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Appendix 1

The main features of the ICES Symposium on Cod and Climate Change

Reykjavík 23-27 August 1993

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The convener's presentation at the closing session.

I would like to start this review of what has happened during this week by dealing with **Session 3**, which was on the physical processes and models of North Atlantic circulation and shelf systems, with special emphasis on changes to be expected in the physical environment of cod. I think that it's fair to say that presentations and discussions in this session focussed on the effects of wind and temperature changes. With respect to winds it was clearly demonstrated that although effects of slow shifts in the large scale North Atlantic windfield were seen simultaneously throughout the area, the actual effects are of different appearance in the various subareas due to varied regional responses. Examples of such a responses relevant to cod stocks were given as follows.

Decadal to centennial changes of the atmospheric circulation pattern, for example as expressed by the North Atlantic cyclonicity/anticyclonicity index, do affect the intensity of the four major cyclonic gyres in the subpolar North Atlantic Ocean, namely Labrador-, Irminger-, Iceland- and Greenland Sea. This implies changes in the intensity of advection by the cyclonic current system and thus changes in larval drift pattern and affect inter-stock exchanges like between Iceland and Greenland. It also implies changes in the upvelling intensity within the gyres. Through the stratification this effects the intensity of deep and intermediate water formation, resulting in changes of upper layer temperatures and a change of the intensity of the polar fronts and the arctic fronts related to the gyres. These changes also control the flux of freshwater from the Arctic Ocean within the system of polar currents, leading to pulses of cold and low saline water like the Great Salinity Anomaly, which persisted for a decade in the subpolar Atlantic.

Changes in the windspeed also occur on large time scales. By enhancing the turbulence in the near surface layers it increases the contact rates between predator and prey. With respect to changes of directional windspeed important effects are known on the exchange of deep waters in semienclosed seas like the Baltic where direct relations between living conditions for cod and series of intense westerly winds have been shown.

With respect to large scale atmospheric temperature changes the effects of global warming were discussed. Since observation cannot yet conclusively distinguish between global warming and natural fluctuations, models with coupled oceans/atmosphere circulation are applied to the case of increasing CO_2 in the atmosphere and the results of these models show maximal warming in high latitudes with several important exceptions like at Greenland and Iceland.

Session 4, dealt with models of biophysical processes influencing the dynamics of cod populations.

The term biological processes addresses a wide range of topics which have the potential of influencing recruitment and growth. From a very general point of view the relevant physical parameters in this context are limited to temperature, salinity, light conditions, buoyancy and motion. All the papers and posters in this session addressed different aspects of motion. Certainly we are all aware of the importance of the dynamics for dirft and dispersion of eggs and larvae from the spawning areas. However, we have just recently become aware of the importance of the currents in the microscale environment for the feeding of larvae. In recent years we have seen large improvement in the numerical models simulating drift and dispersion of eggs and larvae. Partly this has to do with the modelling techniques, while also it is because of input of data on factors like spawning period, spawning site, buoyancy and vertical behaviour of the larvae. The modelling from three regions, Georges Bank, Newfoundland shelf and Barents Sea show that the mechanisms for transport and dispersion are very different. Vertical distribution of eggs and larvae seems to be very important for the resulting transport of Georges Bank and Labrador cod, while for the Arcto-Norwegian cod the horizontal transport is much less sensitive to variations in the vertical distribution of the larvae. However, all three model results demonstrate the importance of wind field variations on the inter-annual variations of the distribution of the juveniles. On the level of small scale dynamics we now see increasing evidence of the Rothschild and Osborn theory.

Session 5 dealt with the biology of cod, stock identity, migration, stock structure, recruitment processes and population dynamics. I think we realized during this session that it is of critical importance to correctly identify descrete populations and associated time and space scales in order to resolve population processes. Our present predisposition to study biology at the stock or management unit level may result in oversights of wider issues and general patterns. For example, it appears that spawning takes place over a more extensive period on the Labrador and Grand Banks compared to the NE Atlantic cod stocks. This difference may be an artifact of aggregating across spawning concentrations and years.

Comparative approach is an effective means of identifying factors which influence cod prodution and distribution. The general distribution of cod stocks is well known and can be related to temperature, salinity, oxygen and depth. It may be useful to look for general pattern in cod growth, such as by examining the relationship between size at age across stocks and the average annual hydrographic condition. One could also seek relationships between mean recruitment and the magnitude of certain attributes common to cod spawning grounds, such as the volume of water of a critical temperature for survival or the distributional area of the eggs or larval stages. It is generally recognized that the processes which limit distribution and production could depend on the geographic location of the stock and levels of data aggregation need to be considered carefully.

Distinguishing between the effects of fishing and environmentally induced changes in stock distribution and production has proved very difficult but it is a highly important task. Several cod stocks have recently experienced declining recruitment, environmental extremes and severe exploitation. In addition, loss of spawning components, low spawning stock biomass and change in age composition due to fishing could possibly increase a stock susceptibility to environmental variation.

Many studies have shown that 0-group abundance indices correlate reasonably well with year class abundance levels leading to the conclusion that year class strength is established during the first few months of life. Although, there was evidence of important periods throughout the first winter of the 0-group. These studies, using correlative and descriptive approaches, have shown that biological and physical factors influence distribution, growth and survival. Warm years are generally associated with higher cod production among high latitude cod stocks. One potential shortcoming of such studies is that proxies, like temperature, may not adequately represent the assumed processes being modelled. The emphasis on studying factors influencing survival during the early life stages is not balanced by a similar number of studies dealing with survival processes acting on juveniles and adults.

Session 6 dealt with the trophic relations of cod in various ecosystems.

Trophic interactions of cod were reviewed for the Barent Sea, North Sea, Iceland, Newfoundland and Baltic ecosystems. Diet composition was similar across ecosystems in that fish were the major prey for adult cod, while crustaceans constituted the most important prey of juvenile cod. However, the particular prey species differed among each of the ecosystems, although, capelin is the main prey in at least three of them. Cod is preyed upon by other fishes, marine mammals, marine birds and several invertebrate species, however, this is mainly true for juvenile cod and the magnitude of these impacts are unknown. Much more information is required before reliable quantiative estimates of predation mortality on cod can be derived.

Cannibalism may at time be important in some regions but not in others. Most cannibalism involves predation on younger age groups and small-sized fish and is most significant on 0-group and 1-group individuals. Again, however, there are only a few reliable estimates of the intensity of cannibalism in any region. Studies of changes in stock distribution for each stock are essential to better understand and evaluate the intensity of cannibalism and its possible significance in affecting recruitment.

Temporal and spatial changes in the abundance and biomass of the prey of cod are generally reflected in the diet composition, although there are few data on the suitability of alternate prey species or the ability of cod to preferentially seek out prey species.

Statistical analysis of cod stomach content data is often hampered by a large proportion of empty stomacs and when stomachs have been bulked or aggregated before the contents have been measured or counted. However, models and procedures have been developed to account for these in deriving statistically, reliable estimates of average stomach contents by length group and also accounting for other independent variables.

Session 7 dealt with experimental studies on the biological performance at various stages of the life history (spawning, larval survival, maturation) and on the growth of cod from contrasting environments.

It was demonstrated how the experimental approach can help to test hypotheses concerning the life history of cod which otherwise would be difficult or impossible in the complex and highly variable marine environment. However, careful design of the experiments is of vital importance and a care must be taken when inferences are made about field situations. Clearly some aspects of the life history of cod are better suited

to experimentation than others. The studies of the egg and larvae seem to be particularly well suited to experimentation as indicated by the numerous papers presented on these subjects. Interesting relationships between egg size and size of spawning cod and time of spawning were presented. These studies may shed some light on the quality of the spawning stock depending on its age/size structure. Further studies may give fisheries managers information about the optimal age/size structure of the spawning stock of cod. Relationships to predict the time of spawning of cod from the size of oocytes and the temperature were also presented. The experimental approach was also used to study the difference in growth rate and survival between two different cod stocks. A new method to study the activity of cod larvae under different light conditions was introduced. Finally, the stage dependent changes in density of cod eggs were studied in the laboratory to try to understand the observed vertical distributions of cod eggs in the sea. In spite of the limitations of the experimental approach it is undoubtedly one of the strongest tools we have to elucidate some processes of vital importance to the dynamics of cod stocks.

Session 8 dealt with studies on physiology and genetics. The most interesting developement in this field is that there seemed to be on the horizon new techniques which together with tagging and migration studies combined with genetic investigations are very promissing. Such studies could explain genetic variation between populations and subpopulations and thus help managers in identifying management units. I think this is something to look forward to.

In closing the circle, I would like to come to **Sessions 1 and 2,** which were on the historic reviews and diagnosis. We learned that archaeological excavations of fish bones indicate that cod of 1-1.5 meters were regularly taken in the period from the 12th to 19th century throughout the North Atlantic. Further historical records of the cod fisheries, both at Iceland and in the North East Arctic since the 16th century, have shown considerable fluctuations and these appear to be linked to changes in climate although it was expressed that the climatic fluctuation could also have affected the actual fisheries but not only the fish stocks. In cold periods it is true that the catch per unit effort fell but showed an increase when environmental conditions became more favourable. This was the case for cod stocks in general until the beginning of the 1950ies.

We have seen that the landings of the North Atlantic cod stocks reached a maximum of 3.7 million tonnes in the late 1960s but have been declining in recent years. This decline is really the main problem of this symposium. One should be aware that the data presented mainly covered the period to 1990 and some very interesting things have happened since then. For the first, there is a moratorium on the Northern cod at Newfoundland and then in the Barent Sea, where a fishing pressure was temporarly released, the Arcto Norwegian cod responded very favourably and there the fishing is now increasing. However, heavy fishing is or has been common to all cod stocks. But they are also affected by environmental conditions although these conditions are very different in the various areas. If we take the Baltic as an example, I think we all can agree that the Baltic cod apart from having suffered from very heavy fishing is also faced with reduction in salinity and oxygen. In the North Sea we have to pose the question: What is the cause for the low level of

recruitment in the most recent years? Is it recruitment overfishing or is it because the North Sea is returing to normal after the gadoid outbust in the sixties. I don't think we have had a clear answer to this. At Faroes the recruitment had not fluctuated very much for several decades until there is a recruitment failure now. Is this because of the heavy fishing which certainly did take place or was it a change in the circulation pattern around the Faroes? Similarily the recruitment to the Icelandic cod stock had remained exceptionally steady for the last three decades. Thus the ratio between the lowest and the highest year class has been only of the order of three, compared to the order of twenty in the Barent Sea. Taking the Iceland-Greenland area as a whole, it is clear that there has been a contraction of cod distribution in recent years. However, even in Greenland, where we agree that the environmental signal is quite clear, we have to addmit that just before the environmental conditions deteriorated very heavy fishing was reducing that stock rapidly.

As regards, the Northern cod at Newfoundland, the results were not all that clear but it was suggested that the low temperature and the salinity change in the northern part of the distribution area is the main reason for the reduction in the distribution of that stock. The most recent changes in distribution had made the stock vulnerable to uncontrolled distant water fishing. In addition a stock recruitment relationship has been observed and finally it was suggested that perhaps increased natural mortality had contributed to the collapse of the stock.

The Georges Bank cod has as the cod in other areas been subjected to very heavy fishing. Under these circumstances, not only on Georges Bank but also in other areas, it is very difficult to decern between the effect of over fishing and changes in environmental conditions. Nevertheless, I think that we have to addmit that all the North Atlantic cod stocks have been exposed to very heavy and increasing fishing pressure in the past. One of the few exceptions is the Arcto Norwegian cod. In 1988 it was decided to act on the advice of ICES to greatly reduce the fishing pressure on the Arcto Norwegian cod for at least two or three years and the stock responded beautifully. But why did it respond so quickly? The answer is of course that this wise decision was taken just when the environmental conditions in the Barent Sea were improving and the cod had plenty to eat. This, I think, brings us to the comment made during the symposium that naturally the cod is a long lived species and the heavy fishing is changing that. The longevity is an adaptation to varying environmental conditions. Thus when environmental conditions did deteriorate for a while the longevity and the high fecundity would help the cod to survive until the conditions returned to normal. However, the present exploitation of the species is generally so hard that it has changed the longlived cod to relatively short lived species.

When exploiting wild animal populations, whether it is marine mammals, codfish or an invertebrates, one has to take into account that we can only control the exploitation rate, we can't control the changes in environment. Therefore, the exploitaiton must always be within the limitation given by nature and I think we should also remember that one should not consider the cod and the environment in isolation. In stead we should study the large ecosystems that we have been harvesting in all their complexty. As far as I can judge, the major message from this symposium is a plea for reduced exploitation rate of the cod.