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Integrating Fisheries Observations with Environmental Data – Towards a Better Understanding of the Conditions for Fish in the Sea

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Abstract

Starting with some historical reflections on the wealth of fish in eastern Canadian waters and the climatic situation at the times of John Cabot's landfall 500 years ago, the presentation gives information on published literature which deal with impact studies. The living marine resources are considered in the contexts of physiological changes in the organisms and the impacts of environmental conditions such as thermohaline, wind, teleconnection and global warming. The effects are then given in a synthesis, along with considerations of modelling and forecasting aspects. It is observed that, whereas the Teleconnection Impacts and the Global Warming Impacts still remain in the "scenario type" of base studies, the modelling attempts are focused on regional forecasts, and thus reflect the results from the "Impact" related studies of the first order. It is proposed that if the input variables are a realistic assessment, the results should then point at a realistic future fisheries resource situation, and thus lead towards a better understanding of the conditions for fish in the sea. The presentation concludes with the statement that the cited literature might reflect a different understanding of the ocean and it's living resources which indeed might point at a shift in paradigm in ocean sciences.

Keywords: climate, cod, environment, fish, global warming, impact, John Cabot, modelling, teleconnection

Introduction

This NAFO Symposium titled '*What Future for Capture Fisheries*' is held in conjunction with the 500th Anniversary Celebration 1497 to 1997 of Giovanni Cabotto's – better known as John Cabot's landfall in Newfoundland, Canada. On an occasion such as this, it is valuable to introduce some historical observations; some reflections of the ocean resources and climatic conditions of this region at a time when mankind had not yet exploited fish stocks to any great extent, or at least not as cruelly exploited as today.

Historical Reflections

In a recent essay Croxton (MS 1990) gives an estimate of the potential site of landfall of John Cabot in 1497. By means of historiographic methods, which highlight some commonly mentioned conditions of fish resources of the Northwest Atlantic some 500 years ago, Croxton attempts to narrow Cabot's voyage down to a specific area on the basis of contemporarian reports. He cites Quinn (1979) who stated that *John Day* – contemporarian of Christopher Columbus and John Cabot – commented on the first impressions of Cabot and his crew,

> "*All along the coast they found many fish like those which in Iceland are dried in the open and sold in England and other countries, and these fish are called in English stockfish. This of course is a reference to cod which was England's primary import from Iceland*."

Croxton (MS 1990) continues with a citation of Putnam (1952): *Raimondo Soncino* – a friend of John Cabot – was more emphatic about the abundance of fish:

"*the sea there is swarming with fish, which can be taken not only with the net, but in baskets let down with a stone ... his companions, say that they could bring so many fish that this kingdom would have no further need of Iceland, from which place there comes a very great quantity of stockfish*".

Coming from experienced sailors who were probably familiar with the Iceland trade, these statements verifies that the ship must have sailed somewhere along the south of Newfoundland or around Nova Scotia, for these areas were reported to have the densest fishing grounds in the world (this was apparently true even in 1952 when Putnam's *Canadian Regions* were published). Of course, the fishing all around this Northwest Atlantic was excellent, and Cabot's voyage cannot be narrowed down further to a specific area on the basis of this information alone.

It is now interesting to compare this information on the abundance of fish from Croxton's essay, with the known general climatic conditions in the area at the time.

If we combine these reports on the abundance of fish – masses of cod, and maybe capelin caught in baskets let down with a stone – during this time 500 years ago with the present day knowledge we have on climatic conditions in the region at that time, we see that the landfall was facing the beginning of the "Little Ice Age" (Fig. 1). The relatively low temperatures and extensive ice conditions in the area at the time, thus suggests that climatic cooling did not seem to have had major adverse effects on the fish stocks. The temperature time series in Fig. 1 can, however, only be taken as a relative measure. When comparing the most recent part of the data with directly measured air temperatures from Greenland (Fig. 2), it would appear that the relative temperature time series as derived from the ice core data – the stable isotopes of oxygen and hydrogen atoms in the water molecule are typically used to infer paleoclimate, particularly paleotemperature (Oeschger, 1991) – reveal the climatic trends fairly well (Fig. 3).

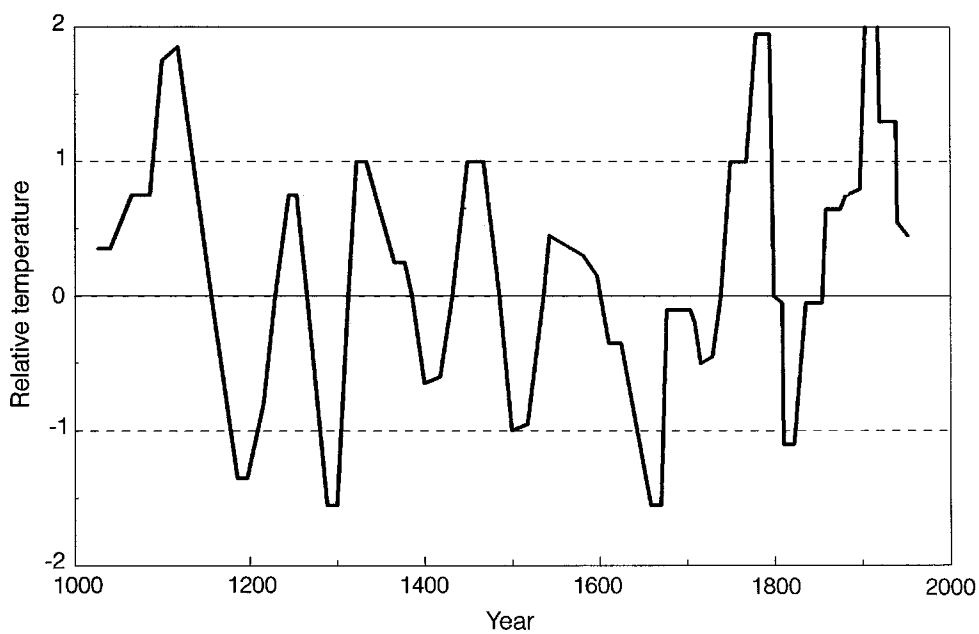

Fig. 1. Greenland air temperature time series derived from ice core data (adopted from Crowley and Kim, 1993); relative temperature scale.

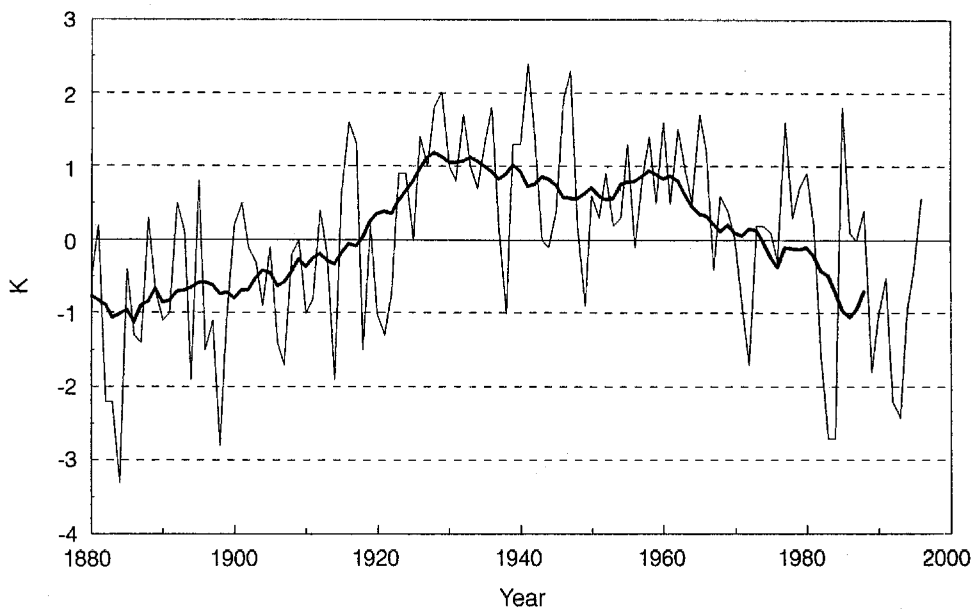

Fig. 2. Time series of annual mean air temperature anomalies (thin line) at Nuuk/West Greenland (1880–1996, rel. 1876–1996) and 13-year running mean (bold line).

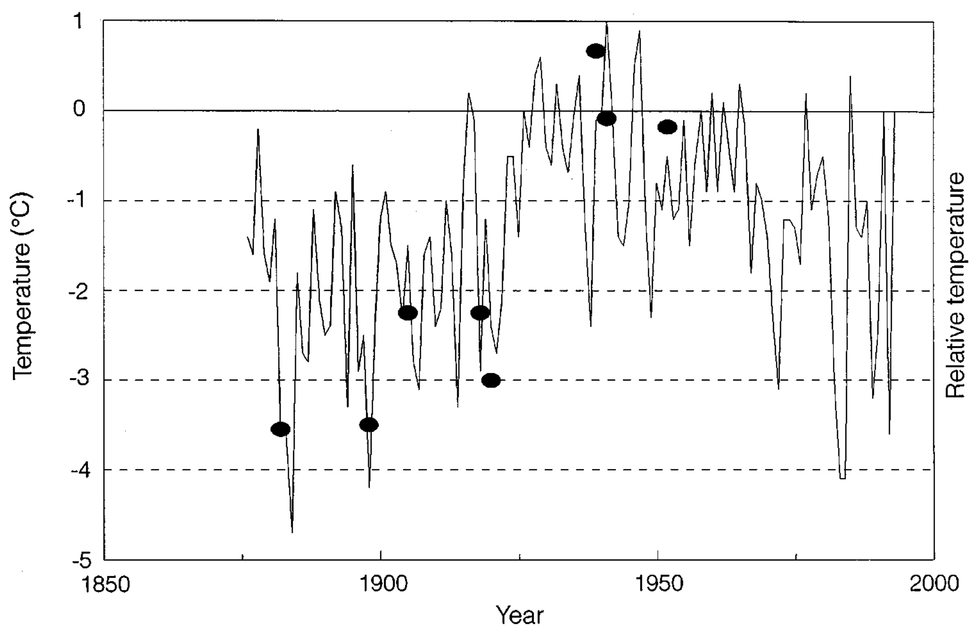

Fig. 3. Overlap of time series of annual mean air temperature anomalies (thin line) at Nuuk/West Greenland (1880–1996, rel. 1876–1996) and relative temperature as derived from ice core data (position of dots is individually adjusted to the Nuuk curve; see Fig. 1).

Case Studies

I would now like to address some Case Studies, which are published in literature, and built mostly on the climatic variability aspects. Climatic variability is defined on time scales ranging from 0 to 10 days (hourly and daily changes) to 10 000–100 000 days (centennial and beyond) (Shukla, 1991). To detect climatic variability in time and space, collecting long time-series of data is necessary. We are fortunate meteorologists in many parts of the world have done this exercise, and for the North Atlantic area data have been collected since the middle of the 20th century. Using an example of West Greenland, we can demonstrate how the variability of recent climate (Fig. 2) can be traced.

The long-term variation is indicated by the thirteen-year overlapping mean (bold line). It reveals there was a period of colder-than-normal conditions from 1880 to the beginning of the 1920s, followed by a warm period until the end of the 1960s, and cooling thenceforth. Superimposed on this, the short-frequency variation of the annual mean air temperature (thin line) reveals that there were regular cold events, which were quite frequent during the first colder-than-normal period. This showed up again at about 10- to 11-year intervals during the recent cooling period after the 1960s. Noteworthy features during this recent cooling are the intermediate decadal warming periods which were encountered during the middle of the 1970s, 1980s and 1990s.

Oceanographers have followed long time-series of data collection at Oceanographic Standard Stations, where measurements were performed at the same position, during the same season of the year. In some cases it was even possible to collect oceanographic profiles of temperature and salinity on a monthly basis (e.g. Station 27 which is off St. John's, Newfoundland). Some good examples are the International Commission of the Northwest Atlantic Fisheries (ICNAF) (predecessor to NAFO) Standard Stations (1950–79) which have been continued for more than 40 years. These stations cover the slope regions on both sides of the Labrador Sea, and across the Labrador Sea at selected stations. Additionally, oceanographic observations were also made by Ocean Weather Ships. The Ocean Weather Ships were observation platforms which were positioned at nine locations in the North Atlantic Ocean. Weather and ocean observations performed from these platforms were used to provide the transoceanic air traffic with better weather forecasts. Such an Ocean Weather Ship, BRAVO, was positioned during 1949 and 1974 between Cape Farewell/Greenland and Seal Island/Labrador at about 56°30'N, 51°W, and contributed much to the knowledge on the variability of the deep waters in that part of the world ocean.

Oceanographic conditions are of course of vital importance to the marine resources, particularly the fish resources. It is common knowledge that fish stocks in the North Atlantic areas have been experiencing considerable amount of short and long term environmental variability on the continental shelf areas, in the slope regions and at coastal sites.

While oceanography and fisheries sciences have tended to be two separate disciplines without much integration, in recent times this integration has been seen as an important step. While the merging process is new, correlation of biotic and abiotic time-series data and their statistical analysis in recent years has brought about tremendous knowledge on impacts of the environment on marine living resources.

To get an overview on some of the facets of these interdisciplinary approaches, it seems quite valuable to define the fields of some disciplines of research that are relevant.

A possible way to look at impacts of the environment on fish could be structured as follows:

Impacts of the Environment on Physiology of Fish
Thermohaline Impacts
Wind Impacts
Teleconnection Impacts
Global Warming Impacts

Impacts of the Environment on Physiology of Fish

Considering some recent results from the Northern Cod Science Program (NCSP), it is observed that NCSP was the first to devote some comprehensive effort to advance our understanding of ocean ecology in the Labrador/Newfoundland region (Anon., 1995). Between 1990 and 1995, NCSP dealt with research on the Physical and Biological Environment, Cod Biology and Related Science (e.g. Cod stock structure: Tagging and Genetics, Environmental Influences on Capelin, Harp and Hooded Seals). Goddard and Fletcher (1994) from the Ocean Science Centre of Memorial University of Newfoundland reported the presence of antifreeze proteins in Atlantic cod (*Gadus morhua* L.) and their role in cod survival and distribution from egg to adult. The Atlantic cod, particularly the cod in the northern distributional range, faces one of the harshest thermal regimes. Winter water temperatures between -1.0°C and -1.8°C (the freeing point of seawater) are frequently observed off the Labrador coast. The equilibrium freezing point of the unprotected plasma of most marine teleosts (cod included) is approximately -0.7°C. Similar to many teleost species living at high latitudes, juvenile and adult Atlantic cod are able to occupy potentially lethal habitats by producing antifreeze proteins in response to low temperatures. These lower the freezing point of the cod and possibly also protect against cold-damage at the cellular level (Fig. 4).

This example shows that nature provides some means for Atlantic cod to survive in a highly variable environment, and, especially during winter time, an adverse environment like the Labrador shelf and slope waters, and that the larval stage seems to be the most vulnerable part in the life of cod.

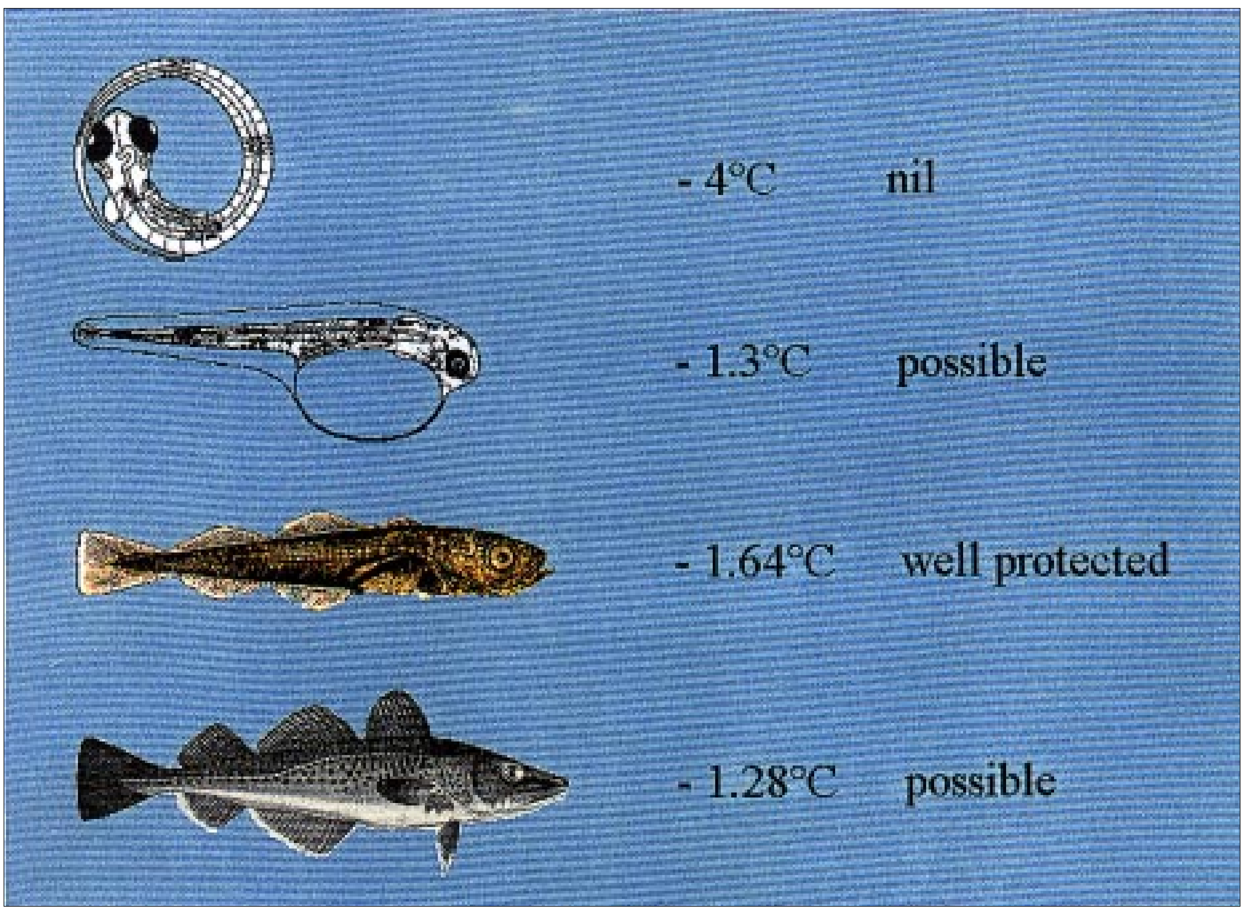

Fig. 4. Mean lethal freezing temperatures and possible risk of mortality in the wild of cod eggs, larvae, juveniles and adults during their period of maximum freeze protection (from Goddard and Fletcher, 1994).

Thermohaline Impacts

Fortier *et al.* (1996) published an interesting study that showed how the salinity levels caused by the Great Whale Rive plume affected the feeding success of Arctic cod (*Boreogadus saida*) and sand lance (*Ammodytes* sp.) larvae in relation to prey density, light, temperature, and potential predator density under the ice cover of southeastern Hudson Bay in the spring of 1988, 1989 and 1990. They revealed that both prey density and light limited larval fish feeding. By affecting both prey density and irradiance, the thickness of the Great Whale River plume (as defined by the depth of the 25 PSU isohaline) was the main determinant of prey availability.

There is at present, a controversial discussion on the severe decline of the fishery off Greenland (Rätz, 1996). In contrast to the commonly mentioned causes of overfishing, climate changes and emigration are now itemized as causal factors. A few years after the beginning of heavy exploitation during the early-1960s, the stocks of cod (*Gadus morhua*), golden and beaked redfish (*Sebastes* sp.) reflected a significant rejuvenation based on catch analysis. Regular scientific surveys for stock assessment purposes commenced in 1982, when the productivity of the stocks was already adversely affected due to low spawning stocks and extremely irregular recruitment. From this point of view, the results of the latest survey in 1995 showing stagnant fish biomass at a record low level since 1991 are not surprising. The status of the cod stock is still considered severely depleted. Taking the high abundance of juvenile redfish into account, recovery of the groundfish stocks is unlikely in the short term and depends on the non-predictable recruitment only.

In a History of the Atlantic cod stock off Greenland during the second half of the present century Rätz (1997) points at the close interrelationships between weight-at-age and bottom water temperature (Fig. 5).

Based upon a hypothesis that periods of low stability of the water column in autumn should parallel good cod year-classes in the following year, Stein and Lloret (1995) analyzed available time series of cod recruitment, subsurface oceanographic stability data and wind stress data off West Greenland. Splitting the autumn-based oceanographic data set into a pre-1970s part (when warm climatic conditions and high recruitment prevailed), and a recent part (for the past 20 years of cooling climate), yielded significant

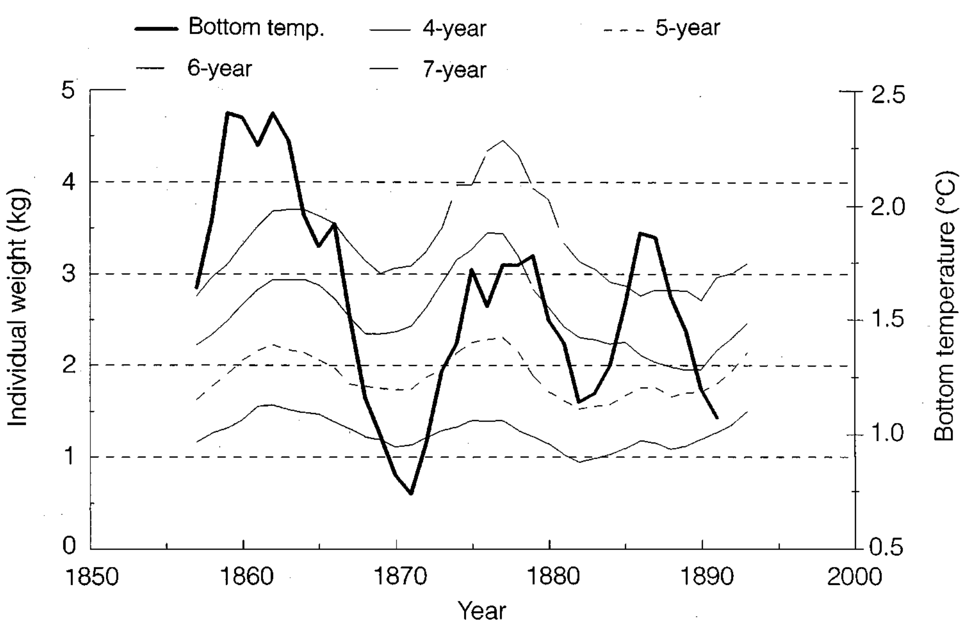

Fig. 5. Weight-at-age of cod and bottom water temperatures at West Greenland (from Rätz, 1997).

coherence of recruitment and a period of cold environmental conditions. It was suggested that during the past 20 years, a new correlation mechanism may explain the variability of recruitment off West Greenland (Fig. 6). Whereas during the warm period low stability of the water column led to enhanced vertical convection of the water column and hence nutritious conditions, recruitment during the cold period was mainly due to import of juvenile cod from Iceland/East Greenland by surface water drift. The latter mechanism was inferred as advective coupling instead of low stability coupling during the warm period (Stein and Lloret, 1995).

In an international survey on 0-group fish carried out annually in the Barents Sea, and a Norwegian survey on early juveniles carried out annually off northern Norway, the growth of larvae of commercially important fish were estimated by Loeng *et al.* (1995). The results showed a positive correlation in the annual lengths of larvae of cod, (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and herring (*Clupea harengus*). This is not surprising because these fish stocks are known to reproduce in the same type of water masses and experience the same temperature conditions and similar food variability. The results also unveiled a relatively close relationship between temperature conditions and the length of larvae of cod, haddock, herring and capelin.

In conclusion from this section on Thermohaline impacts, the first example shows a close dependence of larval fish feeding success on the timing of river discharge which affects the ambient thermohaline conditions in the sea. For the Barents Sea area, a close relationship between temperature conditions and the length of larvae of cod, haddock, herring, and capelin can be documented. It is thus well documented that temperature is quite important, and through the temperature there is a dependency of density and the water mass stability. These covary significantly with the recruitment success and the weight-at-age of cod in West Greenland waters.

Wind Impacts

The external forces, such as wind, influence the surface layer conditions of the ocean. Especially conditions of high wind, like gales, exaggerate the vigour. There are few observations on the potential interactions of these with fish. However, in a recent study of a time-series of plankton surveys and wind, the data were applied to explore the interannual variations and the relative importance of prey concentration

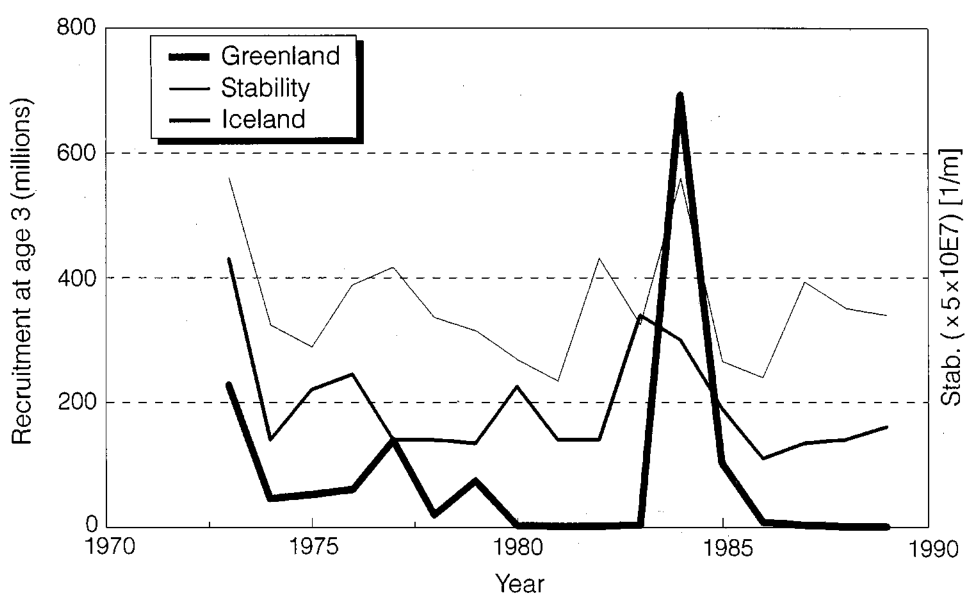

Fig. 6. Recruitment of Greenland and Iceland cod stocks versus stability of water layers off West Greenland.

and turbulence to the overall contact rate between cod larvae and their prey (Sundby, 1995). As cod larvae grow, they increase their swimming speed, and change their diet to larger prey at lower concentrations. The simulations showed that the turbulence-induced contact rate decreased exponentially as the cod grow, but it significantly influenced their feeding capabilities until the stage of 2-month-old juveniles. It was summarized that interannual variations of wind speed substantially influence the overall contact rate between cod and prey.

In another study by Hansen *et al*. (1994) it was shown how vitally important strong winds may be for recruitment success or collapse. The cod stock on the Faroe Island Plateau has traditionally been considered as relatively stable, with fairly constant recruitment levels. In the late-1980s this situation changed dramatically when recruitment levels dropped by one or two orders of magnitude below what appeared to have been the norm during most of this century. Combining the available biological information on this stock with results from investigations on zooplankton and hydrography, Hansen *et al*. (1994) argue that survival during the first three months is critically dependent upon the transport of spawning products from the spawning grounds to the shallow parts of the shelf, and upon the production and advection of the copepod species *Calanus finmarchicus* from the Faroe Bank Channel (see left side of Fig. 7) to the shelf. Evidence was presented that during the period of recruitment collapse, spring winds were abnormally strong from the southwest, increasing the probability of the transport of cod eggs and larvae and copepods off the shelf, and possibly also affecting primary production and hence production of copepod nauplii. In addition, the Faroe Plateau seems to have been less dominated by Atlantic waters with weaker copepod import and less stable advection paths as conceivable consequences.

Teleconnection Impacts

Analysis of climatic time-series of ocean/atmosphere/ice properties (e.g. ocean surface layer temperatures, air pressure variation, sea ice distribution), performed for various observation sites around the globe, has revealed that some of these variations occur at the same time on different hemispheres. This phenomenon is called teleconnection when there is a physical link between the processes concerned (Stein, 1986). Trans-hemispherical teleconnections of events at different time-scales are known to play an essential

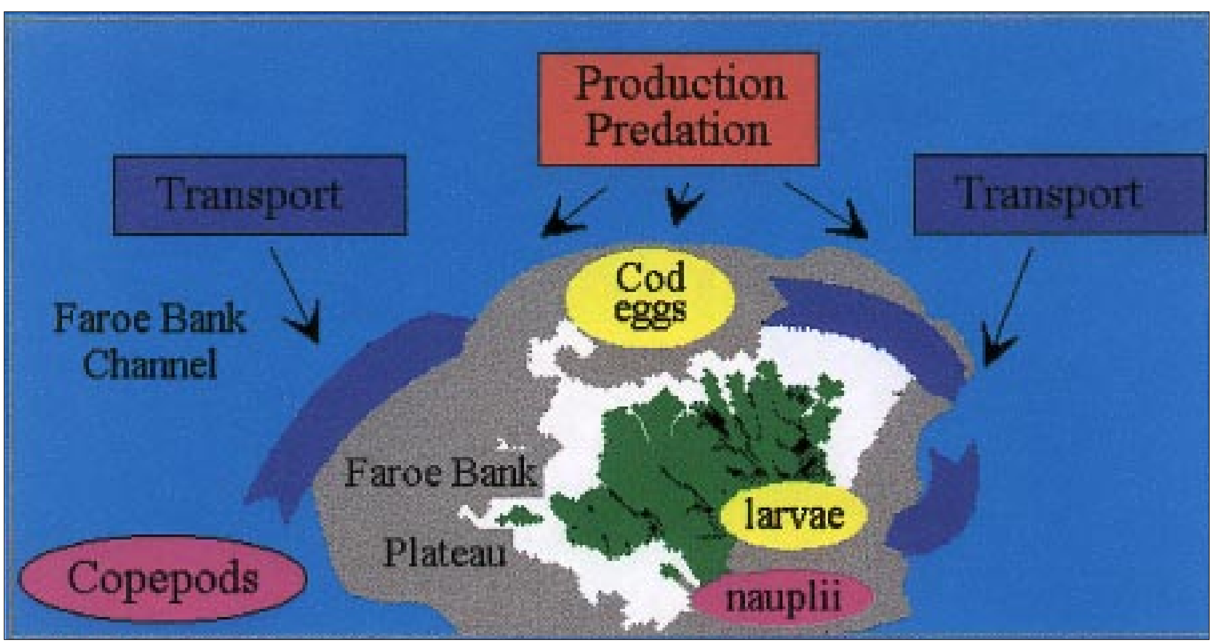

Fig. 7. Scheme of advection of Copepods to nursery grounds of the Faroe Cod Stock (from Hansen *et al*., 1994).

role in the climatic variability of our globe. Widely known is the El Niño phenomenon, which has in some years had dramatic impacts on the fisheries off the Peruvian coast. This phenomenon occurs around Christmas (El Niño = the child) and is caused by anomalous weak Pacific Trade Winds. This leads to accumulation of heat in the near surface layers of the Equatorial Pacific. Parallel to this process, the wind driven cold Humboldt Current off the South America coast weakens, and the tropical warm surface water advances further than normal to the eastern Pacific (Bjerknes, 1966). Accordingly, warm water covers the shelf region off South America suppressing upwelling of nutrient rich waters from the deep ocean layers.

An example of the anomalous 1997/1998 El Niño is given in Fig. 8. In the upper panel of Fig. 8 the average October 1997 vertical temperature field is given along the equator between New Guinea (left side of upper panel) and the Galapagos Islands (right side of upper panel). The lower panel reveals a marked thermal anomaly off South America which amounts to about 12°C above normal. This anomaly influences the entire surface water layer down to about 200 m, leading to the above mentioned suppression of upwelling.

Socio-economic impacts on the tropical southern and Northern Hemisphere are the consequence. However, of similar climatic importance are the intra-hemispherical teleconnections, e.g. the North Atlantic Oscillation (NAO) Index which reflects the winter sea level pressure gradient between Iceland and the Azores (Fig. 9).

Some authors reveal potential teleconnection impacts between these meteorological features and the recruitment failure/success of fish:

NAO. The concept of "biological teleconnections" is considered by Rodionov (1995), based on the analysis of year-classes of 10 cod (*Gadus morhua*) stocks in the northern North Atlantic and European Arctic seas. It is shown that a significant part of the total variance of recruitment to the cod stocks may be explained by means of analysis of two factors. The first factor reflecting the differences in year-class strength in the east compared to the west, appears to be related to atmospheric teleconnections. In fact, all the analyzed teleconnection patterns (four at sea level and three at the 500-hPa level) carry a signature of out of phase fluctuations between sea-surface temperature – surface-air temperature anomalies in the Northwest Atlantic and northern European seas. The second factor exhibits north-south opposition in year-class strength and is probably associated with the different reaction of the cod stocks during periods of general warming and cooling in the North Atlantic.

Since 1988/89 warming climatic conditions in the areas of Norwegian fisheries contributed to good recruitment and growth of the most important fish stocks (Anon., 1994). This period now seems to be coming to an end. In the Barents Sea, the maximum water temperature was reached around 1990/91. Since 1991 there has been a slight but steady temperature decrease. This cooling was more pronounced in the eastern parts and less in the western parts of the Barents Sea. Recent observations indicate that temperatures in the Atlantic water masses of the Norwegian Sea will continue to decline, and in the Barents Sea the temperatures are expected to be further reduced in 1997 with values below the normal. Consequently, the ice conditions will most likely be more severe compared to 1996, and the ice is expected to reach south of 73°N, in the areas around the Central Bank (Anon., 1997).

For 1996 the NAO was highly negative (-9.8, dashed line in Fig. 9). Similar values were found at the end of the 1970s, and this represents the flow of mild air masses from the mid-latitude Atlantic Ocean to the Greenland/Labrador Sea region. In contrast to the situation in the Northwest Atlantic, the Northeast Atlantic encountered increased northeasterly winds. This is concurrent with the above-mentioned cooling in the Barents Sea.

ENSO. The El Niño Southern Oscillation (ENSO) reflects the phenomenon of suppressed upwelling off the west coast of South America and Middle America (as mentioned above). Anomalies observed in the ichthyoplankton off the United States north-western coast during 1983 included temporal shifts in peak abundance of eggs and larvae among certain species, reduced abundance of eggs and larvae among

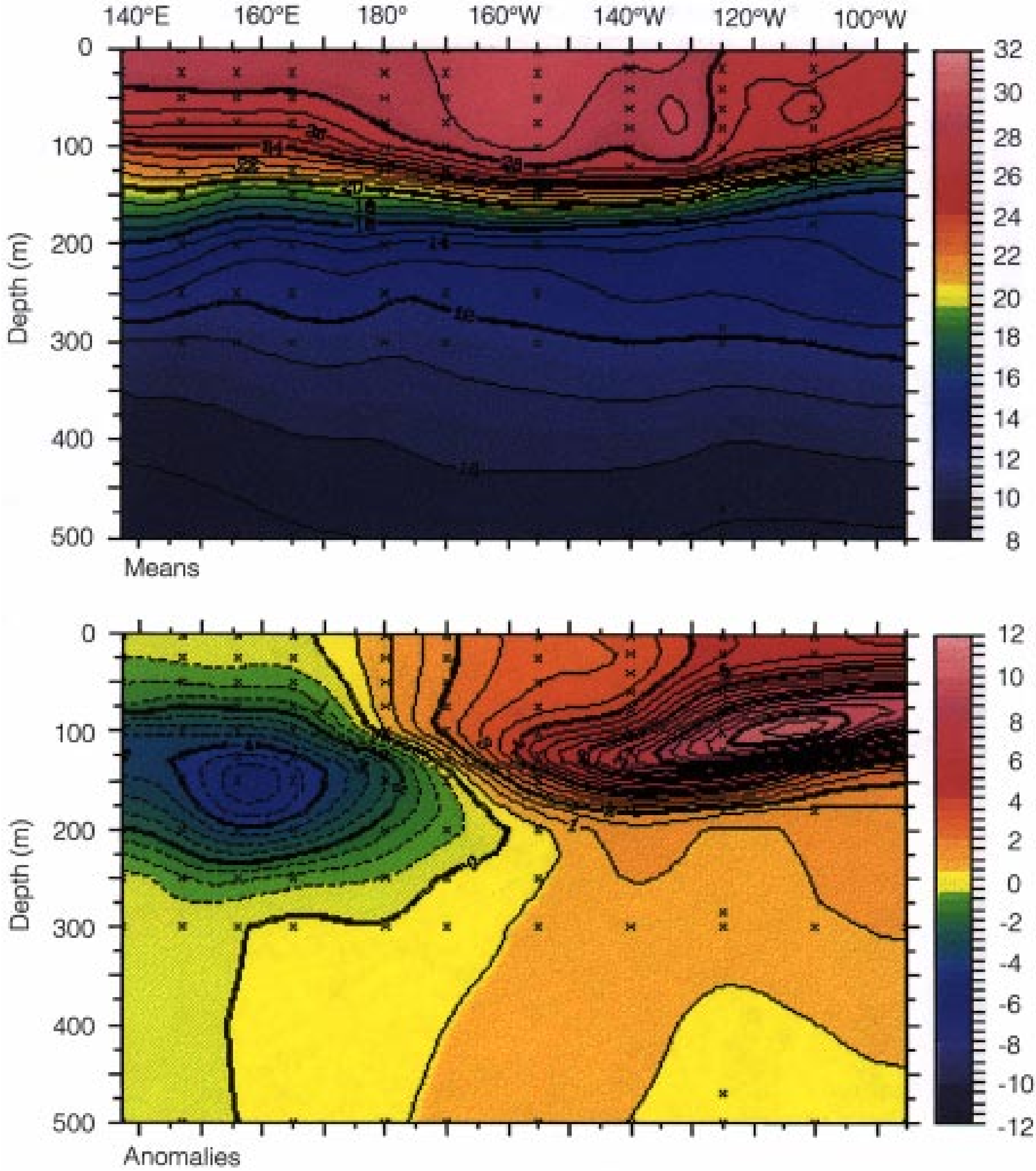

Fig. 8. Upper panel: mean vertical temperature distribution of the upper 500 m along the equator (2°S to 2°N average) during October 1997. Lower panel: temperature anomalies of the upper 500 m along the equator (2°S to 2°N average) during October 1997 (from NOAA: www.pmel.noaa.gov/toga-tao/sumgif/ Dep_Sec_EQ_Mon_48.gif).

other species, the occurrence of rare southern species, and changes in distribution patterns (Doyle, 1995). These anomalies were attributed to changes in spawning patterns and advection of eggs and larvae in response to the physical oceanographic anomalies characterizing the 1983 El Niño event in this region. Such changes, which resulted from the physical forcing on the ecosystem, seem to have been mediated

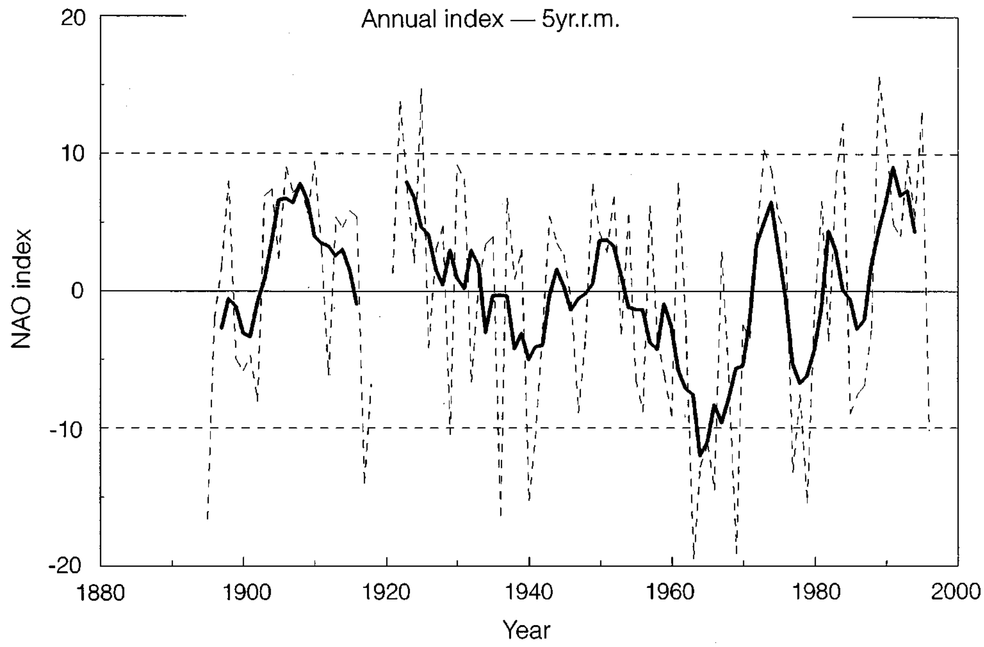

Fig. 9. The North Atlantic Oscillation Index defined as the winter (December, January, February) sea level pressure at Ponta Delgada in the Azores minus Akureyri in Iceland.

mainly through water temperature and transport anomalies. A high level of stability in the spawning and early life history patterns of fish species in this region is implied by the fact that only a small portion of the dominant species seem to have been affected by the strong El Niño event of 1983. As well, in 1984 and 1985, abundance and distribution patterns in the ichthyoplankton had returned to the apparently normal patterns observed in 1980, 1981 and 1982.

Global Warming Impacts

Extensive field work off the Great Whale River in southeastern Hudson Bay (Ingram *et al.*, 1996) has shown the importance of freshwater discharge, sea ice cover and meteorological forcing on the production of under-ice microalgae and the success of first feeding in fish larvae. Recent global climate model (GCM) results show a doubling of the present atmospheric carbon dioxide and indicate increases of both air temperature and precipitation in the Hudson Bay area. Predictions based on these GCM results are used to estimate future changes to the sea ice and runoff regime. Sea ice break-up in the offshore is predicted to occur about one month earlier than recently seen. Estimates of the spring fresh water flood in the Great Whale River indicate it will also advance by approximately one month. Onset of the spring fresh water flood will occur about one month before Hudson Bay ice break-up, similar to present conditions. A predicted reduction of about 35% in maximum sea ice thickness will lead to an increase in the ice-ocean interface irradiance and a decrease in melt water input to the Hudson Bay surface waters. These results point at potential effects of global climate change on northern coastal marine environments.

As a further example on global warming, the impacts on marine community structures in southwest Britain and the western English Channel during the past 70 years are presented as a scenario analysis considered by Southward *et al.*, (1995). Over the same period there was a climatic warming from the early-1920s, then a cooling to the early-1980s, with recent resumption of warming; the change in annual mean temperature was approximately ± 0.5°C. The authors describe marked changes occurred in plankton community structure; the distribution of both plankton and intertidal organisms was affected, with latitudinal shifts of up to 120 miles, and there were also increases or decreases of 2–3 orders of magnitude in abundance. Warm water species increased in abundance and extended their range during periods of warming, while cold-water species declined or retreated, and the reverse occurred during the period of cooling. Climate change can influence marine communities by a combination of; direct effect on the organisms, effects mediated by biotic interactions, and indirectly through ocean currents. From climate models that indicate a rise of mean temperature of 2°C in the next 50 years, and from the observed changes, we can expect future latitudinal shifts of 200–400 miles in distribution of plankton, fish and benthos, with extensive restructuring of planktonic, pelagic and benthic communities. It is suggested that species common now in the Bay of Biscay will become common in the English Channel, those presently restricted to the western English Channel could colonize the central Irish Sea, and changes in community structure could lead to lower abundances of infaunal benthos and fish. The authors, however, claim that to fully prove the effects of global warming, future changes in the marine biota must exceed those recorded in the 1950s and 1960s.

Towards A Synthesis

The case studies presented are the product of studies in recent years, when time-series became long enough (more than 30 years) to analyze climatic trends. The next step required would be a synthesis of the acquired results and the formulation of models which are capable of forecasting, e.g. the development of recruitment and the evaluation of a future situation of fisheries resources. Some promising approaches can be given as examples.

Modelling/Forecasting

Large-scale oceanic and climatic variability have been observed to greatly affect the distribution and abundance of Northeast Arctic cod (*Gadus morhua*) off Northern Norway and in the Barents Sea. Abundance estimates of 0-group cod have exhibited a close relationship with sea-temperature variability at the Kola meridian section in the eastern Barents Sea, with good year-classes tending to coincide either with temperature peaks or with increasing temperatures, and declining recruitment and poor year-classes tending to coincide with decreasing or low temperatures (Nilssen *et al.*, 1994). Construction of a simple multiplicative regression model describing the recruitment of Northeast Arctic cod, incorporating sea temperature along the Kola meridian, spawning-stock biomass, and cannibalism as predictors, explained about 46% of the 1946–88 recruitment variability.

During the recent years an effort has been made to find out more about the relationships between environmental variation and recruitment, growth, distribution and migration of fish. The rationale has to a large degree been to fulfil the needs from fisheries management. To utilize this knowledge for management purposes, it is necessary to be able to make some kind of forecast of the environmental situation (Ottersen *et al.*, MS 1994). This work was an early attempt to quantify the future temperature development in the Barents Sea. Ottersen *et al*. (MS 1994) used three different methods, all applied to the ocean temperature time series from the Russian Kola-Section. Statistics on the historical temperature patterns were then found useful for forecast purposes. The results indicated temperature conditions below the long-term mean up to 1999. Interestingly, the uncertainty of the forecasts grew with the length of the time-span, but the authors believed that the picture for the first 2–3 years was reasonably reliable. It is hoped that this work will help towards taking the environmental situation into consideration when evaluating the future fisheries resource situation.

Conclusions

It has been shown that amalgamation of biotic and abiotic time-series has in recent times led to a better understanding of the conditions for fish in the sea. The majority of such results has been published only during the past five years. This might in fact be a reflection on a different understanding of the ocean and it's living resources. This indeed might also point at a shift in paradigm in ocean sciences. The examples cited in the impact related studies mostly tend to reveal direct ways in which there are interactions between the biota and the ocean water properties and the external forces like wind or tides. I will define these as First Order Impact Studies. The Teleconnection Impacts and the Global Warming Impacts still remain in the "scenario type" of base studies, and the links are not yet understandable.

Modelling attempts are focused on regional forecasts, and thus reflect the results from the impact-related studies of the first order. Their value is based on the multivariate approach which takes into consideration variables like ocean temperature, spawning stock biomass and cannibalism as predictors to describe recruitment in fisheries. Suppose the input variables are realistic assessments, the results should then point at realistic future fisheries resource situation.

In conclusion, returning to the initial considerations of this presentation, we know John Cabot opened the New World fishing grounds to Old World fishermen. With better understanding of the interrelations between environmental conditions and the fisheries resources, I should like to hope that those abundant and paradise like conditions as found by him 500 years ago, might be a reality in near future times in Canadian waters.

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