NORTHWEST ATLANTIC FISHERIES ORGANIZATION

Scientific Council Studies
Number 18

Changes in Abundance and Biology of Cod Stocks and Their Possible Causes

Symposium, 4–6 September 1991

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Foreword

In accordance with its mandate to disseminate information on fisheries research to the scientific community, the Scientific Council of NAFO publishes the *Journal of Northwest Atlantic Fishery Science*, which contains peer-reviewed primary papers and notes on original research, and NAFO Scientific Council Studies, which contains review papers of topical interest and importance, and sometimes includes contributions to special meetings and symposia. Each year since 1981, the Scientific Council has held a Special Session on a topic of particular interest, and many of the documented contributions to those sessions have been published in NAFO publications or in other fishery-oriented periodicals.

During 4–6 September 1991, the Scientific Council held a Symposium on "Changes in Abundance and Biology of Cod Stocks and Their Possible Causes", with H. Hovgård (Denmark, in respect of the Faroe Islands and Greenland) as convener. At its meeting in September 1989, the Scientific Council initially agreed to host the 1991 Special Session on Atlantic Cod, and was pleased to welcome R. (Dick) Wells, the well-known Canadian expert on gadoid biology and fishery management science, to convene a Symposium. With the sad, untimely death of Dick Wells in December 1989, the Council was pleased Hovgård agreed to convene the session, and new ideas on the theme and specific topics were considered. The Council decided to dedicate the Symposium in memory of Dick Wells.

Interest in the contributions to the Symposium resulted in the Scientific Council recommendation that papers presented should be published in full or as extended abstracts in a special issue of *NAFO Scientific Council Studies*, with H. Hovgård and T. Amaratunga undertaking the editorial review of the papers.

Of the 24 presentations (see List of Documents, pages 93–94) made at the Symposium, 8 papers and 10 abstracts were accepted for publication of this issue.

July, 1993

T. Amaratunga, Editor
NAFO Scientific Council Studies
Northwest Atlantic Fisheries Organization
P. O. Box 638
Dartmouth, Nova Scotia
Canada B2Y 3Y9

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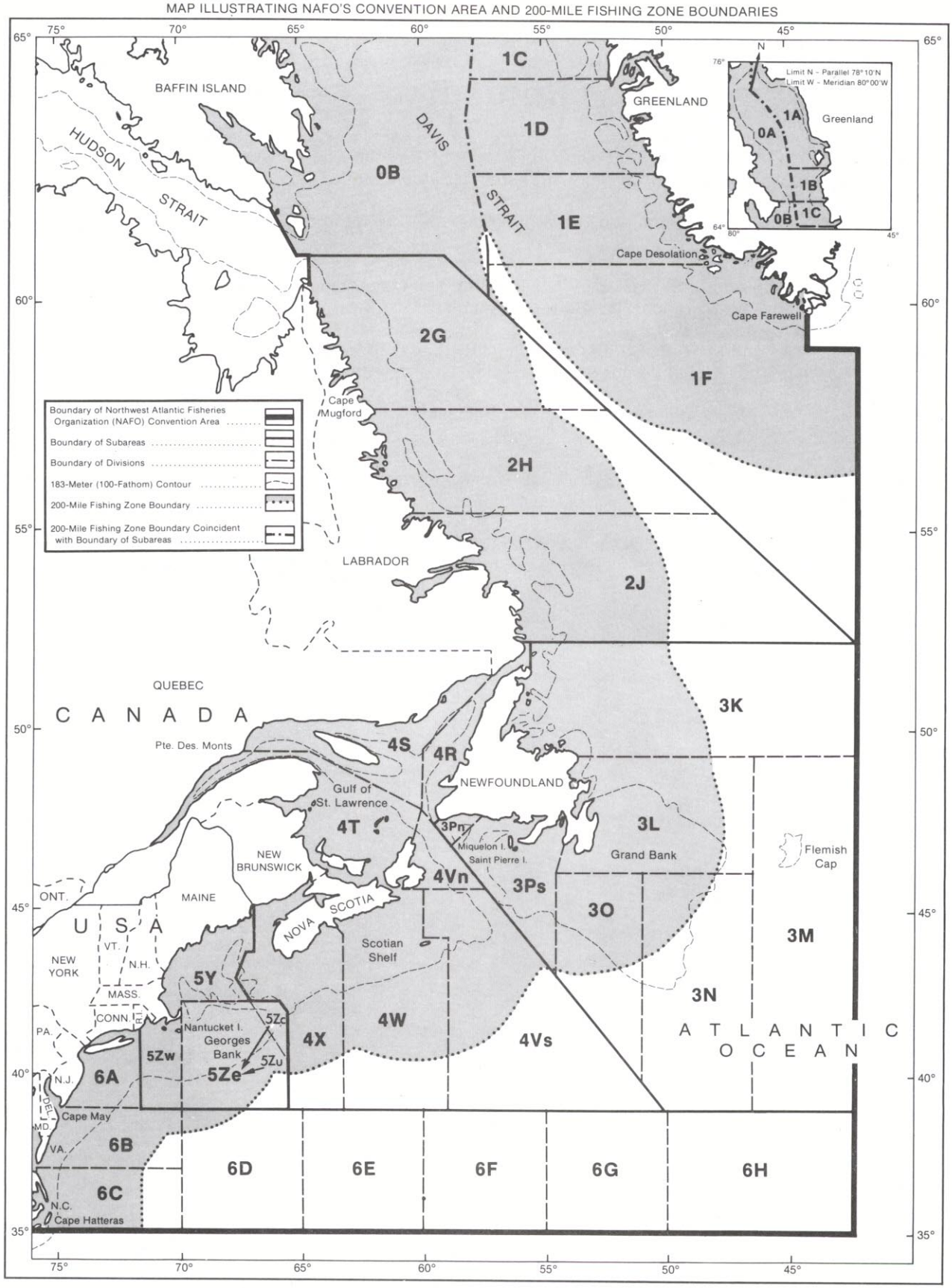

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Report of the Symposium

H. Hovgård (Convener)

Introduction

The Symposium on "Changes in abundance and biology of cod stocks and their possible causes", hosted by the Scientific Council with H. Hovgård (Denmark/Greenland) as convener, was held at NAFO headquarters in Dartmouth Nova Scotia, Canada, during 4–6 September 1991. The Symposium was dedicated in memory of Richard Wells (Canada) who was initially invited to convene the symposium. A total of 24 presentations were made (SCR Doc. 91/97–91/120), in five sections concerned with reproduction and recruitment, case studies, distribution, migration and growth and feeding. The sections were chaired by K. Brander (UK), C. Bishop (Canada), H. Hovgård (Denmark/Greenland) and A. Sinclair (Canada) respectively. The Symposium was attended by scientists from Canada, Denmark (Greenland), EEC, Japan, Norway, USA and USSR (see list below).

Reproduction and Recruitment

Seven papers were presented in this section covering a range of very different studies. Two contributions looked at morphology and anatomy: (a) the gross anatomy and histology of the reproductive stages of cod (SCR Doc. 91/106), and (b) the development of the digestive tract during and after the yolk-sac stage (SCR Doc. 91/105). Both studies have been published or are being prepared for inclusion in an atlas. The detailed studies of anatomy and histology of the reproductive stages show how they could help to define the maturity stages used in fieldwork and population studies, but also bring out some of the difficulties in applying such stages. For example, in detailed studies some fish were classified as spent-ripening because they had empty follicles as well as oocytes starting vitellogenesis. The time scale over which they would once again be ripe was not known. The development of the digestive tract reflected changes in nutrition during the early life, including the switch from endogenous (yolk sac) to exogenous (plankton) nutrition.

A paper analyzed a 13 year data series on maturity for cod in Div. 2J+3KL collected during autumn research surveys (SCR Doc. 91/112). The length and age at 50% maturity was greater in the south (Div. 3L) than further north and the length at 50% maturity also showed a declining temporal trend in all three Divisions. Temperature seemed to have a two-year lagged effect on maturity. Biomass had a one-year lagged positive effect on age at 50% maturity, when temperature was high.

A contribution on the timing of spawning throughout the North Atlantic, obtained as part of the ICES checklists of information on spawning characteristics, was presented (SCR Doc. 91/108). A more detailed look at spawning timing on the Scotian Shelf and around the British Isles showed considerable variability in timing at finer scales, and the possible effects of latitude, temperature and production timing were discussed.

A study of fluctuations of cod year-class strength in the North Atlantic in relation to the spawning stock biomass and survival conditions (SCR Doc. 91/116) used stock biomass as an index of survival (in recruits-per-SSB tons). Greatest variability in this index was observed at West Greenland and Northeast Arctic, whereas the variability at Iceland, Faroe Islands and Subdiv. 3Ps was quite low. The wide variability for West Greenland and for Northeast Arctic cod pointed to extreme environmental factors demanding species specific adaptations during early life.

Recruitment variability for a large number of stocks in the North Atlantic was characterized by examining: (a) variability of recruitment, (b) distributional characteristics of recruitment variability, (c) density-dependent mortality within and between year-classes, and (d) the role of environmental factors (SCR Doc. 91/113). Results from several published studies were discussed including the conclusions that density dependence probably occurred between adjacent year-classes and that recruitment was more variable for stocks at the northern and southern limits of their range.

A paper discussed the use of non-parametric methods to estimate recruitment and concluded that a fixed interval algorithm was the only suitable non-parametric method to estimate recruitment for the cod stock in Div. 3NO for the period 1958-82 (SCR Doc. 91/98). A Markowian approach was found to be inadequate because the transition probabilities was apparently not constant and did not depend only on the previous state.

Case Studies

Six papers provided background information on seven cod stocks occurring in the North Atlantic. Emphasis was placed on providing summaries of historical and current annual catch levels in conjunction with corresponding annual changes in stock status. Some of the possible causes for stock fluctuation were presented which included management strategies and recruitment variation. It was generally recognized that our ability to assess stock status has improved and we are potentially capable of preventing the over exploitations that have occurred in the past. It was agreed that more emphasis should be placed on understanding the processes that influence recruitment levels as well as some of the biological changes that have been observed.

Summaries of the presentations are as follows:

a) **Georges Bank cod** (SCR Doc. 91/107). Prior to the 1980s this stock had remained relatively stable in spite of periods of heavy exploitation. Recent high exploitation levels from 1980 to 1986 reduced the stock size in spite of good recruitment. The decline of the stock was related mainly to an unsuccessful joint management program between Canada and the USA.

b) **Cod stocks in the Newfoundland area** (SCR Doc. 91/115). In general, landings were highest in the late-1960s followed by a decline to the mid- to late-1970s because of high exploitation levels. Subsequent stock declines led to reduced catches until the late-1970s when there was some increase. With the exception of that for Subdiv. 3Ps cod, recruitment levels have not returned to levels observed in the 1960s and, as well, there appears to be recruitment failure in the 3NO stock in recent years. Reasons for the recruitment decline were not known but were most likely related to environmental conditions.

c) **Baltic cod** (SCR Doc. 91/97). Landings in this area have fluctuated due to varying fishing effort and to varying year-class strengths. Stock abundance and landings peaked in the mid-1980s but were followed by a drastic decline. Spawning success and subsequent recruitment were closely related to the salinity and oxygen conditions in the area where spawning occurred. These conditions were dependent on inflow from the North Sea which also increased the availability of bottom nutrients. It was pointed out that limited inflows have occurred in recent years and conditions for egg survival are currently poor.

d) **Barents Sea** (SCR Doc. 91/117). The stock had been historically productive but variation in catches had always been large. During the 1980s, landings and stock abundance declined to the lowest level on record. Three major causes of variation were considered to be: stock reduction through exploitation, environmental influence on recruitment, species interaction effects on maturation and growth and, as well, interactions between the three factors. Environmental conditions were considered to be important directly or indirectly in determining recruitment levels. Determination of long-term effects of environmental conditions were considered important in determining reasons for stock changes.

e) **Cod in Subdivision 3Ps** (SCR Doc.91/114). Variability in stock abundance has been observed since the late-1970s and was related to a combination of biological factors and fishing activity. These biological factors included variability of recruitment, stock distribution, and migrations from neighbouring areas. These were considered to be variable because of variable environmental conditions. Stock levels, especially the spawning biomass, were influenced by variable exploitation levels in the late-1980s along with restrictions of specific zones resulting from international (Canada and France) management activities in the area.

f) **West Greenland cod** (SCR Doc. 91/118). Large variations in abundance and distribution have been observed since the 1920s and, as well, stock structure is believed to have changed significantly. The stock consists of three components: an offshore component of West Greenland origin, a similar component of Icelandic origin, and the fjord stocks. A combination of overfishing, deterioration of climate and low recruitment levels have severely reduced the West Greenland offshore component with landings from this area being obtained from random good year-classes of eastern origin. The fjord stocks are self sustaining but small, and potentially can produce only a small proportion of previously observed large catches.

Distribution

Five papers concerned with distribution were presented in this section.

The age specific distribution in the North Sea as inferred from autumn/winter surveys showed a gradual northern shift in distribution between age 1 to age 3+ cod (SCR Doc. 91/109). This pattern was found consistently in the period studied (1971–91). The youngest age groups were in general found in more shallow and colder waters than older cod. A series of quarterly surveys has been initiated to follow the changes in distribution relative to depth, temperature and salinity over the full course of the year.

A study in Subdiv. 4Vs and Div. 4W (SCR Doc. 91/103) showed that older cod were found at progressively greater depths over the entire age range studied (age 1–12). The temperature where most of the catch was taken, was highest for age 1 cod and decreased to age 5 after which it remained stable. The depth and temperature distribution of the cod catches did not correspond with those observed in the total survey area, hence indicating that cod sought areas with specific conditions. From a management point of view it was pointed out that the depth segregation of ages enables a possible mechanism for year-class targeting in the commercial fishery.

Age specific distribution of cod in southern Gulf of St. Lawrence was analyzed with respect to depth, temperature and regions using Poisson regression models. Depth distribution was age dependent with older cod occurring at greater depths whereas distribution by age was independent of temperature in most years. The abundance and distribution by area changed significantly between the 1971–78 and the 1979–90 periods with the age depth relationship being significantly steeper in the period of high abundance. The change in areal distribution observed was not well understood as it could have been caused by density dependence, differences in migration timing, change in prey abundance or other environmental changes.

In the eastern part of the Gulf of St. Lawrence (Subdiv. 3Pn and Div. 4RS) cod have shown significant variations in depth distribution in winter surveys since 1978 (SCR Doc. 91/110). Highest survey catches were observed at bottom temperatures between 4.7° and 6.3°C. The temperature in the deeper waters fluctuated within this range whereas the temperature in more shallow water (0–180 m) showed annual variations between 2° and 4°C. Years with high catches in the shallow waters were restricted to years with high temperatures. The period since 1987 had been characterized by low temperatures and this had led to movement of the trawler fleet to deeper waters. The effect on the small boat fixed gear fleet had been very significant as it was confined to depths less than 180 m. Catches in winter had dropped from a level of 5 000 tons prior to 1987 to almost nil in 1991.

The conflict between trawlers and longliners was discussed for the Subdiv. 4Vn cod (SCR. Doc. 91/109). It was concluded that the spatio-temporal distribution of the trawler fleet to the areas of the longline fishery was not affecting the longliner fleet significantly. It was of more importance that the trawlers exploited the year-classes before they become available to the longliners, hence affecting the potential yield of the latter fleet.

In the discussion following the session it was noted that factors such as depth, temperature, salinity and areal units may have confounding effects and that this poses difficulties in drawing strict conclusions on the importance of the individual factors.

Migration

A model designed to study the migration of cod, and thus its availability to the fisheries in Div. 2J+3KL was presented (SCR Doc. 91/119). The approach used was to describe the movement of cod in relation to theory based on fisheries oceanography (closed loop migration), behavioral ecology (predation) and physiological (thermal) responses. Model predictions were being tested with physical oceanography, fisheries acoustics, trawling and tagging data. Two migratory channels have been identified and the movements of cod over two years have been observed. Preliminary results indicate consistent migratory pathways, and that the movements are indicated, but not necessarily determined, by water temperature. The program was in the second of a planned five-year study.

The immigration of cod from Greenland to Iceland was estimated by examination of fishing mortalities for specific year-classes (SCR Doc. 91/102). The immigration was indicated by apparent abnormal low fishing mortalities on certain year-classes in a VPA. The extent of the immigration was estimated by re-running the VPA with fishery mortalities estimated for adjacent year-classes and taking the differences between the two estimates of year-class strength.

Growth and Feeding

Three approaches for estimating environmental effects on growth, from either growth increments or

size-at-age data, were compared (SCR Doc. 91/99). The behaviour of the estimation procedures was tested using simulated data which incorporated different environmental effect levels and data errors. It was pointed out that growth increments calculated by differing size-at-age are auto-correlated and thus statistical procedures should be modified accordingly. The preferred approach was to fit von Bertalanffy curves, allowing for environmental effects either on L_∞ or K.

Data on the stomach fullness index-at-age of Flemish Cap cod, collected in 1989 and 1990, were analyzed in relation to year-class strength (SCR Doc. 91/111). Although the data were limited, they suggested a negative correlation between gut fullness and abundance.

A paper compared estimates of daily feeding rates of Newfoundland cod obtained by three different methods (SCR Doc. 91/100). Comparable results were found with the three methods.

Closing Discussion

Two main issues were raised at the final discussion. Firstly, it was asked whether common key processes affecting growth, recruitment, distribution or migration should be expected across the different cod stocks. The second main issue was the temporal and areal scales on which such processes were acting.

It was recognized that the main emphases in the study of cod stocks varied greatly between areas. For southern stocks much effort has been allocated to multispecies studies, whereas several programs have been initiated to try to link cod biology to climatic effects for northern stocks. For some stocks still other processes are important; migrations as seen off Greenland or changes in salinity and oxygen in the Baltic Sea. Between cod stocks living in similar types of environments, ecological similarities are observed *viz.* the cod/capelin linkage for some of the northern cod stocks. However, more detailed studies indicate that the systems are not identical. Despite these differences it was concluded that attempts should be made to develop general conceptual models applicable across the different cod stocks. Such models need to be flexible thus allowing for varying importance of key processes to the different cod stocks.

Much of the data available relevant to the study of cod stock dynamics have been compiled for fish stock assessment purposes, thus introducing a given level of aggregation in time and space. In an assessment context, a disaggregation into small units may well increase the complexity and thereby impede interpretations. The study of biological processes may require data on a more deseggregated level, as an aggregation of sub-populations characterized by differences in biology may well lead to erroneous results.