents	Page
1. Introduction	5
2. Past achievements	5
3. Present synthesis activities	8
4. Remaining gaps and questions	10
5. Action plan for 2005-2009	13
6. Relations to International GLOBEC	17
7. Relations to other Regional Programs	18
Reference list	20
Appendix A. CCC activities 1993-2003	21
Appendix B. List of CCC reports	22

1. Introduction

The ICES Cod and Climate Change program (CCC) was established in 1992 but had its origins in an ICES Study Group on Cod Fluctuations formed in 1990. Atlantic cod (*Gadus morhua*) was chosen as the focus because this species was pan-Atlantic, known to be sensitive to climate fluctuations and there were ample data on cod. It was also felt by the founders of the program that the knowledge learned from studying the effects of climate variability on cod could likely be applied to other, less well-studied species. Some of the program's activities since its beginning are listed in Appendix A. It is the first of the regional programs of International GLOBEC to undertake a formal synthesis of its work (described in detail in section 3). Although the synthesis is scheduled for completion in 2004, the CCC members felt it necessary to continue its work. They outlined a final phase of the Program built upon the synthesis that aims to tackle those essential issues not yet resolved in the earlier work. The CCC will complete its work in 2009, coinciding with the official ending of GLOBEC. This document summarizes the scientific achievements of the CCC, presents the gaps and new questions that have been identified for the final phase of the program and their justification, and outlines a strategy to address them. This revised Strategic Plan was requested by the Scientific Steering Committee (SSC) of International GLOBEC and is principally based upon discussions at the 2003 CCC meeting (ICES 2003a).

2. Past Achievements

Present Strategic Plan

The present strategic plan for the CCC program, initially adopted by International GLOBEC, was formalized during the CCC meeting of May 1998 in Woods Hole, USA (ICES 1998a) and consisted of 7 major themes. The themes and their objectives were:

- 1) **Fisheries Management:** To incorporate environmental information in a quantitative manner into fisheries management strategies and planning.
- 2) **Retrospective Analyses:** To understand the links between changes in the environment and fisheries through examination of past unusual events or periods in either the physical environment or fisheries.
- 3) **Zooplankton-Cod Linkages:** To understand the relative importance of zooplankton in determining the variability in cod abundance and production.

4) **Comparative Analyses:** To understand the life history strategies and causes of interannual variability in growth, distribution, and abundance of cod through comparative studies between different cod stocks around the North Atlantic.

5) **Climate and Atmosphere-Ocean Interactions:** To understand and predict climate variability and its associated ecosystem response.

6) **Data Availability and Management:** To ensure that environmental and fisheries data are easily and widely available.

7) **Synthesis:** To provide a synthesis of the research information obtained on cod stocks.

Several of these objectives followed from the initial work of the CCC. CCC meetings in Dartmouth, Canada (2000) and Hillerød, Denmark (2002) reconfirmed these broad goals.

Methodology

Much of the scientific work within the CCC program to meet the above objectives has been carried out in workshops; focused meetings where 15-25 scientists, often some from outside the core GLOBEC or ICES community, work for 2-3 days. The workshops include presentations, but give more attention to discussion and synthesis of information made available prior to the meeting. The group attempts to establish conceptual as well as statistical, analytical or numerical models of the key variables and control processes in advance of the meeting so that the workshop can focus on the interpretation of results at a more complete and integrated stage. In recent years the program's web site, including bulletin boards specifically set up for each meeting, has been used for pre-meeting exchange of information. This has also been a successful way of involving colleagues not able to attend the workshops. The results of several of these workshops have been published in the ICES Cooperative Research Report series with others in preparation. The CCC has also hosted general meetings focused upon ICES/GLOBEC as well as CCC goals during the ICES ASC (Annual Science Conference). It has also contributed to several other conferences and symposia, such as the GLOBEC Open Science Symposia.

The CCC members are mostly fisheries oceanographers and fisheries biologists, but at the workshops, the program has a policy of involving experts from other fields of knowledge, including history, pure oceanography, climatology/meteorology, numerical modelling, geochemistry, physiology, and others. In this way the CCC program has been able to delve more thoroughly into chosen topics and involve more scientists in the work of GLOBEC.

Scientific Achievements

The retrospective approach, identified early on in the CCC program, consisted of reanalysis and reconstruction of the physical conditions related to specific large events, either biological or environmental, in an attempt to reveal the importance of climate variability on fish stocks. This led to a series of Backward-Facing Workshops (see Appendix A). These combined retrospective and time series analyses, new process studies and modelling to interpret the causes of specific past events and their effect on populations of cod and other fish. The essential aim was to identify and examine instructive past analogues to present day conditions, in which the effects of environmental variability on fish stocks might be more clearly distinguished from the masking effects of fisheries. The four Backward Facing workshops investigated, respectively, the extreme cold period of the 1880s off the northeastern seaboard of the United States (ICES 1995), the incidence, causes, and ecosystem effects of extreme cold in the marine environment of the Barents Sea and Baltic (ICES 1996a), the consequences for gadoid populations of the cooling of the 1960s in the Northwest Atlantic (ICES 1998a, 1999a) and the “gadoid outburst” in the North Sea in the 1960s and 1970s (ICES 1999b, 2001). In the case of the 1880s cold period, modelling and reconstruction of historical data (using oxygen isotope analysis) identified cold water as the most likely cause of the massive tilefish kill in 1882. This was caused by increased flow of cold Labrador Current waters as far south as Georges Bank and the Middle Atlantic Bight (Marsh et al. 1999) and was related to a decline in the NAO index (Marsh 2000). In other cases, such as the gadoid outburst in the North Sea (ICES 1999b, 2001), climate could not be identified as the direct cause of changes in fish stocks, but probably contributed indirectly (Beaugrand et al. 2003).

In addition to the Backward-Facing Workshops, the CCC worked towards improving the data quality and availability of both fisheries and climate data through their Database workshop (ICES 1996b) and held one of the first scientific meetings to focus on decadal variability in the North Atlantic and the NAO (ICES 1997, 1998c).

More recent workshops have focused upon the effects of climate on the processes that govern production of cod (growth, maturation, egg production, transport during early life, survival and natural mortality). One example is the Workshop on Cod Growth. This workshop provided much new information about the role of size-selective fishing, food availability,

environment and genetics in determining the changing growth patterns (ICES 2000a, 2002a). For instance, a new hypothesis regarding the role of sea currents and temperatures in determining growth in juvenile Barents Sea cod was suggested (Ottersen et al. 2002). The growth workshop also led to the development of a major new research program on cod growth within Canada. A workshop on Transport Processes (ICES 2002b) evaluated the effects of variations in transport during early life on subsequent recruitment and examined the coupling of circulation models with early life history models to determine the physical and biological processes responsible for the transport or retention of cod larvae. Cod eggs and larvae travel up to 1600 km during the pelagic stage, but greater distance does not necessarily lead to greater variability in survival and recruitment. Both of these workshops were followed up with theme sessions at the next year's ICES ASC. The ultimate goal for the CCC has been to use the information from the workshops for improved management of sustainable fisheries and the development of methods for achieving this remains an ongoing theme of the programme.

Talks at the Session on Comparative studies of North Atlantic ecosystems at the 2nd GLOBEC Open Science meeting in Qingdao dealt with the response of plankton and fish to climate forcing and the effects of food and environmental limitations on growth production of cod (Dutil and Brander, 2003).

In addition to its own program, the CCC has strongly supported and participated in several other GLOBEC-related activities. Two of the most important were the Trans-Atlantic Calanus Study (TASC) and the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999 (ICES 2003b).

3. Present Synthesis activities

The CCC program is currently undertaking a synthesis of its past work (ICES, 2003c), with three major activities dominating the timetable until the end of 2004:

1. Publication of a book in the IGBP series on the current state of knowledge about cod and its response to climate change

This book will present what we have learned about the effects of climate on cod, especially within the CCC program. A theme throughout the book will be the

comparative approach, i.e. what conclusions can be drawn from differences and similarities between the many North Atlantic cod stocks that occupy a wide range of different physical and biological environments. The relative importance of climate compared to biological and fisheries effects will be addressed. The book will include chapters on the physical and biological oceanographic setting, stock structure, growth, recruitment, larval transport, distribution and migration and the role of cod in the ecosystem. A discussion of the CCC program itself, possible implications for fisheries management of CCC findings, and possible impacts on cod of future climate change will also be covered. As well as reviewing existing research it will include new results and analyses. The book will also assess the progress made since the 1993 Cod and Climate Change Symposium, held in Reykjavik during the very early days of the CCC programme (ICES 1994a).

2. A Symposium on the Influence of Climate Change on North Atlantic Fish Stocks in Bergen, Norway, in May 2004

The main objective of the CCC-sponsored Symposium is to present current knowledge of the impact of climate variability and change on fish stocks and how this may be used in fisheries advice and management. Although the scope of this conference is broader than that of CCC, it fits within the general objectives of the program and CCC science and scientists are heavily involved. The main topics of the conference are

- The impact of climate on the distribution and migration of fish populations
- The effect of climate variability on growth, maturity, recruitment and mortality
- The role of zooplankton in climate-fish relations
- Taking account of climate in the evaluation of the state of fish stocks
- Managing fish stocks under future climate scenarios and in the face of climatic uncertainty

Keynote talks include “Climate variability in the North Atlantic: past, present and future” (J. Hurrell), “The impact of climate on the distribution and migration of fish populations” (G. Rose), “The effect of climate variability on growth, maturity and recruitment” (G. Marteinsdottir), “Zooplankton and the link between climate variability and fish” (M. Heath), “Taking account of climate in the evaluation of the state of fish stocks” (C. O’Brien) and “Managing fish stocks under future climate

scenarios and in the face of climatic uncertainty” (L. Richards). Based upon received abstracts, there will be approximately 60 oral presentations and upwards of 40 posters. Selected papers will appear in a special volume of the ICES Journal of Marine Science. The Symposium also will allow us an opportunity to measure progress relative to the 1993 Cod and Climate Change Symposium (ICES 1994a).

3. A comprehensive report on life history information for North Atlantic cod stocks

The CCC is updating a previous report on life history information on cod stocks throughout the North Atlantic (ICES, 1994b). The 1994 report contained information on most of the major cod stocks and focused upon the early life histories. Much new information has been gathered over the last decade and it was decided at the 2000 Meeting of CCC (ICES, 2000a) and reaffirmed at the 2002 Meeting (ICES 2002c) that this new information should be collated and published in the form of an updated ICES Consultative Research Report. At the 2003 Meeting (ICES 2003a) scientists representing most of the major stocks around the North Atlantic presented information on their particular stock. The scope of the new report will be somewhat wider than the earlier version and will include information on migration and adult growth in addition to landings, spawning stock biomass, recruitment estimates, age of maturity, fecundity as well as data on spawning (dates, duration, temperature, egg size, etc.) and larvae (size, growth and mortality rates, dates of hatching and settlement, distance travelled from spawn to settlement, etc.). The report is intended as a comprehensive data source for those studying cod.

4. Remaining Gaps and Questions

The above synthesis activities will be completed in 2004. At that time two of the Strategic Goals (Retrospective Analysis and Data Management) will have been addressed satisfactorily. However, important questions remain under the other Goals.

Zooplankton Linkages. Early stages of zooplankton are important prey for larval and early juvenile stages of cod. For most cod stocks *Calanus* species are the main prey, while in some areas, e.g. the Baltic, other species dominate. Early studies suggested that *Calanus* were critical for establishing a strong year class in some cod stocks although the mechanisms were

unclear. A major research effort on *Calanus* during TASC focused mainly on the life history of the species and not on its linkages to fish. The theme session on Climate-Plankton-Fish Linkages at the 2000 ICES ASC provided more information on links between zooplankton and fish but various different functional relationships were put forward. Some studies have suggested a negative relationship between abundance of *Calanus finmarchicus* and recruitment of cod whereas others are positive or involve additional factors (Beaugrand et al. 2003). A number of national and regional GLOBEC (or GLOBEC-related) programs have been conducting research on this topic over many years and the aim within CCC will be to draw this work together and look for general conclusions and applications.

Climate and Atmosphere-Ocean Interactions. The objective of this topic was to understand and predict climate variability and its associated ecosystem response. While this was partially addressed in the 1997 Workshop on Decadal Variability (ICES 1997, 1998c), the CCC later felt that further work on the direct links between ocean climate and atmospheric variability should largely be addressed by other programs such as CLIVAR. The decision was made to leave this line of research to those other groups and that we should concentrate on the associated ecosystem response. The assessment of the impact of future climate change on cod is central to GLOBEC concern about effects of global change. Evidence of ecological impacts of rising temperature already exists in northern high latitudes, both from the recent warm period and for the previous warm period, which began in the early 1920s. Scenarios for climate change over the next 50 years show continuing increases in temperature and an investigation of the effects on cod is therefore warranted. The CCC members felt that this topic, which gave the programme its name, should be addressed directly before GLOBEC and CCC end.

Fisheries Management. The ultimate aim of the work under the CCC program was to show how environmental information should be applied in fisheries management. A CCC Workshop was held on this subject in 1998 (ICES 1998d); many scientific communities worldwide have also been struggling with the same issue with limited progress to date. Nevertheless, climate is increasingly recognised as an important component of cod fluctuations, as evidenced by recent discussions over the decline in the North Sea cod stock and the debate over the collapse of the Northern Cod off Newfoundland and Labrador. Continuing work will be encouraged and supported in this area, including collaboration with other groups within ICES, GLOBEC and elsewhere.

Comparative Studies. Most of the cod stocks around the North Atlantic have declined over the past 20 years or so. Landings fell from about 1.6 million tons in 1980 to just over half that in 2000. The decline can be attributed largely to high levels of fishing, but climate variability also played a significant part. In addition to the decline in abundance, there has also been a decrease in growth, particularly in the NW Atlantic, in age composition of the spawning stocks, and in mean age of first maturity. Comparative analysis of the changes in production of cod stocks throughout the North Atlantic give insights into the reasons for the decline, including the relative importance of the environment versus fishing intensity. The causes of the decline and the potential for recovery are among the most important issues for cod fisheries today.

An additional and important gap in our knowledge of cod dynamics and one related to understanding the decline and possible recovery of the cod stocks was identified at the 2003 Meeting. It did not fit clearly under any single one of the existing strategies. Climate influences cod directly through physiology as well as indirectly through prey, predators and competition. There is a need for further understanding of how climate effects on prey species like capelin and sprat and predators such as certain pelagic species and seals influence cod. The decline of cod has occurred at a time when there have been significant changes in ecosystem structure. For example, on the Scotian Shelf, in the North Sea and the Irish Sea there has been an increase in pelagic fish species as well as a general decline in the abundance and condition of the groundfish community, not just cod. This also fits with the general move to more ecosystem-based analysis and management.

Finally, although a Synthesis of our knowledge to date is presently ongoing it was felt that a final synthesis of the entire Cod and Climate Change Program needs to take place.

On the basis of the above the following Strategic Plan is proposed for the final phase of the CCC. It includes some of the former topics and objectives, a modified version of others, and one new objective.

1) **Fisheries Management:** To incorporate environmental information into fisheries management.

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

Although the objectives related to Retrospective Analysis and Data Management in the former Strategic Plan have not been included in the new Plan they will not be ignored. Retrospective analyses will play an important role in achieving the new strategic goals 2, 3 and 4. Also, the CCC will continue to make data and data products available to the wider scientific community.

5. Action Plan for the Final Phase of the CCC (2005-2009)

To achieve the above objectives of the final phase of the CCC program, a schedule of workshops is planned for the period 2005 to 2009. Other activities such as Theme Sessions at the ICES Annual Science Conference and collaboration with other ICES working groups or GLOBEC programmes will also be undertaken. Work is being planned with PICES (see below) and collaboration with relevant ICES groups (e.g. SGROMAT) is ongoing. The following list of workshops and suggested times is from discussions at the New Bedford 2003 CCC meeting (ICES 2003a).

A) Workshop on Impact of Zooplankton on Cod Abundance and Production (2005)

Relations between temporal and spatial dynamics of zooplankton and early stages of cod will be examined. Issues to be addressed would include how timing of zooplankton production and spatial dynamics of nauplii relates to the spawning and distribution patterns of early stages of cod and ultimately cod recruitment; links between later stages of cod and zooplankton; and how the relative importance of *Calanus finmarchicus* to other zooplankton species as the prey for cod varies spatially will be addressed. A combination of statistical data analyses, process studies and a variety of modelling approaches will be applied. The workshop will build on the results of the US and UK GLOBEC studies, Norwegian studies and recent CCC activities

including the 2002 Transport Workshop and the 2003 Theme Session on Transport of Cod Eggs and Larvae as well as output from the ICES 2003 Zooplankton Symposium.

Relation to strategic goals

The workshop is focused directly towards Goal 2 in the new Strategic Plan, while also contributing towards Goals 3, 4 and 5.

Suggested cooperation

ICES Working Group on Zooplankton Ecology (WGZE) and with the PICES/ICES proposed workshop on Evidence for and Impacts of Large-Scale Long-Term Variability in Zooplankton Populations.

B) Workshop on Influence of Climate on Tropho-Dynamics of Cod Ecosystems (2006)

Widely observed changes in abundance, size-at-age and maturity of cod in many stocks throughout the North Atlantic in recent years will be addressed from a tropho-dynamic and bioenergetic perspective. Both observations and theory will be considered, including mass balance and scaling from individual based modelling. The role of forage species will be reviewed, particularly that of capelin in the Barents Sea and Icelandic waters and sprat in the Baltic. This thus addresses the question of cod from a more ecosystem-based perspective. Questions to be answered include: To what extent are observed changes in cod stocks due to climate-induced variability in their principal prey species? What is the role of climate change on predators of cod (e.g. pelagic fish on larvae, harp seals on adults)?

Relation to strategic goals

The Action Item addresses Goal 5 and contributes towards Goals 3 and 4.

Suggested cooperation

Bioenergetic and multi-species modellers.

C) Workshop on Decline (and Recovery) of Cod Stocks Throughout the North Atlantic (2006)

During the presentations on the update of the cod stocks around the North Atlantic at the 2003 meeting, the WG was struck by the similarity in the abundance trends of many of the stocks, from high values in the 1960s that in some cases persisted through into the 1970s and 1980s,

followed by a decline to relatively low levels. In addition, there were often declines in size-at-age and age of maturity. Building upon the work of Dutil and Brander (2003) that showed the effects of temperature on cod production, the updated information on cod stocks throughout the North Atlantic as part of the ongoing synthesis, and the results from the above Tropho-Dynamics Workshop, the Workshop on the Decline of Cod Stocks will compare the changes that have occurred in all of the cod stocks around the Atlantic to assess the relative importance climate-induced ecosystem changes and fishing as causes of the observed declines.

Relation to strategic goals

This Action is linked to Goal 3 and contributes towards Goal 4.

Suggested cooperation

Assessment Working Groups working on cod.

D) Workshop on The Future of Cod in a Changing Climate (2007)

The response in abundance, distribution, and production of cod to climate scenarios for the future will be examined. Results from statistical and dynamic downscaling of output from General Circulation Models (GCMs) will be applied. Established climate-cod relations will be utilised. However, while temperature-cod and NAO-cod links have been studied for many stocks, further analyses through retrospective analyses are necessary for other climate variables. We must also take into consideration that simple linear extrapolation of established relations may be inappropriate due to non-linearities in either climate itself, in the climate-ecology impacts or in the links between cod and other trophic levels. The workshop will build upon the 1997 ICES/GLOBEC Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic (ICES 1997, 1998c), which for the first time brought atmospheric climatologists into the WGCCC community to discuss climate variability and prediction and responses in North Atlantic ecosystems. It will also use information obtained from the CCC program linking the physical environment to distribution, growth, maturity, recruitment, etc. The effects of the expected changes to the cod stocks on human communities will also be addressed.

Relation to Strategic Goals

This Action Item addresses Goal 4.

Cooperation

The CCC will seek input and participation from the CLIVAR community and other scientists working on climate scenarios, in particular statistical or dynamical downscaling from GCMs towards marine settings; climatologists who have shown interest in impacts on marine ecology; and social scientists interested in the societal and economic impacts of the predicted changes to the cod stocks.

E) Workshop on Implications of Results from CCC for Fisheries Management (2008)

Although climate is increasingly acknowledged as important for fisheries management, there has been little success in incorporating environmental information into the stock assessments. Part of this is due to the present fisheries assessment models for cod are primarily based on the premise that fishing controls the observed fluctuations in the cod stocks. Fine-tuning of such models with environment is likely to meet with only limited improvements at best. The aim of the Workshop will be to develop other techniques and methods for incorporating environment into fisheries and ecosystem management and to provide examples.

Relation to strategic goals

The workshop is focused directly towards Goal 1.

Cooperation

Scientists directly involved in cod management, for instance representatives from Arctic Fisheries Working Group (AFWG) or Baltic Fisheries Assessment Working Group (WGBFAS).

F) Synthesis II Workshop (2009)

As an end to the CCC program in 2009, a second Synthesis Workshop will be held to highlight the results of the program, with special emphasis on the final phase. The subjects to be addressed by the Workshop will depend on results and issues that arise during the next five years.

Relation to strategic goals

The workshop is focused directly towards Goal 6.

6. Relations to International GLOBEC goal and primary objectives

All CCC activities lie within the broad aim of GLOBEC, which *is to advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing so that a capability can be developed to forecast the responses of the marine ecosystem to global change.*

GLOBEC has four primary objectives:

Objective 1: To better understand how multiscale physical environmental processes force large-scale changes in marine ecosystems.

This is at the core of CCC activities and is dealt with under Action Item D, as well as B and C.

Objective 2: To determine the relationships between structure and dynamics in a variety of oceanic systems which typify significant components of the global ocean ecosystem, with emphasis on trophodynamic pathways, their variability and the role of nutrition quality in the food web.

Trophodynamics is the focus of Action Item B, but this objective will also be addressed in A. Comparison between different (cod) systems has been and is a much-used approach within CCC and will be the main approach used in Action Item C.

Objective 3: To determine the impacts of global change on stock dynamics using coupled physical, biological and chemical models linked to appropriate observation systems and to develop the capability to predict future impacts.

Linking models of different kinds to field observations has been a chosen approach of CCC. Impacts of global change will be the focus of Action Item D.

Objective 4: To determine how changing marine ecosystems will affect the global earth system by identifying and quantifying feedback mechanisms.

Feedback from the biosphere to the geosphere is not be explicitly dealt with within the CCC program. Societal effects are generally outside the scope of CCC, but will be addressed as part

of the Workshop on Climate Change through the invitation of knowledgeable and interested social scientists.

7. Relations to other GLOBEC Regional Programs

Within the final phase of the CCC Program, we will be seeking collaboration with other regional and national GLOBEC programs, and attempt to identify topics of mutual interest and areas of possible collaboration.

The PICES CCCC Program addresses how climate change affects ecosystem structure and the productivity of key biological species at all trophic levels in the open ocean and coastal North Pacific ecosystems. There is a strong emphasis on the coupling between atmospheric and oceanic processes, their impacts on the production of major living marine resources, and how they respond to climate change on time scales of seasons to centuries. Activities focus both on basin-scale and regional-scale. Although much of the interest within CCCC tends to be on open ocean species such as salmon, the identification of climate effects on fisheries is an obvious common focus to CCCC and CCC, including interest in statistical methods, retrospective analyses, data archaeology, regime shifts, etc. As a result, H. Batchelder, one of the present PICES WGCCCC co-chairs, was invited and attended the Transport Workshop (ICES 2002b) and the ICES WGCCC meeting (ICES 2002c) in May of 2002. In October of 2002, the co-chairs of the CCC and the ICES/GLOBEC Coordinator, attended the PICES/CCC meeting between the OPEN Science Meeting of GLOBEC and the PICES Annual Meeting held in Qingdao, China. CCC co-chair K. Drinkwater made a presentation on the CCC, including its synthesis activities. The discussion centred on fostering cooperation and joint activities between the two WGs. The FOCUS 1 WG of International GLOBEC is planning a comparative workshop to examine the similarities and differences between fish stocks around the world. It was agreed that cooperation between the two WGs should initially be fostered through this FOCUS 1 Workshop. In the interim, the co-Chairs of the two WGs continue to communicate on ways to promote cooperation. At the 2003 ICES ASC a specific proposal for ICES/PICES cooperation was presented in the form of Workshop on Evidence for and Impacts of Large-Scale Long-Term Variability in Zooplankton Populations. This would include members of the CCC as well as the ICES Zooplankton Working Group and other interested parties. Several papers from the North Pacific have been submitted to the

May 2004 Symposium on climate effects on fish stocks in Bergen and offers another opportunity for further discussions.

SPACC focuses on upwelling systems by means of both retrospective studies, in which ecosystem histories are reconstructed by means of time series, paleoecological data, and genetic data and process studies, in which cause-and-effect linkages between fish population dynamics and ocean climate are inferred from comparisons of standard measurements from different ecosystems. SPACC studies linkages between physical forces and biological processes with an emphasis on modelling to interpret multidisciplinary observations, and a focus on zooplankton as a key link between physics and fish productivity. Cause-and-effect linkages between fish, zooplankton and ocean physics can be inferred from comparisons of the many diverse ecosystems dominated by small pelagic fishes. The upwelling regions of SPACC are in many ways different to the geographic areas covered by CCC. However, the SPACC approach of comparing the characteristics and variability of the physical environment, zooplankton population dynamics and fish population dynamics among ecosystems is very similar to the CCC approach of comparing different cod ecosystems. Thus, although no concrete discussions have been entered into, CCC acknowledges common themes of interest and will consider future cooperation with SPACC. Some of this will be fostered through the proposed Workshop by the GLOBEC FOCI 1 Working Group.

ESSAS is in the early implementation phase so it is too early to enter into any collaborative activities. However, CCC expects to establish close links to ESSAS, not least since there is a certain overlap both by geography and species. The CCC co-chairs both being in the ESSAS Planning team allows for a good start too such cooperation.

Strong associations have been established between the US GLOBEC program on Georges Bank and the UK GLOBEC program with several CCC members being involved with one of these programs. The results of these programs are communicated to and incorporated into the CCC program.

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- Ottersen, G., B. Bogstad, and K. Helle 2002. Do abiotic mechanisms determine interannual variability in length-at-age of juvenile Arcto-Norwegian cod? *Can. J. Fish. Aquat. Sci.* 59: 57-65.

Appendix A. CCC Activities 1993-2003

This overview includes ICES/GLOBEC Cod and Climate Change workshops and, for recent years, also CCC theme sessions at the ICES Annual Science Conference and conferences with strong CCC involvement. Working group meetings are not included.

1993	August	ICES Symposium on Cod and Climate Change
1994	August	Aggregation Workshop
1995	March	Backward-Facing Workshop I – The tilefish kill of the 1880s
	November	Database Workshop
1996	March	Backward-Facing Workshop II – Ecosystem effects of cold events in the NE Atlantic
1997	September	Workshop on Prediction and decadal-scale ocean climate fluctuations of the North Atlantic (NAO)
1998	March	Workshop on Application of environmental data in stock assessment
	May	Backward-Facing Workshop III - Ocean climate of the NW Atlantic during the 1960s and 70s and consequences for gadoid populations
1999	March	Backward-Facing Workshop IV - The Gadoid Outburst in the North Sea
	August	TASC Symposium on Calanus
	September	ICES ASC Theme Session on Bio-Physical Modelling
2000	May	Workshop on the Dynamics of Growth in Cod
	September	ICES ASC Theme Session on Climate-Plankton-Fish Linkages
2001	August	ICES Symposium on Hydrobiological Variability in the ICES Area, 1990–1999
	September	ICES ASC Theme Session on the Dynamics of Gadoid Growth
2002	April	Workshop on the Transport of Cod Larvae
	October	Theme Session on Comparative Studies of North Atlantic Ecosystems, GLOBEC 2002 Open Science Meeting
	October	Contributed Session on Zooplankton-Climate Linkages in Different Regions of the Northern Hemisphere, GLOBEC OSM
2003	May	Workshop on Synthesis of the Cod and Climate Change Program
	September	ICES ASC Theme Session on the Transport of Cod Larvae

Appendix B. List of CCC reports

- ICES 1994a. Cod and Climate Change. ICES Marine Science Symposium. Vol. 198. 693+5 p.
- ICES 1994b. Spawning and Life History Information for north Atlantic Cod Stocks. ICES Coop. Res. Rep. 205.
- ICES 1994c. Report of the ICES/GLOBEC Cod and Climate "Aggregation workshop". ICES CM 1994/A:10,13 pp.
- ICES 1995. Report of the Cod and Climate Backward-Facing Workshop, Bedford Institute of Oceanography, Dartmouth, Canada. ICES CM 1995/A:7, 23 pp.
- ICES 1996a. 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 1996b. 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 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 1997a 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 1997b. Report of the Working Group on Cod and Climate Change (by correspondence) ICES CM 1997/A:9, 4pp
- ICES 1997c. Report of the ICES/GLOBEC North Atlantic Regional Co-ordination Group. ICES Headquarters, 16-17 June 1997 ICES CM 1997/A:8, 13pp.
- ICES 1997d 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 1998a. Report of the Working Group on Cod and Climate Change ICES CM 1998/C:10, 19pp.
- ICES 1998b. Report of the third Backward-Facing Workshop. Ocean Climate of the NW Atlantic during the 1960s and 70s and Consequences for Gadoid Populations. ICES CM 1998/C:9, 89pp.
- ICES 1998c. Report of the Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic. ICES CM 1998/C:14, 53pp
- ICES 1998d. Report of the ICES/GLOBEC workshop on application of environmental data in stock assessment. ICES CM 1998/C:1, 97pp.
- ICES 1998e. Report of the ICES/GLOBEC North Atlantic Regional Co-ordination Group. Woods Hole, USA 9 May ICES CM 1998/C:13, 4pp.
- ICES 1998f. 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 1999a. Report of the Workshop on Ocean Climate of the NW Atlantic during the 1960s and 70s and Consequences for Gadoid Populations. ICES Cooperative Research Report 234, 81pp.
- ICES 1999b. Workshop on Gadoid Stocks of the North Sea during the 1960's and 1970's. The Fourth Backward-Facing Workshop. ICES CM 1999/C:15, 89pp.
- ICES 1999c. Report of the Working Group on Cod and Climate Change ICES CM 1999/C:10, 19pp.
- ICES 1999d. Report of ICES/GLOBEC North Atlantic Regional Co-ordination Group. ICES CM 1999/C:1, 10pp.
- ICES 1999e. Report of the Steering Group for the ICES/GLOBEC North Atlantic Regional Office ICES CM 1999/C:12, 19pp.
- ICES 2000b. ICES/GLOBEC Workshop on the Dynamics of Growth in Cod ICES CM 2000/C:12, 114pp.
- ICES 2000b. Report of the Working Group on Cod and Climate Change ICES CM 2000/C:11, 16 pp.
- ICES 2001a. Workshop on Gadoid Stocks in the North Sea during the 1960's and 1970's. ICES Cooperative Research Report 244, 55pp.
- ICES 2001b. Report of the Working Group on Cod and Climate Change. ICES CM 2001/C:12, 10pp.
- ICES 2001c. Report of the Steering Group for the ICES/GLOBEC North Atlantic Regional Office ICES CM 2001/C:13, 13pp.
- ICES 2002a. Report of the ICES/GLOBEC Workshop on the Dynamics of Growth in Cod. ICES Cooperative Research Report 252, 97pp plus 1 CD.
- ICES 2002b. Report of the Workshop on the Transport of Cod Larvae ICES CM 2002/C:13, 44pp.
- ICES 2002c. Report of the Working Group on Cod and Climate Change. ICES CM 2002/C:12, 10pp.
- ICES 2002d. Report of the Steering Group for the ICES/GLOBEC North Atlantic Regional Office ICES CM 2002/C:17, 18pp.
- ICES 2002e ICES/GLOBEC Sea-going Workshop for Intercalibration of Plankton ICES Cooperative Research Report 250, 25pp plus 4 CDs.
- ICES 2003a. Report of the Working Group on Cod and Climate Change. ICES CM 2003/C:11, 16pp.
- ICES 2003b. Report of the Workshop on a Synthesis of the Cod and Climate Programme. ICES CM 2003/C:10, 28pp.