ICES/GLOBEC Newsletter

Number 7, April 2001

Editorial

by Keith Brander

Many thanks to all those who sent in material for this Newsletter and apologies to those who received multiple copies of my request for contributions, due to a problem with our mailer. Whether the two things are connected or not, I was inundated with articles and announcements, which I have tried to include by editing, reducing the font size and passing some on to the ICES Newsletter.

The range of subjects is wide, but relevant to the GLOBEC theme - *effects of physical variability on the marine ecosystem*. The subjects relate to each other, as is the case with the biological detail and long term oceanographic records in the final article. The author, Eero Aro, wrote: "Please find enclosed a short story about Baltic cod, which I developed this late evening here in my kitchen." Send more! This is an informal Newsletter, intended to stimulate cooperative thinking and work, not a journal. It took two days from Eero's article arriving to finalising the copy and I aim to send it to you inside a week.

I won't repeat the information about the Cod and Climate Change programme, which was in the previous Newsletter, but please get in touch if you want to know more about any specific elements and to take part.

ICES decided at its meeting last September to continue with the ICES/GLOBEC office, provided that direct costs were covered by external funding. Financial support from the US, UK, Norway and Canada has made this possible for at least another year. The direct costs of the office, including work undertaken for ICES, as well as for GLOBEC, have always been paid entirely from external funding and the renewed ICES support is very welcome.

The Steering Group for the programme has been re-established and is due to begin work this month. It is chaired by Scott Parsons, Ken Drinkwater and Fritz Köster and is open to participants in the ICES/GLOBEC programme. Its remit includes identifying strategic and funding avenues, as well as reviewing and advising on work plans. A Bureau Working Group on International Programmes met recently for the first time to develop an ICES policy for involvement with other international programmes.

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

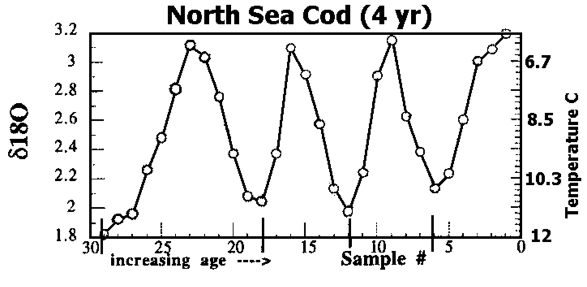
Estimating ambient temperature

Temperature affects almost all rate processes, but it is not easy to measure the appropriate temperature which fish experience. Two new approaches, discussed and initiated during the Cod and Climate Change (CCC) programme are introduced below. They can be expected to generate an enormous amount of new, detailed information over the coming years. They also provide excellent examples of the value of bringing colleagues from other scientific disciplines into programmes such as CCC, which was one of the goals set by ICES when it endorsed GLOBEC.

(1) New information from old otoliths

Don't throw away old otolith collections; they contain a record of the temperature history of individual fish, which can be used to build time series going back several decades. Seasonal temperature variability can aid the interpretation of annual growth rings and can be used to fit growth models. The otoliths can also provide information about migration and stock structure.

The methodology for high resolution temperature reconstructions of individual cod was developed by Chris Weidman (WHOI), after he took part in a Cod and Climate Change (CCC) workshop and was persuaded to look at some cod otoliths. Successive tiny (40µg) samples of carbonate are milled off the edge of an otolith and the oxygen isotope ratios determined by mass spectrometry (see Weidman and Millner, Fisheries Research 46(2000) 327-342). Resolution is up to 20 values per year and accuracy is about 0.5 - 1 C^{o}.



Otolith ring width has often been used to back-calculate growth history, so in combination with temperature reconstruction it may be possible to fit individual temperature/growth relationships. A proposal to carry out a research programme with this aim was discussed at the last meeting of the CCC Working Group and colleagues who are interested should get in touch with Keith Brander. An independent check on the results from the isotope analysis could be provided by data storage tags, which record temperature (see below) , or by enclosure reared fish.

Elemental analyses of the otoliths provide other kinds of information (reviewed recently by Campana and Thorrold Can. J. Fish. Aquat. Sci. 58:30-38 (2001)), about the history and origins of individual fish. Also, traces of blood and tissue left on the otolith or on the paper envelope in which individual otoliths are usually stored can be used for genetic analysis. For example microsatellite DNA is revealing more about the discreteness of cod breeding units, but also the prevalence of (non-breeding) mixing, which appears to take place between fish from different breeding units, such as the North Sea and the Baltic.

The combination of these analyses for individual fish can provide a detailed reconstruction of several aspects of their life history and origins. This may not make the life of assessment scientists any easier in the short term, but will enhance our understanding of the underlying processes of growth, migration and reproduction.

(2) Data storage tag study - comparison of northern and southern Gulf of St. Lawrence cod stocks

The ICES/GLOBEC Workshop on the Dynamics of growth in cod (Dartmouth, Canada, May 2000; ICES CM 2000/C:12) concluded that refining the measurements of temperatures occupied by cod, the ambient temperatures, was needed to support the parameterisation and validation of bioenergetic growth models. As part of this effort, a study is being undertaken in Canada to compare ambient temperatures between the two cod stocks of the Gulf of St. Lawrence. Drs Doug Swain and Martin Castonguay from the Canadian Department of Fisheries and Oceans purchased 2,000 data storage tags (temperature loggers - see above) that will be installed on adult cod from various locations in both the northern and southern Gulf in 2001 and 2002. They will rely on recaptures from commercial fishermen to get data storage tags back. A high-reward program will be put in place to maximise the probability of recapture. A pilot study indicated that internal implantation of data storage tags may lead to a significant proportion of them going unnoticed. For this reason, they are developing an external attachment method. For more information, feel free to contact Martin Castonguay (castonguaym@dfo-mpo.gc.ca) or Doug Swain (swaind@dfo-mpo.gc.ca).....♋

The IButton records only temperature. It is made by Dallas Semiconductor for commercial purposes such as keeping track of ambient temperature of perishable food during transport. Its main advantage is its sale price: 9 $US a piece! We expect resolution of +/- 0.5 to 1°C. IButtons will log a maximum of 2048 points, sampled at a rate of 1 to 255 min. A sample every 4 h will provide a one year time series.

Theme Session V - Oslo ,September 2001

Growth and Condition in Gadoid Stocks and Implications for Sustainable Management

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

The ICES/GLOBEC Workshop on the Dynamics of Growth in Cod in May 2000 reviewed recent findings on cod growth and condition in contrasting environments. A building body of evidence has demonstrated linkages among growth, physiological condition, reproductive effort, and production in Gadoid stocks and suggests that not all Gadoid stocks or all individuals within a stock exhibit similar growth responses under similar environmental conditions. Within a stock, fishes of different size, for instance, have different requirements, with larval and juvenile fish growing better at higher temperatures than adult fish. Predictions on the production of a stock and the consequences for sustainable management require a better understanding of the genetic, ontogenic, and phenotypic aspects of individual growth, as well as better growth models. Growth encompasses a host of physiological mechanisms ranging from ingestion to assimilation and synthesis of new tissue. Enhanced growth is generally accompanied with an improvement in physiological condition. Indices of the physiological condition have long been used as proxies to estimate growth rate in larval fish. Recent applications of physiological indicators in juvenile and adult fish offer new avenues of research to investigate growth dynamics, reproductive effort, and production in wild fish. The aim of this Session is to explore these new tools and to examine stock- and size-specific growth responses to various factors, including climate variability, stock density, and size selective fishing. The Session will consider both multivariate analyses at the stock level and field and laboratory studies on growth and condition.

General information about the Annual Science Conference can be found at the ICES website (http://www.ices.dk/asc/2001). The deadline for abstracts set by ICES is Monday May 7, when both a title and abstract are due at the ICES Secretariat. It would be helpful if you forwarded a copy of that correspondence to one of the co-convenors at the same time.

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

National GLOBEC programmes

A new report on national, multinational and regional GLOBEC activities has just been published (GLOBEC Special Contribution no 4) and can be obtained from the International GLOBEC web site:
http://www.pml.ac.uk/globec/

Some additional information is provided here about programmes in the ICES area:

Germany

Latest news about the substantial proposal for a German GLOBEC programme, which was reviewed early this year, is that funding has not been approved yet.

UK

Bids for the second phase of the UK Marine Productivity programme will be evaluated at the end of June. About 4 - 6 cruises are planned over the next three years, covering the Celtic, Irish and Irminger Seas. Projects from phase one, such as the one described below by Doug Beare, are contributing to our understanding of the nature and causes of observed long term changes in the plankton ecosystem.

Long term variability in North Sea zooplankton

by Doug Beare: d.beare@marlab.ac.uk

Calanus finmarchicus, is the dominant zooplankton species in much of the North Atlantic and a major component of the plankton in the northern North Sea. There are two main hypotheses concerning long-term trends in abundance of *Calanus* (and other species), related to changes in the North Atlantic Oscillation:

(1) Abundance is driven by the advection of individuals from off the shelf.

(2) Abundance is controlled by the seasonal timing of the onset of thermal stratification and phyoplankton production in the North Sea.

Zooplankton data from the Continuous Plankton Recorder (CPR) SAHFOS database, and oceanographic data from the ICES database were used to fit spatial and time series models for ten zooplankton taxa and four physical variables (temperature, salinity, density and stratification). An index of “Atlantic species” in the North Sea, shows a steep decline since the late 1950s. At the same time, changes in the abundance of “resident” zooplankton species show allopatric spatial and temporal patterns, while the North Sea has become steadily more stratified. There are also well documented changes in phytoplankton abundance and species composition. Improvements in the resolution of the biological indices, and of the depth of the wind mixed layer, are anticipated before the end of the project.

Spain

A symposium to review GLOBEC related studies in Spain will take place in Puerto de Santa María (Cádiz) from 28-30 November 2001. More information from:
http://www.uca.es/symposium_globec/ .....♋

Ecosystem models and the impacts of fishing on ecosystem function.

An ICES group, with members from Canada, Denmark, France, Norway and the UK met in March 2001 to plan a workshop, which will consider currently available ecosystem models and their ability to (1) assess the relative importance of direct and indirect effects of fishing and (2) guide the development of management objectives for conserving ecosystem ‘health’.

The planning group found that few appropriate models are available and that differences in their architecture make comparisons, such as challenging different models with the same data/parameter sets, impossible. The limited number and type of model restricts what can currently be achieved by a workshop, but the consensus was that this would still be a very useful exercise, which would increase our understanding of the effects of fisheries on marine ecosystems and contribute to the developing discussions about ecosystem management and the appropriate reference points and metrics.

The report will appear on the ICES web site in due course but in the meantime interested parties are invited to contact the Chair, Chris Frid (c.l.j.frid@ncl.ac.uk) for further information. Colleagues with other models or case studies, which they feel should be included, should contact the Chair and if possible take part in the workshop.

Zooplankton News

Working Group on Zooplankton Ecology meet in Bergen, March 2001

This is a condensed version of their Executive Summary. Interested readers should check the full report, which will appear on the ICES web site.

The group has produced several major "deliverables" recently (notably the Zooplankton Methodology Manual and the Zooplankton Monitoring Reports - see below). Much of the meeting was taken up with the design and planning of new, operational products, including:

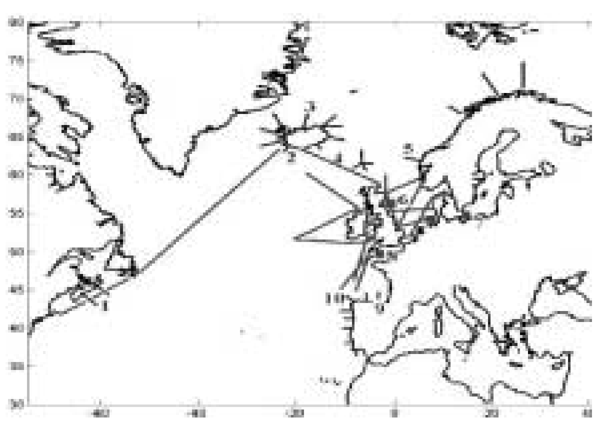
- indices of zooplankton variability and ecosystem functioning
- compilation of results from the 1993 Storfjorden Seagoing Workshop on zooplankton sampler intercomparison. The information is now archived in four CDs - Methods and Results (1 CD), Acoustic data (2 CDs) and Video images on the use of plankton gears at sea (1 CD). It was proposed that the four CDs set should be offered to ICES for wider distribution.
- results of the Workshop on taxonomy of Calanoids (Germany, 14-17 May, 2000) conducted under the auspices of this WGZE
- a “demonstration CD” to be available during the 2001 ASC, with a scanned version of all the plankton leaflets published by ICES since 1939, linked by a numerical and taxonomic index (i.e. Plankton leaflet No. 187).

The group discussed the use of biological indices and data produced on a routine basis for fisheries and environmental assessment groups. The joint meeting with the WG on Phytoplankton Ecology also developed this theme when addressing the question "can symptoms of eutrophication result from a collapse in grazing pressure?" They supported the inclusion of zooplankton as well as primary production in eutrophication monitoring programmes. The annual monitoring report should include standard sections for phytoplankton as well as zooplankton.

Belgium has offered to host the ICES/PICES/GLOBEC Symposium on "The Role of Zooplankton in Global Ecosystem Dynamics: Comparative studies from the World Oceans" in Bruges in the spring of 2003. Dr. P. Wiebe and Dr. L. Valdés were nominated as representatives of ICES on the Steering Committee and Dr. M. Tackx was nominated as member of the Organising Committee.

Two Theme Sessions will be put forward for the ICES ASC in 2002: (i) Environmental conditions in years with extraordinary fish year classes (e.g. North Sea haddock in 1967) (ii) Oceanic inputs (physical and biological) to shelf seas and their impacts on biology and fisheries.

Monitoring



Zooplankton sampling programmes in the ICES area include 4 fixed stations and 27 standard sections (approx. 200 sampling stations) distributed around the continental margins of both America and Europe from the temperate latitudes south of Portugal to the boreal regions north of Norway. In addition, there are fixed CPR routes that cover coastal and oceanic waters in the Atlantic.

The Working Group on Zooplankton Ecology has produced a monitoring report for the ICES area for several years: http://www.ices.dk/status/zssr/zoo9900/

Zooplankton Methodology Manual

There's a web page for this Manual under: http://www.ices.dk/pubs/pubs.htm, which includes updates and corrections.

Xabier Irigoien, xi@mail.soc.soton.ac.uk will be pleased to hear from you with comments, questions or new material. You can of course also find out about buying a copy of the manual. .....♋

SAHFOS News

(1) Plankton communities in the northwest Atlantic

Much has been written about the abundance and distribution of the calanoid copepod *Calanus finmarchicus* in the North Atlantic, but the more arctic boreal *Calanus hyperboreus*, a larger species, has not been subject to such scrutiny. Recent studies from the Continuous Plankton Recorder Survey show how this species responds to the varying hydro-climatic processes in the northwest Atlantic. *C.hyperboreus* numbers increased considerably during the 1990s, and extended further south, with a record at 39.5°N in 1998. Increased production of Labrador Sea Water during this period and a more southerly extension of the Labrador Slope Current in 1998 is thought to be a response to the North Atlantic Oscillation, which, in its' positive state in the late 1990s, caused colder conditions in the northwest Atlantic.

In the autumn of 2000 the colonial pelagic ciliate *Zoothamnium pelagicum* was recorded for the first time in the CPR survey southeast of the Labrador Sea. It is frequently found in the Bay of Biscay and southwest of the Georges Bank and although little is known concerning its physiological tolerance, CPR records indicate a preference for warmer conditions.

Why was the species found in large numbers south of the Labrador Sea, for the first time last year? Hydrographic data suggest a period of anomalously warm SST, which could have been caused by a Gulf Stream eddy or meander. Of course, *Z.pelagicum* could have been expatriated to the area by a change in the hydrography, and survived for the autumn, but why has this not been noted before? These questions are the subject of ongoing research. .....♋

Bergen Advanced Training Site in Marine Ecology (BATMARE)

a Marie Curie Training Site hosted by the University of Bergen funded by the European Commission

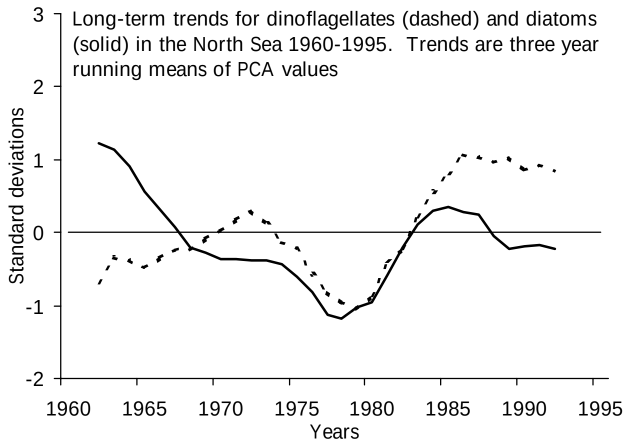
The Bergen Advanced Training Site in Marine Ecology (BATMARE) consists of closely interrelated research units working together to offer interdisciplinary education and training in marine environmental and ecological science through research. BATMARE offers doctoral training in studies of marine processes, ecosystems and interactions, covering the range from microbial ecology to macroplankton and fish, and from physical and organismal processes to ecosystem dynamics.

PhD students enrolled in universities from member states of the European Union are invited to apply for a 3-12 months stay at the University of Bergen to conduct research or to follow courses as part of their PhD studies

http://www.ifm.uib.no/batmare/

SAHFOS News

(2) Diatom/dinoflagellate trends in the north-east Atlantic



Long-term trends for dinoflagellates (dashed) and diatoms (solid) in the North Sea 1960-1995. Trends are three year running means of PCA values

The ratio between diatoms and dinoflagellates may provide a good indicator for both regional environmental changes, such as eutrophication, and wider scale climatic changes, as these two groups show consistent patterns of ecological succession and distinct responses to eutrophication. Both diatoms and dinoflagellates declined to low levels in the North Sea in the late 1970s and then increased considerably during most of the 1980's. This decline was associated with a decrease in phytoplankton biomass, a loss in diversity and a shift in community structure. The late 1970s/early 1980s anomaly was common to diatom assemblages, particularly in the oceanic regions of the north-east Atlantic, which could indicate a winter/spring phenomenon. There is evidence that the spring bloom was delayed, or reduced during this period. Amongst the diatom assemblage, *Chaetoceros* spp. showed the most persistent decline throughout the north-east Atlantic regions from the 1960s to the 90s. They were the most frequently recorded diatom in the northern oceanic region (31.1 % in the 1960s), dropping to a frequency of 7 % in the early 1990s. During the 1960s *Chaetoceros* spp. were abundant during the spring bloom, but also showed a peak during the autumnal bloom. In the North Sea regions, *Chaetoceros* (*Hyalochaete* spp.) were abundant in the autumn for each year from 1960-1967, after which the autumn peak virtually disappeared, except for 1973 and 1978. .....♋

Coming to Edinburgh in August?

Information about the ICES Symposium on **Hydrobiological Variability in the ICES Area, 1990-1999** (8-10 August) can be found at: http://www.ices.dk/symposia/decadal2/

You are also invited to submit a poster for the Symposium on the occasion of the **70th Anniversary of the Continuous Plankton Recorder Survey of the North Atlantic**, taking place at the Royal College of Physicians in Edinburgh on 7th August.

Title and contributing author(s) should be sent to Martin Edwards at maed@wpo.nerc.ac.uk by 1 May. Posters should be no larger than A0.

Announcing a Workshop

"The North West Atlantic Ecosystem (NORWATE) – A basin-scale approach"

Halifax, Nova Scotia
Thurs. June 21-Sat. June 23, 2001

Contact Erica Head
HeadE@mar.dfo-mpo.gc.ca

The NW Atlantic will be the focus of modelling and field studies for several groups in the next few years, including the UK Marine Productivity program in the Irminger Sea (Dec. 2001- Aug. 2003); US studies in the Gulf of Maine; the continuing occupation of the WOCE transect across the Labrador Sea (Clarke et al., BIO; Uwe Send et al. IFM, Kiel, Germany); a series of transects as part of the Canadian SOLAS project (Miller et al., 2002-2003) and the associated deployment of ARGO floats as the Canadian contribution to GOOS (Clarke et al. 2002-2003). Such a large international research effort provides an opportunity to tackle basin scale issues, such as: hydrodynamical and biogeochemical modelling; inter-regional comparisons of *Calanus finmarchicus* population dynamics and phytoplankton bloom dynamics; inter-regional comparisons of primary production and *C. finmarchicus* production (NPZ-Cal biological modelling); linkages between *C. finmarchicus* populations from different regions (transport mechanisms; rates for deep overwintering and surface spring and summer populations). Co-ordination of these activities will add value to the overall output, avoid overlap and lead to opportunities for pooling of ideas and resources.

A session at the EurOCEAN 2000 conference in Hamburg, on 30 August last year on "GLOBEC in the North Atlantic: A perspective for European and North American research co-operation" gave impetus to a proposal for a co-funded, basin scale program supported by the EU, the US National Science Foundation and other national funding agencies. *C. finmarchicus* was suggested as one species to focus on, given its North Atlantic wide distribution and its importance as a prey source for many commercial species of fish. At the ICES Annual Science Conference a proposal for such a study was drafted by a group of US, European and Canadian scientists for discussion at meetings between the NSF and the EU Commission.

The objectives for the Workshop include:

- reviewing existing knowledge and identifying major knowledge gaps
- engaging physical oceanographers and modellers in the development and planning of *C. finmarchicus* related studies
- encouraging co-ordination of current and planned research programmes in the NW Atlantic
- fostering collaboration leading to the development of new research proposals for basin scale studies
- developing a research plan for the North West Atlantic.

Fish Abundance Analysis

Miles Sundermeyer

School for Marine Sciences and Technology
University of Massachusetts Dartmouth

Historical commercial fish catch data can be used to determine the relationships between environmental variables and the distributions and abundances of commercial fish stocks. Empirical analysis indicates that both cod and haddock prefer water temperatures of approximately 5.4 ^{o}C in winter/spring, rising to 9 ^{o}C during summer/fall. Both species also showed an affinity toward particular bottom sediment types as well as overall bottom depths; they tended to be found over coarse sand and gravel as opposed to fine sand, and in regions where water depths were between 60-70 m. These empirically derived environmental preferences are used in a numerical model in which the fish "swim" toward their preferred environments, and disperse away from less favorable environments. Hence, the model attempts to predict how changes in environmental variables affect distributions of commercially important species on Georges Bank. Comparisons between predicted and observed distributions of cod and haddock over Georges Bank show that bottom temperature alone accounts for up to 40% of the spatial variance in monthly distributions of both species. A much smaller amount of the observed variance, up to 20%, is explained by bottom sediment type and bottom depth. The same model generally accounts for a smaller percent of the monthly catch variance observed in individual years. **.....♋**

NAO and North Sea cod recruitment

Assiduous readers of this Newsletter may recall that in the March 1999 the editor rashly wrote:

"The NAO index up to the end of February 1999 is higher than in any winter back to 1950 (and probably back to 1862). The effects of this on recruitment are not well understood, but the 1999 year class of cod in the North Sea, which has barely hatched out, is likely to be poor. The editor will offer to buy drinks at the ICES 2001 ASC to facilitate a discussion of whether this prediction came true, what the word "poor" means etc."

So what happened? Well, March 1999 pushed the NAO index (winter average December to March) back down, so it ended up as the 11th highest in the 37 years since 1963. And what about North Sea cod recruitment? It was 11th lowest over the same period, within the lower third of the distribution.

Just Published

The report of the Workshop on Gadoid Stocks in the North Sea during the 1960s and 1970s: The Fourth ICES/GLOBEC Backward-Facing Workshop has just been published as ICES Cooperative Research Report No. 244. Copies can be obtained from ICES: http://www.ices.dk/pubs/crr/crr.htm **.....♋**

Big changes from small causes - Baltic cod case

Eero Aro,

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Considerations of environmental factors, both abiotic and biotic, can make quite a big difference to how one might manage Baltic cod stocks. Our current perception of the potential benefits of including environment in fish stock assessment is conditioned by our ability to relate environment to population parameters. The benefits of including environmental signals in stock assessment may extend from short-term to medium-term projections but need to be evaluated in the context of specific stocks. An important measure of skill of fisheries scientists and managers will be the establishment of a sustainable balance between natural variation of stock abundance, prey species abundance and fisheries.

The Baltic Sea environment

The Baltic Sea is the product of the last glacial period and thus has many quite unusual characters. It hosts a community, where both marine and freshwater organisms live side by side with a number of living relict species.

Because the Baltic Sea is located within the west-wind zone, where cyclones coming from the west or southwest dominate, the environmental conditions and their variability are strongly linked to the meteorological-, hydrological-, and hydrographic processes and their interaction. All these processes influence the temperature and ice conditions, inflow of fresh water from rivers, exchange of water between various Baltic Sea sub-basins and with the Skagerrak-Kattegat system and the transport and mixing of water inside the Baltic Sea. In the Baltic, where environmental parameters and their high variation regulate physical and biological processes and the system dynamics, the acclimatisation and adaptation responses are even more pronounced than in the marine systems.

Baltic cod – very special or very regular?

Baltic cod is holobiont, euryhaline and eurythermic although it has certain salinity and temperature preferences. Baltic cod originated from the North Sea, but has developed appropriate physiological characteristics during the adaptation process into the Baltic Sea brackish water environment.

Baltic cod has extended its distribution into the whole Baltic Sea area, except the northernmost parts of the Baltic, where it occurs only sporadically. Adult Baltic cod can live and survive even in salinities lower than 5 per mille, which are observed in the northern parts of the Baltic Sea and in the eastern parts of the Gulf of Finland. Moreover juveniles are able to tolerate an almost freshwater environment over long periods. However, the adaptation process into the Baltic Sea environment is not complete. This is clearly observed in Baltic cod reproduction strategy and its adaptation in terms of egg buoyancy.

The success of Baltic cod reproduction is, among other things, dependent on salinity and oxygen concentration for the fertilisation and survival of the eggs and larvae. Baltic cod females arel batch spawners and the number of batches is dependent on the size and/or age of the fish, which is normal cod reproduction strategy. The average fecundity of cod in the Baltic is higher than in the North Sea. Moreover, the size of eggs decreases with decreasing salinity from southern spawning grounds towards the north.

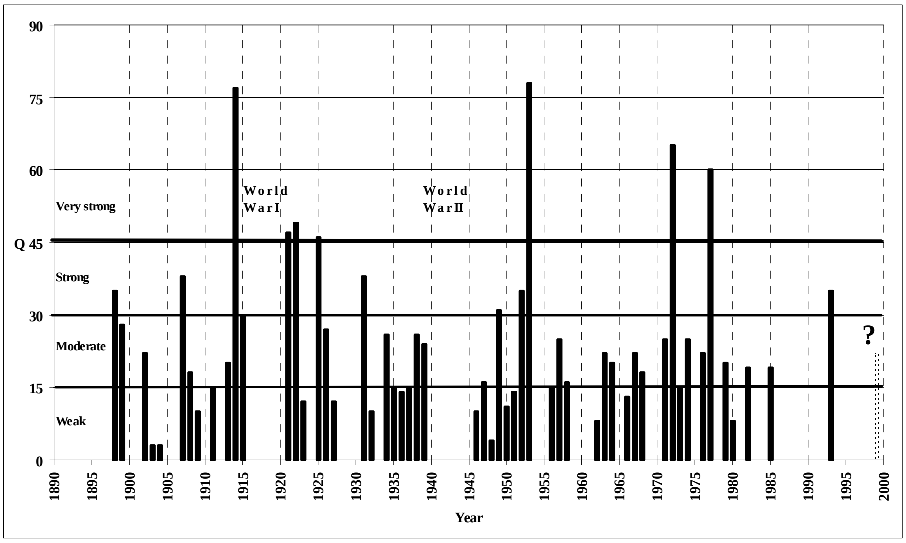

Figure 1 Major inflows of highly saline and oxygenated water into the Baltic Sea in 1890-2000

The recruitment of Baltic cod is highly variable and very much dependent on the influx of the North Sea water into the Baltic. The unusually long period with low influx from the late 1970s to the early 1990s was in general a period of low recruitment. Then influx in 1993 resulted in improved environmental conditions, which allowed the possibility of improved recruitment. Since February 1993 there have been no major inflows (Fig. 1). On the other hand the water exchange between Baltic Sea and Kattegat is a continuous process and the balance between inflow and outflow depends on total river runoff, hydrography and prevailing meteorological conditions. It is not very clear, how much inflows and continuous exchange contribute to the total balance, but what we know is that the effect of a major intrusion of North Sea water into the Baltic Sea is usually sufficient to support better environmental conditions at maximum for two spawning seasons (about 1.5 years), because after that period the salinity and oxygen levels in the deep water layers usually decrease below the level at which cod eggs can survive.

Big changes from small causes

The total volume of the Baltic Sea is about 230 000 km^3; it has a very restricted water exchange with the open ocean via the Danish Sounds. The sea is nearly non-tidal and it is characterised by a significant fresh water surplus due to river runoff (c. 440 km^{3}a^{-1}). The renewal time of the water is estimated to be in general about 30 years, but it is spatially very variable. Due to these factors, there is a continuous two-layer salinity stratification, which affects the basic physics and biology of the sea. The currents in the Baltic Sea are mainly driven by wind stress. However, the pronounced spatial and temporal variability of salinity and temperature results in thermohaline circulation playing an important role in the system. In all parts of the Baltic Sea, the complicated bottom topography modifies the physical processes.

The last effective inflows occurred in 1976/77 and 1993/94 (Fig. 1). The 1993 event was about 310 km^3 in volume, and updated calculations indicate that it was a strong one. All the major inflows are very small compared to the total volume of the Baltic (range 0.1-0.5 % of the total volume), but the effects may be very significant for the food web and species distribution.

Baltic cod spawning strategy – just testing adaptation ability

An understanding of reproductive strategy of Baltic cod rests on identifying the selective processes that have led to the evolution of observed strategies. The causal factors responsible for the reproduction strategy selection may be plastic so an individual can exhibit a wide range in their expression. On the other hand, the environment experienced by Baltic cod will determine the expression of the trait. Consequently, the variations of this expression of a trait in response to environmental changes are the tactical responses of the individual to those changes. Such tactics represent a homeostatic response of Baltic cod that minimizes the cost of changes.

Baltic cod starts to form pre-spawning concentrations in October-November in the Western Baltic cod stock and November-December in the Eastern Baltic cod stock depending on the onset of winter. The main spawning grounds of the Baltic cod stocks are shown in Fig. 2.

In the western cod stock, spawning starts in January and peak spawning is usually in March. The main spawning time is February-March in the westernmost areas and March-April in the eastern area. Spawning is completed usually in May.

The spawning time of cod in the south eastern and northern Baltic was in the past March-August and it usually peaked in May- mid-June, but the timing varied between years. However, the spawning period of the stock is now very extended and peak spawning is later in the year than before. The peak spawning has shifted from May-mid-June to late July-August. The difference is substantial and at present we have several hypotheses of possible causes, but we do not have a clear explanation yet, why this adaptation or change in timing has taken place.

In most North Atlantic cod stocks, eggs are released over a period of a few weeks in spring. Cod in the Baltic on the other hand have a rather late and prolonged spawning period. Surveys conducted since the beginning of the last century have shown, that cod eggs can be found in the Baltic Main Basin from March to October, but annual peaks vary considerably.

The importance of variation in gadoid reproductive output as a function of spawner age, size, maturation, condition and reproductive history has been addressed recently by many authors. Only during the last decade the maternal and paternal subject has got an eyeful of attention in Baltic cod research (EU-projects CORE = Cod Recruitment in 1994-1997 and STORE = Stock Recruitment project in 1999-2001).

The assumption that SSB adequately represents stock reproductive potential has been common in fisheries science and the commonly used biological reference points rely heavily on the term SSB. This is the case also in Baltic cod. We assume that a certain weight of spawning biomass has an equal likelihood of generating the same level of recruitment. This deduction occurs regardless of whether the SSB is comprised of low condition fish or healthy, good condition, highly fecund fish. In our projects, however we have tried to incorporate some environmental variability, both abiotic and biotic, into the stock-recruitment relationship parameter estimation. The process is going on and we will see where we end up.

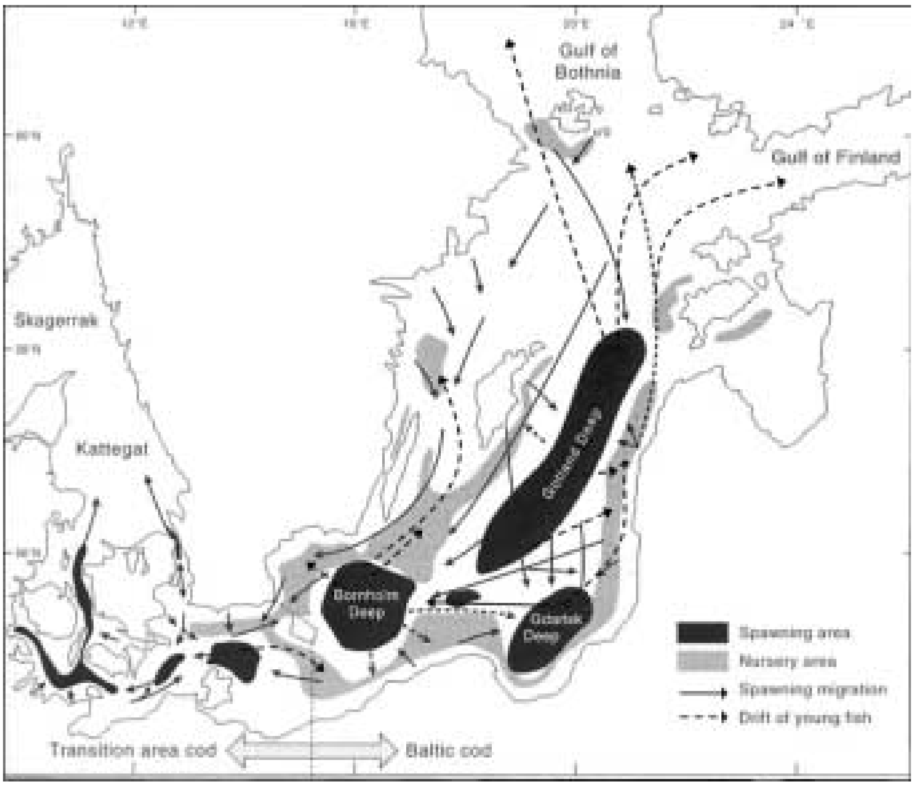

Figure 2 The spawning and nursery areas of Baltic cod stocks

When comparing spawning stock biomass and population fecundity estimates routinely used in stock assessment to stock reproductive potential (SRP) estimation, it seems obvious that SRP may represent more accurately the annual variation in a stock's ability to produce viable eggs and larvae that may eventually recruit to the adult population and fishery. Thus SRP seems to be the correct avenue to proceed in the Baltic cod case. This process has started already years back (CORE- & STORE-projects) and presently we are in a position to take some of the SRP attributes into account when assessing the state of the Baltic cod stocks.

It matters where to release gametes

Variations in the Baltic cod stock are correlated with spawning efficiency. This in turn depends on abiotic conditions and cod egg survival is correlated with hydrographic conditions in the spawning grounds. Although Baltic cod is partly well adapted to low-salinity environment, there are limits to its adaptation capacity. There are differences in salinity requirements for successful spawning between the eastern Baltic cod and the western Baltic cod and adaptation to ambient salinity is obvious.

Activation of the spermatozoa occurs at salinity greater than or equal to 11 to 12 for eastern Baltic cod and at greater than or equal to 15 to 16 for western Baltic cod. Neutral egg buoyancy is obtained at salinities 14.5 psu ± 1.2 in the eastern stock and at salinities 20 to 22 in the western stock. Transfer of fish from more marine to brackish water conditions has shown that these characteristics will remain essentially the same. The results suggest population specific characteristics. Regarding the hydrographic conditions in the spawning grounds of cod in the Baltic, the results indicate that stock interactions may be possible in the western Baltic spawning areas where salinity requirements for both stocks are fulfilled, but not necessarily in the eastern spawning areas, as low salinity prevents successful spawning of western Baltic cod. Salinity and oxygen conditions in the Baltic vary with irregular saline water inflows (Fig. 1). Periods of stagnation without inflows may, due to decreasing salinity, act as a one-way ecological barrier between these stocks.

The only Baltic cod spawning grounds in the Baltic Main Basin are the deep basins where salinity is high enough to keep cod eggs floating or sinking rate low enough to ensure an adequate fertilization rate. In deeper layers spawning is limited, because of the low oxygen content in the hypolimnion.

The prolonged stagnation period between 1981-1993 has partially caused the decline in the reproduction success of the cod stock in the Baltic Main Basin. In addition to oxygen and salinity conditions, as listed above, there are a number of other factors, which have significant impact on Baltic cod reproductive success. These factors are relevant also in the absence of a basic limiting factor i.e. oxygen deficiency and too low salinity.

Cod eggs and larvae are preyed upon by Baltic herring, (Clupea harengus membras L.) and sprat, (Sprattus sprattus L.) when prey and predator distributions overlap. While sprat is the main predator on cod eggs in the Bornholm Basin in spring, herring prey on cod eggs during summer, when returning from their coastal spawning habitat into the open sea feeding habitat. During the last 10 years, a gradual delay in cod spawning time has been observed and one consequence of this may be that the importance of herring as a predator has substantially increased. On the other hand, both Baltic herring and sprat are preyed upon by Baltic cod, and there is evidence for top-down and bottom-up control.

The size at first spawning of Baltic cod has changed, especially in males, to smaller sizes but also in females and the duration of spawning period has shifted from spring-early summer spawning to July-September spawning during the last decade. This change may simply reflect physiological effects of no adaptive significance, but may represent an adaptive response to environmental change.

Is reproductive volume a good measure of environmental condition for recruitment ?

The variation and annual extent of minimum hydrographic conditions to cod spawning has been estimated as the available reproductive volume, defined as the water mass characterized by temperature, oxygen and salinity conditions which meet the minimum requirements for successful egg development.

The present definition of threshold levels (S > 11 psu, T 1.5 °C, and O^2 2 ml l^{-1}) is the minimum condition required for eggs to survive, but mortality of eggs is related also to oxygen deficiency, which is not a knife-edge effect. Eggs and hatching larvae at oxygen levels close to the minimum may have a reduced viability, and thus the reproductive volume used presently are likely to represent overestimates to an unknown extent.

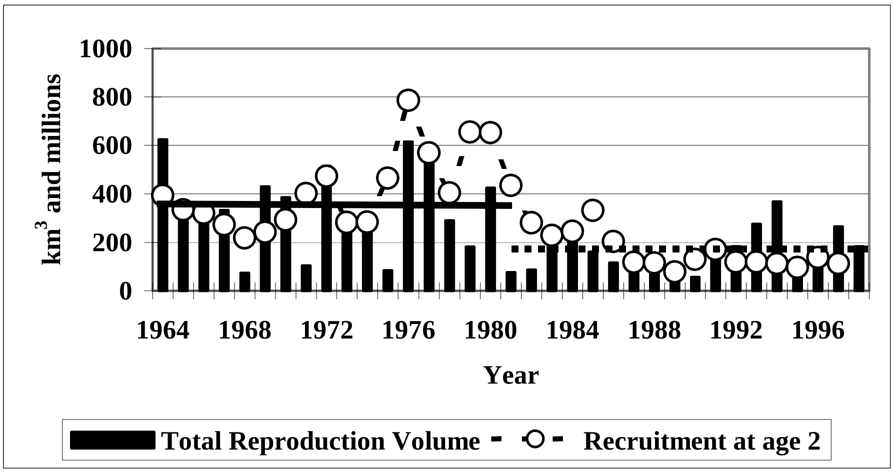

Figure 3 Total reproduction volume and corresponding recruitment at age 2 in the eastern Baltic cod stock in 1964-1998 showing two different regimes of recruitment (solid and dashed horizontal lines).

The reproductive volume has fluctuated strongly (Fig. 3). However, it was on average much higher before 1980 than thereafter. Between 1985-1992, the Bornholm Basin represented almost the only suitable area for cod reproduction.

Eggs spawned in a given year and given area have different probability of survival. The specific gravity of cod eggs implies that they sink to deeper water and the distribution of viable eggs is narrowed by oxygen deficiency and/or low temperature.

The total reproduction volume (Figure 3) seems to be rather good indicator of the Baltic cod spawning possibilities and thus recruitment. However, the fit between reproductive volume and recruitment at age 2 is far from conclusive and there are a number of other abiotic and biotic variables influencing our perception of stock-recruitment relationship. In any case, there is no doubt that Baltic cod recruitment benefits from higher reproductive volume.

Is the S/R relationship driven by environmental processes in the Baltic ?

The underlying and dominant mechanisms through which Baltic cod recruitment processes are influenced by fluctuations in the physical environment include both direct and indirect impacts. Temperature stratification, upwelling and downwelling are known to alter physiological processes and turbulence is believed to influence the probability of encountering food particles. Variations in circulation can transport larvae into environments of different suitability.

Environmental variability is strongly linked to the meteorological-, hydrological-, and hydrographic processes and their interaction. As a result, the impact or change of one factor may well be correlated with that of others. How they interact must be considered and understood in exploring relationships between recruitment and hydrodynamic processes.

Baltic Sea oceanographic data usually consist of indices that reflect and integrate multiple processes. They often contain indices that reflect the influence of remote forcing over a broad geographic area, direct measurements that reflect measured variables on a local scale or predicted elements generated from detailed models of a specific area. The use of these indices instead of local observations or predictions is often the result of limited monitoring resources or limited knowledge at the local scale.

The input of oceanographic data into the Baltic cod stock-recruitment models and stock projections, if there is a significant environmental link, should also reflect the structure of the time series of oceanographic conditions.

Multispecies considerations – where to go next?

The population dynamics of Baltic cod is clearly influenced by Baltic herring and sprat interaction and on the other hand, their main predator, Baltic cod, controls the population dynamics of Clupeoids.

The present high abundance of the sprat stock is partly an outcome of decreased predation pressure from Baltic cod and it has been shown, that the reduction of the abundance of the eastern Baltic cod stock in the late 1980s and early 1990s was aggravated substantially by too intensive fishery.

Studies on other animals show that the functional response in predator-prey relationships significantly affects the dynamics and growth of populations. We expect such functional responses to exist in fish populations, but at present they are very seldom included in marine fisheries models, primarily because of the difficulty of collecting relevant data at appropriate temporal and spatial scales.

Combination and integration of the knowledge of different fields of marine science may rectify this omission.

In the multispecies approach, individual species would generally serve as the starting point, but there may be a need for some level of aggregation in the system, guided by a necessary temporal and spatial scale. Although the effects of environmental variability may be incorporated in the models, depending on data availability, the focus of multispecies approaches is clearly on species interaction as well as technical interaction between different fleets. The development of an "ecosystem" analysis may have to seek new avenues, if incorporation of environmental variability is necessary.

From a theoretical point of view, multispecies catch-at-age analysis is superior to single species catch at-age analysis, because in the multispecies approach, predation removals are caused by a 'suite' of predators and can be estimated. In single species analysis predation is usually built into natural mortality estimates, without variation.

Comparisons of multi and single species predictions suggest that in most cases the differences between the two approaches are negligible in the short term but show that they can be significant in the long term. Present multispecies approaches depend heavily on the availability of reliable catch data for all species included. Thus, in practice, the application of multispecies models may be problematic. The development of multispecies models has been substantial, but they do not have a status of routine analysis yet. This is a very strange, because the seed was already planted 24 years ago.

Further reading

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The Bjerknes Collaboration

In 2000, the University of Bergen (UoB), the Nansen Environmental and Remote Sensing Center (NERSC) and the Institute of Marine Research (IMR) formally agreed to establish the **Bjerknes Collaboration** in order to develop a joint, internationally acknowledged climate research unit in Bergen. A strong motivation for establishing the collaboration is the large socio-economic impacts of climate fluctuations and climate change in Norway and Northern Europe, particularly on marine and terrestrial bioproduction and on transportation. The vision of this joint venture is to carry out novel and innovative research on marine climate processes and climate change in the northern North Atlantic and Polar Regions. Scientifically it focuses on ocean-ice-atmosphere climate processes, coupling of high latitude marine and terrestrial climates, and on past, present and future climatic evolution in the North Atlantic, the Nordic Seas, the Arctic Ocean and surrounding regions.

The operational organisation of the **Bjerknes Collaboration** builds upon an integration of the partner's scientific expertise into four collaborative teams around sub-disciplines: (i) Climate processes in the ocean and ocean circulation; (ii) Coupled ocean-ice-atmosphere processes and modelling; (iii) Paleoclimates; and (iv) Oceanic carbon and biogeochemical cycles. Within and across these sub-disciplinary teams the research is organised in joint projects. Current activities total about 50 man-years of scientific work and approximately 25 million NOK in externally funded projects.

The administrative organisation is located at UoB´s newly established **Bjerknes Center for Climate Research**. The Center functions as the Secretariat for the Collaboration and will take care of the day-to-day administration of the activities, serve as a channel of communication within and outside the community, and will organise externally funded climate research. The Center will also network extensively with leading national and international centres and research groups.

In addition to the scientific scope, the Collaboration will have an academic, social and political mission as well. This will build upon: (i) research training and capacity building of young scientists and students, (ii) dissemination of results to assist in climate impact analyses for policy makers and socio-economic decisions, and (iii) outreaching activities to enhance public awareness.

The **Bjerknes Collaboration** was named in honour of **Vilhelm and Jacob Bjerknes**, whose research originating within the "Bergen School of Meteorology" has paved the way for many of the modern studies of climate change.

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