

ICES WGCCC Report 2006

ICES Oceanography Committee
ICES CM 2006/OCC:11

Report of the ICES/GLOBEC Working Group on Cod and Climate Change (WGCCC)

8-9 May 2006

St. Johns, Canada



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

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Executive Summary

- WGCCC discussed its possible contribution to the ICES Strategy and to the advisory process and made three proposals, which are set out more fully in section 3.
 1. Support for the Action Plan being prepared by the ICES/GLOBEC coordinator with specific suggestions concerning the application of results from CCC within the ICES advisory process. The chair of the Consultative Committee, Dr. Harald Loeng, took part in the discussion and provided valuable guidance.
 2. Bringing forward to 2007 the planned workshop on Implications of Results from CCC for Fisheries Management.
 3. Support for widening the activities of the ICES/GLOBEC office to include work on small pelagic species and on fisheries induced adaptive change.

The WG will continue to work to apply a wide range of science to the improvement of marine ecosystem management and sustainable utilisation and will support the integration and synthesis, which is now underway in the International GLOBEC programme.

- The proceedings of the Symposium on the Influence of Climate Change on North Atlantic fish stocks containing 32 papers have been published as Volume 62(7) of the ICES Journal of Marine Science
- Presentations on chapters of the forthcoming book on cod were given at the Theme session “Cod in a changing climate” at the ICES ASC in 2005. Completion of the final manuscripts for the book is now expected for then end of the year.
- A workshop on the Application of Environmental Information in Fisheries Management is planned in 2007. For this workshop, contributions on other gadoids than cod and small pelagics are welcome. Dates and venue and co-convenors have yet to be finally decided.
- A workshop on cod and future climate change is now scheduled for 2008 (instead of 2007 as envisaged in the CCC Strategic Plan).

Scientific highlights

- An ICES Cooperative Research Report (#274) synthesising information on spawning and life history of North Atlantic cod stocks has been published. This has already proved to be a valuable source of data for other publications.
- Recent studies by participants in the CCC programme have shown that stocks become less resilient to climate change as they decline. This may be due to the effect of reduced stock biomass, but lower mean age, reduced age diversity and loss of geographic sub-structure probably play a part. The processes which result in reduced resilience include low growth rates, low net reproductive output and high natural mortality. In some cases there may be genetic changes, which may greatly lengthen the time-scale for stock recovery, even under favourable conditions.

1 Opening of the meeting

The Working Group on Cod and Climate Change (WGCCC) met in St John's, Canada from 8-9 May 2006, under the co-chairmanship of Dr Geir Ottersen (Institute of Marine Research, Bergen, Norway) and Dr. Kai Wieland (Greenland Institute of Natural Resources, Greenland). There were 13 participants from 6 countries (Canada, Greenland, the Netherlands, Norway, Sweden and USA) and the ICES/GLOBEC Coordinator. A list of participants is provided in Annex 1.

The meeting was opened by Dr George Lilly who welcomed the participants to St John's followed by Dr Geir Ottersen who presented the Terms of Reference (ToR's, see section 2) and the Agenda (see Annex 2).

Immediately following the Working Group meeting, the Workshop on the Decline and Recovery of Cod Stocks Throughout the North Atlantic including tropho-dynamic effects was held, co-convened by Drs George Lilly (Canada), Brian Rothschild (USA), Svein Sundby (Norway) and Kai Wieland (Greenland).

2 Terms of reference and adoption of the agenda

According to C.Res. 2005/2/OCC11 the **ICES/GLOBEC Working Group on Cod and Climate Change** [WGCCC] (Co-Chairs: G. Ottersen, Norway and K. Wieland, Greenland) will meet in St John's, Canada, from 8-9 May 2006 to:

- a) review and evaluate the progress on the Synthesis Activities including:
 - i) publication of the book on cod,
 - ii) publication of the proceedings of the Symposium on the Influence of Climate Change on North Atlantic fish stocks;
- b) review and evaluate the Workshop on the Impact of Zooplankton on Cod Abundance and Production;
- c) review and evaluate the Theme Session on Cod in a Changing Climate (ASC 2005);
- d) make final preparations for the Workshop on the Decline and Recovery of Cod Stocks Throughout the North Atlantic including tropho-dynamic effects;
- e) continue planning for a Workshop on Cod and Future Climate Change and discuss other Workshops.

WGCCC will report by 31 May 2006 for the attention of the Oceanography Committee.

The group had been approached shortly before the meeting concerning an improvement of the links between the WGCCC and the ICES Advisory bodies. The ToR's and the agenda has been extended accordingly and an action plan for presentation by the ICES/GLOBEC coordinator, Dr. Keith Brander, during the ACFM and ACE meetings in late May 2006 was discussed.

3 Developing closer links with the ICES Advisory Process

The CCC programme has always regarded the application of results from the scientific work to the advisory process as a major justification for its existence and therefore welcomes help and cooperation in developing more effective ways to bring this about. The following proposal and recommendations are intended to further this:

WGCCC supports the request that the ICES/GLOBEC Coordinator should develop an Action Plan to be presented to ACFM, which will make specific suggestions concerning the application of results from CCC within the ICES advisory process. WGCCC suggests that the North Sea cod should be used as an initial case, because there is evidence that the stock is being affected by climate and ecosystem change and because it has received considerable attention within CCC.

WGCCC will recommend to the Oceanography Committee that the workshop on Implications of Results from CCC for Fisheries Management should take place in 2007 instead of 2008 as proposed in its Strategic Plan.

WGCCC notes that the activities of the ICES/GLOBEC programme office are being widened to include work on small pelagic species and on fisheries induced adaptive change. While being concerned that the immediate priority for the coordinator should remain on major uncompleted tasks, in particular the writing and editing of the Synthesis book on Cod in a Changing Climate, which must be finalised by the end of 2006, WGCCC is keen to explore how its work and that of the coordinator can support and eventually merge with other ongoing efforts in the field of climate and environmental impacts on fisheries.

WGCCC notes that the International GLOBEC SSC endorsed activities within its Synthesis, which will seek to bring about fuller application of scientific results in the management of marine ecosystems and sustainable utilisation.

4 Review of Synthesis Activities

4.1 Proceedings of the Symposium on the Influence of Climate Change on North Atlantic fish stocks

Following peer review 32 of the submitted papers were selected for publication. The symposium proceedings have been printed as Volume 62 (7): 1203–1541 of the ICES Journal of Marine Science in October 2005. The guest editors of the issue were Drs K.F. Drinkwater, H. Loeng, B.A. Megrey, N. Bailey and R.M. Cook. All participants of the conference have got a copy of the symposium proceedings, which has also been issued as ICES Marine Science Symposia Vol. 223.

4.2 Review of the Theme Session on Cod in a Changing Climate (ASC 2005)

Drs K. Brander and K. Drinkwater, co-conveners of the theme session, presented their report to the group. The first two sessions of this Theme Session presented twelve chapters of the forthcoming book “Cod in a Changing Climate” and the final session included eight papers, which dealt with closely related topics. The full report is given in Annex 4 to provide an overview of the content and of the major emerging issues and findings.

4.3 Progress with the CCC book

Delivery of manuscript to the publisher has been further delayed due to late submission of drafts and the heavy workload on the editors on other prioritised elements of their work programme. Completion of the final manuscript is now set for end of 2006. The editors (Drs Keith Brander and Ken Drinkwater) presented a summary showing the current status of drafting and editing together with their proposed timetable for completing the remain chapters and for carrying out the review and editing process. They requested cooperation and help from authors with (i) refereeing other chapters of the book (ii) preparing Figures to the required standard (iii) copyright permissions (iv) preparing complete, correct reference lists and (v) responding quickly to editors.

The editors outlined some of the issues that they will be addressing during the editorial process including (i) ensuring that the chapters deal with topics which were agreed in the outline (ii) producing clear, linked chapter summaries (iii) harmonising style (this is a book, not a collection of scientific papers) (iv) checking for gaps, overlaps and linkages across chapters (v) considering how to include emergent (and new) findings.

The International GLOBEC programme agreed some time ago to provide a budget for some of the production costs for the book (e.g. preparing artwork and illustrations) and this has been rolled over into their budget for the current year.

5 Workshop on the Impact of Zooplankton and Cod abundance

Svein Sundby gave an overview. The workshop (WKIZC) took place in Copenhagen June 6-9 2005 with 18 participants from 6 different nations. Several WGCCC members noted that the workshop had produced interesting results and that the report was good and prompt. However, one member requested, in general terms, more exciting highlights and also that key points be added in addition to the executive summary. It was also commented that some topics could not be dealt with to the extent one could wish due to few pure zooplankton ecologists participating.

The WG noted that the recommendation to publish the report from WKIZC as an *ICES Cooperative Research Report* was adopted at the 2005 Council Meeting (C. Res. 2005/1/OCC01) with an expected length of 100 pages.

WKIZC recommended two theme sessions for the 2006 ICES ASC: *What zooplankton are fish really eating? Species and diets, availability and dependency* convened by Drs. Xabier Irigoien and Christian Möllmann, and *Biogeographical changes in zooplankton communities; consequences for marine ecosystems* convened by Drs Luis Valdes and Peter Wiebe. The WGCCC noted that the first of the two theme sessions has been accepted for the ICES ASC in Maastricht 2007.

6 Workshop on Transport of cod larvae

The WGCCC Cod Transport Workshop (ICES CM 2002/C:13) was held 4–14 April 2003, in Hillerød, Denmark under Co-Chairs, J. Quinlan (USA) and B. Ådlandsvik (Norway). At the 2002 WGCCC Meeting (ICES CM2002/C:15), it was recommended that the Workshop Report be published as an ICES Cooperative Research Report. Following a brief discussion, the group agreed that it would not be right to allocate the necessary resources to this now and decided not to publish the report as a CRR. Instead the results from the workshop should be disseminated through other channels, in particular the book.

7 Theme Session at ICES ASC on Physical Processes Influencing Marine Ecosystems

During the past several years the PICES (WGCCCC-Climate Change and Carrying Capacity) and ICES (WGCCC) regional GLOBEC programmes having been communicating on climate-related topics of common interest. In 2002, Co-Chairs of the two WGs attended and made presentations at the other's annual WG meeting. Discussion has centered on fostering cooperation and joint activities between the two WGs. The WGCCC has earlier proposed that similar theme sessions be held at the PICES and ICES 2006 ASC with hopefully members from both WGs in attendance at each. The topic of the theme session will be Physical Processes Influencing Marine Ecosystems. When revising these plans WGCCC noted that there will be a theme session at the 2006 ASC towards these ends: *Large-scale changes in the*

migration of small pelagic fish and the factors modulating such changes (Co-sponsored by PICES) convened by Drs Jürgen Alheit (Germany), Dave Reid (UK), and Yoshiro Watanabe (Japan). Furthermore, there will be a GLOBEC workshop on *Impact of Climate Variability on Marine Ecosystems: A Comparative Approach* held in Berlin, from 4-8 September 2006. Given these planned activities WGCCC decided not to add further proposals for theme sessions.

8 Planning for future workshops

8.1 Workshop on Application of Environmental Information in Fisheries Management

WGCCC proposes that the planned workshop on Application of Environmental Information in Fisheries Management should take place in 2007, instead of 2008 as envisaged in the CCC Strategic Plan. Meeting dates and venue should be determined in close contact with the chairs of the Advisory Committees and relevant Assessment WGs in order to avoid conflict in timing with assessment related activities. A recommendation in preliminary form is appended and will be further developed in discussion between the CCC co-chairs, the ICES-GLOBEC coordinator, Dr G. Chouinard (as a possible convenor), the chairs of the Advisory Committees and relevant Assessment WGs for consideration by the Oceanography and the Living Marine Resources Committees (see Annex 5).

8.2 Workshop on the Future of Cod in a Changing Climate

Dr K. Drinkwater presented a first outline of the workshop (see Annex 6). WGCCC now recommends that this workshop be postponed to 2008 to avoid having two workshops in 2007.

8.3 Synthesis workshop

It was suggested that an ICES ASC theme session may be held in 2009 rather than a workshop. The group decided to postpone any detailed discussion until the plans for the Workshops on *Application of Environmental Information in Fisheries Management* and *The future of cod in a changing climate* have been further developed.

9 Matters arising from the International GLOBEC SSC meeting

Drs Sundby and Brander attended the International GLOBEC SSC meeting in Hawaii on 16–18 April and gave a brief verbal report. The four principal issues of concern to CCC and ICES were:

- Products during the Synthesis phase of the programme and in particular the application of the scientific knowledge arising from the programme in relation to marine ecosystem and fisheries management. The International GLOBEC SSC is concerned to ensure that the scientific legacy of GLOBEC is fully published and applied, where it is appropriate. The role of CCC, particularly in relation to ICES fisheries issues was recognised and encouraged. The contribution, which GLOBEC science could make to improve estimates of future regional and global fisheries production under different scenarios, was also discussed and an initiative to investigate this issue further was established.
- Integration with IMBER. IGBP is encouraging a single marine science programme under IMBER which will eventually absorb and continue with some elements of the work currently being carried out under GLOBEC. We need to consider what if any part ICES can play in this and to develop proposals for establishing a relevant programme. IMBER will be carrying out work related to

the global carbon budget (and biogeochemical cycling in general) and on marine production and sustainable management.

- The International GLOBEC SSC noted the current state of preparation with the CCC book and encouraged publication as soon as possible. Their funding to assist with this is again rolled over. There was some discussion of the future of the IGBP book series and of the planned volume on the SPACC programme
- Links with the SPACC programme. The ICES/GLOBEC coordinator is now funded partly to assist with work on small pelagic species and this was an opportunity to introduce some of the current activities within ICES.

10 Report from ICES/GLOBEC Coordinator

Dr. K. Brander gave a detailed presentation of his activities in the past year, the present funding situation and future perspectives. A full report is attached as Annex 8.

Annex 1: List of participants

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* part time (May 9)

Annex 2: Agenda

Monday, May 8 (Confederation Boardroom)

09:00 Welcome and Introductory Remarks (*Geir Ottersen and Kai Wieland*, Co-Chairs, *George Lilly*, local host)

- Welcome and Practical Items
- Review Terms of Reference [TOR] for Meeting
- Agenda

Review of Synthesis Activities [TOR a]

- Proceedings of the Symposium on the Influence of Climate Change on North Atlantic fish stocks (*Ken Drinkwater*) [TOR a ii]
- Book (*Keith Brander and Ken Drinkwater*) [TOR a i]

Theme Session on Cod in a Changing Climate [TOR c]

Review and evaluate the Theme Session on Cod in a Changing Climate (ASC 2005) (*Keith Brander and Ken Drinkwater*)

Zooplankton - Cod Workshop [TOR b]

Review and evaluate the Workshop on the Impact of Zooplankton on Cod Abundance and Production (*Svein Sundby*)

Workshop on the Transport of Cod Larvae

Decide if the 2002 Workshop on The Transport of Cod Larvae should be published as a CRR (*Keith Brander and Geir Ottersen*)

Contributions from WGCCC to ICES in general and Fisheries Management (*Keith Brander and Geir Ottersen*)

The chair of ICES Consultative Committee, Harald Loeng, has approached the group and proposed that we develop an action plan to be presented to ACFM during their meeting later in May. We should discuss and develop such a plan.

Workshop on the Decline and Recovery of Cod Stocks Throughout the North Atlantic [TOR d]

- Make final preparations for the Workshop on the Decline and Recovery of Cod Stocks Throughout the North Atlantic including trophodynamic effects (*George Lilly, Brian Rothschild, Svein Sundby and Kai Wieland*)

17:30 Adjourn

Tuesday, May 9 (Avalon/Battery Boardroom)

9:00 Report from ICES/GLOBEC Coordinator (*Keith Brander*)

- Activities for past year and coming year
- Funding

Theme Session on Physics Relevant to Marine Ecosystems

Review plans for a Theme Session on Physics Relevant to Marine Ecosystems (ICES ASC 2007?) (*Ken Drinkwater and Geir Ottersen*)

Planning for Future Workshops [TOR e]

- Start planning for Workshop on Cod and Future Climate Change (2007 or 2008) (*Ken Drinkwater*)
- Start planning for Workshop on Implications of results from WGCCC for Fisheries Management (2007 or 2008)(*Kai Wieland*)
- Discuss Synthesis Workshop (2009) (*Geir Ottersen and Kai Wieland*)

Potential conveners, times and locations, and possible other workshops not previously identified that should be undertaken will be discussed (note that any new workshops will mean replacement of one that has previously been identified). WGCCC is scheduled to finalize in 2009. Should the Synthesis Workshop be replaced with a Conference?

Other future WGCCC activities (*Kai Wieland*)

- Need for 2007 WG Meeting or Work by Correspondence?
- Other possible activities of WGCCC
 - Theme Sessions for ASCs?
 - Others?

Brief report from GLOBEC SSC and GLOBEC/PICES Symposium (*Svein Sundby and Keith Brander*)Other Business (*Geir Ottersen and Kai Wieland*)Wrap-up and Summary (*Geir Ottersen and Kai Wieland*)

- Recommendations
- Action Items
- TORs for 2007

12:00 Adjourn

Annex 3: WGCCC Terms of Reference 2007

The ICES/GLOBEC Working Group on Cod and Climate Change (Co-Chairs: Dr. G. Ottersen, Norway and Dr. Kai Wieland, Greenland) will work by correspondence in 2006-2007 to:

- a) review, evaluate and develop results from the Workshop on the Decline and recovery of cod stocks throughout the North Atlantic including tropho-dynamic effects;
- b) plan the Workshop on Application of Environmental Information in Fisheries Management in 2007 (see Annex 5);
- c) initiate plans for the Workshop on Cod and Future Climate Change, which is postponed to 2008 (see Annex 6);
- d) initiate plans for a Synthesis workshop or Theme Session in 2009.

WGCCC will report by 15 May 2007 for the attention of the Oceanography Committee, ACE, and ACFM.

PRIORITY:	The group is developing the application of environmental information in the Advisory Process and also the relationship between ecosystem change and fish population dynamics. It therefore has high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan Principally Goals 1.6, 3.5 and 5 Term of Reference a) The WG will follow up on the report of the 2006 workshop in order to support further research and collective publication. Term of Reference b), c), d) Planning and preparatory work will be carried out for the workshops in 2007 and 2008. This will include selecting co-convenors, establishing dates and locations and drafting the terms of reference.
RESOURCE REQUIREMENTS:	The research programmes which provide the main input to this group are already underway, and resources already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
PARTICIPANTS:	by correspondence
SECRETARIAT FACILITIES:	None.
FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	Linkages with the advisory committees are being developed.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Linkages with other committees (RMC and LMR) will be developed in the context of the Action Plan for application of results from the CCC programme.
LINKAGES TO OTHER ORGANIZATIONS:	Close linkages with other GLOBEC activities and also some links to PICES.
SECRETARIAT MARGINAL COST SHARE:	100%.

Annex 4: Report on the Theme Session at the 2005 ASC on Cod in a Changing Climate

Co-convenors: Keith Brander, ICES, Denmark and Ken Drinkwater, Norway

Introduction

The first two sessions of this Theme Session presented twelve chapters of the forthcoming book “Cod in a Changing Climate” and the final session included eight papers, which dealt with closely related topics. The book is part of the syntheses being undertaken by the ICES/GLOBEC Cod and Climate Change (CCC) program. The commercial importance of North Atlantic cod has resulted in a long history of research, including the CCC programme over more than a decade. Much has been learned about the biological and life history processes underlying climate-driven changes for this species and about their interaction with each other and with predators, the food chain, and other components of the marine ecosystem. Cod is probably the most comprehensively studied marine fish species, occupying a key role in several North Atlantic ecosystems. An understanding of its dynamics is of direct and indirect relevance to other species and to gaining general insights into the response of the marine ecosystem to climate change and variability.

The successive chapters, which were presented, included:

- History of cod and climate research in the North Atlantic-past, present, and future;
- History of the North Atlantic cod stocks;
- Physical oceanography of Atlantic cod habitats;
- A review of the biological oceanography of cod early life stages;
- Growth, condition and production of cod in a changing climate;
- An overview of the state of knowledge of the transport of cod eggs and larvae;
- Cod recruitment and climate change – a comparative approach;
- The impact of climate on distribution and migration of Atlantic cod;
- The role of cod in the ecosystem;
- The response of Atlantic cod to future climate change;
- The human dimensions: demographic impacts of fisheries decline;
- Relevance of the programme to the assessment and management of cod stocks.

Historic overview

The CCC programme developed from longstanding concerns about the “recruitment problem” and about the relationship between the effects of fisheries and environment on the observed variability in fish stocks. The analysis of these issues, which was articulated over many years, is still valid, although considerable progress has been made. Cod was chosen as a means to focus effort onto an intensely studied species that occurred throughout most of the ICES region. The guiding principles have included (i) emphasis on processes rather than correlative analysis (ii) encouragement of coupled physical-biological partnerships (iii) deployment of advances in population genetics and biotechnology (iv) development and utilisation of advanced sampling technology, and (v) application of the comparative approach. The areas for investigation included (i) linkages between different temporal and spatial scales (ii) dynamics of individual organisms (iii) key physical processes (iv) ecological mechanisms for population persistence and (v) theory and modelling.

Almost all cod stocks in the North Atlantic have declined over the past three decades, with total catches falling from around $4 \cdot 10^6$ tons to under $1 \cdot 10^6$ tons. This is primarily a

consequence of intensive fishing, but adverse changes in their environment have also played a part. Our knowledge of the structure of stocks and of the levels of genetic separation, which exist both between and within current stock boundaries, has improved as new molecular techniques have become available and affordable. Continuing high levels of fishing give rise to concerns about possible selective changes and loss of genetic diversity.

The Physical and Biological Background

Cod occupy a temperature range from close to 0°C to as high as 20°C, but the annual mean temperatures at which they occur are between about 1 and 12°C. They also occur in a range of salinities from around 35 to less than 10 (in the Baltic).

The food environment of cod larvae is critical to their growth and survival. The copepods *Calanus finmarchicus* and *Para/Pseudocalanus* are an important part of their diet in all areas. Other suitable-sized, abundant zooplankton species are not found in the stomachs of cod larvae, either because they occur at the wrong season (e.g. *C. helgolandicus*) or because cod larvae appear to reject them (*Acartia*, *Limacina*, *Oithona*). The boundary between the cold areas occupied by *C. finmarchicus* and the warm areas occupied by *Para/Pseudocalanus* shifted northward between the late 1970s and the 1990s, but it is not yet clear whether this had consequences for zooplankton production in general and cod in particular.

Life history and ecosystem processes

Substantial progress has been made in understanding and modelling growth processes of cod, from hatching through to adult life. It has become apparent that variability in growth is a much more important factor in generating fluctuations in cod stocks than had been thought at the start of the CCC programme. Very large changes in weight-at-age have been observed in many stocks and all major stock collapses were accompanied by (or preceded by) a decline in growth. Changes in condition also have a major impact on reproductive output, with cod in poor condition (<5% liver weight) producing few or no viable eggs.

Most cod larvae and juveniles in the wild grow at rates close to their maximum (i.e. for the temperature at which they occur and with unlimited food). Cod larvae have no food reserves (liver or lipids) and those that grow slower than maximum may not survive. Temperature for optimal, food-unlimited, growth decreases with size of the fish and is probably in the range 8-10°C for cod weighing over 1 kg. Because of the ontogenetic change in the effect of temperature on growth, the seasonal variability in temperature, and the effects food availability, it is not easy to predict the consequences of climate change on growth.

Improved understanding of the causes of recruitment variability in fish was a major motivation for the GLOBEC programme, but it remains elusive. New information on the spatial and temporal dynamics of plankton production indicates that there is no simple, universal relationship determining survival of cod during early life. Indeed, the “critical period” governing recruitment may occur at different times in the life history in successive years, depending on the prevailing physical and biological conditions.

Sophisticated coupled physical-biological models have been developed for a number of cod stocks to reproduce the observed transport and dispersion of cod eggs and larvae and to explore the causes and consequences of variability in their geographic fate. Some interesting paradoxes emerge. Transport over long distances (away from their origin) might be expected to result in mixing between stocks, yet even geographically proximate stocks frequently show a degree of genetic isolation. There is some evidence that transport affects survival of larvae, but the sign of the effect can be positive or negative, depending on the food environment they encounter. Long transport pathways (e.g. around Iceland and across to Greenland) do not entail high variability in subsequent recruitment, but are always followed by homing of most (perhaps all) of the maturing fish to their original spawning site.

Recent studies using acoustics, mid-water and bottom trawling, and data storage tags have shown that cod are capable of significant behavioural thermoregulation at diel and seasonal scales. In a number of areas (e.g. Gulf of St Lawrence, Norwegian Sea) the ambient temperature for cod is lower in summer than in winter, due to their horizontal and vertical movements. There may also be density dependent components of these migrations.

With the decline of cod populations throughout the North Atlantic due to fishing and in some cases additional detrimental environmental effects, the ecological role of the species has also diminished. It is not clear how continuing climate change will further alter the ecological balance, but compensatory effects are possible and may already be at work. This would reduce the resilience of the species and slow down or halt stock recovery, even if fishing mortality is kept very low. Cod are highly plastic and opportunist in their feeding habits and this is unlikely to alter as a result of climate change, however the high productivity of the stocks at the cold end of the range is probably quite dependent on the availability of particularly suitable forage species as prey, in particular capelin.

Climate change, human impacts and management

Comparative information on distribution, abundance, growth and recruitment of cod in relation to temperature throughout its range provides a first order basis for predicting the consequences of climate change. This is supported by historic evidence from earlier periods, such as the warm period from 1920–1950s or 1960s, when temperature conditions were similar to those currently developing in the North Atlantic. Recent observations show a northward retreat of cod at the warm end of their range e.g. in the southern North Sea and recolonisation of cold offshore areas at Greenland, where cod experienced good recruitment, growth and condition during previous warm periods. good recruitment, high condition and high growth rates during previous warm periods. Such trends can be expected to continue as a result of further warming. Changes in the annual mean may not be a very reliable indication of limiting temperatures, since the limits may be set by short-term extremes in summer and winter, which are related to the magnitude of seasonal variability. So, for example, cod in the Celtic Sea, which is much more oceanic than the southern North Sea, may survive there at a higher annual mean, because they do not experience such extreme warmth in summer.

Past changes in cod stocks at Newfoundland, Greenland and Faroes have had varied impacts on the human economy and demography. Fisheries-dependent societies show rapid quantitative responses, such as outmigration of young adults, but also rapid adaptation to the changing circumstances, by development of alternative fisheries or by alterations to the economy to make it less dependent on capture fisheries.

Although the consequences of climate change for marine ecosystems are increasingly well documented and in some cases can be shown to affect the distribution and productivity of cod stocks, fisheries management advice within the ICES area has to date not taken this into account. One reason is that the sequential population models used for short-term advice are based only on information from fishing. Since the founding of ICES, views on the effects of fishing and environment on fish stocks have tended to polarise and we are still striving for a balanced approach. Environmental and biological information (including results from the CCC programme) should be included, provided that it makes a significant difference, is based on some understanding of the underlying processes and is available in a timely, cost effective way. In practice, such applications of environmental considerations are more likely in a medium or long-term context and short-term assessments should be kept as simple and robust as possible. More complex models, which include the kind of results produced by the CCC programme, can play a valuable role in simulations designed to test the robustness of simple assessment methods and the management procedures derived from them.

Annex 5: Draft Resolution to establish a Workshop on Application of Environmental Information in Fisheries Management

The WGCCC proposes that a **Workshop on Application of Environmental Information in Fisheries Management** [WKAEI] be held in 2007 (instead of 2008 as envisaged in the CCC Strategic Plan) in order to ensure that lessons learned from GLOBEC and related programmes are effectively applied in relation to fisheries management. The detailed plans for the workshop (ToR, dates, venue, co-convenor) will be further developed in discussion between the CCC co-chairs, the ICES-GLOBEC coordinator, Dr G. Chouinard (a possible convenor), the chairs of the Advisory Committees and relevant Assessment WGs for consideration by the Oceanography, Resource Management and Living Marine Resources Committees.

Terms of Reference

The **Workshop on Application of Environmental Information in Fisheries Management** [WKAEI] (Co-Chairs: Ghislain Chouinard*, Canada, (tentative), and NN) will meet in [to be decided] from [to be decided] to:

- a) assemble and evaluate case studies in which environmental factors can be shown to have had a significant impact on fish population dynamics;
- b) estimate the consequences of environmental variability (including “regime shifts”) for the biological reference points and other measures which are currently used to guide fisheries management;
- c) identify, develop and evaluate procedures for improving fisheries management strategies by including environmental information.

WKAEI will report by [to be decided] 2007 for the attention of the Oceanography Committee, ACE, and ACFM.

Supporting information

PRIORITY:	The workshop aims to develop the application of environmental information in the Advisory Process. It therefore has high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	<p>Action Plan - Principally Goals 1.6, 3.5 and 5</p> <p>There is increasing concern about the effects of climate and other environmental changes on sustainability of fisheries but the means of introducing environmental information into the advisory process require further development. The aim of the workshop is to contribute to this development by bringing together and evaluating cases showing how scientific results from the CCC and other GLOBEC related programmes can be applied in fisheries assessments.</p> <p>The Terms of Reference are provisional and may be updated during consultation process</p> <p>Term of Reference a)</p> <p>Case studies will principally be from the ICES/GLOBEC programme, including work on small pelagics. In judging whether these case studies of past variability should be the basis for future inclusion of environmental information, three criteria must be satisfied (i) the introduction of environmental information must have a significant effect (ii) underlying processes must be reasonably well established (i.e. not just correlation) (iii) necessary environmental information must be obtainable in a timely and affordable way.</p> <p>Term of Reference b)</p> <p>Major changes in oceanographic and biological conditions have resulted in changes in growth, recruitment, mortality and distribution of cod and other species, with consequences for surplus production. The consequences of these changes for biological reference points need to be evaluated</p>

	<p>Term of Reference c)</p> <p>Section 9 of the 2006 ACE report many of the issues concerning inclusion of environmental and ecosystem information in ICES advice and this ToR will support the current “best practice” as it develops.</p>
RESOURCE REQUIREMENTS:	The research programmes which provide the main input to this group are already underway, and resources already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
PARTICIPANTS:	25–30
SECRETARIAT FACILITIES:	Support from ICES/GLOBEC coordinator
FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	Linkages with the advisory committees are being developed.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Linkages with other committees (RMC and LMR) will be developed in the context of the Action Plan for application of results from the CCC programme. Close working links will be encouraged with assessment groups whose stocks are being used as case studies.
LINKAGES TO OTHER ORGANIZATIONS:	Close linkages with other GLOBEC activities and also some links to PICES.
SECRETARIAT MARGINAL COST SHARE:	100%.

Annex 6: Recommendation concerning the Workshop on cod and future climate change

The WGCCC proposes that the **Workshop on Cod and Future Climate Change** will be held in 2008 (instead of 2007 as envisaged in the CCC Strategic Plan) under the chairmanship of K. Drinkwater (Norway). Because of the delay of one year a Resolution is not required at this stage and the recommendation is directed at WGCCC, for further consideration and to be put forward as a Resolution in 2007.

The terms of reference are:

In response to future climate change scenarios

- a) to determine the most likely response of the physical oceanography, including nutrient concentrations, in the North Atlantic;
- b) to develop impact scenarios for phytoplankton and zooplankton production and distribution, especially those species eaten by cod and their predators or prey during their life histories;
- c) to determine the most likely response of the prey or predators of cod including the forage fishes, such as capelin, herring, sprat and mackerel;
- d) to develop future scenarios for cod production (growth, reproduction, mortality, recruitment) and distribution.

This will be carried out using a combination of retrospective data analyses and a variety of modelling approaches. The Workshop report will be presented to the Oceanography Committee at the 2008) ICES Annual Science Conference.

Supporting Information

PRIORITY:	This Workshop will contribute to the Cod and Climate Change strategic plan.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	The Symposium will contribute to Goals 1, 4, 5 and 10 of the ICES Strategic Plan. Many of the regions presently occupied by Atlantic cod are predicted to undergo significant warming in response to climate change and in recent years much of the North Atlantic has experienced such warming. Increasingly, managers, politicians and the general public have been asking what will be the impacts of future climate change. Such information for cod and the marine ecosystems have been limited. Indeed, the few published studies have usually considered the response of individual species to increased warming without considering other components of the marine ecosystem, such as their prey or predators. However, climate change is expected to impact both the structure and function of marine ecosystems and to develop more plausible impact scenarios we must consider the species as part of the ecosystem. Using our increased understanding gained through the ICES/GLOBEC Cod and Climate Change program, including past workshops, plus other research on the effects of climate variability on cod and its supporting ecosystem, the impact of future climate scenarios on the marine ecosystems of the North Atlantic and especially cod will be developed.
RESOURCE REQUIREMENTS:	Assistance of the ICES/GLOBEC Coordinator in maintaining and exchanging information and data to potential participants.
PARTICIPANTS:	This Workshop is expected to attract 15-25 participants, most of who would contribute papers. The majority will be drawn from the ICES scientific community, although a number of scientists from outside ICES are also expected to contribute.
SECRETARIAT FACILITIES:	Secretariat Facilities: None
FINANCIAL:	Financial: None.
LINKAGES TO ADVISORY COMMITTEES:	Linkages to Advisory Committees: Relevant to the work of the ACFM and ACE.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Linkages to Other Committees or Groups: Living Resources, SGNARO, WGZE, WGRP, WGBPI.
LINKAGES TO OTHER ORGANIZATIONS:	Linkages to Other Organizations: GLOBEC is a co-sponsor of the WGCCC.

Annex 7: Report from ICES/GLOBEC Coordinator

Activities in 2005/2006

The GLOBEC programme as a whole is concerned with “understanding how Global Change will affect the abundance, diversity and productivity of marine populations”. Such understanding is frequently sought in relation to policy making on the issues of climate change, biodiversity and ecosystem management. Many of the scientists involved in national and regional GLOBEC programmes (including CCC) contribute to reports and presentations on these subjects, but because their work is generally funded from other sources, it is difficult to claim GLOBEC ownership. However the ICES/GLOBEC coordinator has been involved in a number of recent activities which illustrate the scope of the applications. These include:

- The Arctic Climate Impact Assessment (<http://www.acia.uaf.edu/>) was published in late 2005. The chapter on Marine Systems included three CCC members among its ten authors.
- The IPCC Fourth Assessment Report, for which Dr Brander is lead author on fisheries, is currently under Government review and will be published in 2007.
- Numerous media interviews took place with CCC participants during the 2005 ASC and the WG meeting in St John’s in May 2006. A series of articles, including contributions by Dr Ottersen and Dr Brander, appeared in *Industrias Pesqueras* (No 1880, August 2005) under the title “Does climate change affect fishing?”.
- A paper on Climate Change and Fisheries was commissioned by the German Advisory Council on Global Change and talks on the same subject were given at the International Conference on “Biodiversity: Science and Governance” and the EU Green Week in 2005.
- Dr Brander has given talks in 2006 on biodiversity, climate and objectives for fisheries and marine ecosystem management at the University of Oslo, the Society for Experimental Biology and DEFRA, London.

The workplan for the ICES/GLOBEC office is set out in detail at the beginning of the calendar year and is reviewed and approved by the Steering Group (SGNARO) and by the ICES Bureau early in the year. The 2006 workplan is appended below and the targets and milestones are steadily being achieved. The two most substantial targets were the preparation for the Workshop on Decline and Recovery of Cod Stocks and the preparation of the Second Order Draft of the IPCC report. The former involved setting up the website and data exchange for the workshop, soliciting and bringing together the working papers and preparing an analysis of the comparative data sets. The result of this work can be seen on the website, in the report of the workshop and in a paper which has been accepted for publication in the *ICES Journal*.

Recent papers on climate impacts on cod are listed below. Work on the impacts of fishing and climate on biodiversity is taking a more prominent role and will be boosted by the appointment of a post-doctoral fellow later this year, for a two year period.

Brander, K.M. 2005. Cod recruitment is strongly affected by climate when stock biomass is low. *ICES Journal of Marine Science*, 62: 339–343.

ICES 2005. Spawning and life history information for North Atlantic cod stocks. *ICES Cooperative Research Report* 274.

Brander, K.M. (accepted). The role of growth changes in the decline and recovery of North Atlantic cod stocks since 1970. – *ICES Journal of Marine Science*.

Stige, L.C., Ottersen, G., Brander, K., Chan, K.-S., Stenseth, N.C. (submitted) Cod and climate: effect of the North Atlantic Oscillation on recruitment in the North Atlantic *Marine Ecology Progress Series*.

Present funding

The funding of the ICES-GLOBEC office is provided by Denmark (DIFRES), France (IFREMER), UK (DEFRA) and Norway (Norwegian Research Council). Due to restricted funding, the salary provided from the ICES/GLOBEC budget has now been reduced to 60%, with some of the shortfall being paid from the FishACE budget (EU Marie Curie Research Training Network).

Future perspectives

The strategic plan for the ICES/GLOBEC office matches and supports the plan for the programme as a whole over the period to the end of 2009. For the remainder of 2006 the principal activities will be to complete the editing of the book and of the IPCC report, to support and attend three workshops and to co-convene a Theme Session on “Integrated assessments in support of regional seas ecosystem advice”. The workshops are (i) FishACE annual team workshop (ii) Impact of Climate Variability on Marine Ecosystems (iii) Long-term Variability in SW Europe. The latter two workshops herald a change in the overall direction of the work in that they will be focussing mainly on small pelagic fish.

From early 2007 the direction of the work will also change somewhat, in order to concentrate more on the application of results from the Cod and Climate Change programme to fisheries and marine ecosystem management. Part of this will involve preparation for the proposed workshop on Application of Environmental Information in Fisheries Management and part will involve the development of an Action Plan, as initiated by the Consultative Committee and which is to be discussed and developed further during the 2006 Council Meeting and the lead-in to it. It will also be strengthened by the appointment of a Marie Curie post-doctoral fellow who will work in the FishACE programme.

TASKS AND TARGETS for 2006 agreed by SGNARO and the ICES Bureau

Task 1 Implementing the Cod and Climate Change work programme, in fulfilment of the contracts and commitments made with funding bodies. (60% of KB's time)

Targets and Milestones:

- 1) Assist with the work of the **Cod and Climate Change Working Group**. Attend the meeting and assist with report due on 31 May 2006. - 10 days
- 2) Prepare for and take part in the **Workshop on the Decline and Recovery of Cod Stocks throughout the North Atlantic including tropho-dynamic effects** 9-12 May 2006. Assist with report and publication - 25 days.
- 3) Coordinating, writing and editing the book synthesising results from the Cod and Climate Change programme. - open ended time requirement.
- 4) Assist with publication of the report of the **Workshop on Impact of Zooplankton on Cod Abundance and Production** as a CRR – 10 days
- 5) Prepare for and take part in the **ICES/GLOBEC Workshop on Long-term Variability in SW Europe** 20-24 November 2006. Assist with report and publication - 15 days
- 6) Maintain regular ICES/GLOBEC Newsletter and pages on the WWW. 10 days
- 7) Establish and oversee the new post-doctoral post in the **Fisheries Induced Adaptive Change Network**. The holder will work on management implications and development of advice under the precautionary approach - 20 days
- 8) Attend author meetings in January, March and September and prepare 2nd draft of **IPCC WG2** report – 25 days
- 9) Assist with aspects of the EU UNCOVER (mechanisms of stock recovery) programme – 10 days

- 10) Preparing for and convening Theme Session on **Integrated assessments in support of regional seas ecosystem advice – beyond Quality Status reporting** at ASC. - 10 days

Task 2 Writing proposals for continued funding, preparing reports and accounts, dealing with ad hoc requests for data and information, evaluating papers and research proposals (40% of KB's time)

Targets and Milestones:

- 1) Proposals for new or renewed funding - 10 days
- 2) Deal with ad hoc requests for data, information, reviews - 10 days
- 3) Steering and review for GLOBEC related programmes, including SSC meeting in Hawaii (April). Present talks on North Atlantic GLOBEC programme. 15 days
- 4) Give seminars in Oslo, Canterbury, DEFRA (London), Aarhus 5 days