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REPORT OF THE ICES STUDY GROUP ON COD STOCK FLUCTUATIONS.

Cod and Climate Change (CCC),

Framework for the Study of Global Ocean Ecosystem Dynamics

This report has not been approved by the International Council for the Exploration of the Sea and therefore does not necessarily represent the views of the Council.

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CONTENT

PREFACE

The ICES Study Group on Cod Stocks Fluctuations was established according to the ICES Council Resolution 2:14/1989 (Appendix I). The Resolution called for The Study Group to communicate by correspondence in 1990. However, because of the great interest in cod stock fluctuations, particularly in relation to environmental and climate and Global Ocean Ecosystem Dynamics (GLOBEC) 20 scientists on their own initiative met in Bergen 16 - 18 January 1990 to study the relations between air-sea interactions, ocean physics, and the fluctuations of cod and related organisms in the North Atlantic. (A preliminary report of the meeting, "Development of a plan to study Cod and Climate Changes in the North Atlantic", was distributed in April 1990).

The Study Group (listed in Appendix II) wishes to thank the following contributors of the regional syntheses (appearing in Appendix III):

S.Campana, G.A.Chouinard, P.Fanning, A.Frechet, J.M.Hanson, J.J.Hunt, T.Lambert	(Canadian cod stocks and Georges Bank)
E.Buch, H.Hovgaard	(West Greenland cod)
V.P.Serebryakov	(White Sea cod)
S.Sundby, K.Sunnanå	(North-east arctic cod)
A.Kristiansen, B.Hansen	(Faroes cod)
J.Gjøsæter	(Norwegian coastal Skagerrak cod)
P.O.Larson	(Baltic Sea cod)
H.Heessen	(North Sea cod)
K.Brander	(Irish Sea cod)

The present report was worked out during a meeting in Lowestoft, August 14.-16. 1990, attended by R. Beverton, K. Brander, D. Cushing, N. Daan, B. Rothschild and S. Sundby. It brings together comments from both Study Group members and others on the preliminary report, a more detailed discussion on the life history of the cod throughout the Atlantic, and reemphasizes the need to study the integration of biological and physical processes. In addition, the present report expresses the need to support model development through laboratory, mesocosm and field studies.

Bergen, Gwent, Lowestoft and Solomons.

August/September 1990

1 INTRODUCTION

1.1 The GLOBEC context

The dynamics of marine ecosystems in the context of climatic change are of considerable practical and scientific concern. The practical concern stems from the need to manage the global ocean or at least large parts of it. The study of ecosystem dynamics helps to identify those parameters that drive long-term variability of biological productivity and hence provide a starting point for long-term forecasts for the optimal management of fisheries. Ecosystem dynamics also provides insights into the way in which systems in the sea are affected by pollution and reveals where regulation is needed. As anthropogenic inputs into the sea increase, their impact upon the fish stocks will become more obvious and the need for interaction between fisheries and pollution management will become more urgent. The stakes are raised by the climatic change now facing us.

The practical importance of these problems only serves to enhance their scientific potential, particularly as inquiry shifts from description to understanding.

It is immediately obvious that tackling the problem of global ecosystem dynamics is not only necessary but extremely difficult and long-term. It is also obvious that a clearly enunciated strategy will be necessary to coordinate the diverse activities that will be necessary for its execution, and ensure that the work is moving toward a common goal.

A strategy will not simply happen, nor is it likely to occur through some abstract design. A practical approach which can be implemented in its own right is needed to serve as a model.

1.2 The scale of climate change

An attractive strategy can be based upon the well known variability in the fish stocks. A review of marine ecosystems shows that many fish stocks exhibit very large fluctuations in biomass. To what extent are the variations caused by the physical environment, and what is the effect of these considerable perturbations on other elements of the ecosystem? In turn, to what extent do fluctuations in non-fish components of the ecosystem influence the variations in the fish stocks?

Frustration has been associated with attempting to answer these questions, and it is a consensus that a new approach has to be taken. Such a new approach would need to involve a) heavy emphasis on modelling b) recognition of the importance of the interaction between the physical environment and population dynamics c) the development of new sampling techniques and d) the enhancement of our institutional capabilities to focus on assessing the opportunities for forecasting, monitoring, and managing the human influence of major sectors of the marine environment (EOS, 1989).

1.3 Cod and climate

Following this strategy , the cod and climate-change program has been designed to be both a model for organizing the study of global ecosystem dynamics while at the same time providing new insights on the the fluctuation of cod stocks of the North Atlantic, as they might be affected by climate fluctuation.

There are a number of factors which dictate the choice of cod as a target for the pilot study.

a) The biology, physiology, and ecology of the life history stages of cod are probably better understood than for other marine species.

b) Long and for the most part reliable time series of data on landings, biomass and recruitment are available for many of the North Atlantic cod stocks.

c) The prey organisms of cod are largely well known, and for most stocks the predators of the adult cod are relatively well known.

d) The capability for numerical modelling of the physical environment gives us an opportunity to study physical variability and to link, as it has not been done before, basin-wide changes in physics with the productivity of individual population.

e) The diversity of the cod population and their environment enable the development of a general understanding which could be transferable to other species and regions.

f) The geographical range of cod stocks is such that several stocks are particularly sensitive to climate fluctuation at the northern and perhaps at the southern extreme of its range, and therefore a useful test case for assessing our capability to forecast interactions of fish stocks with the environment.

g) The diversity of laboratories and disciplines already involved in studies on recruitment, multispecies modeling, climate and physical numerical models provides an opportunity for attacking the problem from all necessary aspects.

h) Considerable work is ongoing, and the institutional capability of ICES and other organizations is staged to coordinate activity and to create opportunities for considerable improvement in stock-assessment techniques by the more direct employment of ecosystem dynamics in stock and population-dynamics assessments.

i) Because of a wide range of interest, placing cod dynamics in the context of global ocean ecosystem dynamics provides the opportunity to bring new funding into fisheries research.

In laying out the program we set the stage by providing background information on the North Atlantic cod stock and the environment.

We the provide a template for developing a five year plan for a general CCC model. The template is built up by considering the way that a North Atlantic Physical Model (NAPM) drives Regional Physical Models (RPMs) and the way that Biophysical Process Models (BPMs) are integrated into the Regional Physical Models (RPMs). Such a scheme would be applicable to other species (in the North Atlantic, e.g. herring) and other ocean basins (e.g. sardines in the North Pacific).

The urgency of beginning this program cannot be understated in as much as it is a long-term program and many uncoordinated activities are already underway.

2 ENVIRONMENTAL DEMOGRAPHY OF NORTH ATLANTIC COD STOCKS

The distribution of Gadus morhua in the North Atlantic (Figure 1) may be interpreted in relation to the shelf topography, the prevailing current systems (Figure 2) and the general temperature regimes of the area. A lack of symmetry in the distribution of cod stocks is introduced by the predominant SW-NE flow of the Gulf-Stream and its branches. Because the demography of cod stocks depends upon the strength and direction of the current systems as well as the temperature regime it can be easily seen how climate fluctuation in the near and long term can affect the demography of cod.

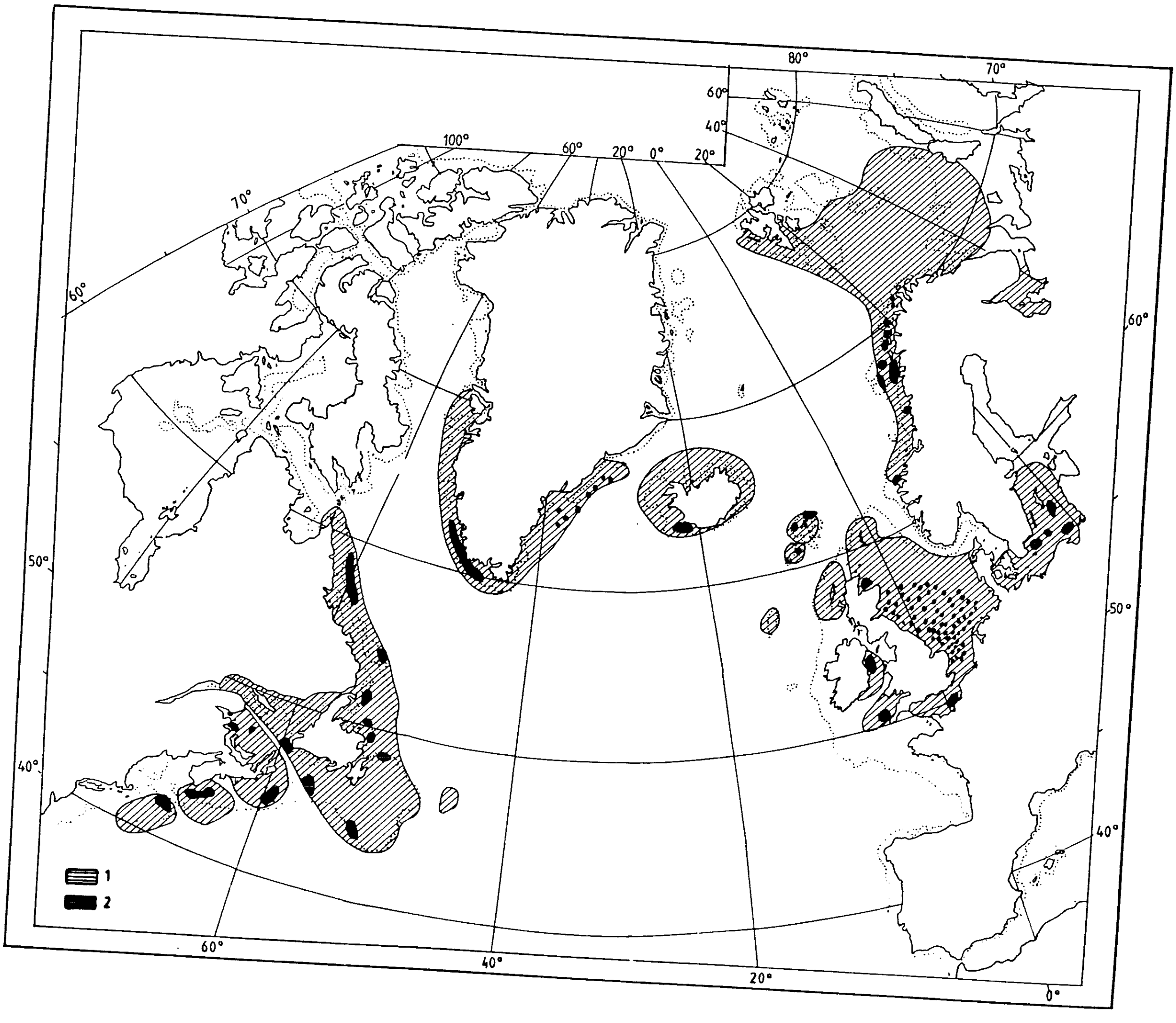


Figure 1. Distribution of the cod stocks in the North Atlantic. 1) Area of distribution. 2) Area of spawning.

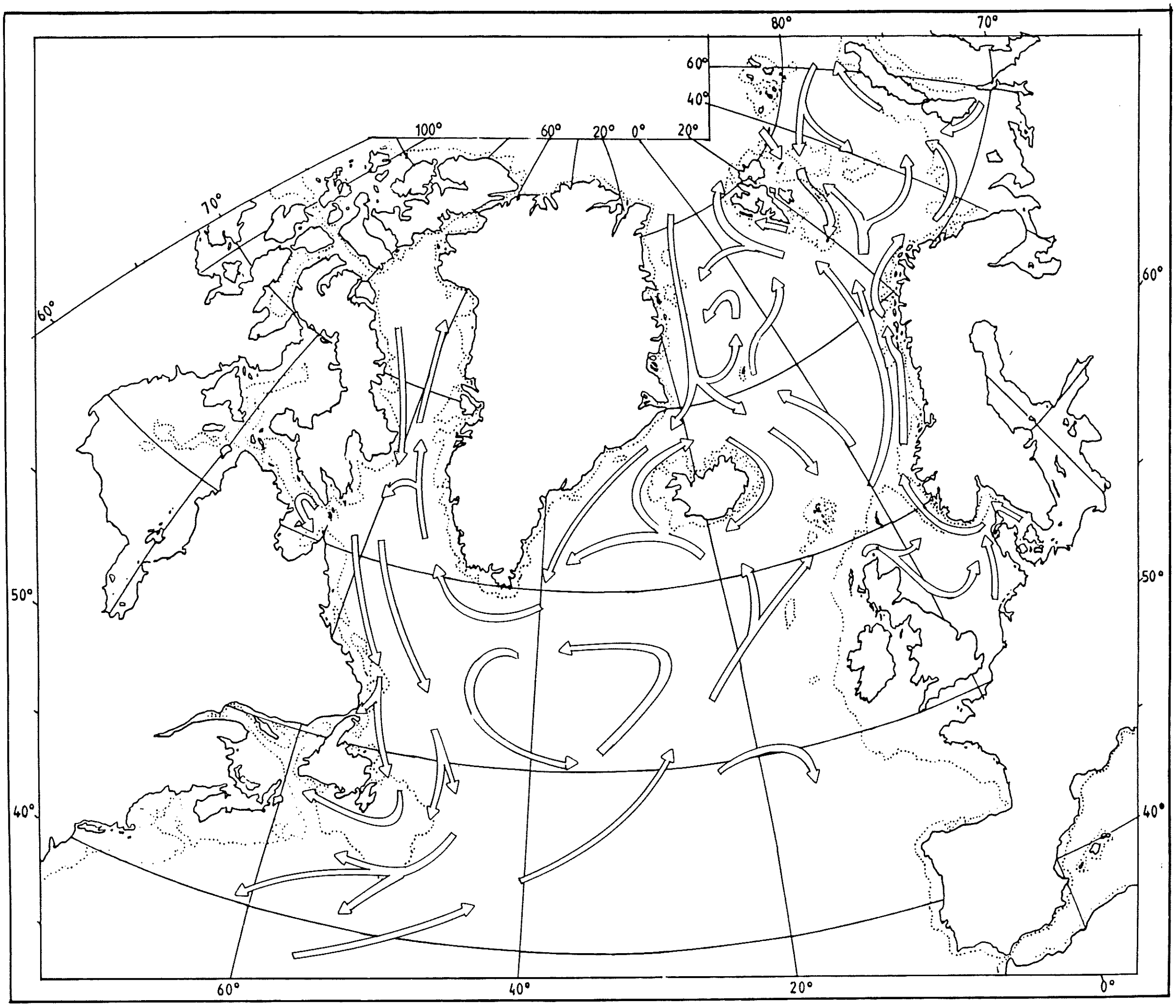


Figure 2. Main current system of the Northern North Atlantic.

2.1 Arcto-Norwegian and Icelandic stocks

In the North and Northeast Atlantic the shelf environments are dominated by interaction between the two major branches of the Gulf Stream - the Norwegian and Irminger currents, and outflow from the Arctic basin. Major (and permanent) spawning grounds (Arcto-Norwegian and Icelandic) are found in the coastal water adjacent the parallel flowing Atlantic water - eg Lofoten Islands in Norway and Vestmanna Islands in SW Iceland. The eggs and larvae are carried from the coastal water into the Atlantic water to nursery grounds, which are bounded to the North by Arctic water (ie in the Barents Sea, Spitsbergen and North Iceland). The adults must make major oriented return migrations to the spawning grounds. These features give rise to strong stock coherence with nursery grounds much influenced by the contemporary relative strengths of the Atlantic/Polar influences.

2.2 The West Greenland stock

The West Greenland stock can be regarded as a special case of the above, in which not only the nursery grounds but also the spawning grounds (North of 60 degrees N particularly on the Hellafiske Banks), are vulnerable to the Atlantic v Polar influences (Irminger v East Greenland currents). Thus, unlike either the Arcto-Norwegian or the Icelandic stocks, the West Greenland stock virtually disappears when the Atlantic influence weakens and polar water dominates (prior to 1920 and after 1960).

2.3 The open Canadian shelf (Labrador to Southern Nova Scotia)

The open Canadian shelf (Labrador to Southern Nova Scotia) offers a wide range of environmentally favourable localities for cod, with many long-established fisheries. It is not, however, a mirror-image of the Northeast Atlantic shelf owing to the absence of a corresponding Atlantic water influence as a strong directional current system. Spawning is widespread, nursery grounds are less clearly delineated and strongly directional adult migration is not necessary to life-cycle continuity. There is, for example, no analogue on the Northwest boundary of the North Atlantic cod (ie Labrador - Northern Grand Banks) to the long-distance adult migrations of Arcto-Norwegian cod to localised spawning grounds at Lofoten.

2.4 The southern Canadian/US shelf

On the other hand, the southern Canadian/US shelf is influenced by transient warm core rings spun-off from the Gulf Stream and, in addition, there are semi-permanent "retention areas" due to interaction between currents and features of shelf topography, which support reasonably discrete stock units. Southern Georges Bank is the best example. A similar process is responsible for the discreteness of the Faroes cod (Bank and Plateau).

2.5 Special environments

There are several special environments and stock complexes which do not fit geographically into the above pattern:

a) Gulf of St Laurence stocks (Northern and Southern), which complete their life-cycle in a strong seasonally changing environments resulting from St Laurence river, Labrador current and Atlantic inflows.

b) North Sea, where although there are substantial variations in Atlantic water inflows, it is not dominated by strong directional of currents and the environment for cod is benign. There is widespread spawning with no clearly separated stock units.

c) Fjord cod. In all the fjordic coasts (Norway, Greenland, Labrador etc) there are numerous local cod stocks that appear to complete their whole life-cycles within confined areas. Their precise genetic status is not altogether clear, but in most cases they seem to be distinct from their off-shore counterparts. West Greenland fjord cod were evidently affected by the major climatic warming and cooling that caused the appearance and disappearance of the major offshore stocks.

d) Two extreme low temperature environments, which nevertheless support permanent stocks, are the White Sea and Labrador, where the locally discrete stocks are able to spawn and the eggs develop successfully in temperatures as low as -1 degrees C.

e) The Baltic is a special case, where combinations of salinity and oxygen tension combine to form "reproductively-friendly" volumes in which cod can spawn successfully.

2.6 The southern boundaries of North Atlantic cod

The southern boundaries of North Atlantic cod, both on the East and West sides, are less clearly defined than the northern. This could be explained by (a) the lack in the south of a sharp water mass boundary comparable to the Atlantic-Polar front in the North, and (b) the fact that the prevailing currents are northerly. The southernmost limits of a cod stock must therefore be the spawning ground, and this may cause an erratic occurrence which does not support a coherent commercial fishery and for which scientific records are scattered and incomplete, with the exception of the recent MARMAP data set.

2.7 General considerations

Climate change might affect a great variety of processes in the life history of a fish population. However, the likely important effects might be grouped into two major classes of a very different nature. Firstly, climatic change might affect the recruitment process because the environmental conditions are generally believed to have a great impact on the survival of eggs and larvae. Since the recruitment process is finished within one year and since there is no 'memory' of past conditions carried over from former years, effects of climatic change will only be understood as far as trends can be superimposed on the interannual variation in environmental conditions.

Secondly, climatic change may affect the adult population. However, in contrast to eggs and larvae which are completely left at the fate of the environment, the adult fish may actively respond to changes in the environment by adjusting migration and distribution patterns. Because cod are long- lived and because biological conservatism is an important component of individual behaviour (herring), effects of climate change on distribution may be expected to become integrated over years and show up on gradual trends. Of course, climate change may also affect the energetic expenditure within a population (growth and maturation), but such effects will be largely controlled by the extent to which the behaviour response of the population counteracts the climatic change.

This distinction between the effects of climate change during the recruitment and adult phase suggests that very different models would be required to study these effects. In addition, one might argue that the strongest effects of climate change in respect of the adult phase may be expected in cod populations near the northern and southern limits of their Atlantic range. For these areas, modelling exercises to try to understand changes in distribution would seem to have a much higher priority than for populations in the middle of the range. On the other hand, the recruitment processes are likely to be affected in all areas and therefore should receive a high priority among all populations.

Up till now, recruitment studies have hardly taken into account species interactions. However, apart from direct effects of the physical environment on the survival of eggs and larvae, there may be strong indirect effects through other biota. Therefore, including predators and prey in these studies would seem a prerequisite for an understanding of the recruitment process. The type of multispecies modelling approach that has been applied among adult populations of exploited fish species should to a much greater extent be adapted for application in recruitment studies.

3 PLAN OF COD AND CLIMATE PROGRAM

3.1 Basic principles of the plan

The underlying philosophy of CCC involves the idea that physical variables are a major source of variability in the population-dynamics of cod and associated species, and that a modeling structure needs to be developed to explicitly account for physically induced variability as well as to facilitate the continuing cycle of empirical activity and theoretical development in cod and climate research.

It is our view that the study of the system of cod populations across the entire Atlantic will lead to an understanding of cod stocks that could not otherwise be achieved. For this reason models and approaches need to be both "universal" and taylored to specific regions. Accordingly the plan will need to make provision to take to completion the work specified in the Terms of Reference on assembly and analysis of already collected data on cod, associated populations, and on the physical oceanography. The assembly of data is both important in its own right and important in providing the raw material for the modeling activity. In addition to continuing to build an information system for the data base, there are four other activities that need to be undertaken:

1. The development of the North Atlantic physical model covering the range of cod and other important stocks.
2. The development of regional physical models.
3. The development of special-purpose physical process models.
4. The development of basic biological process models.
5. The development of regional biological process models.

Figure 3 shows how this set of models are linked together. The present report concentrates on 1, 3 and 4, as 2 and 5 will largely be left to the design of various national programs although many possible linkages among national programs might be developed.

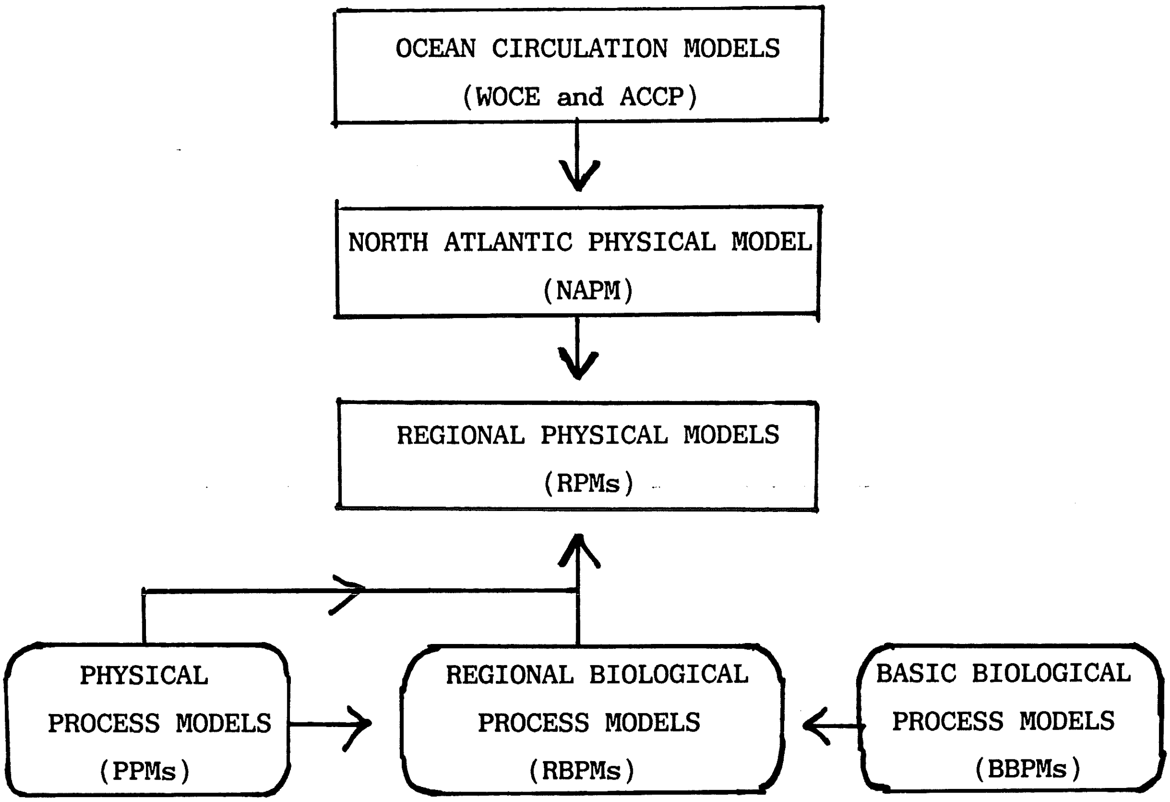


Figure 3. The principles of the Cod and Climate biological-physical coupling strategy. The aim is to develop a better understanding of biological-physical coupling through linking physical circulation models (NAPM and RPMs) with process models (PPMs and BPMs).

3.2 North Atlantic Physical Model (NAPM)

It is obvious for the cod, other fish stocks, and their predators and prey in the North Atlantic that the physical environment plays an important role in affecting the variability of fish stocks and other populations. The physical environment is complex and can affect the stocks in many different ways. For example the mid-1970s anomaly could be traced as a climate wave propagating through the habitat regions of several cod stocks during a period of more than three years. The North Atlantic Current is the most important conveyor of heat into the Nordic Seas, and variations of inflow between Britain and Iceland has been shown to have an important impact on the climate changes in the Norwegian Sea, North Sea, Greenland Sea and the Barents Sea. In the western region, the variations of the Irminger current and the East Greenland current influence the ocean climate downstream towards the east coast of North America. The East Greenland current is the direct continuation of the out-flow of Arctic water through the Fram Strait.

A NAPM is necessary to begin to 1) provide perspective for linking larger-scale physical events with the changes in North Atlantic biota that have been recorded on both sides of the Atlantic for nearly a century, 2) create a setting for the development of biophysical population-dynamics models, 3) provide insights for the assessment of predicting stock and production changes.

The NAPM can be characterized by its function. It will 1) model how large scale (ocean wide) climate changes influence the state and circulation in the habitat of all the North Atlantic cod stocks and 2) give boundary conditions for the smaller scale Regional Physical Models. The North Atlantic Physical Model should have a grid net which resolve the topography of the northern European and American shelves, and it should include the Arctic Basin. The geographical boundaries of the model should approximately equal the frame of Figure 4. The processes causing ice freezing and formation of bottom water should be a part of the model. It should be driven by the local wind field, heat exchange across the sea surface and the water fluxes at the southern boundary should be created by the model results from models like the ACCP.

While the ACCP and other Atlantic circulation models yield realistic equatorial currents and describe the main gyres well, the results from the Northern borders of the models are insufficient, because model topography in the nordic Seas is too crude and because water exchange with the Arctic basin is not included.

The work to create a North Atlantic Physical Model should be one of the key studies within the Cod and Climate Program. Such a model would bridge the large scale processes, covered by the modelling efforts within the WOCE program and the ACCP program, to the regional scale processes important for the individual cod stocks.

3.3 Regional Physical Models (RPMs)

The RPMs are generally numerical (but also analytical depending on which problem at hand) ocean models geographically covering the area of distribution of one or more cod stocks and their most important interactive species. The RPMs should described the physical processes which influence the biological processes. The RPMs should

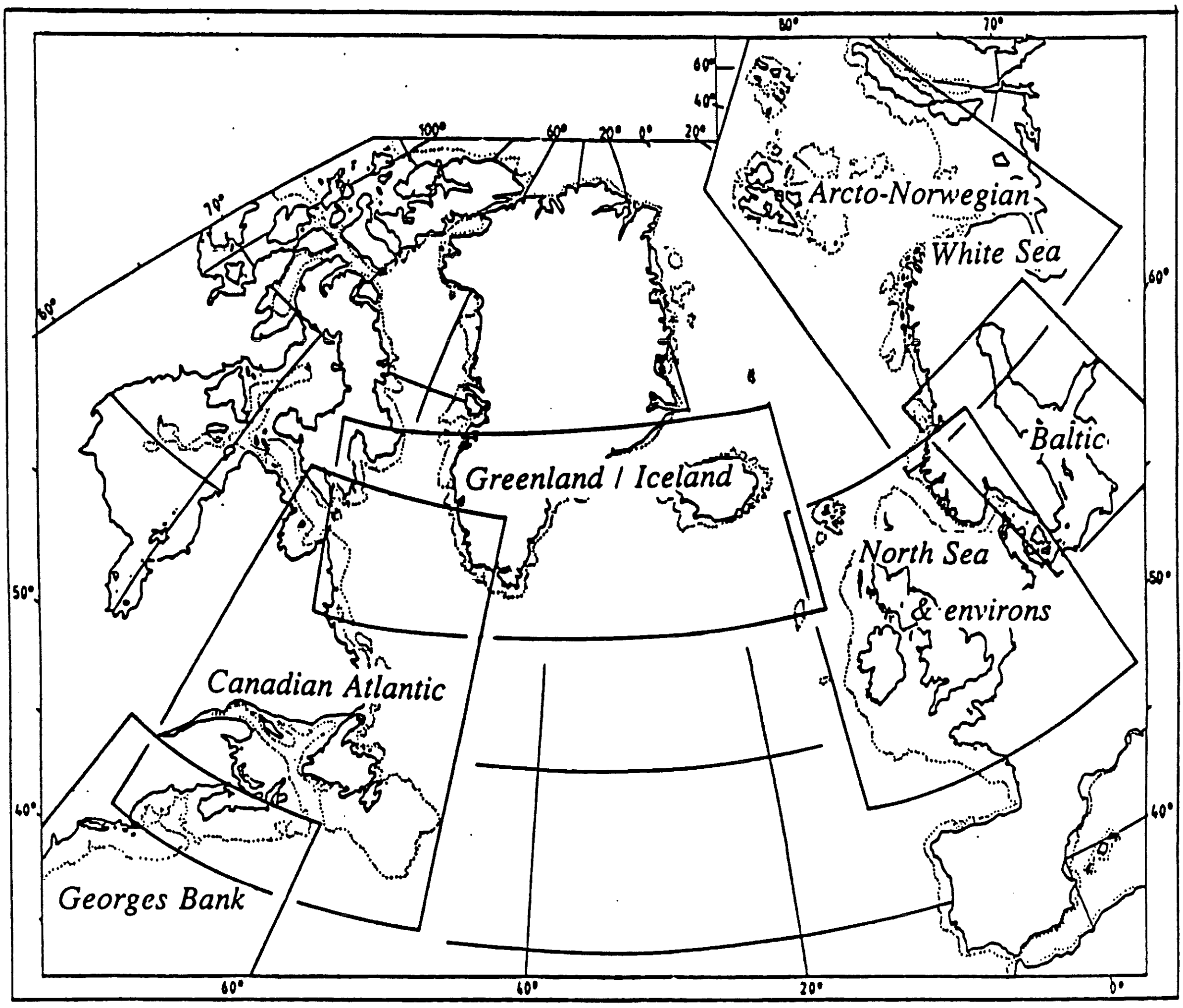


Figure 4. Tentative boundaries of 6 main Regional Physical Models (RPMs). Nested models or separate smaller scale RPMs will be needed in specific regions, eg. in the spawning regions. The principle of the circulation models is to develop an hierarchy of models where the larger scale models give the boundary conditions for the smaller scale models.

resolve standard hydrographical sections so that model hindcasts could be compared with historical data. The work of Bartsch et al. (1989) is an example on how a regional physical model is applied together with decription of biological processes. They modeled drift of herring larvae in the North Sea from the hatching areas to the nursery grounds.

Figure 4 shows tentatively the geographical extent of 6 RPMs. However, it is clear that the extent of the models should be set by the biological processes to be studied. It is obvious that detailed models are needed in several regions, as for example in the Gulf of St Laurence, the Irish Sea, the Faroe region, the White Sea and in regions for coastal cod.

The demands on the different RPMs should be set by the specific biological processes we want to study. For example, if we want to study the drift and dispersion during the important period when most of the year class strength is determined, we need a wind driven numerical model which has a grid net fine enough to resolve the most important eddies, especially near the spawning regions. It has to be robust enough to be run for 4-5 months to cover the entire drift phase of the eggs/larvae/juveniles. For most stocks and regions heat exchange is not very important for describing horisontal drift and dispersion. However, for other processes the description of the heat exchange is crucial to the problem. If we have a Biophysical Process Model for how cod respond to temperature and we want to describe how the distribution of adult year classes of cod changes due to seasonal variations in the temperature field, we need a RPM which includes thermal processes, but not on a very fine grid net as in the drift model.

3.4 Physical Process Models (PPMs)

There is a great need for basic studies to develop special-purpose physical process models (PPMs). These models are necessary not only to understand the biological processes but to achieve a better understanding of the physical processes as well. The physical processes are important sources of variability in plankton production and survival of cod eggs and larvae. In particular the turbulent forces influence the plankton productivity in several ways: The vertical distribution of plankton is a result of the interaction between the turbulent forces, the buoyancy forces and the vertical migration/behaviour of the plankton. The contact rate between low-speed predators and prey is a result of the interaction between predator and prey speed and the velocity of small-scale turbulence. As a final example, the transport of nutrients from deeper layers into the euphotic zone depends on turbulent entrainment.

These biophysical interactions tend to be driven by phenomena associated with air-sea interactions. Within the field of air-sea interaction there are a variety of physical processes important for ocean productivity. These include the dynamics of wind waves, mixed layer turbulence, heat exchange, flux of gases, freezing, termohaline convection and frontal processes. Many of the parameters within the air-sea interaction are intercorrelated, eg. in the Northeast Atlantic a high frequency of winter cyclones are more or less followed by an increase in several other physical parameters as southwesterly winds, wave activity, turbulent mixing, sea temperature, cloud cover, precipitation and fresh water run-off. Therefore, to understand the influence of climate variability on ocean productivity correlative investigations must be backed up by investigations on how single physical processes influence the basic biological processes.

These physical processes are most often parameterized in a simplyfied way in numerical ocean circulation models, partly due to their complexity and partly due to lack of measurements and theory. It is clear that new air-sea interaction models which are structured to explicitly interrelate with population dynamic variability need to be developed. The task of developing useful models in this mode may require a better understanding of fundamental biological physical processes.

3.5 Basic Biological Process Models (BBPMs)

The continuity of the life-cycle can be visualized as being dependent on a series of inter-connecting phases (e.g. spawning, larval survival, maturation etc.) each in turn being the net result of a set of underlying Basic Bio-demographic Processes (cf. First Principle Processes in the GLOBEC paper).

The definition of a BBPM is to some extent subjective depending in particular on the details of the problem. A necessary condition is that BBPM's comprise the most fundamental ecological processor so that the processor can be linked to the physical environment. Put another way BBPM's reflect common and essential elements in the population dynamics of all stocks and environments.

Our primary interest involves the interactions between dynamics of (a) cod population, (b) associated species, and (c) the physical environment. As a point of departure in the most simplistic sense interactions might be identified between the most general population-dynamic and physical variables. As an example, one set of relationships would involve nine biophysical interactions between mortality, growth, and reproduction on one hand, and temperature, motion, and light on the other hand. While this classification sets the stage, more detail is needed. For example, reproduction may be related to growth while temperature may be related to water motion. As another example, each of the population dynamic variables comprise a complex of processes that need to be considered first individually, then in concert in order to control statistical variability. To do this, mortality might be partitioned into predatory and non-predatory mortality. Predatory mortality might increase with temperature while non-predatory mortality might decrease with temperature. The statistical behaviour of total mortality (predatory plus non-predatory mortality) with respect to temperature would then depend upon the relative proportion of predatory and non-predatory mortality. If the components of mortality were not recognized or accounted for in a model then conclusions on the change of mortality with respect to temperature might be misleading.

Accordingly, it is desirable to study the most fundamental components of the population dynamics variables. It is of course difficult to specify the details of models in the abstract. However, feeding and reproductive models seem useful beginnings for the study of the interrelationships identified above.

Feeding models involve both predatory mortality and growth. This is because the ingestion of a prey causes prey mortality, but it also contributes to a component of predator growth. Growth contributes to both somatic and reproductive biomass.

The simplest components of a feeding model which would be compatible with studying physical variability would be:

* prey density and velocity
* predator density and velocity
* predator/prey encounter rate
* perceptive or capture field for predator
* avoidance field for prey.

The model(s) would then consider each of these components as a function of temperature, motion, light, etc. Ingestion is then translatable into predator growth and prey mortality in a physical setting.

Reproductive models may be more difficult to conceptualize than feeding models, suggesting that much work needs to be accomplished in general in understanding how the reproductive processes depend upon changes in the physical environment. The particular biological components that seem important are:

* abundance of food
* quality of food
* growth
* migration route
* age or size of "reproducer"
* age of maturity

Again the model would consider each of these components in the context of temperature, motion and irradiance and calculate reproductive output.

3.6 Interaction between mesocosm/lab studies, field studies and modelling

The opportunity for developing a model system of Biological Process Models and Physical Models for a given problem (e.g. transport and spreading of eggs and larvae from the spawning areas to the settling regions) depends on the background information which is available. From the information the Study Group has gathered (Appendix III) about the North Atlantic cod stocks it is clear that the background data are very uneven for the different stocks. For the cod stocks along the Northern rim, where temperature clearly influence both the recruitment phase and the adult stages, climate studies and the influence of physical processes has been more focussed on than in the Southern stocks where the influence of climate is a more complex matter. On the other hand, in the North Sea the problems around interactions with other species has been much more studied than in other regions. Again in some regions the early stages has been more studied than the adult stages. It implies that field studies must be given priority to a larger extent in some regions before Biological Process Models can be formulated. The model systems to be emphasized in the different regions should also be adapted to the available information. It is the advantage of a program like this that each region develops their specialities so that the research effort on the entire spectrum of models systems can utilized to mutual benefit.

The activities should be a continuous interactive process between modelling, field studies and lab/mesocosm studies where the modeling part should not be considered as the final product, but as a way to communicate between the disiplines and to initiate improved studies.

The example below shows what kind of background information is needed to create a model system describing the drift and dispersion of eggs/-larvae/juveniles from spawning until they settle to the bottom as juveniles. As a start we make the very simplified assumption that mortality is exponentially declining and is constant through space. We need 4 BPMs as input to a RPM as illustrated in Figure 5.

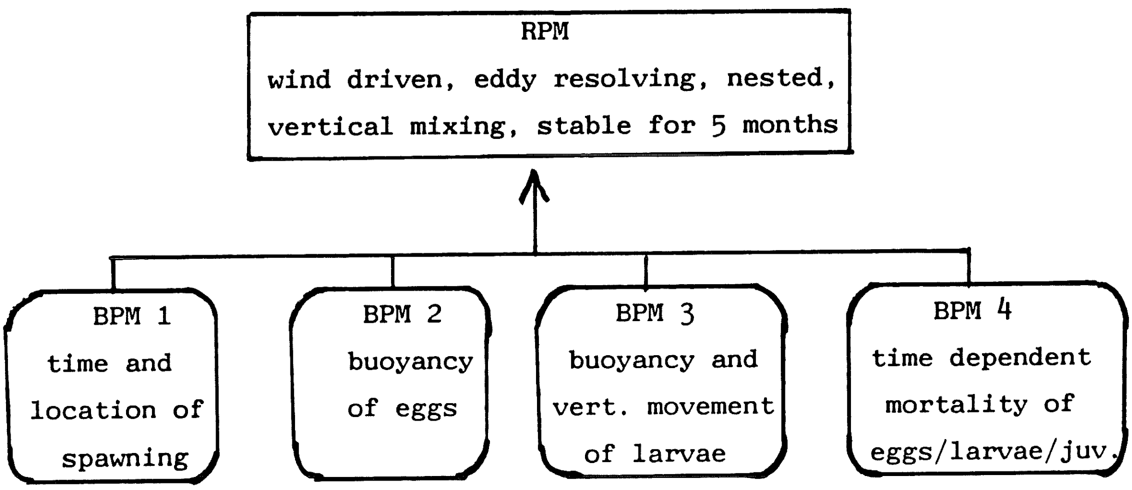


Figure 5. Schematic illustration of the set of process models and a regional physical model needed to solve the problem of transport of eggs/larvae/juveniles from the spawning area to the nursery ground.

The information gathered on the Atlantic cod stocks shows that sufficient information to run such a model is available for about 3 - 5 stocks. For the other stocks there is a general lack of detailed knowledge on spawning period, spawning location and vertical distribution. However, viewing the interaction between field studies, lab studies and modelling as an iterative process, results from a circulation models may give input to the strategy of field investigations on time and location of spawning.

Equally important as cod population dynamics are the population dynamics of the predators and prey. The information gathered in Appendix III shows that the prey items in general are rather well known. For example, during the early life history stages Calanus finmarchicus is an important prey item of cod for many stocks. However, there is a general lack of knowlegde on the population dynamics of C. finmarchicus and other copepods and how they are influenced by the physical processes.

The information of predators on the early stages is even more limited, the North Sea cod being the only stock with some limited information. As for the prey organisms investigation on the population dynamics of the predators should be emphasized.

A central part of the Cod and Climate Program is to understand the adaptation of the Atlantic cod stocks through out the habitats. The opportunity to forecast changes in the various stocks depends on that the biological process models are basic in a way that we also know how genetic pecularities influence the response to environmental changes. Comparative studies on growth, mortality and behaviour in laboratory and mesocosm will give important insight in how the genetics material has developed in the different regions and to what extent generalizations between stocks can be allowed. Such studies should be executed both on the larval and adult stages.

3.7 Time series

The plan described in the preceeding sections focusses to a large extent on activities based on "first principle" studies succeeded by formulation of Biophysical Process Models (BPMs). The study of time series, should nevertheless be an important supplement to the program.

Correlations of time series may give important contributions to forming testable hypotheses, but the understanding of the processes can only be achieved through the study of the biological processes.

Temperature in the sea and in the atmosphere is a frequently used physical parameter in correlation with cod abundances and biomass because of its easy availablity and large number of relatively long time series. But the physical parameters are highly inter-correlated, and a number of them, not only the temperature, are expected to have substantial influence on the biological productivity of the ocean.

Figure 6 shows the relation between the year class strength of Arcto-norwegian cod and the temperature at the spawning grounds. (Ellertsen et al., 1989). Figure 7 shows the relation between the year class strength of Greenland cod and the temperature (Hansen and Buch, 1987). Both figures indicate that a high temperature is a necessary (but not sufficient) condition for the formation of a strong year class. The low recruitment during years of low temperature in the Greenland waters is explained to be due to less influence of the warm Irminger Current which also give a reduced import of juveniles from Icelandic waters, while Ellertsen et al. (1989) indicate that the negative influence of low temperatures on the Arcto-norwegian cod is caused by temperature induced mismatch of the production of the prey organisms for cod larvae. While Hansen and Buch (1987) indicate that the temperature is only an indirect signal for the recruitment, Ellertsen et al. (1989) indicate a more direct relation to temperature. It is easy to point out a series of other possibilities of how temperature influence the recruitment both directly and indirectly.

Temperature (at least in the Northern regions) is correlated with the extent of ice coverage, with the prevailing wind direction and with the influx of Atlantic Water. Heat budget considerations also indicate that sea temperature is correlated with wind mixing of the surface layers, cloud cover, relative humidity and the insolation. The extent to which the different parameters are correlated varies through the seasons. In addition, because of the advection of physical properties of the sea, one single property in different regions is with a certain time delay correlated with itself. Therefore we suggest a study of the intercorrelations among time-series of biological and physical parameters as a unit within the program.

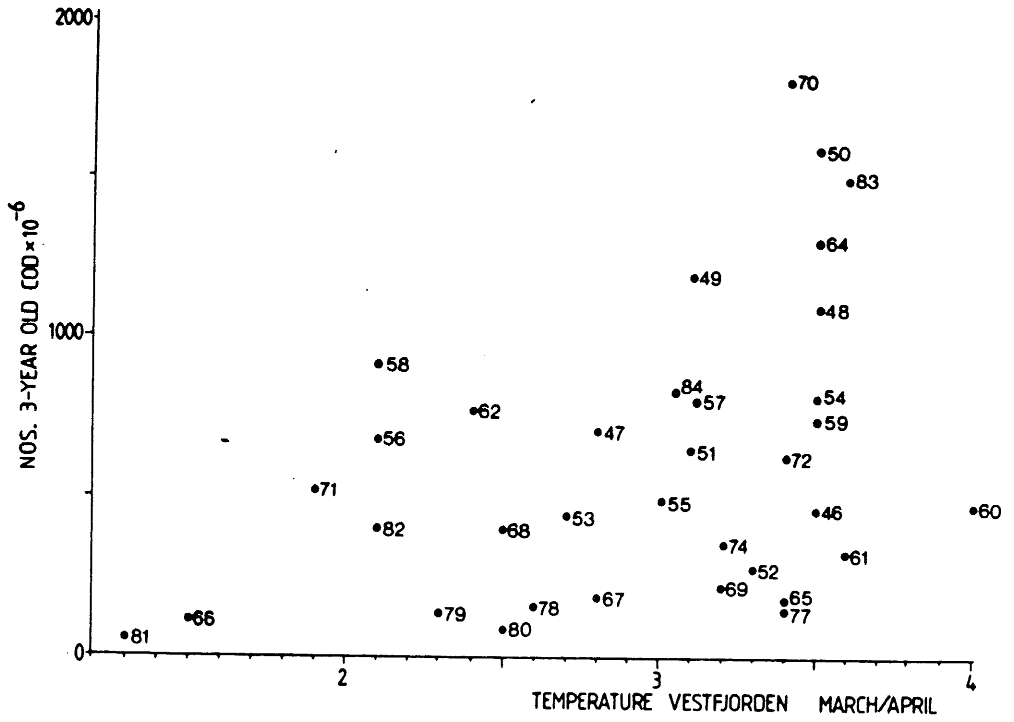


Figure 6. Arcto-norwegian cod. The relation between year class strength at 3 years and the mean temperature at the Lofoten spawning region in March-April. (Ellertsen et al., 1989).

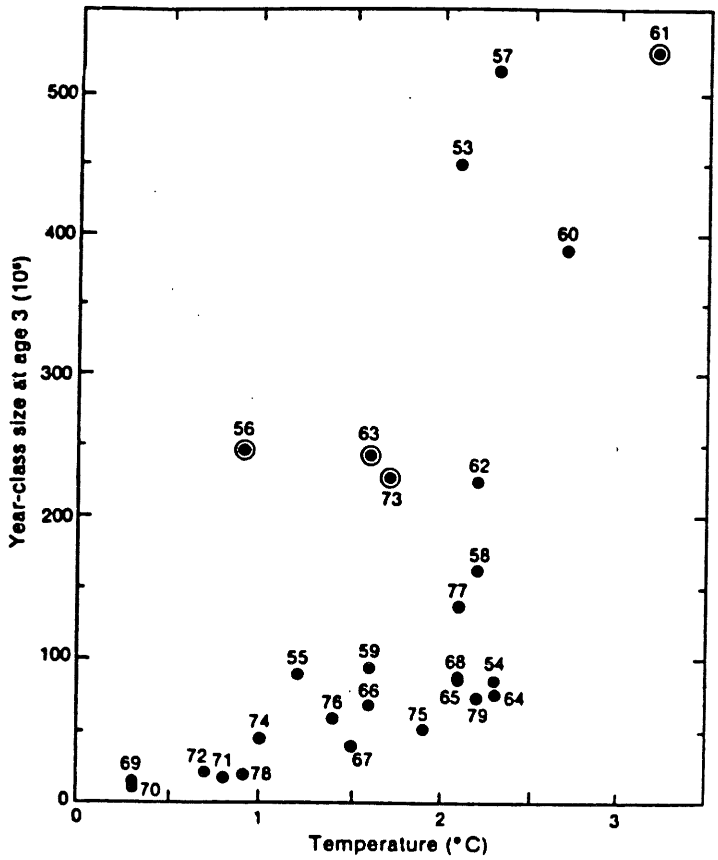


Figure 7. West Greenland cod. Relation between year class strength at 3 years and the temperature off West Greenland. The four circled year classes were classified as being mainly of eastern origin. (Hansen and Buch, 1986).

4 RECOMMENDATIONS

1. That the Hydrography Committee be asked to encourage the development of a model of the North Atlantic circulation for application to the needs of the Cod and Climate program. It should specify the boundary conditions for the regional models (including interannaul variations) and describe how changes in climate propoagate through the North Atlantic region, including the areas in which the cod live.

2. That the Hydrography Committee encourage, facilitate and monitor the development of Regional models. which might include the Lagrangian spread of eggs, larvae and early juveniles and the heat budget to forecast the temperature regime. For this purpose they should cooperate with the Biological Oceanography Committee.

3. That the Hydrography Committee should encourage studies on how the production of turbulent energy on a small scale, developed from wind stress and energy affect the distribution and encounter rate of planktonic organisms. For this purpose they should cooperate with the Biological Oceanography Committee.

4. That the Biological Oceanography Committee should be asked to consider that existing models of the population dynamics of copepods be reviewed and new ones developed, particularly Calanus finmarchicus, the food species in the North East Atlantic, and Pseudocalanus sp, the food species on George's Bank. The model should describe the advection of overwintering populations and variation in the time of onset of the production of such copepod populations.

5. That the Biological Oceanography Committee reviews any shortfalls that might exist in sampling instrumentation and specify any new direction in sampling technology that might be undertaken during the next decade.

6. That the Demersal Fish Committee be encouraged to study phenotypic and genotypic differences between stocks at all stages in the life history. Comparative studies should be started on growth, fecundity and migration, with special reference to the current structure of the North Atlantic. Part of such studies may be executed in laboratories and mesocosms.

7. The program on Cod and Climate should be sustained as a long term exercise. A Working Group should be established to meet at the Statutory Meeting to facilitate and coordinate and serve as liaison with other initiatives such as GLOBEC.

5 SUMMARY

The ICES Study Group on Cod Stock Fluctuations, appointed by the Council in October 1989 (Terms of Reference in Appendix I), has considered the factors influencing cod stocks variability in the North Atlantic. As part of this consideration the Study Group has developed a draft, "The North Atlantic Program on Cod and Climate". The program is intended to improve the understanding of how climate variability influences the system of prey-cod-predator in which predators and prey of cod interact with the cod populations. A basic idea of the program is that during the recruitment and adult stages of cod both the influence of ocean climate and the dynamics of the most important interacting species need to be considered. The energy (mass) flux through the cod populations is structured by the predator and prey field of cod while climate parameters affect the rates of the fluxes.

The program is also intended to be a framework of studies within the program of Global Ecosystem Dynamics (GLOBEC). The understanding of how climate variability influences the population dynamics of fish can be thought of in terms of a geographical hierarchy of physical numerical models where the large-scale models set the boundary conditions for the smaller-scale models. In this way large-scale and long-term climate are linked to the smaller-scale and shorter-term climate which in turn exert direct influence on the cod stocks.

The smaller scale Regional Physical Model (RPM) is a numerical circulation model covering the geographical extent of one cod stock and its interacting species. Together with Regional Biological Process Models (RBPMs) and Physical Process Models (PPMs) the RPM constitute a model system which links the physical variability to the biological processes and the population dynamics of prey-cod-predator. The model system provides a setting for communication and interaction and a basis for modeling more complex ecosystems. The formulation of appropriate Biological Process Models is based on the continuous interaction between field studies, laboratory studies and studies in mesocosm. Comparative studies between stocks on behaviour, growth and mortality of both larval and adult populations should be an important contribution to understand possible differences in response to climate variability.

The Study Group has surveyed the state of knowledge of the various cod stocks throughout the North Atlantic (Appendix III). During the early stages of cod there is a general lack of knowledge on the population dynamics of interacting species. In particular, increased research effort on the population dynamics of copepods is needed. Improved data on spawning location and spawning time are needed for most cod stocks. A North Atlantic Physical Model (NAPM) needs to be developed to link global ocean climate variability to the regional variability. Physical process studies of the mixed layer, including improving of measuring techniques, needs to be emphasized.

APPENDIX I

Terms of reference for the ICES Study Group on Cod Stocks Fluctuations (ICES Council Resolution 2:14/1989):

"A Study Group on Cod Stock Fluctuations will be established under the chairmanship of Mr. S. Sundby (Norway) to develop a plan to predict cod stock fluctuations using climatological indices, and will work by correspondence in 1990 to:

a) assemble time series of population dynamics variables for each cod population;

b) assemble physical oceanographic and meteorological time/space series;

c) assemble and develop models that relate physical variables to adult and larval population dynamics;

d) attempt to explain variation in population dynamics in terms of climatic variability, taking into account not only individual populations but covariance among populations, regionally and on an Atlantic-wide basis."

APPENDIX II

Members of the ICES Study Group on Cod Stock Fluctuations:

V.A. Borovkov, USSR
K. Brander, UK
E. Buch, Denmark
S. Ehrich, FRG
B. Hansen, Faroe Islands
H. Heessen, Netherlands
H. Hovgaard; Denmark
A. Kristiansen, Faroe Islands
P.O. Larson, Sverige
M.C. Leroy, France
S.Å. Malmberg, Iceland

J. Netzel, Poland
D.B. Olson, USA
T.R. Osborn, USA
B.J. Rothschild, USA
S.A. Schopka, Iceland
V.P. Serebryakov, USSR
M. M. Sinclair, Canada
S. Sundby, Norway (Chairman)
K. Sunnanå, Norway
K. Thompson, Canada
W. Weber, FRG

Professors R.J.H. Beverton and D.H. Cushing have been members of the Study Group as special advisors.

This appendix not to be cited without prior reference to the authors

International Council for the Exploration of the Sea

C.M. 1990/G:50
Ref.C + L

Demersal Fish Committee
Ref. C Hydrography Committee
Ref. L Biological Oceanography Committee

REPORT OF THE ICES STUDY GROUP ON COD STOCK FLUCTUATIONS.

APPENDIX III

SYNTHESES OF ATLANTIC COD STOCKS.

Appendix III of ICES C.M. 1990/G:50
Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

CANADIAN COD STOCKS AND THE GEORGES BANK COD STOCK

Prepared by S.Campana, G.A.Chouinard, P.Fanning, A.Frechet, J.M.Hanson, J.J.Hunt,T.Lambert

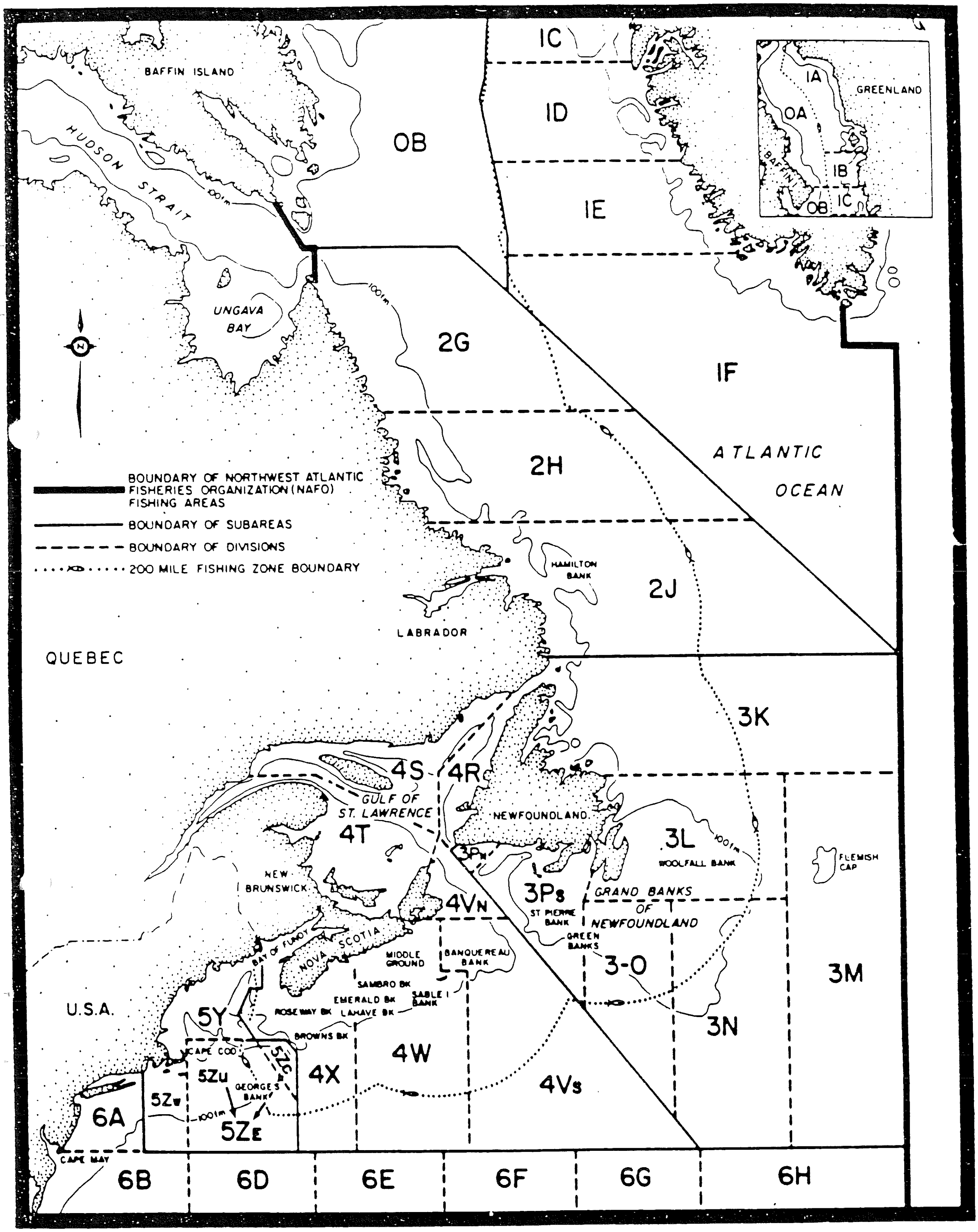


Figure 1. Subareas and divisions of the NAFO Convention Area and limits of Canadian fishing zones (east coast). Includes modifications to Subdivision 5Ze to take into account the Canadian side of 5Ze (5Zc) and USA side of 5Ze (5Zu).

2J3KL Cod

History

Nominal catches declined from a high of about 800,000 t in 1968 to a low of about 139,000 t in 1978. Since that time the catch has gradually increased. For the 1982-87 period, catches have bee about 230,000 t in 1989. The decline between 1988 and 1989 was due mainly to reductions in allocations to the Canadian offshore fleet. Catches during the 1960's and into the 1970's were taken mainly by foreign fleets. Since 1977, when Canada extended its fisheries jurisdiction to 200 miles, most of the catch has been taken by Canada.

There are two major fisheries that contribute the total catch; an inshore fishery, comprised of fixed gear (traps, gillnets, handlines, and line trawls) and an offshore fishery, comprised mainly of mobile gears (otter trawls). The large catches during the 1960;s taken by foreign fleets were from offshore areas. Only since 1977 has there been a relatively extensive fishery in offshore areas by Canadian vessels. While the offshore fishery has a relatively short history, the inshore fishery has been a part of life in Newfoundland outports for centuries. The catch by inshore gears was at its lowest in 1974 (35,000 t) and subsequently increased to 113,000 t in 1982. Thereafter, catches decreased to 72,000 t in 1986 but increased to about 80,000 t in 1987. catches by inshore gears for 1988 and 1989 have been about 100,000 t.

This stock is defined as those cod which inhabit NAFO Divs. 2J, 3K, and 3L. It is generally agreed that some interchanges occur between Divs. 2J and 2H in the north and between Div. 3L and 3NO in the southern extremes of the stock. However, it is assumed that these interchanges balance some way and may be fairly consistent from year to year.

General structure of the stock

The age 3+ biomass of cod for the Div. 2J3KL stock was just over 2.5 million tons during the early 1960's. Large amounts of fishing effort by foreign fleets caused the stock to decline and by the mid-1970's the population biomass had shrunk to an all-time low of about 500,000 t. When Canada extended fisheries jurisdiction in 1977 and dramatically reduced the amount of fishing effort, the stock responded and by 1984 had increased to about 1.2 million tons. Since 1984 the biomass has declined slightly because of the size of the extremely weak 1983 and 1984 year-classes. The age 3+ biomass for 1989 is estimated to be about 800,000 t.

It is generally believed that cod of the Div. 2J3KL management unit are comprised of a number of somewhat discrete subgroups that gather for spawning on the shoreward slopes of offshore banks between April and June. There may be many spawning components, some of which have been defined: Hamilton Bank, Belle Isle Bank, Northern Funk Island Bank, Southern Funk Island Bank, North Cape of the Grand Bank, and Woolfall Bank. While a large portion of the stock is distributed on these offshore banks during spawning, after that time large quantities of post-spawners move to inshore areas during the early summer to feed on capelin which have aggregated at the coast to spawn. It is during this time when cod are in inshore areas that a large degree of intermingling of the cod from the discrete offshore spawning components occurs.

Fishing pattern

During the time of the intensive foreign fisheries in this area, the 1960's and early 1970's, fishing mortality levels on those cod that were fully recruited to fishing gear were quite high. It was common for fully recruited F to be in excess of 0.60. Fully-recruited fishing mortalities were at their highest during 1969 and 1974-76 in the range of 0.7 to 1.0. Since 1977, after the extension of jurisdiction, fully recruited F has been fairly stable at about 0.50. Notable exceptions are lower values (about 0.30) during 1980-81 and a slight increase to 0.56 during 1989.

Environment

Water movement over the continental shelves of Div. 2J3KL is generally southward. The Labrador Current, the largest influence on this southward movement, transports some of the coldest surface water in the North Atlantic. The vertical structure of 2J3KL water is comprised of three layers. The upper layer which extends to about 40-50 m has temperatures in the warmest mouths reaching 10-12°C. The cold intermediate layer extends to depths of about 150-200 m with temperatures as low as -1.8°C. The warmer bottom layer is influenced by waters from deeper more oceanic areas.

Growth and maturity

There have been fish in this stock up to about age 30 years, but since the mid-1970's very few cod older than age 20 years have been taken in commercial fisheries. There have been some major changes in the growth of cod in Div. 2J3KL. For example, during 1977 an age 5 cod weighed about 1.0 kg. The weight at this age increased to about 1.3 kg during 1983 and subsequently declined and is currently about 1.0 kg again.

From the results of research vessel cruises conducted during autumn it has been determined that for cod in Div. 2J3KL the age of 50% maturity increases slightly from north to south with the average over the entire area being between 5 and 6 years old. The age of 50's maturity would be closer to 5 years in Div. 2J while in Div. 3L the A50 is almost 6 years.

Table 1. Historical catches of cod from NAFO Divisions 2J3KL for the period 1959-89.

	2J					3K				
	Offshore mobile gear			Inshore fixed gear		Offshore mobile gear			Inshore fixed gear	
Year	Can.	Other	Total		Total	Can.	Other	Total		Total
1959	-	46372	46372	17533	63905	-	97678	97678	56264	153942
1960	1	164036	164037	15418	179455	53	69855	69908	47676	117584
1961	1	243147	243148	17545	260693	-	60574	60574	31159	91733
1962	-	226841	226841	23424	250265	-	45554	45554	42816	88370
1963	1	197868	197869	23767	221636	-	79331	79331	47486	126817
1964	13	197359	197372	14787	212159	-	121423	121423	40735	162158
1965	-	246650	246650	25117	271767	21	50097	50118	26467	76585
1966	39	226244	226283	22645	248928	13	58907	58920	32208	91128
1967	28	217255	217283	27721	245004	114	78687	78801	24905	103706
1968	4650	355108	359758	12937	372695	1849	119778	121627	40768	162395
1969	30	405231	405261	4328	409589	56	80949	81005	24923	105928
1970	-	212961	212961	1963	214924	92	78274	78366	21512	99878
1971	-	154700	154700	3313	158013	31	61506	61537	21111	82648
1972	-	149435	149435	1725	151160	7	133369	133376	14054	147430
1973	1123	52985	54108	3619	57727	108	159653	159761	13190	172951
1974	-	119463	119463	1804	121267	19	149189	149208	10747	159955
1975	410	78578	78988	3000	81988	189	112678	112867	15518	128385
1976	94	30691	30785	3851	34636	771	79540	80311	20879	101190
1977	525	39584	40109	3523	43632	1051	26776	27827	28818	56645
1978	4682	17546	22228	6638	28866	7027	6373	13400	29623	43023
1979	9194	6537	15731	8445	24176	21579	16890	38469	27018	65487
1980	13592	7437	21029	17210	38239	21920	6830	28750	37015	65765
1981	22125	4760	26885	14215	41100	23112	3847	26959	23002	49961
1982	58384	8923	67307	14429	81736	8881	4074	12955	42141	55096
1983	37281	4158	41439	10743	52182	31623	2815	34438	40681	75119
1984	10754	1259	12013	13150	25163	48114	11059	59173	35143	94316
1985	1541	5	1546	10209	11755	72111	9714	81825	30368	112193
1986	4627	7373	12011	12567	24578	58239	2226	60465	28539	89004
1987	38216	3620	41836	16139	57975	39240	6119	45359	27141	72500
1988	41465	9	41474	17082	58556	39933	50	39983	33509	73492
1989	22709	-	22709	21684	44393	35082	-	35082	20320	55402

(Cont'd.)

Table 1. (Cont'd.)

Year	3L Offshore mobile gear Can.	3L Offshore mobile gear Other	3L Offshore mobile gear Total	3L Inshore fixed gear	3L Total	2J3KL Total inshore fixed gear	2J3KL Total offshore mobile gear	2J3KL Total	TAC
1959	4515	51515	56030	85695	141725	159492	200080	359572	-
1960	7355	60213	67568	94192	161760	157286	301513	458799	-
1961	4675	70318	74993	70659	145652	119363	378715	498078	-
1962	4383	87463	91846	72271	164117	138511	364241	502752	-
1963	4446	83015	87461	73295	160756	144548	364661	509209	-
1964	10158	142370	152528	75806	228334	131328	471323	602651	-
1965	7353	130387	137740	58943	196683	110527	434508	545035	-
1966	8253	120206	128459	55990	184449	110843	413662	524505	-
1967	13478	200343	213821	49233	263054	101859	509905	611764	-
1968	15784	211808	227592	47332	274924	101037	708977	810014	-
1969	18255	151945	170200	67973	238173	97224	656466	753690	-
1970	14471	137840	152311	53113	205424	76588	443638	520226	-
1971	11976	148766	160742	38115	198857	62539	376979	439518	-
1972	4380	109052	113432	46273	159705	62052	396243	458295	-
1973	1258	97734	98992	24839	123831	41648	312861	354509	666000
1974	880	67918	68798	22630	91428	35181	337469	372650	657000
1975	670	53770	54440	22695	77135	41213	246295	287508	554000
1976	2187	40998	43185	35209	78394	59939	154281	214220	300000
1977	5362	26799	32161	40282	72443	72623	100097	172720	160000
1978	9213	12263	21476	45194	66670	81455	57104	138559	135000
1979	14184	12693	26877	50359	77236	85822	81077	166899	180000
1980	15523	13963	29486	42298	71784	96523	79265	175788	180000
1981	21760	15070	36830	42821	79651	80038	90674	170712	200000
1982	27192	9271	36463	56479	92942	113049	116725	229774	230000
1983	39125	10920	50044	54999	105043	106423	125922	232345	260000
1984	49620	13944	63564	49428	112992	97721	134750	232471	266000
1985	39112	28927	68039	39306	107345	79883	151410	231293	266000
1986	55117	51555	106672	31263	137935	72369	179137	251506	266000
1987	43185	25883	69068	35467	104535	78747	156263	235010	256000
1988	56679	26634	83313	51058	134371	101649	164770	266419	266000
1989	39254	25000	71234	57237	128471	99241	140924[a]	240165	235000

[a]Includes catch by France (3217t) and additional 15,662t from production estimates.

BLE 50. FISHING MORTALITY MATRIX FOR COD IN DIV. 2J3KL FROM ACCEPTED FORMULATION OF ADAPT USING RV AND C/E INDICES.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
	0.013	0.010	0.025	0.006	0.013	0.020	0.009	0.007	0.027	0.024	0.029	0.031	0.026	0.019	0.036
	0.053	0.053	0.061	0.046	0.090	0.093	0.163	0.077	0.130	0.144	0.204	0.250	0.138	0.151	0.217
	0.109	0.166	0.151	0.139	0.208	0.193	0.380	0.262	0.227	0.313	0.369	0.397	0.352	0.428	0.503
	0.186	0.300	0.251	0.262	0.280	0.346	0.494	0.593	0.459	0.462	0.445	0.326	0.629	0.711	0.772
	0.315	0.293	0.450	0.461	0.392	0.423	0.575	0.814	0.731	0.522	0.526	0.384	0.653	0.827	0.961
	0.328	0.330	0.443	0.640	0.413	0.482	0.619	0.907	0.540	0.486	0.557	0.534	0.855	1.132	1.031
	0.364	0.312	0.415	0.604	0.482	0.434	0.604	0.737	0.465	0.432	0.444	0.573	0.900	0.970	1.468
	0.404	0.370	0.435	0.594	0.304	0.715	0.554	0.778	0.300	0.353	0.446	0.579	1.206	1.240	1.175
	0.341	0.325	0.528	0.473	0.358	0.349	0.585	0.747	0.265	0.285	0.425	0.527	1.334	0.997	0.877
	0.419	0.223	0.449	0.453	0.278	0.496	0.599	1.505	0.294	0.272	0.359	0.627	1.054	1.177	0.843
	0.329	0.305	0.443	0.554	0.415	0.444	0.591	0.831	0.651	0.500	0.524	0.460	0.746	0.962	1.096

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	0.023	0.005	0.008	0.017	0.007	0.006	0.008	0.002	0.002	0.005	0.017	0.012	0.004
	0.241	0.072	0.056	0.110	0.062	0.122	0.057	0.057	0.043	0.055	0.071	0.143	0.100
	0.440	0.222	0.217	0.180	0.170	0.231	0.243	0.183	0.194	0.176	0.159	0.219	0.300
	0.422	0.414	0.257	0.271	0.232	0.283	0.382	0.363	0.304	0.398	0.302	0.370	0.427
	0.457	0.525	0.413	0.250	0.327	0.396	0.407	0.468	0.489	0.406	0.463	0.507	0.520
	0.508	0.517	0.475	0.321	0.258	0.451	0.421	0.461	0.529	0.520	0.612	0.625	0.616
	0.471	0.453	0.429	0.303	0.363	0.451	0.458	0.490	0.475	0.470	0.399	0.640	0.653
	0.725	0.344	0.425	0.304	0.324	0.391	0.461	0.408	0.593	0.490	0.382	0.582	0.550
	0.376	0.530	0.301	0.221	0.298	0.227	0.370	0.337	0.550	0.476	0.303	0.385	0.472
	0.426	0.261	0.443	0.193	0.293	0.241	0.259	0.278	0.392	0.415	0.399	0.304	0.544
	0.475	0.260	0.213	0.232	0.152	0.212	0.212	0.237	0.247	0.222	0.251	0.274	0.282

ABLE 51. POPULATION BIOMASS AT THE BEGINNING OF THE YEAR (TONS) FOR COD IN DIV. 2J3KL FROM ACCEPTED FORMULATION OF ADAPT USING RV AND C/E INDICES.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
3	194204	170891	235488	277558	319447	231092	195162	179205	197611	163162
4	243905	253816	224082	304318	365578	417580	300090	256073	235648	254636
5	510784	303019	316960	277779	382767	439987	501005	335915	312347	272556
6	400287	523957	314304	333705	296048	380453	444250	419674	316338	304899
7	284087	367097	436470	274974	288689	251690	302711	304912	260874	224809
8	206454	216732	294441	299157	186315	209626	177182	183117	145252	134943
9	175349	151579	160950	195126	162939	127245	133615	98507	76340	87428
0	175566	120123	111305	106617	106996	100873	82641	73233	47257	48085
1	143068	113527	81039	70383	57514	77130	48238	46381	32851	34207
2	104939	91954	76702	44706	41006	37609	50876	25133	20544	23577
3	152846	82497	76501	50901	29547	32275	23812	29063	5799	15908
3+	2591489	2395190	2328240	2235223	2236845	2305560	2259582	1951213	1650864	1564211
4+	2397285	2224299	2092752	1957665	1917399	2074468	2064421	1772008	1453253	1401049
5+	2153380	1970483	1868670	1653347	1551821	1656888	1764330	1515935	1217605	1146413
6+	1642596	1667464	1551710	1375568	1169054	1216901	1263325	1180021	905257	873858
7+	1242310	1143508	1237406	1041863	873006	836448	819076	760346	588919	568958
	1972	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**
3	109143	31236	36438	91733	166700	123850	90204	55765	71849	164958	137714
4	203291	92679	52672	52326	99927	175504	158568	135976	75805	85086	204924
5	247616	196220	84988	65043	60067	96643	171619	191398	179221	88653	98544
6	228560	185168	156306	77505	48353	48295	82018	187665	194338	182482	92871
7	206694	145749	154110	95435	43234	28513	42171	70691	179754	170481	159377
8	143757	120927	97719	88438	46682	20929	23227	29957	57470	150062	125571
9	89194	77610	67439	44357	30986	21503	15683	15603	21761	42461	108122
10	57885	54030	40701	27026	19061	8725	16137	11136	10790	16064	26205
11	33821	33356	25938	12287	8564	7090	5179	12122	7676	7785	10549
12	23961	19772	16418	6375	4779	4470	5974	3358	9760	5842	5414
13	16956	15044	9654	5736	2261	2492	3550	5158	2282	7405	3893
3+	1360877	971791	742383	566260	530615	538013	614331	718830	810706	921280	973184
4+	1251734	940554	705945	474527	363915	414163	524127	663065	738857	756322	835470
5+	1048444	847875	653273	422202	263988	238659	365559	527089	663052	671236	630546
6+	800828	651656	568285	357159	203920	142017	193940	335691	483831	582583	532002
7+	572268	466488	411979	279654	155567	93722	111922	148026	289493	400101	439131
	1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**				
3	189770	250801	150758	82106	50354	102494	182214				
4	184036	218798	253599	184800	86559	68808	125208				
5	230111	214135	225369	263976	209777	96086	75582				
6	95932	215767	187124	200973	243798	202891	93307				
7	79974	73872	153575	140301	144105	187027	152956				
8	110733	53930	46705	88312	88951	88970	115441				
9	78217	70662	33156	25583	50126	45984	46339				
10	62410	47474	39976	19097	15038	31318	24826				
11	16271	37930	29195	20494	11675	10241	17041				
12	8316	11195	25281	15373	12324	8883	7083				
13	4183	6136	8412	15623	9880	8893	6710				
3+	1059951	1200699	1153150	1056637	922587	851596	846710				
4+	870182	949898	1002392	974531	872233	749102	664496				
5+	686146	731100	748793	789731	785675	680294	539287				
6+	456035	516965	523424	525755	575898	584208	463705				
7+	360104	301199	336300	324783	332099	381317	370398				

BLE 52. AVERAGE POPULATION BIOMASS (TONS) FOR COD IN DIV. 2J3KL FROM ACCEPTED FORMULATION OF ADAPT USING RV AND C/E INDICES.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
	222439	196047	268263	319103	365924	263871	223961	205866	224803	182505
	272586	285176	250884	343097	403575	460297	320118	284497	255282	274004
	519394	320999	338130	298044	397473	460253	480964	340195	321632	269639
	385722	487466	299089	315908	278019	346616	378773	342603	273915	263643
	250888	336719	372853	233696	253081	217592	244727	222630	197184	186032
	178966	190155	245393	228762	157387	171705	136696	125150	116006	110351
	147066	132407	134179	149650	131796	105145	102454	71345	62225	72316
	143331	100472	90423	80754	92236	72548	63685	51267	40815	40531
	116100	96030	62597	55693	47932	64534	36340	32592	28570	29467
	94537	78787	59287	34493	34245	28469	36814	12671	17029	19743
	143462	78261	68173	43199	26673	28752	19885	21919	4718	13827
3+	2474491	2302521	2189271	2102400	2188340	2219781	2044417	1710733	1542177	1462059
4+	2252052	2106474	1921009	1783297	1822416	1955910	1820457	1504868	1317375	1279553
5+	1979467	1821298	1670124	1440199	1418841	1495613	1500339	1220371	1062093	1005549
6+	1460072	1500298	1331994	1142156	1021369	1035361	1019375	880176	740461	735910
7+	1074351	1012832	1032905	826248	743350	688745	640602	537573	466546	472267

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
3	100795	40652	43758	95933	171443	140428	110943	65135	78342	184185	159480
4	208846	77135	65142	59215	95114	163854	175594	163155	84323	90817	216542
5	203680	171009	90861	57384	52426	90015	184288	196043	186691	91355	99302
6	186600	176335	132834	57930	36271	48044	78224	190879	190667	176177	90591
7	163328	121136	119264	66761	31146	27767	36517	65937	172839	151347	135834
8	114198	93250	66132	57192	32762	19039	19612	26239	53875	131958	100807
9	76384	54930	43645	31120	17100	20253	13801	13467	20259	33591	82620
0	47604	37270	24427	16157	12049	7491	14129	9427	9457	12885	20724
1	28034	23344	13974	7894	6217	6814	4180	10875	7088	6563	9241
2	19217	13178	9674	3743	3468	4294	5675	2932	9403	4727	4681
3	13243	11547	7114	4017	1646	2295	3271	4880	2023	6020	3396
3+	1161929	819786	616825	457347	459642	530293	646235	748968	814965	889626	923218
4+	1061134	779134	573067	361414	288199	389865	535291	683833	736623	705440	763738
5+	852288	701998	507925	302198	193085	226011	359697	520679	652301	614623	547196
6+	648608	530989	417064	244814	140659	135996	175408	324636	465610	523268	447894
7+	462008	354654	284230	186884	104388	87952	97185	133756	274943	347091	357303

	1983	1984	1985	1986	1987	1988	1989
3	204134	252624	167197	84450	58978	113496	202560
4	207915	229858	250390	199780	86264	75900	132934
5	233080	208901	208220	262658	210840	100393	70651
6	87817	192167	160424	178983	215956	179017	80043
7	68041	61511	119039	119698	116098	150790	125559
8	91966	43030	35818	67244	62205	65867	87857
9	62675	54359	26319	19602	41162	35474	34073
0	48605	38103	29230	14297	12455	22640	19158
1	13275	32456	21657	15937	10792	8651	14162
2	7487	10119	19672	12141	10248	7464	5559
3	3850	5169	7229	13807	8942	8415	6223
3+	1028844	1128296	1045196	988597	833940	768106	778780
4+	824709	875672	877999	904146	774962	654611	576220
5+	616794	645814	627609	704366	688697	578711	443287
6+	383715	436913	419389	441708	477858	478318	372635
7+	295898	244746	258965	262725	261901	299301	292592

BLE 53. POPULATION NUMBERS AT THE BEGINNING OF THE YEAR (000S) FOR COD IN IV. 2J3KL FROM ACCEPTED FORMULATION OF ADAPT USING RV AND C/E INDICES.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
3	726475	639266	880910	1038287	1194982	864465	730059	670369	739222	599153
4	560942	586946	518187	703730	845393	965649	693954	592164	544934	588842
5	686224	435559	455598	399280	550189	632437	720144	482844	448968	391771
6	378066	503618	302104	320751	284556	365685	427005	403384	304059	293064
7	193400	256906	305456	192435	202034	176140	211846	213387	182568	157328
8	108673	115531	156955	159469	99317	111744	94449	97613	77429	71933
9	72897	64072	68033	82479	68874	53786	56479	41639	32269	36956
10	60034	41458	38415	36797	36928	34814	28522	25275	16310	16596
11	39975	32832	23436	20354	16633	22306	13950	13413	9501	9893
12	30556	23278	19417	11318	10381	9521	12879	6362	5201	5969
13	30478	16450	15255	10150	5892	6436	4748	5795	1156	3172
3+	2887721	2715917	2783766	2975051	3315178	3242983	2994037	2552245	2361615	2174677
4+	2161246	2076651	1902856	1936764	2120196	2378518	2263978	1881877	1622394	1575524
5+	1600304	1489706	1384668	1233034	1274803	1412869	1570024	1289712	1077460	986682
6+	914080	1054146	929070	833754	724615	780432	849880	806869	628492	594910
7+	536014	550528	626966	513003	440058	414747	422874	403485	324433	301846

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
3	256368	142294	139675	237340	427752	348131	306725	156845	164457	370654	332908
4	478894	203801	112915	111433	190728	337757	278576	249928	127371	132335	301489
5	417356	319871	129954	80502	78474	125637	217256	212194	193439	93402	101857
6	234448	236232	176070	74794	42954	38869	66251	142399	139804	132303	64535
7	151166	123005	139570	76831	30086	16258	20869	35857	90164	87303	85880
8	76451	73108	68619	59493	27521	9421	8428	10109	19420	57517	51558
9	36223	35852	35108	23889	15695	8035	4641	4115	5146	11529	36371
10	19641	19025	16547	11684	7415	2959	4108	2415	2193	3112	6567
11	9543	10296	8731	4054	2767	1875	1173	2383	1292	1325	1843
12	6088	5110	4978	1884	1225	943	1054	565	1445	848	805
13	3722	3482	2236	1421	475	432	504	665	297	976	518
3+	1689901	1172078	834402	683325	825092	890318	909586	817475	745028	891304	984331
4+	1433533	1029784	694727	445984	397340	542187	602860	660630	580571	520649	651423
5+	954639	825983	581812	334552	206612	204430	324284	410702	453200	388314	349934
6+	537283	506112	451858	254050	128138	78793	107028	198508	259761	294912	248077
7+	302835	269879	275788	179256	85184	39923	40776	56109	119956	162609	183542

	1983	1984	1985	1986	1987	1988	1989
3	364654	472838	384668	183143	152578	257051	466506
4	271022	296214	386420	314351	149193	122813	207931
5	218529	209574	229064	302960	243598	113809	87165
6	66199	140369	142847	154412	208078	170179	74821
7	39810	36982	79976	86259	84918	125968	96250
8	47298	21696	18965	40138	47075	43765	62089
9	26893	25423	11207	9148	19541	20893	19184
10	18978	13935	12752	5704	4681	10735	9017
11	3636	9800	7584	5770	2861	2615	4911
12	1203	2056	5729	3581	2935	1730	1457
13	518	760	1275	3169	1935	1613	1046
3+	1058741	1229647	1280486	1108636	917394	871171	1030379
4+	694087	756808	895818	925493	764815	614119	563872
5+	423065	460594	509399	611142	615622	491306	355941
6+	204536	251021	280335	308181	372024	377497	268776
7+	138337	110652	137488	153770	163946	207318	193955

Table 17. Biomass estimates (000't) of cod from autumn research vessel surveys in NAFO Div. 2J, 3K and 3L.

Div.	1981	1982	1983	1984	1985	1986	1987	1988	1989	
2J	228.8	216.5	267.1	181.7	136.7	404.6	174.8	252.9	145.5	
3K	185.4	142.2	183.7	181.9	86.0	356.4	123.3	75.4	219.2	
3L	114.5	89.1	157.0	190.5	164.7	191.2	151.9	139.7	84.3	
Total	528.7	447.8	607.8	554.1	387.4	952.2	450.0	468.0	449.0	
Percentage										Ave.
2J	43	48	44	33	35	43	39	54	32	41
3K	35	32	30	33	22	37	27	16	49	31
3L	22	20	26	34	43	20	34	30	19	28
Total	100	100	100	100	100	100	100	100	100	100

TABLE 23. MEAN NUMBERS PER TOW OF COD AND COEFFICIENTS OF VARIATION FROM AUTUMN RV SURVEYS IN DIVISIONS 2J3KL.

MEAN NUMBERS PER TOW

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	0.02	0.41	0.27	0.16	0.51	1.05	0.36	0.02	0.14	0.21	0.59	0.53
2	0.40	0.32	3.02	1.61	2.51	6.14	5.57	1.10	1.85	1.56	2.15	7.27
3	5.52	1.96	2.50	5.23	5.90	12.41	10.80	7.27	4.77	2.04	3.94	7.97
4	11.82	11.93	3.85	2.80	6.00	10.73	15.25	12.35	20.70	4.03	3.21	7.25
5	14.30	17.04	13.37	3.32	3.90	11.01	11.36	10.02	31.29	13.23	5.31	5.38
6	5.68	10.69	13.45	9.84	2.83	3.92	9.61	7.28	21.29	11.61	10.64	5.87
7	1.68	2.30	5.03	8.93	5.89	2.47	2.31	4.24	10.14	4.38	10.21	7.54
8	0.66	0.94	1.20	3.70	5.38	5.40	1.38	0.92	5.26	2.67	2.60	4.44
9	0.49	0.32	0.38	0.74	2.61	2.98	2.09	0.78	1.37	1.38	1.56	1.42
10	0.34	0.27	0.23	0.23	0.57	1.43	1.31	0.67	0.58	0.34	0.80	0.83
11	0.12	0.19	0.11	0.10	0.16	0.37	0.54	0.41	0.68	0.17	0.15	0.36
12	0.13	0.08	0.17	0.11	0.09	0.14	0.28	0.15	0.42	0.19	0.11	0.14
13	0.09	0.05	0.07	0.11	0.07	0.13	0.12	0.06	0.19	0.13	0.08	0.08
1+	41.25	46.50	43.65	36.89	36.43	58.18	60.97	45.27	98.69	41.95	41.35	49.08
2+	41.23	46.09	43.38	36.73	35.92	57.13	60.61	45.25	98.55	41.74	40.76	48.55
3+	40.83	45.77	40.36	35.12	33.41	50.99	55.04	44.15	96.70	40.18	38.61	41.28
4+	35.31	43.81	37.86	29.89	27.51	38.58	44.24	36.87	91.93	38.14	34.67	33.31
5+	23.49	31.88	34.01	27.08	21.51	27.85	28.99	24.52	71.23	34.11	31.46	26.06
6+	9.19	14.84	20.64	23.76	17.61	16.83	17.63	14.51	39.93	20.88	26.15	20.68

COEFFICIENTS OF VARIATION - PERCENT

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	25	18	32	33	23	45	26	64	28	38	33	28
2	26	22	39	21	23	28	17	16	18	24	12	16
3	20	17	53	21	18	19	16	20	16	15	17	16
4	20	22	38	20	14	23	16	18	24	13	21	18
5	23	25	27	24	17	26	20	16	31	16	19	22
6	25	31	28	29	19	28	15	14	35	18	17	22
7	24	33	24	29	20	24	15	12	36	18	17	23
8	21	32	20	32	17	25	14	9	33	18	14	27
9	20	24	21	27	16	22	13	9	32	16	14	37
10	19	25	23	25	11	25	12	9	29	17	13	53
11	26	23	33	23	15	25	12	10	25	16	13	51
12	23	19	24	23	26	24	13	11	30	15	14	61
13	29	23	24	20	15	6	13	13	23	13	13	85

TABLE 29. COMMERCIAL CATCH RATE INDEX FOR COD IN DIV 2J3KL FOR 1978-89.

	PREDICTED CATCH RATE					
	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1978	0.3119	0.0119	1.542	0.168	57104	37021
1979	0.6305	0.0086	2.125	0.197	81007	38126
1980	0.8339	0.0098	2.602	0.257	79265	30459
1981	1.0428	0.0078	3.210	0.282	90674	28246
1982	0.9805	0.0074	3.017	0.260	116725	38689
1983	1.1729	0.0068	3.658	0.300	125922	34420
1984	1.2977	0.0066	4.145	0.335	134750	32511
1985	1.4417	0.0071	4.786	0.403	151410	31639
1986	1.3245	0.0068	4.257	0.351	179137	42081
1987	1.1422	0.0071	3.547	0.299	156263	44056
1988	1.3098	0.0068	4.195	0.346	164770	39281
1989	1.2928	0.0072	4.123	0.349	140924	34178

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.088

ABLE 39 , COMMERCIAL CATCH RATE INDEX (NUMBERS AT AGE) FOR COD IN
DIVISIONS 2J3KL FOR THE YEARS 1978-89.

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	0.33	0.13	0.08	0.33	0.09	0.46	0.21	0.28	0.02	0.02	0.09	0.09
4	4.75	3.93	1.41	1.46	3.91	2.19	3.48	3.69	2.72	0.60	0.55	3.23
5	11.94	13.57	13.10	5.44	4.12	14.10	11.81	15.17	13.67	10.97	4.19	5.18
6	6.64	11.42	15.28	14.83	4.35	7.13	18.43	18.48	21.04	21.05	20.53	9.62
7	1.98	3.00	6.26	12.40	11.23	4.44	5.68	15.62	12.05	11.32	20.86	16.42
8	0.84	0.62	1.17	4.86	6.70	6.79	3.12	3.71	6.94	8.46	8.00	13.13
9	0.37	0.23	0.25	1.01	5.19	4.24	4.98	2.04	1.38	1.90	3.93	4.29
0	0.29	0.14	0.14	0.21	0.55	3.62	2.11	3.16	0.96	0.47	1.92	1.70
1	0.14	0.10	0.06	0.09	0.09	0.44	1.37	1.76	0.95	0.26	0.24	0.86
2	0.05	0.03	0.05	0.05	0.05	0.07	0.24	1.11	0.54	0.33	0.16	0.29
3	0.02	0.02	0.02	0.04	0.02	0.04	0.06	0.16	0.29	0.16	0.15	0.12
3+	27.35	33.19	37.81	40.72	36.30	43.51	51.49	65.18	60.55	55.53	60.61	54.94
4+	27.02	33.06	37.74	40.39	36.21	43.05	51.28	64.90	60.53	55.52	60.52	54.85
5+	22.26	29.13	36.33	38.93	32.30	40.86	47.80	61.21	57.81	54.92	59.97	51.62
6+	10.32	15.56	23.23	33.49	28.19	26.77	35.99	46.04	44.14	43.95	55.78	46.43
7+	3.68	4.14	7.95	18.66	23.84	19.64	17.56	27.56	23.11	22.90	35.25	36.81

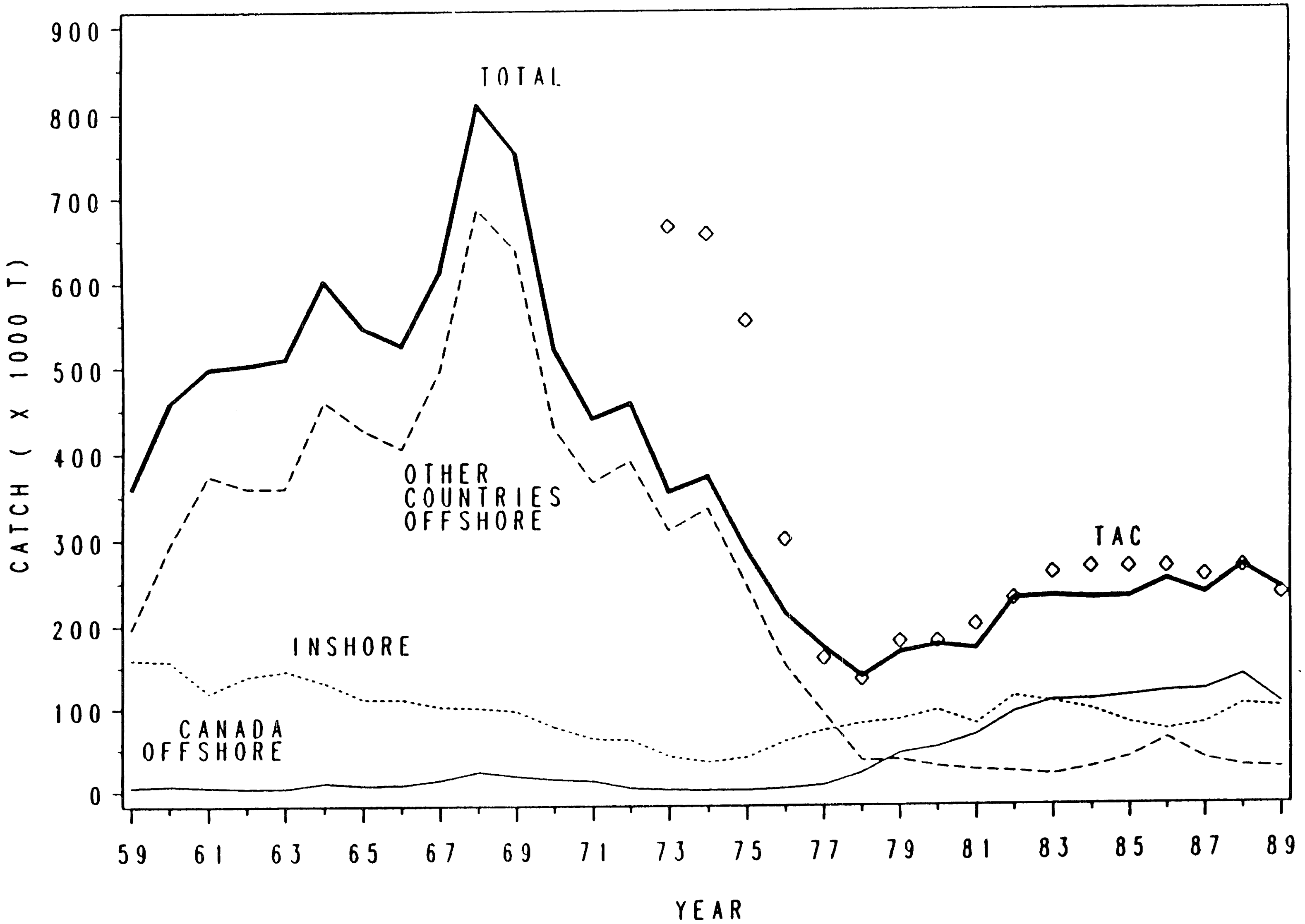


FIG. 1. CATCHES OF COD WITH ASSOCIATED TACS FROM DIVISIONS 2J3KL FOR THE 1959-8^ PERIOD.

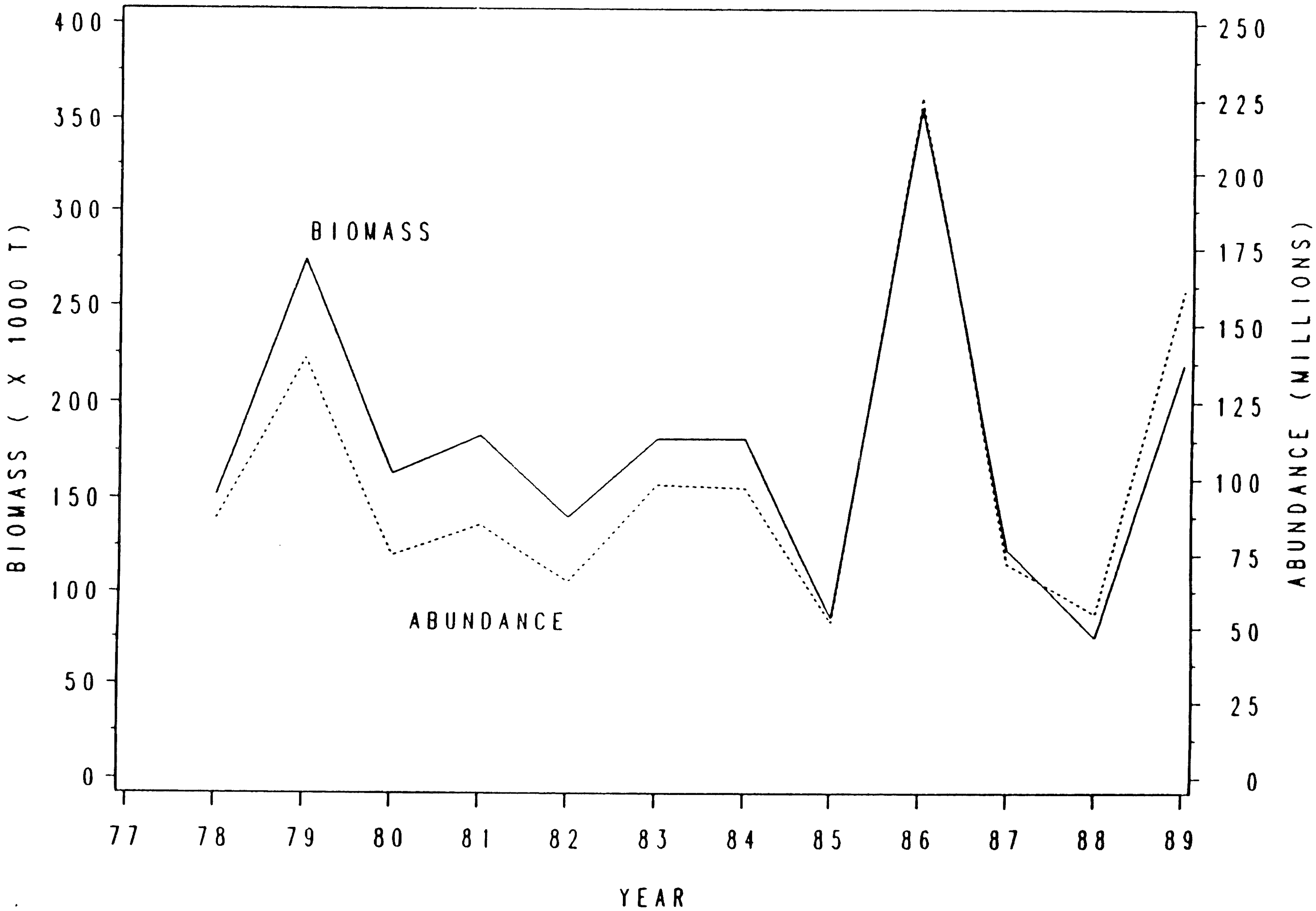


FIG. 9 . COD BIOMASS AND ABUNDANCE IN DIVISION 3k OBTAINED FROM AUTUMN RV SURVEYS.

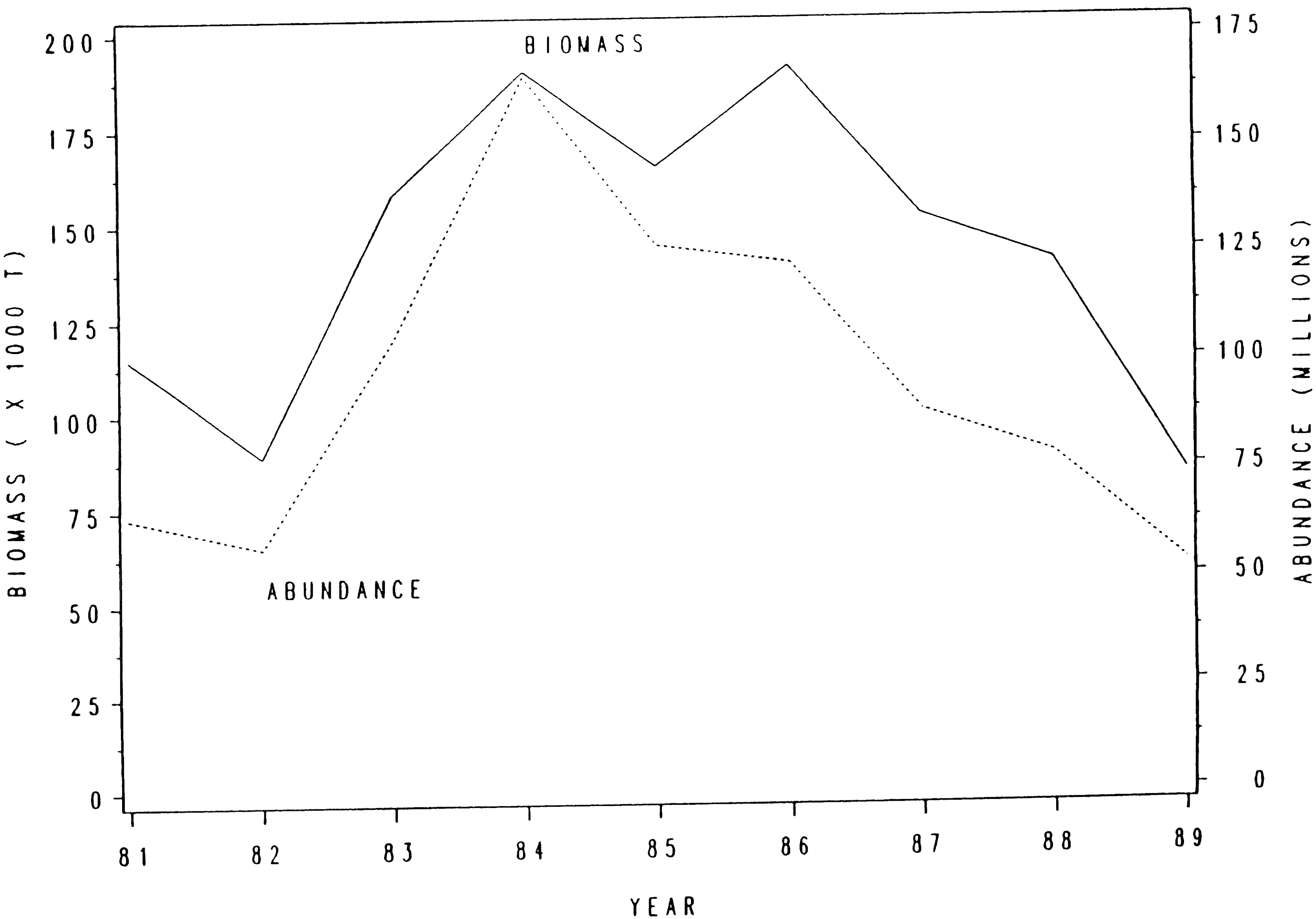


FIG. 10 . COD BIOMASS AND ABUNDANCE IN DIVISION 3L OBTAINED FROM AUTUMN RV SURVEYS.

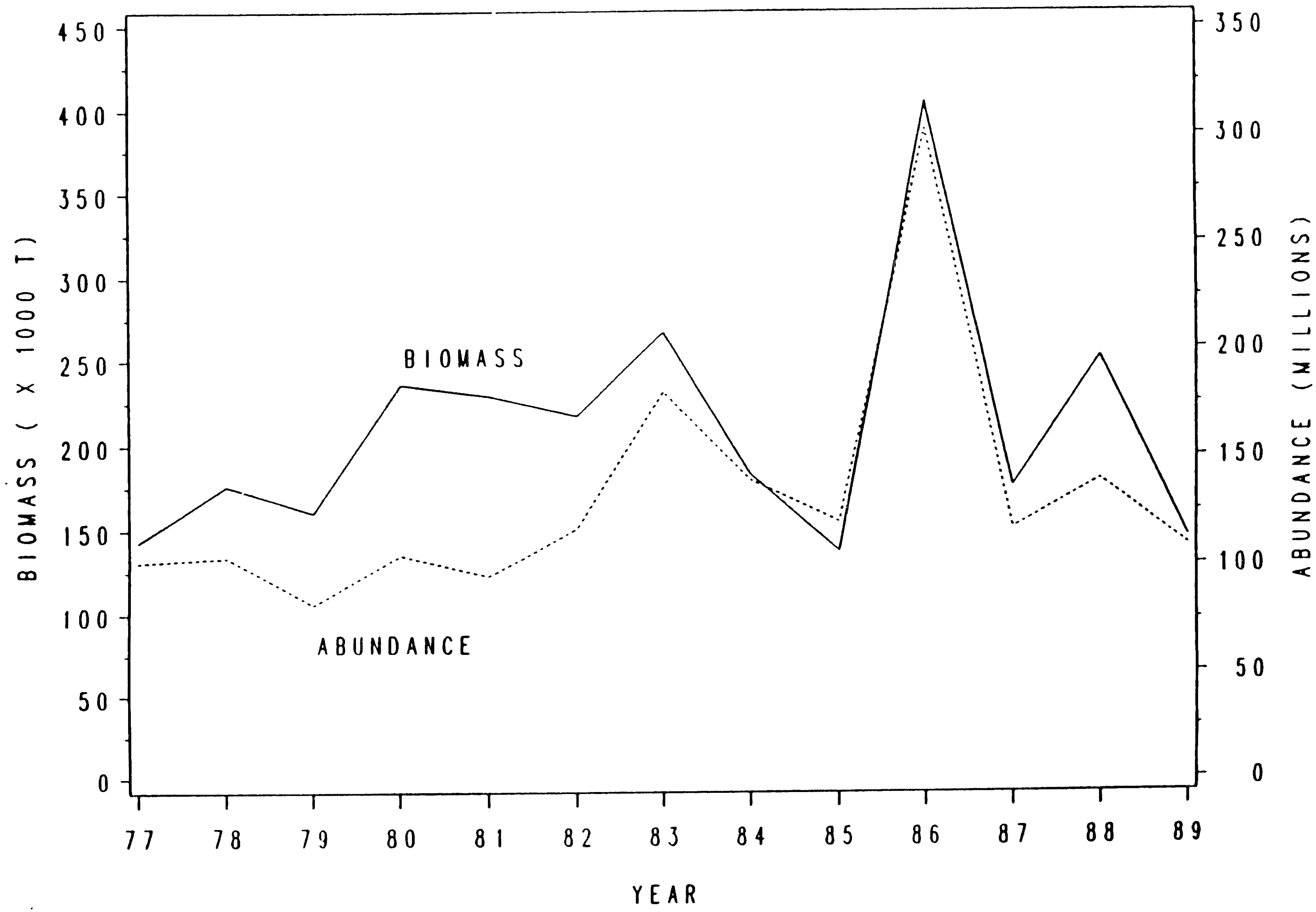


FIG. 8 . COD BIOMASS AND ABUNDANCE IN DIVISION 2J OBTAINED FROM AUTUMN RV SURVEYS.

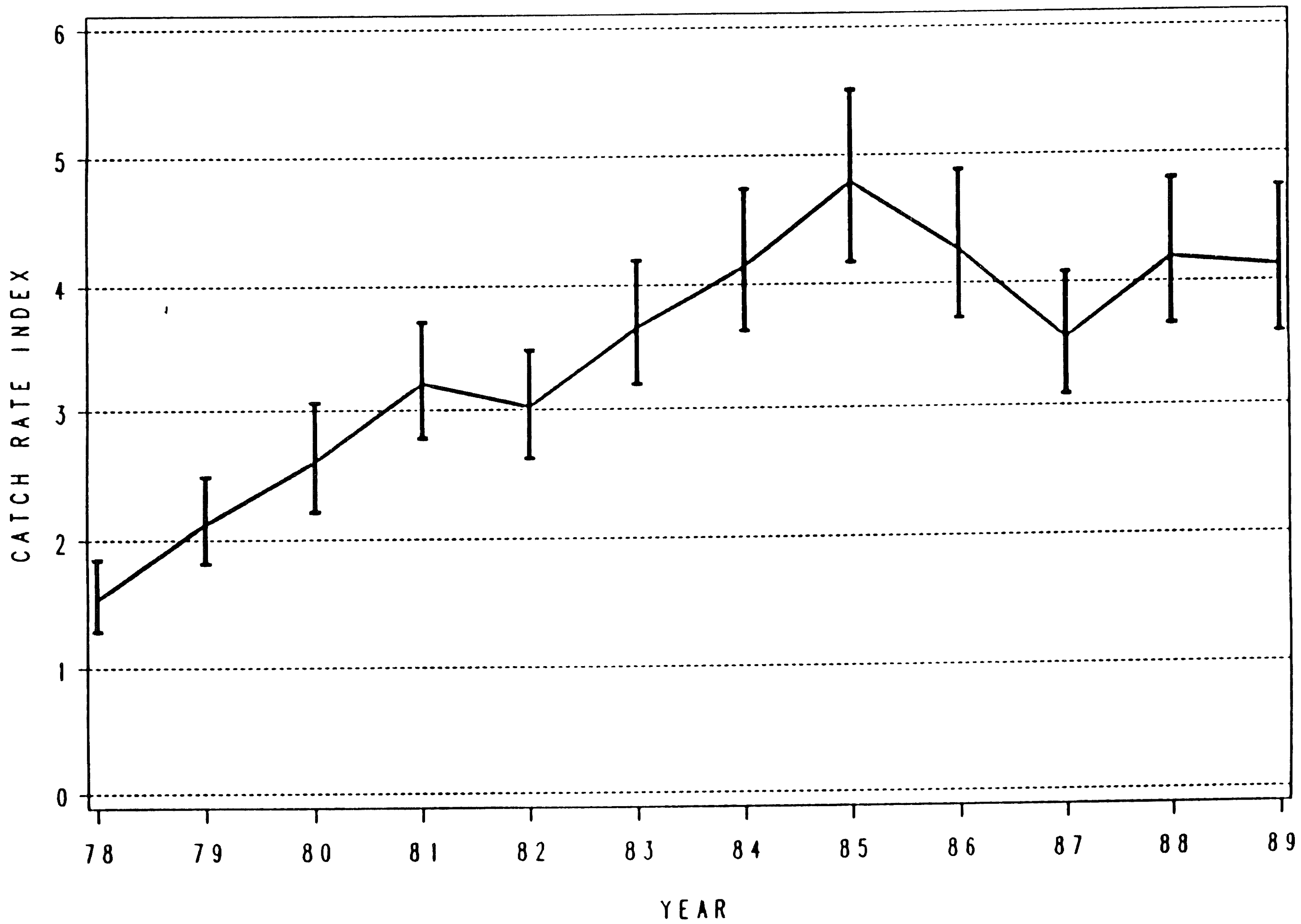


FIG 13. CATCH RATE INDEX WITH APPROXIMATE 90% C. I.
FOR DIV. 2J3KL COD (1978-89).

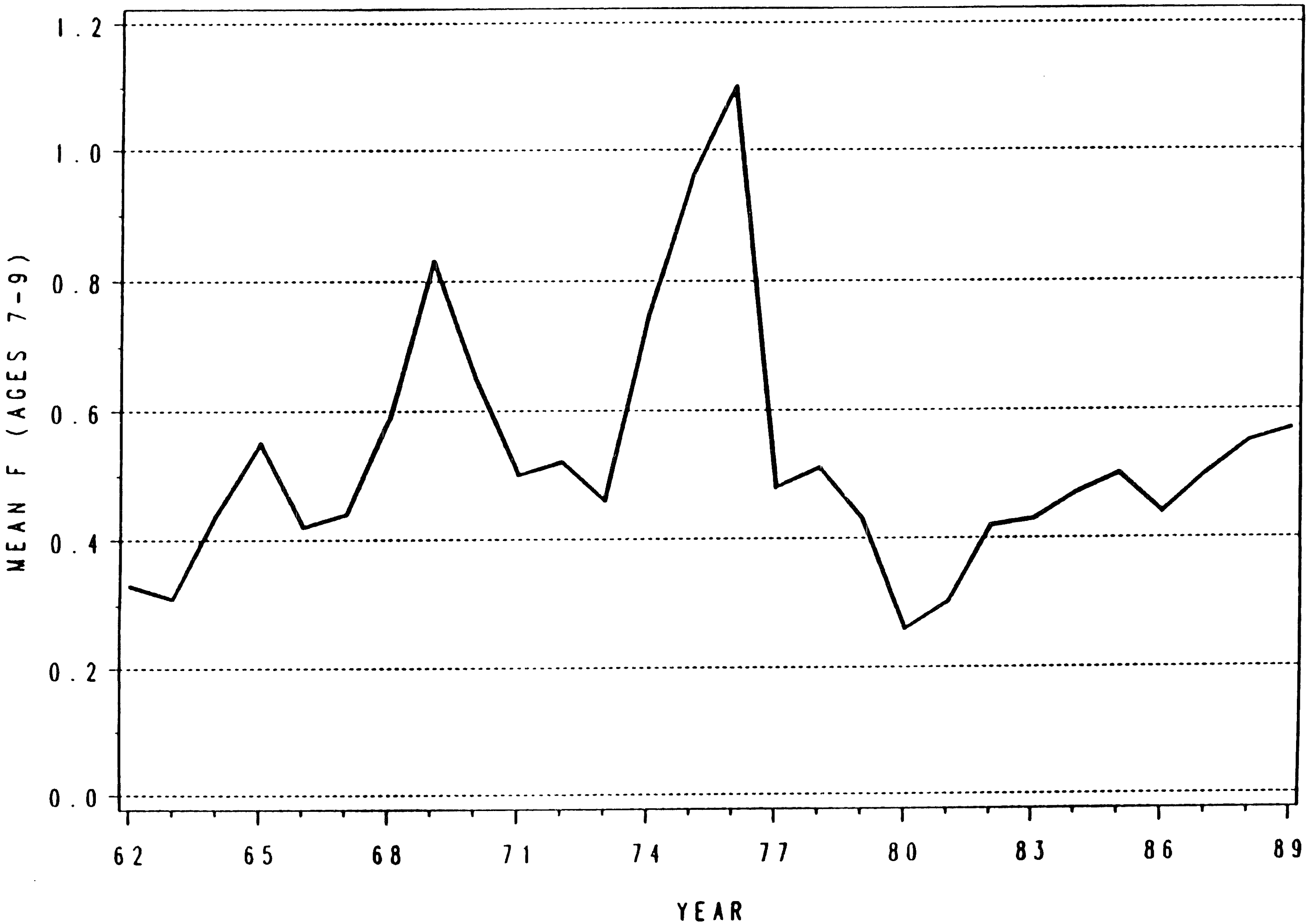


FIGURE 23. MEAN FISHING MORTALITY AT AGES 7-9 (WEIGHTED BY POPULATION NUMBERS FOR COD IN DIVISIONS 2J3KL.

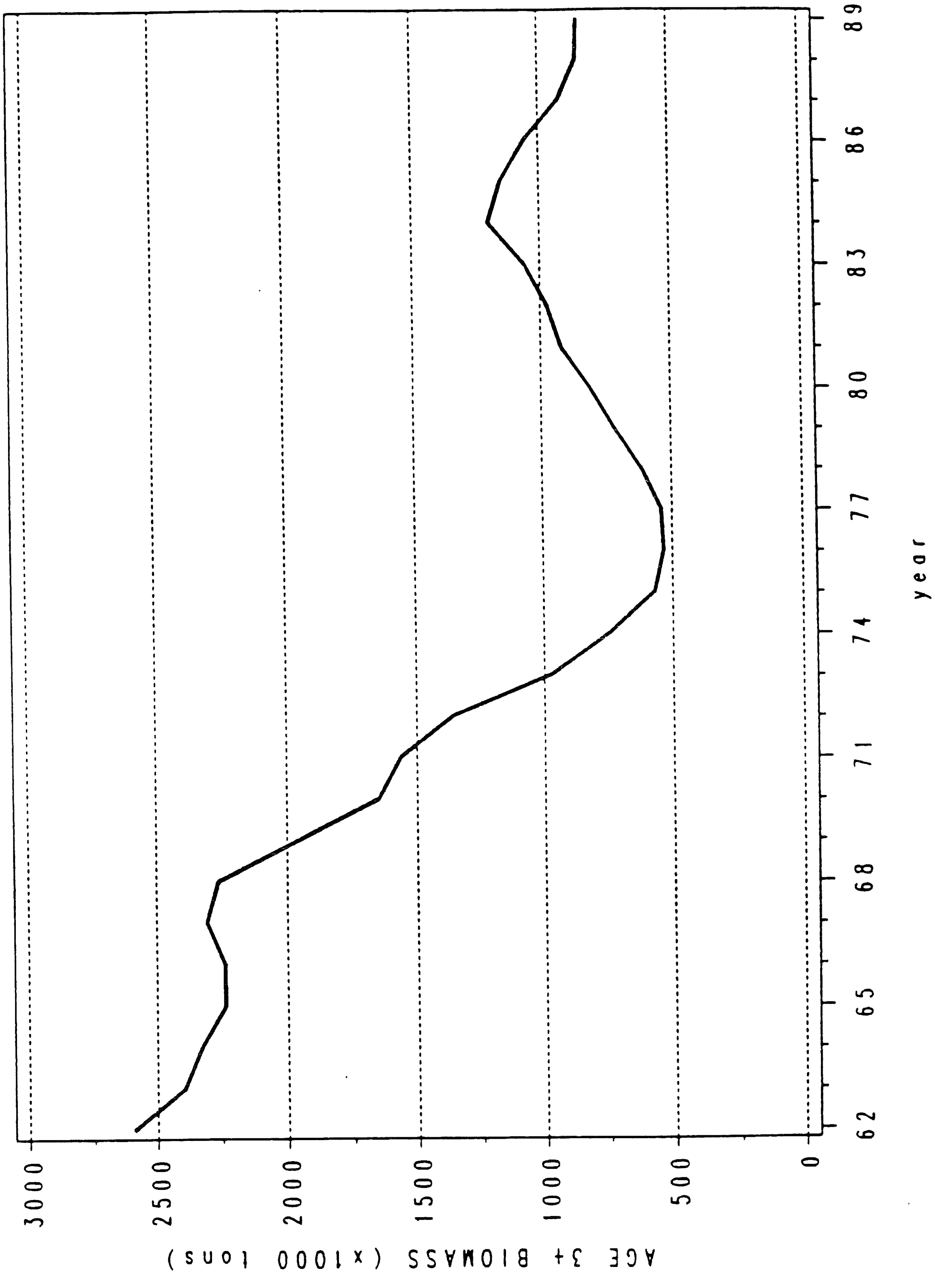
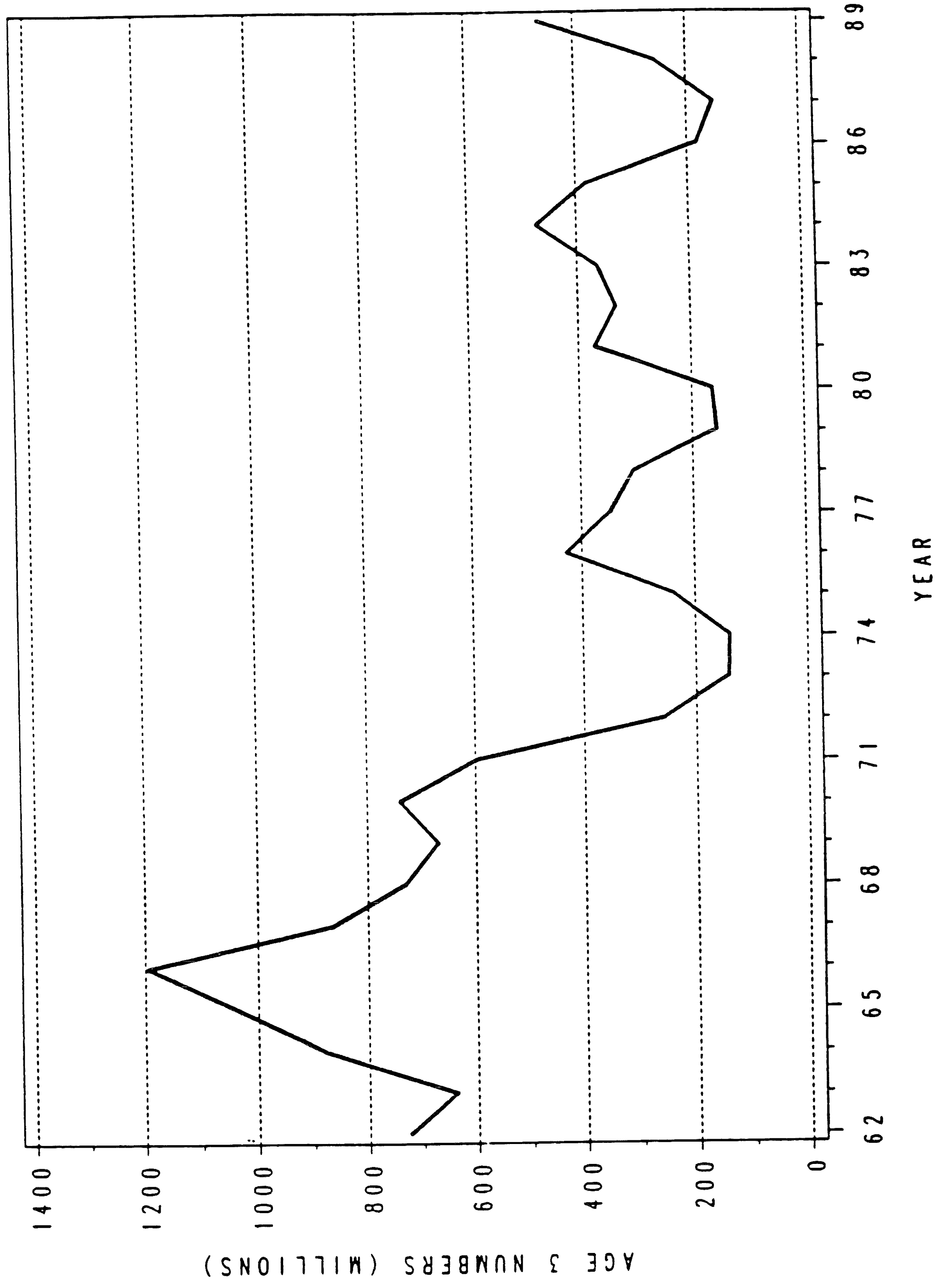


FIG. 24. POPULATION BIOMASS (JANUARY 1) FOR 2J3KL COD.


AGE 3 NUMBERS (MILLIONS)
0
200
400
600
800
1000
1200
1400
YEAR
62
65
68
71
74
77
80
83
86
89

3Ps Cod

History

Catches have ranged from a high of 84,000 t in 1961 to a low of 27,000 t in 1978; were stable at about 37,000 t from 1979 to 1984; increased and averaged 56,000 t from 1985 to 1987 and have subsequently declined. The 1989 catch is estimated to be slightly less than 40,000 t.

Catches since 1976 have been by Canada and France. French catches have increased substantially since the early 1980's whereas those by Canada have been relatively stable. Canadian catches have traditionally been taken mainly by an inshore fixed gear fleet.

Tagging studies have shown that the stock interacts seasonally with NAFO Div. 3Pn4RS and 3NO.

Stock structure

The stock had been at its lowest level in the mid 1970's, but increased sharply in the mid 1980's because of the recruitment to the fishery of a succession of strong year-classes. Age 3+ biomass has declined in recent years and sizes of recruiting year-classes have been lower than those in the early to mid 1980's.

Fishing mortality levels have fluctuated but have been most often at or above the F_{max} level.

Environment

The main environmental influences on this stock are the Labrador Current and to a lesser extent the Gulf Stream in the deeper water areas to the south. Temperature gradients can be considerable within a relatively short distance.

Spawning

Spawning is reported to occur mainly in May and June on the southern and southwestern slopes of the banks.

Adults

Migration

The major migration pattern is an inshore offshore movement in the spring and fall, respectively. Tagging studies have shown that there is some migration from the southern region onto the Grand bank in Div. 30 in summer.

Growth

In this stock, the growth rate is such that at 2 years of age an individual will be approximately 20 cm and 50 cm by age 5. Sexual maturity commences at about age 4 and by age 8 virtually all are spawners. Cod ranging to age 15 are common in commercial and research catches but those beyond age 20 are rare.

Table 1. Cod catches (MT) from Subdivision 3Ps, 1959-88.

	Can(N)			France						
	Offshore	Inshore		STPM						
Year	(mobile)	(fixed gear)	Can(M)	Ins.	Off.	Metro	Spain	Portugal	Other	Total
1959	2,726	32,718	4,784	3,078	-	4,952	7,794	3,647	471	60,170
1960	1,780	40,059	5,095	3,424	210	2,460	17,223	262	2,123	72,636
1961	2,167	32,506	3,883	3,793	347	11,490	21,015	4,985	3,434	83,620
1962	1,176	29,888	1,474	2,171	70	4,138	10,289	1,873	1,560	52,639
1963	1,099	30,447	331	1,112	645	324	10,826	209	6,828	51,821
1964	2,161	23,897	370	1,002	1,095	2,777	15,216	169	9,880	56,567
1965	2,459	25,902	1,203	1,863	707	1,781	13,404	-	4,535	51,854
1966	5,473	23,785	583	1,157	2,050	4,607	23,678	519	4,355	66,207
1967	3,861	26,331	1,259	2,244		3,204	20,851	980	4,044	62,774
1968	6,538	22,938	585	-	880	1,126	26,868	8	18,611	77,556
1969	4,269	20,009	849	1,415	1,062	15	28,141	57	7,982	63,799
1970	4,650	23,410	2,166	1,307	663	35	35,750	143	8,734	76,858
1971	8,657	26,651	731	1,196	455	2,730	19,169	81	2,778	62,448
1972	3,323	19,276	252	990	446	-	18,550	109	1,267	44,213
1973	3,107	21,349	181	976	189	-	19,952	1,180	5,707	52,641
1974	3,770	15,999	657	600	348	5,366	14,937	1,246	3,789	46,712
1975	741	14,332	122	586	189	3,549	12,234	1,350	2,270	35,373
1976	2,013	20,978	317	722	182	1,501	9,236	177	2,007	37,133
1977	3,333	23,755	2,171	845	407	1,734	-	-	-	32,245
1978	2,082	19,560	700	360	1,614	2,860	-	-	45	27,221
1979	2,381	23,413	863	495	3,794	2,060	-	-	-	33,006
1980	2,809	29,427	715	214	1,722	2,681	-	-	-	37,568
1981	2,696	26,068	2,321	333	3,768	3,706	-	-	-	38,892
1982	2,639	21,351	2,948	1,009	3,771	2,184	-	-	-	33,902
1983	2,100	23,915	2,580	843	4,775	4,238	-	-	-	38,451
1984	895	22,865	1,969	777	6,773	3,671	-	-	-	36,950
1985	4,529	24,854	3,476	642	9,422	8,444	-	-	-	51,367
1986	~~4,981~~ 5218	24,208 4821	~~2,120~~ 1963	389	~~13,65[illegible]~~	11,939	-	-	7	~~57,290~~ 5799 ~~5745~~
1987	3,693	26,589	2,517	551	15,214	8,737	-	-	-	57,301
1988	3,395	19,561	2,361	282	10,011	7,373	-	-	-	42,983
1989	~~3759~~ 2714	23496	2141		10284				-	

Table 7. Cod abundance (000's) from stratified-random cruises in Subdivision 3Ps. Numbers in brackets are estimates for non-sampled strata.

Depth range (fath)	Strata	Area	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
0-30	314	974	0	(33)	1,170	(17)	1,060	73	0	(282)	279	307	2,237	1,859	91	21	1	0	42	8	24
	320	1,320	(424)	545	(412)	(141)	867	(266)	(473)	(1,087)	528	10,354	1,362	1,589	1,870	476	99	129	180	238	0
31-50	308	112	(35)	29	122	65	34	166	21	74	59	46	235	238	395	563	0	13	13	4	8
	312	272	337	(50)	225	221	257	597	378	157	(126)	92	296	347	153	1,644	31	51	20	7	0
	315	827	186	0	62	(46)	745	1,273	(181)	621	171	0	145	489	410	177	787	147	103	133	217
	321	1,189	223	0	(116)	(22)	312	(66)	179	(352)	196	402	1,227	785	342	76	27	54	162	0	11
	325	944	(48)	(8)	(46)	(0)	35	(20)	567	850	35	213	76	111	63	0	27	47	24	18	35
	326	166	(3)	(0)	(2)	(0)	(6)	(0)	0	12	6	0	69	63	0	(4)	0	19	19	0	6
51-100	307	395	1,621	2,627	2,609	423	756	1,090	1,186	2,090	949	5,505	2,372	569	193	2,006	5,802	1,433	4,700	1,710	395
	311	317	2,261	820	2,847	433	670	119	309	1,124	3,105	690	1,888	1,348	381	3,692	127	2,427	898	103	119
	317	193	275	354	742	127	974	196	(268)	309	1,391	623	913	2,062	14	1,427	420	420	101	101	7
	319	984	1,717	842	1,182	638	4,136	2,958	(2,356)	15,068	2,733	13,000	3,176	2,058	1,637	111	3,241	6,968	6,795	2,401	(2,161)
	322	1,567	(534)	(251)	(519)	(179)	2,235	(336)	706	118	2,641	471	2,632	1,882	509	860	1,382	1,082	206	260	154
	323	696	418	(128)	(262)	(93)	78	111	1,097	(683)	261	78	392	383	901	871	2,069	3,466	199	112	13
	324	494	(97)	(42)	(94)	(28)	37	(58)	(109)	93	0	(166)	352	593	321	10,476	178	111	185	0	15
101-150	306	419	(319)	(159)	145	309	110	65	115	440	204	2,810	692	763	47	267	577	6,172	1,329	231	1,342
	309	296	678	141	86	152	89	63	67	870	289	1,811	700	496	56	933	1,700	1,067	1,355	833	733
	310	170	264	51	70	2,038	(149)	0	183	121	0	651	434	72	57	102	179	115	315	351	421
	313	165	121	56	89	215	54	26	17	1,018	81	266	217	37	12	111	0	173	43	508	81
	316	189	60	528	76	43	103	14	(73)	85	35	21	(97)	128	78	38	14	38	24	634	5,881
	318	123	32	9	5	0	0	5	(24)	503	379	(36)	92	3	0	(24)	14	374	9	3,241	(21)
151-200	705	195	(35)	(15)	55	0	0	48	7	66	432	988	15	5	0	285	366	102	271	22	29
	706	476	(82)	(34)	5	(22)	(124)	46	(92)	202	518	250	9	7	0	697	241	5,041	411	27	27
	707	93	(25)	(12)	3	0	0	171	(28)	91	122	(43)	(38)	2	0	(29)	565	565	1,714	93	(26)
	715	132	(81)	(40)	(79)	10	30	20	149	221	248	84	45	106	25	(93)	817	367	2,145	74	456
	716	539	(204)	(97)	(198)	(70)	(298)	20	587	334	223	1,123	81	91	13	170	3,004	1,119	1,432	212	162
201-300	708	117	(59)	(29)	(58)	0	(86)	9	(66)	92	3,636	(98)	(87)	0	0	(68)	202	6,148	9,274	26	(60)
	711	961	(92)	(31)	(89)	(15)	(146)	(49)	(105)	(271)	649	0	0	9	14	54	4,857	258	206	93	240
	712	973	(131)	(51)	(127)	(31)	(202)	(75)	(149)	8,180	146	73	97	0	(100)	426	162	37	313	82	555
	713	950	(102)	(36)	(99)	0	160)	(56)	(116)	(295)	0	214	0	20	(76)	62	57	713	153	312	9,352
	714	1159	(169)	(67)	(163)	(41)	(258)	(97)	(191)	(467)	0	56	0	27	(128)	(197)	466	157	379	1,749	11,123
Total		17,443	10,634	7,085	11,758	5,377	14,013	8,093	9,796	36,178	19,441	40,471	19,984	16,158	7,896	25,963	27,410	38,812	33,021	13,603	33,676
Estimated mean no. per tow			8.12	5.41	8.98	4.11	10.70	6.18	7.48	27.63	14.85	30.91	15.26	12.34	6.03	19.83	20.93	29.64	25.22	10.39	25.72

Table 7. Cod biomass (MT) from stratified random cruises conducted by Canada in Subdivision 3Ps.

Depth range (fm.)	Strata	Area	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
0-30	314	974	0	–	1328	–	2357	249	0	–	432	369	2028	13103	567	25	0	0	24	8	139
	320	1320	–	729	–	–	1335	–	–	–	2946	23087	1920	5618	5456	5259	284	495	1729	1026	0
Total			0	729	1328	–	3692	249	0	–	3378	23456	3948	18721	6023	5284	284	495	1753	1034	139
31-50	308	112	–	181	279	205	193	311	38	125	240	305	490	766	681	1024	0	3	4	2	2
	312	272	210	–	243	355	456	1047	343	151	–	165	766	524	674	1016	61	33	3	3	0
	315	827	1480	0	592	–	1747	1550	–	1836	235	0	528	2451	1894	329	2762	885	1247	1641	523
	321	1189	1917	0	–	–	1742	–	2037	–	1880	1419	2845	2419	1183	89	335	223	1738	367	2
	325	944	–	–	–	–	2	–	180	820	28	1109	85	294	449	0	35	130	31	7	26
	326	166	–	–	–	–	–	–	0	2	3	0	54	326	0	–	0	16	28	0	3
Total			3607	181	1114	540	4140	2908	2598	2934	2386	2998	4768	6780	4881	2458	3193	1290	3051	2020	556
51-100	307	395	2918	6133	3919	884	1127	2097	3222	4105	1763	13723	3028	892	771	5189	12339	2688	13936	3138	340
	311	317	3885	590	2432	763	627	411	154	1106	3792	761	1943	3256	863	4870	399	4331	593	361	18
	317	193	101	286	589	164	551	491	–	368	536	268	1582	3685	30	14064	2180	886	109	243	0
	319	984	4604	662	478	481	3102	2493	–	10637	1652	15068	3548	3799	3995	1282	10189	7784	12609	10170	–
	322	1567	–	–	–	–	5183	–	491	14	2599	26	3705	4932	2597	1073	2004	1503	369	52	38
	323	696	736	–	–	–	368	63	1652	–	775	491	1215	858	2247	1263	2881	18047	143	281	3
	324	494	–	–	–	–	8	–	–	29	0	–	430	618	136	10756	230	187	125	0	6
Total			12244	7671	7418	2292	10966	5555	5519	16259	11117	30337	15451	18040	10639	38497	30222	35426	27884	14245	405
101-151	306	419	–	–	376	719	214	161	416	710	457	2652	1211	1250	236	590	755	11032	3589	267	779
	309	296	662	975	479	311	178	192	103	1558	863	2983	838	926	156	1611	3216	2539	2722	1900	1415
	310	170	1008	191	377	2183	–	0	154	119	0	817	608	134	134	268	332	198	417	147	194
	313	165	371	29	144	242	142	41	50	1036	127	446	283	74	130	250	0	279	69	570	105
	316	189	271	937	63	58	77	17	–	65	61	25	–	207	170	85	71	71	25	2847	4707
	318	123	173	11	4	0	0	6	–	36	790	–	136	11	0	–	81	782	106	13266	–
Total			2485	2143	1443	3513	611	417	723	3524	2298	6923	3076	2602	826	2804	4455	14901	6928	18997	7200
151-200	705	195	–	–	66	0	0	60	1	91	674	1310	22	27	0	542	611	121	501	18	123
	706	476	–	–	23	–	–	76	–	356	827	304	30	32	0	2068	447	8319	11314	130	69
	707	93	–	–	5	0	0	228	–	326	190	–	–	7	0	–	3124	1529	6667	370	–
	715	132	–	–	–	1	1	31	142	352	499	168	154	338	54	–	1523	810	4575	220	298
	716	539	–	–	–	–	–	92	781	303	248	1608	168	147	15	344	3464	1544	2379	384	570
Total					94	1	1	487	924	1428	2438	3390	374	551	69	2954	9169	12323	15256	1122	1060
201-300	708	117	–	–	–	0	–	11	–	177	4633	–	–	0	0	–	327	8816	27852	57	–
	711	961	–	–	–	–	–	–	–	–	1113	0	0	7	87	109	6949	477	502	361	303
	712	973	–	–	–	–	–	–	–	9077	282	259	353	0	–	993	300	128	692	184	748
	713	950	–	–	–	0	–	–	–	–	0	850	0	36	–	87	271	1339	332	535	17075
	714	1195	–	–	–	–	–	–	–	–	0	161	0	163	–	–	1857	258	700	4090	19821
Total			–	–	–	0	–	11	–	9254	6028	1270	353	206	87	1189	9704	11018	30078	5227	37947
Total area per depth range																					
0-30		2294								–	3378	23456	3948	18721	6023	5284	284	495	1753	1034	139
31-50		3510								2934	2386	2998	4768	6780	4881	2458	3193	1290	3051	2020	556
51-100		4646								16259	11117	30337	15451	18040	10639	38497	30222	35426	27884	14245	405
101-150		1362								3524	2298	6923	3076	2602	826	2804	4455	14901	6928	18997	7200
151-200		1435								1428	2438	3390	374	551	69	2954	9169	12323	15256	1122	1060
201-300		4196								9254	6028	1270	353	206	87	1189	9704	11018	30078	5227	37947
Total										33399	27645	68374	27970	46900	22520	53184	57028	75453	84967	42645	47307
Confidence interval																					
Upper										126620	51812	182436	35732	75157	30681	109276	85724	122746	447584	67528	90622
Lower										-59817	3481	-45684	20204	18640	14359	-2908	28332	28156	-277649	17797	39935

BLE . MEAN NUMBERS PER TOW AT AGE ADJUSTED FOR MISSING STRATA FOR COD IN SUBDIVISION 3PS FOR THE YEARS 1972-90.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.02	0.01	0.52	0.17	0.16	0.00	0.00	0.84	0.16	0.03	0.51
2	0.52	0.60	1.60	0.33	2.34	0.14	0.47	0.35	4.53	0.53	1.95
3	0.92	0.71	1.58	0.93	1.53	1.88	0.72	0.51	1.38	3.02	0.99
4	1.90	1.08	1.13	0.85	2.81	1.64	2.64	5.37	0.97	4.97	4.91
5	1.27	1.20	1.52	0.52	1.75	1.26	1.13	15.84	3.30	5.45	2.25
6	0.85	0.34	1.41	0.48	0.80	0.65	0.81	3.33	2.91	7.04	1.05
7	1.13	0.67	0.39	0.43	0.49	0.20	0.58	0.75	0.53	6.62	1.42
8	0.67	0.26	0.31	0.16	0.45	0.10	0.41	0.36	0.50	1.33	1.47
9	0.28	0.35	0.25	0.11	0.10	0.15	0.24	0.13	0.14	1.31	0.40
0	0.17	0.08	0.13	0.06	0.08	0.06	0.23	0.10	0.13	0.31	0.11
1	0.07	0.02	0.04	0.02	0.06	0.01	0.08	0.03	0.10	0.06	0.08
2	0.04	0.02	0.03	0.01	0.06	0.02	0.03	0.01	0.11	0.08	0.03
3	0.03	0.00	0.02	0.01	0.00	0.02	0.03	0.01	0.04	0.08	0.02
4	0.05	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.02
5	0.03	0.00	0.00	0.01	0.02	0.00	0.03	0.00	0.02	0.01	0.03
6	0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.02
1+	8.01	5.37	8.96	4.10	10.66	6.17	7.39	27.63	14.84	30.88	15.26
2+	7.99	5.35	8.44	3.94	10.50	6.16	7.39	26.79	14.68	30.85	14.75
3+	7.47	4.75	6.84	3.60	8.16	6.02	6.93	26.45	10.15	30.33	12.80
4+	6.55	4.05	5.26	2.67	6.63	4.14	6.20	25.93	8.78	27.31	11.81

	1983	1984	1985	1986	1987	1988	1989	1990
1	0.25	0.01	0.01	0.01	0.04	0.02	0.02	0.00
2	0.47	0.20	0.26	0.26	0.37	0.42	0.28	0.06
3	1.02	0.31	1.68	0.54	0.83	0.78	0.68	1.33
4	0.55	0.56	4.31	2.54	2.01	1.18	1.33	5.03
5	3.05	0.42	5.58	5.40	10.26	1.79	0.97	6.28
6	1.56	1.80	2.57	5.83	8.01	5.90	1.01	4.21
7	0.54	0.72	2.40	2.28	3.82	6.14	2.29	3.16
8	1.06	0.37	0.76	1.71	1.60	4.13	1.42	2.92
9	1.99	0.46	0.45	0.99	0.97	1.85	0.82	1.26
10	0.92	0.72	0.43	0.34	0.39	1.04	0.46	0.68
11	0.45	0.17	0.44	0.28	0.31	0.90	0.51	0.36
12	0.17	0.13	0.48	0.32	0.24	0.44	0.15	0.16
13	0.07	0.05	0.20	0.18	0.24	0.18	0.13	0.12
14	0.06	0.03	0.11	0.11	0.24	0.18	0.06	0.08
15	0.05	0.00	0.03	0.07	0.09	0.11	0.11	0.01
16	0.04	0.03	0.04	0.03	0.06	0.11	0.06	0.04
1+	12.26	6.00	19.74	20.90	29.48	25.18	10.30	25.69
2+	12.01	5.99	19.73	20.89	29.44	25.16	10.28	25.69
3+	11.54	5.79	19.46	20.63	29.07	24.74	10.00	25.63
4+	10.52	5.48	17.79	20.09	28.24	23.96	9.31	24.30

Table . Mean number of cod per tow from stratified-random cruises conducted by Canada in Subdivision 3Ps (depths to 300 fathoms).

Age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0.04	0.03	1.08	0.52	0.22	0.01		1.30	0.16	0.03	0.52	0.25	0.01	0.01	0.01	0.04	0.02	0.02	
2	1.04	1.40	3.31	1.04	3.14	0.29	0.47	0.54	4.57	0.55	1.98	0.47	0.23	0.29	0.26	0.37	0.42	0.28	0.06
3	1.83	1.64	3.27	2.94	2.05	3.76	0.73	0.80	1.39	3.16	1.01	1.02	0.36	1.84	0.54	0.83	0.78	0.68	1.33
4	3.77	2.50	2.34	2.67	3.77	3.29	2.66	8.34	0.98	5.20	4.99	0.55	0.65	4.72	2.54	2.01	1.18	1.32	5.05
5	2.52	2.79	3.16	1.64	2.35	2.53	1.14	24.61	3.33	5.71	2.29	3.05	0.49	6.11	5.39	10.25	1.79	0.96	6.30
6	1.69	0.78	2.92	1.52	1.07	1.30	0.82	5.17	2.94	7.37	1.07	1.56	2.09	2.82	5.82	8.00	5.89	1.00	4.22
7	2.24	1.56	0.81	1.36	0.65	0.41	0.59	1.16	0.54	6.93	1.44	0.54	0.84	2.63	2.28	3.82	6.13	2.27	3.17
8	1.32	0.61	0.65	0.51	0.60	0.20	0.41	0.56	0.50	1.39	1.50	1.06	0.43	0.83	1.71	1.60	4.13	1.41	2.93
9	0.56	0.82	0.52	0.34	0.14	0.31	0.24	0.20	0.14	1.37	0.41	1.99	0.53	0.49	0.99	0.97	1.85	0.81	1.26
10	0.33	0.19	0.26	0.20	0.11	0.12	0.23	0.16	0.13	0.32	0.11	0.92	0.84	0.47	0.34	0.39	1.04	0.46	0.68
11	0.14	0.05	0.08	0.07	0.08	0.02	0.08	0.04	0.10	0.06	0.08	0.45	0.20	0.48	0.28	0.31	0.90	0.51	0.36
12	0.08	0.05	0.06	0.03	0.08	0.05	0.03	0.02	0.11	0.08	0.03	0.17	0.15	0.53	0.32	0.24	0.44	0.15	0.16
13	0.05		0.04	0.04		0.05	0.03	0.02	0.04	0.08	0.02	0.07	0.06	0.22	0.18	0.24	0.18	0.13	0.12
14	0.09	0.02	0.04			0.01		0.02		0.05	0.02	0.06	0.03	0.12	0.11	0.24	0.18	0.06	0.08
15	0.05	0.01	0.01	0.02	0.03	0.01	0.03		0.02	0.01	0.03	0.05		0.03	0.07	0.09	0.11	0.11	0.01
16 '	0.15	0.03	0.02						0.03	0.02	0.02	0.04	0.04	0.04	0.03	0.06	0.11	0.06	0.04
17	0.11	0.05	0.01	0.02	0.01		0.02		0.01	0.01		0.01		0.05	0.02	0.05	0.01	0.04	0.01
18	0.07	0.04	0.01			0.01						0.02	0.03	0.02		0.04	0.01	0.02	0.01
19	0.01		0.01		0.04		0.02					0.01				0.02	0.01	0.01	0.01
20	0.01			0.01		0.02				0.02		0.02			0.01	0.01	0.01	0.01	
20+	0.01	0.01	0.01				0.05					0.02	0.01	0.03		0.04		0.01	
NK		0.01									0.02								
Totals	16.09	12.60	18.62	12.93	14.34	12.40	7.54	42.94	14.99	32.35	15.53	12.31	7.00	21.74	20.89	29.64	25.16	10.33	25.79
Confidence limits																			
Upper	25.10	21.58	24.37	18.32	21.20	17.15	11.56	292.57	45.34	87.54	20.30	16.66	9.91	140.96	32.80	48.40	120.38	16.92	48.40
Lower	7.09	3.62	12.87	7.53	7.48	7.64	3.52	-206.69	-15.37	-22.85	10.76	7.96	4.08	-97.48	8.97	10.88	-70.05	3.75	3.18
Sets	44	55	81	62	69	102	44	78	80	71	92	171	95	112	145	135	152	157	109
Survey dates	Mar 20-30	Mar 16-23	Apr 19-30	Jun 2-13	May 11-21	Apr 14-26	Feb 21-28	Feb 16- Mar 5	Mar 19- Apr 2	Mar 7-26	May 28- Jun 9	Apr 22- May 8	Apr 9-18	Mar 7-26	Mar 6-23	Feb 13- Mar 22	Jan 27- Feb 14	Feb 1-16	Jan 31- Feb 20
Trip #	ATC 197	ATC 207	ATC 221	ATC 234	ATC 247	ATC 261	ATC 273	ATC 287	ATC 302	ATC 316	ATC 330	AN 9	AN 26	WT 26	WT 45	WT 55, 56	WT 68	WT 81	WT 91

Table 12. Cod abundance (000's) from stratified-random cruises conducted by France in Subdivision 3Ps. Numbers in brackets are estimates for non-sampled strata.

Depth (m)	Strata	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
< 55	314	33	0	(73)	267	22	133	0	33	33	67	(354)	33
	320	36	241	(256)	784	90	572	663	136	45	(785)	0	90
	TOTAL	69	241	329	1051	112	705	663	169	78	352	354	123
56-90	308	189	12	35	35	161	46	157	50	134	31	38	65
	312	605	99	28	677	456	99	6837	155	298	0	75	56
	315	368	57	0	269	113	85	3597	28	321	868	265	28
	321	20	896	326	502	387	221	147	16	55	(628)	1222	0
	325	(108)	(152)	(138)	129	(567)	275	647	65	226	0	485	0
	TOTAL	1290	1216	527	1612	1684	726	11385	314	1034	1527	2085	149
91-180	307	1948	1154	3084	640	4662	2958	2624	785	21238	4694	1136	8852
	311	402	1628	1158	4357	3995	4147	15162	1954	18038	9503	16231	5973
	317	0	119	(697)	724	4940	1696	16436	989	1182	8457	5410	7993
	319	1051	4583	1146	3262	3516	7666	5473	3909	2887	5695	3639	9413
	322	939	617	5742	1149	4916	5720	2603	4239	4883	11270	4776	6735
	323	349	226	318	1156	572	3671	3683	2670	4576	1907	1668	1621
	324	(479)	(611)	(570)	0	(1845)	2605	3147	1607	727	237	3164	1878
	TOTAL	5168	8938	12715	11288	24446	28463	49128	16153	53531	41763	36024	42465
181-270	306	765	870	698	9691	2841	6333	947	278	14560	2956	2589	3935
	309	355	1642	264	1453	595	1500	1588	872	4906	831	2859	5852
	310	396	186	15	489	1095	935	105	9513	175	382	2276	146
	313	130	328	11	859	814	678	83	2359	138	1432	23	1639
	316	65	95	39	165	423	30	173	4088	826	215	667	4871
	318	21	8	(191)	247	34	1182	604	576	5810	101	2786	1097
	TOTAL	1732	3129	1218	12904	5802	10658	3500	17686	26415	5917	11200	17540
271-365	705	254	982	27	423	3286	672	908	69	224	220	274	267
	706	22	0	98	672	3054	179	532	163	1981	8977	791	157
	707	(140)	586	(166)	13	2603	183	19	827	1172	81	80	51
	715	922	597	895	628	2473	588	1636	917	1132	961	882	276
	716	123	357	923	455	1772	1196	1058	25	2258	5353	4836	406
	TOTAL	1461	2522	2109	2191	13188	2818	4153	2001	6767	15592	6863	1157
366-545	708	(52)	(68)	(63)	45	353	8	4	315	381	1543	88	172
	TOTAL	52	68	63	45	353	8	4	315	381	1543	88	172
0-545	TOTAL	9775	16115	16960	29091	45585	43378	68833	36638	88206	67194	56614	61608
Confidence Interval		12225	22211	19582	41387	59497	52592	113553	49004	136843	91756	77558	82570
		7325	10019	14338	16795	31673	34164	24113	24272	39571	42632	35670	40648

Table 13. Cod biomass (MT) from stratified-random cruises conducted by France in Subdivision 3Ps.

Depth (m)	Strata	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
< 55	314	17	0		1390	111	30	0	7	13	133		17
	320	108	814		3797	513	2803	3526	104	14	0	0	316
	TOTAL	125	814		5187	624	2833	3526	111	27	133	0	333
56-90	308	371	9	150	88	299	151	111	65	100	29	6	25
	312	820	270	112	2304	454	636	1403	145	343	0	28	55
	315	771	850	0	1076	821	326	16918	8	1813	2058	2134	198
	321	183	4785	3746	2199	3746	1362	1026	3	543	0	649	0
	325				2101		1332	1466	81	259	0	453	0
	TOTAL	2145	5914	4008	7768	5320	3807	20924	302	3058	2087	3270	278
91-180	307	3598	2714	4428	1876	9009	6269	5384	2976	23172	8089	565	6168
	311	87	3199	1136	5797	8202	3572	19599	1276	20627	1356	4815	675
	317	0	260		813	454	421	21353	1502	2562	1049	815	973
	319	997	5810	1303	4435	4078	11349	8101	2831	3179	5746	5434	5889
	322	605	1945	3381	1793	2404	967	1122	2388	5944	2734	215	864
	323	91	572	858	822	54	794	803	512	2399	953	311	60
	324				0		815	964	594	288	99	171	90
	TOTAL	5378	14500	11106	15536	24201	24187	57326	12079	58171	20026	12326	14719
181-270	306	3080	2660	2162	12197	3716	11967	2296	804	23131	8294	4041	4691
	309	167	2743	804	2176	1122	3318	3852	1581	7434	1901	4827	7947
	310	411	190	19	481	1683	739	229	4675	169	503	739	164
	313	113	331	1	1099	1279	840	170	1753	142	562	26	373
	316	91	121	39	282	544	36	332	38395	695	334	320	2324
	318	42	25		593	34	5282	786	1828	28349	259	4558	941
	TOTAL	3904	6070	3025	16828	8378	22182	7665	49036	59920	11853	14511	16440
[illegible]1-365	705	321	1115	13	574	4550	984	1661	99	414	354	394	325
	706	11	0	293	952	4010	375	1141	333	3896	13845	1413	296
	707		1303		13	10980	652	49	2314	3338	134	102	118
	715	836	832	1564	827	4159	1261	3806	2282	2613	1908	1772	542
	716	178	455	1169	554	2104	1934	2326	86	2775	5685	6264	439
	TOTAL	1346	3705	3039	2920	25803	5206	8983	5114	13036	21926	9945	1720
365-545	708				85	373	44	8	593	849	6136	264	429
	711				0		296						
	712				0		300						
	713				108								
	714				354		0						
	TOTAL				547	373	640	8	593	849	6136	264	429
0-545	TOTAL	12899	31002	21178	48787	64699	58856	98433	67235	135061	62164	40316	33918

Table 14. Mean numbers of cod at age from R.V. surveys conducted by France in NAFO Subdivision 3Ps adjusted for missing strata.

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1		.07		.06	1.03	4.63	.03	.13	.08	3.29	5.27	1.87
2	.73	.43	7.38	.18	12.00	10.79	11.58	5.49	7.24	20.62	14.86	24.70
3	1.57	.39	1.72	4.91	1.96	5.40	7.64	14.49	4.21	11.51	14.89	16.02
4	3.08	2.08	.50	4.94	8.32	2.98	15.07	7.47	15.19	2.83	9.22	8.20
5	2.05	7.29	2.67	5.14	7.97	7.21	8.74	3.93	26.47	8.30	3.62	5.81
6	1.20	3.27	4.52	7.45	6.06	6.11	18.97	1.06	21.66	12.49	6.53	3.48
7	.89	1.82	1.66	5.64	4.55	4.55	5.59	1.95	9.12	8.32	4.69	4.43
8	.52	.96	.67	1.60	5.30	2.77	2.13	1.14	6.97	2.95	1.60	2.03
9	.30	.38	.29	1.19	1.58	2.08	3.09	.78	3.85	1.94	.78	1.01
10	.22	.22	.22	.47	.87	.75	2.21	.86	.79	.95	.35	.27
11	.02	.29	.18	.15	.42	.25	.61	1.09	.59	.20	.35	.13
12	.04	.09	.11	.14	.15	.19	.16	1.32	.72	.36	.16	.06
13	.01	.10	.08	.06	.21	.08	.13	.12	.22	.15	.15	.07
14+	.03	.22	.18	.13	.10	.06	.12	.23	.32	.29	.33	.08
3+	9.94	17.12	12.80	31.82	37.49	32.42	64.46	34.43	90.11	50.25	42.64	41.59
6+	3.23	7.35	7.92	16.83	19.23	16.84	33.00	8.55	44.25	27.62	14.93	11.56
Total	10.72	17.71	20.25	32.14	50.59	47.92	76.11	40.05	97.47	74.24	62.76	68.16
Nb traits (NO. SETS)	69	64	40	83	74	88	74	84	82	69	73	106
	Feb 21-Mar 25	Feb 21-Mar 20	Mar 3-Mar 12	Feb 24-Mar 31	Mar 5-Apr 2	Feb 10-Mar 19	Feb 15-Mar 19	Feb 9-Mar 10	Feb 9-Mar 10	Feb 4-Mar 6	Feb 9-Mar 11	Feb 15-Mar 18

17. COMMERCIAL CATCH RATE INDEX FOR COD IN SUBDIV 3PS FOR 1977-88.

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.	CATCH	EFFORT
1977	¯0.2661	0.0318	0.919	0.163	7645	8321
1978	0.1065	0.0359	1.331	0.250	7256	5452
1979	0.0099	0.0279	1.213	0.202	9098	7499
1980	¯0.1462	0.0297	1.037	0.178	7927	7644
1981	0.0300	0.0296	1.237	0.212	12491	10100
1982	0.3318	0.0285	1.673	0.281	11542	6897
1983	0.5215	0.0247	2.027	0.317	13693	6755
1984	0.8431	0.0370	2.778	0.530	13308	4790
1985	0.9492	0.0279	3.104	0.516	25871	8336
1986	0.4520	0.0251	1.890	0.298	32693	17294
1987	0.4189	0.0252	1.829	0.289	30161	16493
1988	0.1252	0.0247	1.364	0.213	23140	16968

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.169

BLE . CANADIAN COMMERCIAL CATCH RATE INDEX FOR COD IN SUBDIV 3PS FOR 1977-89.

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.	CATCH	EFFORT
1977	¯0.4715	0.0223	0.629	0.094	5494	8736
1978	¯0.1039	0.0250	0.907	0.143	2699	2976
1979	¯0.2307	0.0228	0.800	0.120	3074	3843
1980	¯0.3736	0.0247	0.693	0.108	3505	5060
1981	0.0716	0.0231	1.082	0.164	3457	3195
1982	0.3527	0.0252	1.432	0.226	3555	2483
1983	0.4094	0.0233	1.517	0.231	3546	2338
1984	1.1502	0.0447	3.148	0.660	2660	845
1985	1.2964	0.0234	3.682	0.562	7671	2083
1986	0.3127	0.0198	1.379	0.193	6770	4908
1987	0.4104	0.0203	1.521	0.216	5468	3596
1988	0.3410	0.0180	1.420	0.190	5174	3643
1989	0.3615	0.0266	1.443	0.234	3752	2599

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.155

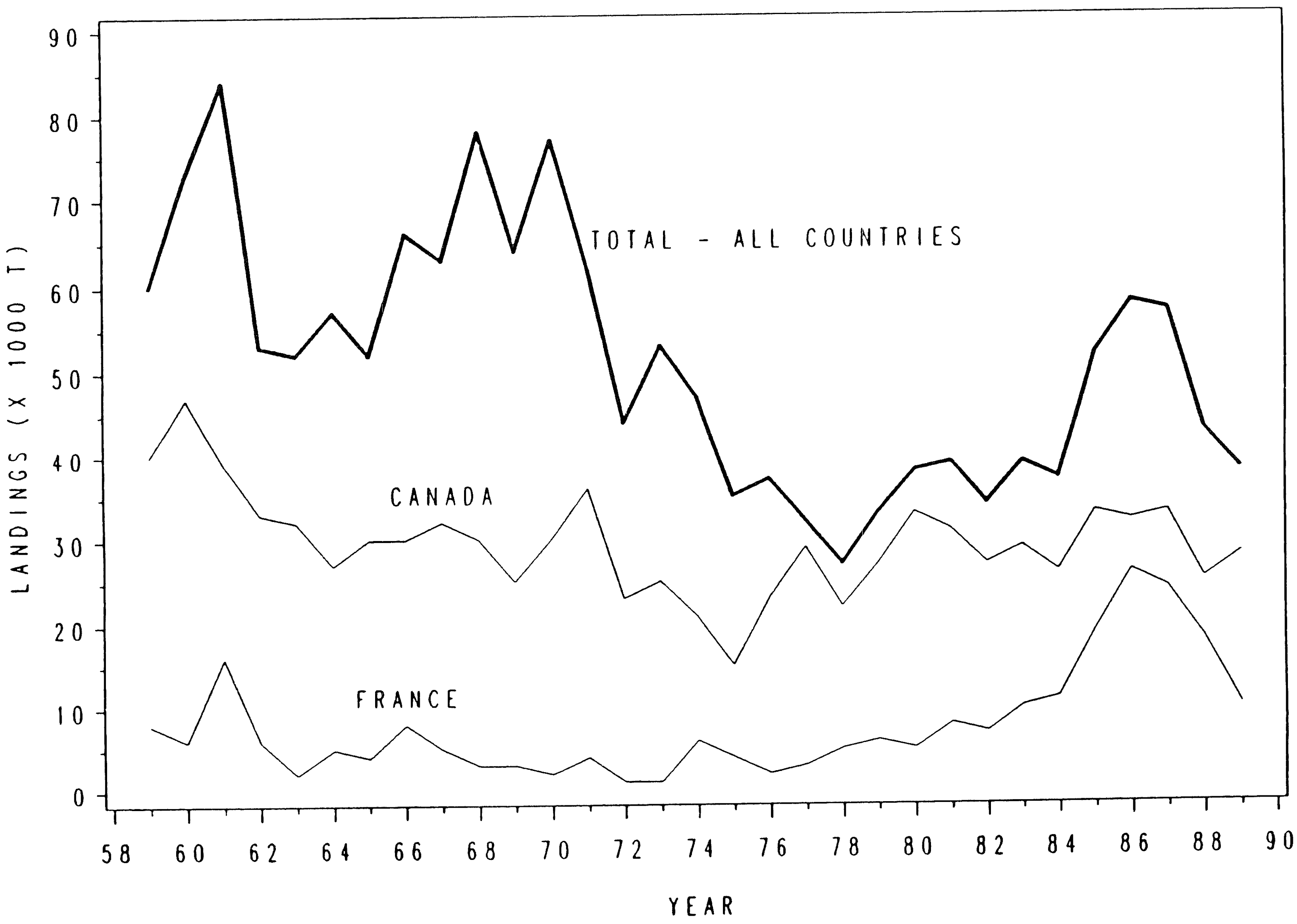


FIG. 1. LANDINGS OF COD IN SUBDIVISION 3PS FOR CANADA AND FRANCE FOR THE YEARS 1959-89.

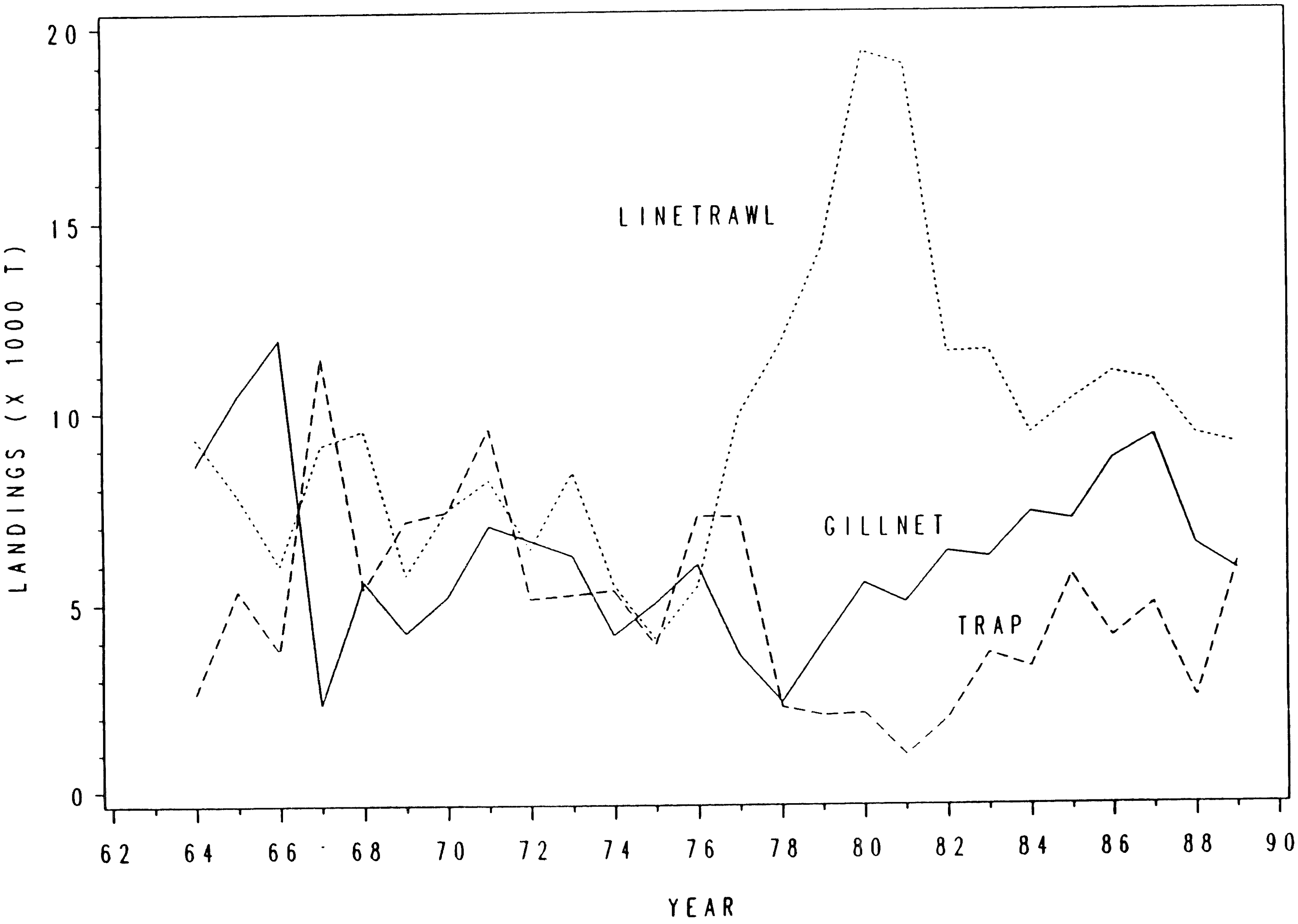


FIG. 2. INSHORE COD LANDINGS BY GEAR IN SUBDIVISION 3PS FOR THE PERIOD 1964-89.

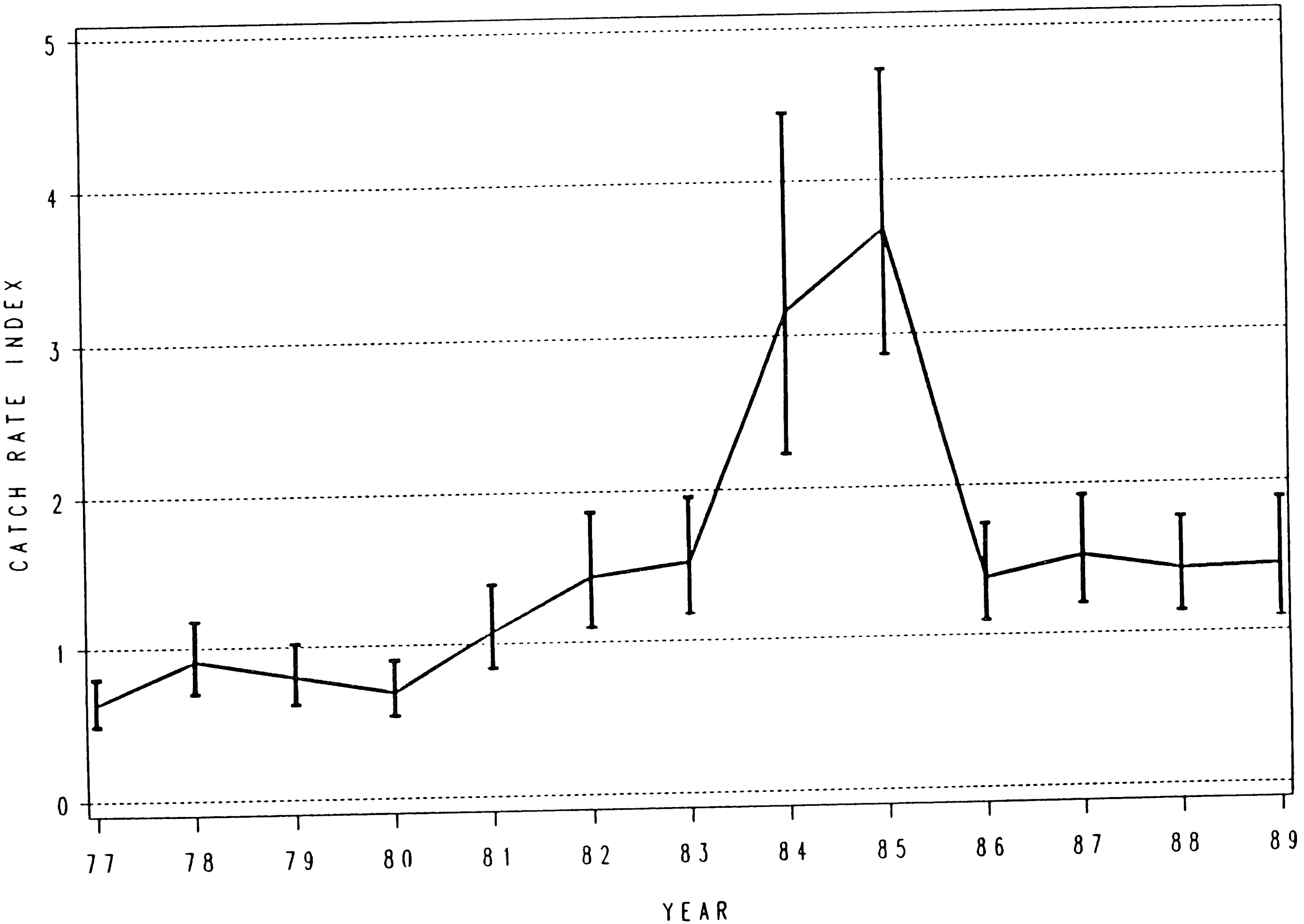


FIG . CANADIAN CATCH RATE INDEX WITH APPROXIMATE
90% C. I. FOR SUBDIV. 3PS COD (1978-88).

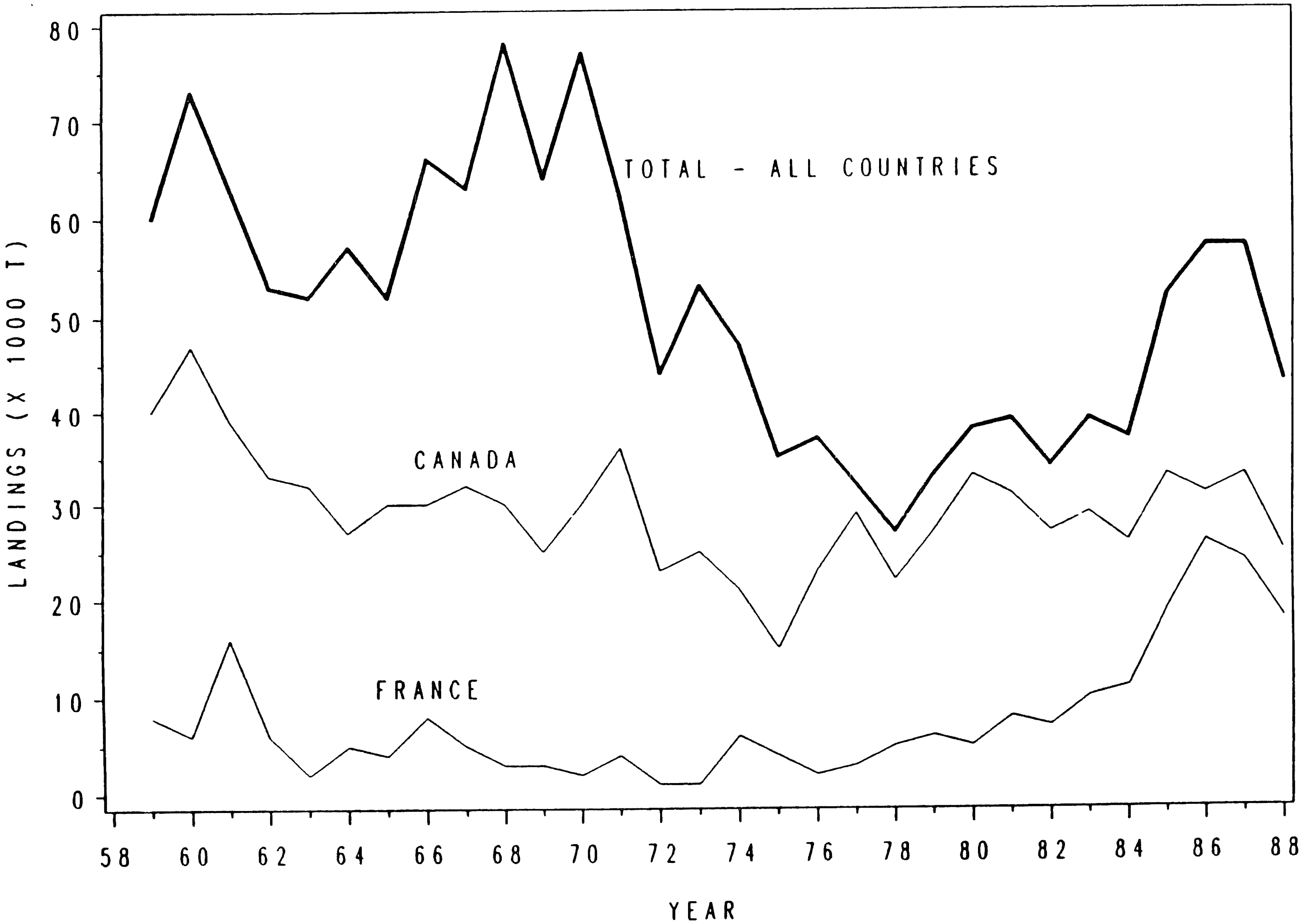


FIG. 1. LANDINGS OF COD IN SUBDIVISION 3PS FOR CANADA AND FRANCE FOR THE YEARS 1959-88

ABLE 26. BEGINNING OF THE YEAR POPULATION NUMBERS AND FISHING MORTALITY DERIVED FROM ADAPT USING CANADIAN AND FRENCH RV SURVEY AND COMMERCIAL C/E AGES 3-12 IN A SINGLE ANALYSIS FOR COD IN SUBDIVISION 3Ps.

POPULATION NUMBERS (000S)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	39103	23240	35547	64038	43361	74801	73804	67956	27395	43663	81168
4	60173	31561	18905	28770	51505	35383	60555	60242	55451	22178	35224
5	26917	44609	23060	14008	20942	37562	26542	45487	45053	40944	15519
6	12123	16522	27184	14307	8631	13137	22452	17625	26861	27694	23751
7	4267	6301	8943	14877	7504	4942	7064	12032	8894	11875	14087
8	1580	1907	3030	4264	6882	3555	2461	3774	5262	3439	5044
9	627	703	909	1346	2024	2975	1870	1486	1736	2368	1590
10	418	301	365	448	614	1078	1494	1041	840	843	865
11	156	181	170	195	209	283	662	917	511	488	397
12	144	62	100	89	99	96	149	420	450	266	258
13	52	93	29	41	41	54	45	91	226	241	149
14	24	27	65	5	18	24	28	30	52	114	88
3+	145584	125507	118307	142389	141830	173891	197126	211101	172730	154115	178139

FISHING MORTALITY

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	0.014	0.006	0.012	0.018	0.003	0.011	0.003	0.003	0.011	0.015	0.013
4	0.099	0.114	0.100	0.118	0.116	0.087	0.086	0.091	0.103	0.157	0.166
5	0.288	0.295	0.277	0.284	0.266	0.315	0.209	0.327	0.287	0.345	0.412
6	0.454	0.414	0.403	0.445	0.358	0.420	0.424	0.484	0.616	0.476	0.342
7	0.605	0.532	0.541	0.571	0.547	0.497	0.427	0.627	0.750	0.656	0.492
8	0.610	0.541	0.611	0.545	0.639	0.442	0.304	0.576	0.598	0.572	0.532
9	0.534	0.456	0.507	0.585	0.430	0.489	0.386	0.371	0.522	0.807	0.602
10	0.636	0.369	0.424	0.564	0.575	0.288	0.288	0.511	0.342	0.553	0.440
11	0.715	0.391	0.451	0.477	0.579	0.439	0.253	0.513	0.451	0.439	0.402
12	0.233	0.553	0.685	0.571	0.406	0.556	0.300	0.422	0.425	0.379	0.324
13	0.451	0.167	1.559	0.656	0.351	0.458	0.219	0.347	0.481	0.801	0.504
14	0.604	0.520	0.550	0.566	0.571	0.461	0.375	0.586	0.652	0.650	0.504

3NO Cod

History

Catches since 1959 have ranged from a high of 225,000 t in 1967 to a low of 15,000 t in 1978. With the exception of 1986, catches since 1984 have been stable and averaged about 38,000 t. The fishery is conducted mainly by Canada and Spain, the Canadian fishery mainly by otter trawl while that for Spain is almost exclusively by pair trawlers. The Spanish fishery is conducted outside the 200 mile fishery zone, mainly on the Tail of the Grand Bank.

This stock interacts with some degree of mixing with neighboring Subdiv. 3Ps cod and probably to a greater degree with the 2J3KL (3L portion) stock.

Stock structure

The mean 3+ biomass increased from 45,000 t in 1976 to 190,000 t in 1986 and subsequently declined to about 126,000 t in 1988. Earlier data (since 1959 would suggest that the age 3+ biomass had been as high as 220,000 t in the mid 1960's. High fishing mortalities in the latter period along with declining recruitment levels led to reduced stock size and subsequent reduced catches. Fully recruited F since 1978 ranged from 0.17 to 0.36, with the estimate of 0.36 occurring in 1988.

The major reason for declines in recent years has been lower than average sizes of recruiting year-classes. The 1983 and 1984 year-classes are the lowest observed in the time series.

Environment

As with the 3Ps cod stock, the major environmental influences on distribution are the Labrador Current and the Gulf Stream. Seasonally the cold Labrador Current can cover an extensive portion of the stock area causing cod to be distributed in deeper waters on the edge of the bank. The Gulf Stream occasionally makes incursions onto the bank such that temperature gradients can be steep and produce substantial local variations in water temperature.

Spawning

Spawning occurs mainly in May and June; most likely along the slopes of the bank.

Migration

The main migration pattern in this stock is from the slope areas in spring to the plateau of the bank where the cod feed mainly on sand lance, and a return to the warmer water slope areas in winter.

Growth

Cod in this area grow fairly rapidly. At age 2 they are approximately 24 cm long, at age 4 about 43 m, and by age 6 over 60 m. Sexual maturity commences at about age 4 and by age 8 all are mature. Cod ranging to age 15 are common in commercial and research catches but those beyond age 20 and rare.

Judge, C. C., V. E. Griffiths, R. C. Hills, and T. C. Lee. 1980. The theory and practice of econometrics. John Wiley and Sons, New York. 793p.

NAFO Scientific Council Reports. 1988. 149p.

Vasquez, A. 1988. Spanish Research Report. NAFO SCS Doc. 88/14. Ser. No. N1472. 10p.

Table 1. Catch (metric tons) of cod in NAFO Divisions 3NO.

Year	Canada	Spain	Portugal	USSR	Others	Total
1953	39,884	12,633	7,919	-	5,761	66,197
1954	17,392	88,674	24,045	-	4,650	134,761
1955	6,053	64,987	27,711	-	15,605	114,356
1956	5,363	42,624	15,505	-	1,390	64,882
1957	9,641	51,990	21,740	-	6,819	90,190
1958	4,812	29,436	11,608	-	2,195	48,051
1959	3,687	39,994	17,730	48	2,911	64,370
1960	3,408	33,972	14,347	24,204	3,746	79,677
1961	5,428	32,284	9,059	22,854	3,099	72,724
1962	3,235	17,413	3,653	7,971	2,712	34,984
1963	5,079	37,632	10,004	10,184	6,843	69,742
1964	2,882	37,185	8,095	9,510	6,789	64,461
1965	4,229	64,652	1,692	17,166	11,448	99,187
1966	6,501	52,533	5,070	39,023	5,792	108,919
1967	3,446	77,948	9,703	118,845	16,842	226,784
1968	3,287	69,752	6,752	78,820	6,900	165,511
1969	3,664	71,160	4,940	29,173	8,768	117,705
1970	4,771	67,034	3,185	28,338	8,233	111,561
1971	2,311	89,915	6,589	19,307	8,174	126,296
1972	1,736	76,324	11,537	12,198	1,579	103,374
1973	1,832	42,403	7,759	27,849	586	80,429
1974	1,360	38,338	6,602	26,911	178	73,389
1975	1,189	16,616	5,560	20,785	24	44,174
1976	2,065	9,880	2,620	8,992	726	24,283
1977	2,532	8,827	1,742	4,041	462	17,604
1978	6,246	5,813	641	1,819	199	14,718
1979	9,938	13,782	1,140	2,446	545	27,941
1980	~~5,084~~ 5589	8,999	1,145	3,261	~~871~~ 997	19,360
1981	6,096	13,299	1,091	3,187	671	24,344
1982	10,185	14,361	2,466	3,985	608	31,605
1983	11,374	12,320	1,109	3,238	~~778~~ 780	28,818
1984	8,705	13,590	1,071	3,306	431	27,103
1985	18,179	13,682	608	3,968	462	36,899
1986[a]	17,204	23,395	6,890	1,181	2,802	51,472
1987[a]	18,426	15,788	4,108	375	233	38,930
1988[a]	19,625	16,502		2,590	401	39,118

[a]Provisional.

TABLE 4. CATCH, AVERAGE WEIGHT AND LENGTH AT AGE FOR THE COMMERCIAL FISHERY FOR COD BY CANADA IN DIVISIONS 3NO DURING 1988.

AGE	AVERAGE		CATCH		
	WEIGHT	LENGTH	MEAN	STD. ERR.	C. V.
3	0.742	43.789	32	7.95	0.25
4	1.018	48.751	148	22.89	0.15
5	1.418	54.159	700	68.87	0.10
6	1.865	59.115	2765	109.73	0.04
7	2.321	63.263	1556	95.67	0.06
8	4.093	75.532	421	36.66	0.09
9	5.685	83.807	219	23.94	0.11
10	7.533	92.073	188	14.68	0.08
11	9.709	100.961	139	10.80	0.08
12	11.200	105.775	81	7.67	0.09
13	12.745	110.440	98	8.18	0.08
14	14.235	114.569	67	6.44	0.10
15	14.723	115.385	31	4.05	0.13
16	17.520	122.813	7	1.45	0.21
17	18.567	125.184	5	2.55	0.49
18	20.751	130.000	1	0.53	0.65
19	30.971	148.000		0.00	0.01

Table 5. Biomass estimates (MT) by stratum from survey cruises in Div. 3N.

Strata	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	1988	1989
357			1383				29		52	332	135	92	0	2102	259		18	22
358		1061	1772				383		483	1054	229	236	182	122	547	1803	229	486
359		312	258			660	147		190	478	208	13	71	0	134	43	44	21
360		1966			306	1950	4040	2182	1416	1738	3743	1238	7877	9161	1945	1282	494	1202
361	2909	4525	2525	350	3246	2618	5894	8203	2666	4173		8125	12838	29220	50957	27584	15887	12722
362	2127	9695	4222	2233	306	1666	6836	6621	1632	5847	8701	3708	40764	16509	19686	69852	12714	16464
373	8159	3423	1855	2362		1031	1750	4300	1838	857	4578	6647	17916	2446	2897	6788	5959	6090
374	501	702	273	0	135		1248	1324	479	0	146	2369	8335	877	769	1058	4032	489
375	3270	9977	1042	955	1060		5429	3598	369	3229	29835	5943	2404	18475	14586	8034	16512	20104
376		1892	806		383	77	9672	102	868	855	2208	2	1049	391	1883	2876	4454	745
377		550	14	83	283		1380	130	22	287	428	22	29	13	54	328	0	9
378	530	4146	404	632			687	90	281	939	104	303	133	470	256	73	96	81
379			1828	515			50	0	601	178	53	179	129	324	365	4	15	22
380	9	322	1317	206			52		232	57	25		224	847	135	454	181	176
381	480	1429	2386	359	122		2677	393	196	427	533	2186	478	1544	747	82	270	39
382	142	2458	9	69		42	948	2215	220	285	182	36	0	16	61	12	7	419
383	231	1479	1	16		44	324	1564	146	0	430	5	294	0	0	818	71	335
Total	18357	43935	20096	7781	15381	8088	41546	30722	11692	20736	51538	31104	52725	82515	95280	121091	60982	59425
Upper limit	35959	58509	29260	13257	35224	13399	61360	37915	16334	28150	120675	46068	123845	108355	162513	159883	80483	81925
Lower limit	755	29362	10931	2304	-4462	2776	21732	23529	7051	13322	-17600	16141	61605	56674	28046	82300	41481	36925

Table 6. Biomass estimates (MT) by stratum from survey cruises in Division 3O.

Strata	1973	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	1988	1989
329	211		6422	180	2008	357	18	487	373	560	840	304	45335	9436	682
330	9251	475	287	593	2218	3753	470	3371	123	3626	4642	2130	5654	2767	1713
331	288	729	454		342	150	609		38	2630	3423	685	804	1224	183
332		830	351	94[illegible]	4525	2266	9		3474	2358	13471	2499	9808	8681	1369
333		525	82	0	2	0	28		153	0	147	232	1057	0	1040
334			6	0	6	0	43		8	0	570	3481	59	248	136
335	22		3		0	0	10		11	0	0	126	18	39	7
336	29	0	0	136	3	1	286		104	0	34	45	17	18	23
337	78	1906	32	630	614	23	133		610	434	1203	8497	2674	382	2787
338	4298	5563	1876	6953	1334	5729	1795		5659	29905	7485	14405	9838	9124	14874
339	1547	49			249	1475		505	610	1087	359	29	354	233	146
340		2029	2690	298	966	3718	386	4294	2849	6827	5431	5796	77479	12421	2977
351	3092	1562	2684	8141	4334	47954	5629	6621	4498	43455	23490	38217	66032	15852	11619
352	3075	426	1429	6120	3961	10008		5625	6236	34168	29692	15071	49765	57457	34373
353	3265	77	2	262	84	1573	2		472	0	6083	951	9610	626	2371
354	439		38	8		34	273	44	125	489	219	180	2179	530	25
355	76	0	4			24	367	32	135	0	135	12	114	19	195
356	11					12	49	9		0	0	32	7	102	74
Total	25581	14161	16360	24261	20646	76966	15733	15363	25478	125339	97223	92699	280807	119157	74595
Upper Limit	35514	58392	65071	38015	34853	133278	24517	25164	33766	169942	126100	136099	382599	179304	134314
Lower Limit	15848	30070	-32350	10508	6442	20645	6950	5561	17191	80736	68346	49299	179014	59009	14876

Table 7. Mean number and weight of cod per standard tow from research vessel surveys in NAFO Division 3N, 3O, and 3NO.

Div.	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	1988	1989	
Mean Number per tow																			
3N	44.60	33.33	12.17	8.51	17.10	10.30	32.37	25.00	5.59	11.28	16.38	15.54	40.01	24.96	10.34	55.37	8.30	7.01	8
3O			10.48		10.31	12.63	18.93	16.93	46.36	8.52	8.62	21.86	36.36	15.84	33.72	116.31	16.20	9.82	10
3NO			11.90		13.23	11.61	25.70	20.78	26.28	9.85	14.60	18.77	38.03	20.24	22.44	87.07	12.39	8.46	9
Mean Weight per tow																			
3N	24.51	34.05	18.03	8.91	17.57	8.24	33.32	25.98	9.34	16.56	46.30	25.01	74.05	65.90	76.09	97.66	48.70	47.43	6
3O			25.19		12.17	12.63	19.42	15.93	57.28	12.17	22.32	19.13	93.8	72.35	68.98	208.96	88.67	55.48	5
3NO			21.40		14.48	10.71	26.36	20.72	32.74	14.29	37.00	21.92	84.01	69.24	72.41	155.55	69.35	51.60	6

Table 8. Cod abundance (000s) from stratified-random cruises in Division 3N. Numbers in brackets are estimates for non-sampled strata.

Depth range (fath)	Strata	Area	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	[illegible]
0–30	375	1593	5076	3826	353	1435	6616	(1328)	7474	4329	263	508	10583	1578	1746	3184	912	2167	1116
	376	1499	(1740)	788	37	(243)	1294	113	3601	225	225	113	225	33	7933	48	177	2813	375
31–50	360	2992	(7146)	1516	(863)	(1095)	2302	3425	4211	1011	1273	2695	523	2118	5680	3005	552	1198	1422
	361	1853	5747	5796	835	904	3623	723	5610	4764	1166	1808	(4622)	4961	3283	10293	3310	10484	2841
	362	2520	2484	11823	984	1466	431	1021	5830	7440	757	1203	3859	1608	18971	4385	2391	43871	1702
	373	2520	18897	3831	142	426	(1942)	76	946	5959	327	331	1892	1589	8160	770	675	4307	1097
	374	931	1563	175	175	1	140	(186)	1607	1817	297	1	163	1677	2893	175	47	266	363
	383	674	74	1644	51	25	(124)	17	320	1493	34	1	118	25	34	1	1	422	51
51–100	359	421	(1903)	822	622	(303)	(688)	4709	1359	(1392)	549	2133	611	126	95	0	1264	332	269
	377	100	(621)	1066	143	613	413	(104)	2800	105	73	490	1146	278	56	105	23	758	0
	382	647	425	3447	16	130	(243)	24	2639	1943	243	255	146	194	0	134	12	16	24
101–150	358	225	(2425)	861	4189	(397)	(885)	(414)	262	(1776)	431	1993	135	1343	380	448	760	1478	549
	378	139	619	3673	459	1683	(620)	(290)	657	120	400	1645	193	1236	318	2181	433	151	157
	381	182	1195	779	861	79	156	(280)	3267	364	155	379	779	1851	301	2391	1312	68	191
151–200	357	164	(373)	(320)	1157	(57)	(133)	(60)	12	(272)	49	336	37	382	0	2381	137	(319)	6
	379	106	(406)	(349)	1802	785	(146)	(67)	24	0	671	408	40	322	175	525	801	4	8
	380	116	17	118	641	70	(104)	(47)	22	(212)	96	26	15	(104)	83	788	136	313	226
Total		16682	50712	41732	13373	9709	19861	12844	40640	33220	7008	14124	25085	19426	50108	31262	12943	68968	10397
Estimated mean per tow			40.50	33.33	10.68	7.75	15.86	10.28	32.45	26.53	5.60	11.28	20.03	15.01	40.02	24.97	10.34	55.08	8.30

Table 9. Cod abundance (000s) from stratified-random cruises in Division 3O. Numbers in brackets are estimates for non-sampled strata.

Depth range (fath)	Strata	Area	1973	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	1988	1989
31-50	330	2089	2144	419	679	889	1071	3674	1411	941	359	1921	1461	823	3763	993	342
	331	456	34	49	624	(325)	240	205	1284	(219)	377	993	548	214	650	240	137
	338	1898	2451	4987	3230	9047	1311	2666	1681	(2621)	4103	10116	2391	2976	5305	1781	3818
	340	1716	(1739)	215	4164	258	708	1730	386	859	2340	2898	2733	2576	55431	1178	615
	351	2520	2837	936	615	4843	2535	39981	1513	3689	8701	18538	4413	32509	28753	2913	1470
	352	2580	3409	1290	1791	5965	4648	3486	2113	(3288)	3486	11814	4859	2988	12097	8821	3769
	353	1282	224	705	48	320	1732	4388	48	(310)	257	1	674	165	1700	1674	385
51-100	329	1721	129	(551)	3682	172	1731	1012	65	129	753	775	501	501	42933	22133	388
	332	1047	(1255)	1729	367	1729	7309	2613	118	(930)	5678	236	1839	458	2546	1297	393
	337	948	735	688	356	249	320	516	48	(276)	285	142	939	882	451	249	1281
	339	585	220	22	(212)	(250)	329	1361	(127)	198	2448	1054	88	29	278	102	15
	354	474	261	(186)	712	36	(401)	729	2075	107	107	142	261	178	1975	160	36
101-150	333	151	(17)	958	85	0	4	0	6	(11)	60	0	17	53	340	0	283
	336	121	9	0	0	141	5	2	95	(4)	41	0	9	45	9	5	5
	355	103	19	0	4	(18)	(24)	19	128	19	151	0	398	12	54	12	178
151-200	334	92	(8)	(4)	7	0	2	0	21	(5)	3	0	152	856	14	70	52
	335	58	7	(0)	1	(1)	0	0	3	(0)	4	0	0	40	4	7	4
	356	61	2	(0)	(1)	(1)	(2)	5	18	2	(2)	0	0	9	2	30	37
Total		17902	15498	12738	16580	24242	22372	62388	11140	13609	29155	48628	21283	45316	156302	21767	13206
Estimated mean no. per tow.			11.53	9.48	12.34	18.04	16.65	46.43	8.29	10.13	21.70	36.19	15.84	33.72	116.31	16.20	9.82

Table 10. Mean number of cod at age and per standard tow from research vessel surveys in NAFO Divisions 3NO.

	1971[a]	1972[a]	1973	1974[a]	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	1988
# Sets	45	45	94	37	58	78	88	88	172	140	77	130	116	178	203	191	161
Age																	
1	0.0	0.01	0.07	0.05	0.46	0.58	0.01	0.55	3.09	0.01	0.35	1.56	0.01	0.01	.02	.21	.01
2	4.18	1.17	2.64	1.39	3.16	3.89	2.35	0.71	0.93	5.39	0.38	9.37	3.28	0.41	.70	2.77	1.67
3	42.14	9.01	2.69	4.97	4.70	2.89	9.71	7.07	2.33	1.38	5.39	1.18	6.20	4.47	.71	2.85	2.22
4	5.80	19.28	1.88	0.89	2.64	1.83	6.29	8.17	9.25	0.67	1.58	3.54	9.90	6.05	7.71	9.33	.46
5	4.43	1.72	2.48	0.44	0.59	1.66	4.63	2.48	7.84	1.07	1.83	.60	5.29	2.41	6.46	34.86	.41
6	1.06	.71	0.50	0.38	0.31	0.26	1.54	0.96	1.76	0.44	2.32	.47	5.60	.88	1.62	21.25	1.06
7	1.08	.58	0.28	0.14	0.60	0.07	0.49	0.61	0.52	0.21	1.13	.78	1.87	.97	.68	8.33	1.17
8	0.48	.41	0.20	0.04	0.25	0.13	0.22	0.04	0.26	0.18	0.50	.58	1.00	.73	.65	1.78	.78
9	0.24	.30	0.22	0.01	0.25	0.06	0.10	0.01	0.10	0.18	0.53	.26	1.81	.88	.50	1.94	.82
10	0.03	.17	0.13	0.07	0.08	0.07	0.10	0.03	0.02	0.09	0.24	.16	1.57	1.34	.74	.69	.87
11	0.08	.08	0.06	0.03	0.01	0.02	0.01	0.04	0.06	0.05	0.04	.07	.86	.98	1.20	.77	.44
12	0.14	.05	0.09		0.02		0.04	0	0	0.07	0.14	.05	.32	.49	.65	.71	.55
13			0.14		0.01		0.09	0.04	0.04	0.03	0.06	.01	.11	.24	.36	.81	.79
14+	0.47	.36	0.50	0.15	0.15	0.05	0.12	0.01	0.10	0.12	0.17	.14	.22	.39	.52	.77	1.24
Mean no. per tow	60.13	33.85	11.89	8.56	13.23	11.51	25.70	20.72	26.30	9.89	14.66	18.76	38.03	20.24	22.42	87.07	12.39
Upper Limit	117.35	51.51	15.47	12.50	25.93	17.94	33.96	31.81	47.18	12.85	23.61	25.28	47.82	24.06	44.11	119.64	15.18
Lower Limit	2.93	16.10	8.33	4.62	0.52	5.09	17.45	9.90	5.49	6.91	5.70	12.24	28.25	16.42	0.74	54.49	9.60

[a]Survey 3N only.

Table 11. Mean number per tow at age of cod from RV surveys conducted by Canada in Div. 3NO (1971, 1972 & 1974 surveys in 3N only). Estimates adjusted for non-sampled strata.

1/ 6/89

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1984	1985	1986	1987	1988
1	0.00	0.01	0.07	0.05	0.44	0.57	0.01	0.57	3.14	0.01	0.36	1.54	0.01	0.01	0.02	0.21	0.01
2	2.82	1.15	2.47	1.26	3.00	3.84	2.29	0.73	0.95	5.30	0.39	9.73	3.28	0.41	0.70	2.76	1.67
3	28.38	6.87	2.52	4.50	4.46	2.85	9.44	7.31	2.37	1.36	5.48	1.16	6.20	4.47	0.71	2.84	2.22
4	3.91	18.98	1.76	0.81	2.51	1.80	6.12	8.45	9.40	0.66	1.61	3.49	9.90	6.05	7.72	9.30	0.46
5	2.98	1.69	2.32	0.40	0.56	1.64	4.50	2.56	7.97	1.05	1.86	0.59	5.29	2.41	6.47	34.75	0.41
6	0.71	0.70	0.47	0.34	0.29	0.26	1.50	0.99	1.79	0.43	2.36	0.46	5.60	0.88	1.62	21.18	1.06
7	0.73	0.57	0.26	0.13	0.57	0.07	0.48	0.63	0.53	0.21	1.15	0.77	1.87	0.97	0.68	8.30	1.17
8	0.32	0.40	0.19	0.04	0.24	0.13	0.21	0.04	0.26	0.18	0.51	0.57	1.00	0.73	0.65	1.77	0.78
9	0.16	0.30	0.21	0.01	0.24	0.05	0.10	0.01	0.10	0.18	0.54	0.26	1.81	0.88	0.50	1.93	0.82
10	0.02	0.17	0.12	0.06	0.08	0.07	0.10	0.03	0.02	0.09	0.24	0.16	1.57	1.34	0.74	0.69	0.87
11	0.05	0.08	0.06	0.03	0.01	0.02	0.01	0.04	0.06	0.05	0.04	0.07	0.86	0.98	1.20	0.77	0.44
12	0.09	0.05	0.08	0.00	0.02	0.00	0.04	0.00	0.00	0.07	0.14	0.05	0.32	0.49	0.65	0.71	0.55
13	0.00	[illegible]	0.13	0.00	0.01	0.00	0.09	0.04	0.04	0.03	0.06	0.01	0.11	0.24	0.36	0.81	0.79
14+	0.32	0.25	0.47	0.14	0.14	0.05	0.12	0.01	0.10	0.12	0.17	0.14	0.22	0.39	0.52	0.77	1.24
1+	40.50	23.33	11.11	7.75	12.56	11.35	24.99	21.42	26.74	9.73	14.91	18.48	35.05	20.25	22.54	86.80	12.49
2+	40.50	23.32	11.05	7.70	12.12	10.78	24.98	20.85	23.60	9.72	14.55	16.94	35.04	20.24	22.52	86.59	12.48
3+	37.65	22.17	8.58	6.45	9.12	6.94	22.70	20.12	22.65	4.42	14.17	7.72	34.76	19.83	21.82	83.83	10.81
4+	9.31	[illegible]	6.06	1.95	4.66	4.09	13.25	12.81	20.28	3.06	8.69	6.56	28.56	15.36	21.11	80.99	8.59
5+	5.40	4.31	4.30	1.14	2.16	2.29	7.14	4.36	10.98	2.40	7.08	3.07	18.65	9.31	13.39	71.69	8.13
6+	2.41	2.52	1.98	0.74	1.59	0.55	2.64	1.80	2.91	1.35	5.22	2.48	13.36	6.90	6.93	36.94	7.72

TABLE 16. Jan 1 Population numbers for cod in Div. 3NO with F_t = 0.358 for 1988.

POPULATION NUMBERS (× 10^{-3})

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
3	5368	5309	8214	10776	7825	11238	16252	20999	18324	10050
4	9390	4240	4180	6652	8729	6378	8640	13215	17124	13185
5	1949	6508	2863	3024	5095	6626	3815	6385	9153	8370
6	1646	1137	3333	1302	2276	3157	3661	2434	3447	2941
7	1234	802	651	1348	923	1425	1868	1798	925	1147
8	428	654	442	351	779	581	961	637	704	326
9	286	225	309	210	217	290	375	350	117	156
10	336	166	131	176	112	72	166	209	121	75
11	220	191	101	90	105	37	30	23	18	83
12	30	70	75	80	53	57	27	10	8	8
3+	20888	19303	20320	24009	26115	29862	35795	46060	49942	36340
4+	15520	13994	12106	13234	18290	18623	19542	25061	31619	26290

AGE	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
3	12785	9032	8442	6211	3502	3654	2283	2714	4536	4258	1807
4	6749	9731	6396	6826	5079	1957	2410	1808	1855	3659	3403
5	5658	4355	6183	2794	3797	1661	743	1179	799	1296	2603
6	2455	2194	2589	2321	1176	1743	373	289	427	425	833
7	735	997	938	1061	685	421	443	78	138	214	274
8	365	413	487	451	336	382	141	86	45	61	143
9	123	173	190	172	217	187	119	20	49	21	41
10	82	54	93	111	115	114	62	14	12	21	12
11	45	40	30	58	71	72	32	9	8	4	13
12	60	25	13	16	40	46	20	3	6	3	3
3+	29055	26013	25351	20020	15018	10236	6625	6200	7876	9962	9132
4+	16270	17981	16908	13810	11516	6583	4342	3486	3340	5704	7324

AGE	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	2078	2921	2306	3549	5079	4716	952	1000	3300
4	1473	1676	2349	1861	2799	4153	3856	766	775
5	2440	1103	1279	1744	1465	2201	3133	2900	591
6	1298	1654	795	903	1257	1072	1241	1988	2080
7	430	877	1158	559	630	818	603	622	1338
8	144	292	555	810	396	406	442	357	407
9	93	101	190	319	559	259	260	275	237
10	28	70	67	102	191	374	171	161	154
11	8	21	49	35	62	107	258	104	90
12	9	6	14	25	22	41	64	177	51
3+	8002	8722	8760	9907	12459	14147	10979	8351	9024
4+	5925	5800	6454	6358	7380	9431	10027	7351	5724

TABLE 17. Average population biomass for cod in Div. 3NO with F_t = 0.358 for 1988

POPULATION BIOMASS (AVERAGE)

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
3	2008	1983	3110	4081	2972	4151	6166	9118	7495	3979
4	6446	2885	2928	4789	6256	4090	6114	9954	11007	8007
5	1884	5931	2486	3291	5061	6247	3841	6434	7387	6510
6	2289	1700	4276	2148	3544	4790	5109	3338	4473	3405
7	2577	1704	1369	2926	2083	3321	3227	3687	1815	2159
8	1071	1561	1057	945	1677	1595	2051	1294	1529	875
9	879	692	942	621	525	885	1131	1367	599	727
10	1202	612	511	645	315	224	340	600	775	452
11	686	653	474	367	413	164	93	120	106	597
12	137	312	343	382	229	285	101	56	48	52
3+	19178	18033	17498	20192	23077	25751	28172	35968	35233	26764
4+	17170	16050	14388	16111	20104	21601	22006	26850	27738	22785

AGE	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	197
3	5370	3445	3651	3038	1513	1255	774	1129	2327	2746	106
4	4918	7041	3911	5010	3058	915	1532	1124	1559	3256	283
5	4916	4584	5321	2692	3773	1034	615	1044	876	1623	260
6	3463	2163	3665	2788	1509	1861	402	476	765	774	127
7	1766	2249	2103	1822	1883	732	685	196	333	659	58
8	1034	1210	1274	1139	1178	1052	257	266	149	233	43
9	523	317	931	843	999	827	269	104	239	99	16
10	451	314	569	710	880	352	182	93	65	121	7
11	288	202	188	404	641	345	67	66	58	31	8
12	447	183	90	105	428	204	67	32	46	29	2
3+	23250	23207	21702	18551	15963	8577	4850	4530	6417	9573	913
4+	17880	19762	18051	15514	14449	7322	4076	3401	4090	6827	807

AGE	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	1327	2362	1951	2685	3634	2050	334	432	2203
4	1330	1865	2377	1936	2861	3112	3355	553	687
5	3417	1731	1620	2781	1900	2295	4154	3208	634
6	2685	3743	1475	1995	2330	1670	1926	3004	2805
7	1316	2497	3729	1798	1550	1986	1643	1460	2262
8	667	1265	2241	3518	1307	1523	1912	1396	1202
9	645	590	1057	1565	2652	1402	1644	1516	956
10	225	533	434	646	1046	2602	1314	1095	810
11	75	152	352	251	451	763	2133	737	647
12	100	50	134	231	221	358	497	1781	437
3+	11787	14789	15870	17406	17952	17762	18912	15183	12645
4+	10460	12426	13418	14721	14317	15712	18578	14751	10441

TABLE 19. Fishing mortality for cod in Div. 3NO with F_t = 0.358 in 1988.

FISHING MORTALITY

GE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
3	0.036	0.039	0.011	0.011	0.004	0.063	0.007	0.004	0.129	0.198	0.073
4	0.167	0.186	0.124	0.067	0.076	0.314	0.102	0.167	0.516	0.646	0.238
5	0.339	0.469	0.595	0.084	0.279	0.393	0.249	0.416	0.935	1.027	0.747
6	0.519	0.358	0.705	0.144	0.268	0.325	0.511	0.767	0.901	1.186	0.701
7	0.434	0.397	0.418	0.349	0.264	0.194	0.876	0.737	0.844	0.944	0.377
8	0.445	0.550	0.542	0.279	0.787	0.237	0.810	1.491	1.310	0.777	0.547
9	0.345	0.336	0.361	0.432	0.898	0.357	0.384	0.862	0.251	0.444	0.629
0	0.363	0.298	0.180	0.316	0.919	0.693	1.771	2.250	0.180	0.305	0.503
1	0.950	0.732	0.028	0.326	0.412	0.119	0.934	0.673	0.570	0.128	0.398
2	0.465	0.478	0.440	0.349	0.559	0.243	0.863	1.044	0.961	0.882	0.463

GE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	198
3	0.029	0.013	0.001	0.382	0.216	0.033	0.180	0.015	0.024	0.004	0.015	0.01
4	0.253	0.627	0.386	0.918	0.769	0.515	0.617	0.159	0.140	0.133	0.089	0.07
5	0.320	0.780	0.666	0.579	1.294	0.745	0.815	0.431	0.242	0.496	0.188	0.12
6	0.649	0.692	1.021	0.828	1.169	1.358	0.536	0.491	0.239	0.461	0.192	0.15
7	0.518	0.532	0.949	0.383	0.892	1.436	0.353	0.611	0.202	0.441	0.187	0.25
8	0.575	0.839	0.532	0.385	0.970	1.767	0.363	0.568	0.203	0.229	0.153	0.23
9	0.424	0.343	0.202	0.446	0.914	1.953	0.223	0.635	0.365	0.169	0.093	0.22
0	0.368	0.272	0.243	0.266	1.070	1.763	0.352	0.891	0.307	0.172	0.111	0.15
1	0.969	0.453	0.161	0.240	1.062	2.057	0.182	0.847	0.243	0.109	0.099	0.23
2	0.505	0.571	0.715	0.379	0.945	1.603	0.350	0.821	0.220	0.346	0.165	0.24

GE	1982	1983	1984	1985	1986	1987	1988
3	0.015	0.037	0.001	0.001	0.018	0.055	0.009
4	0.098	0.039	0.040	0.082	0.085	0.059	0.046
5	0.148	0.128	0.113	0.373	0.255	0.132	0.326
6	0.152	0.159	0.229	0.376	0.491	0.196	0.396
7	0.158	0.146	0.241	0.416	0.323	0.223	0.382
8	0.353	0.171	0.224	0.245	0.274	0.209	0.311
9	0.425	0.312	0.200	0.218	0.276	0.383	0.300
0	0.431	0.300	0.383	0.171	0.293	0.383	0.358
1	0.456	0.292	0.211	0.315	0.177	0.505	0.358
2	0.248	0.196	0.240	0.302	0.297	0.269	0.358

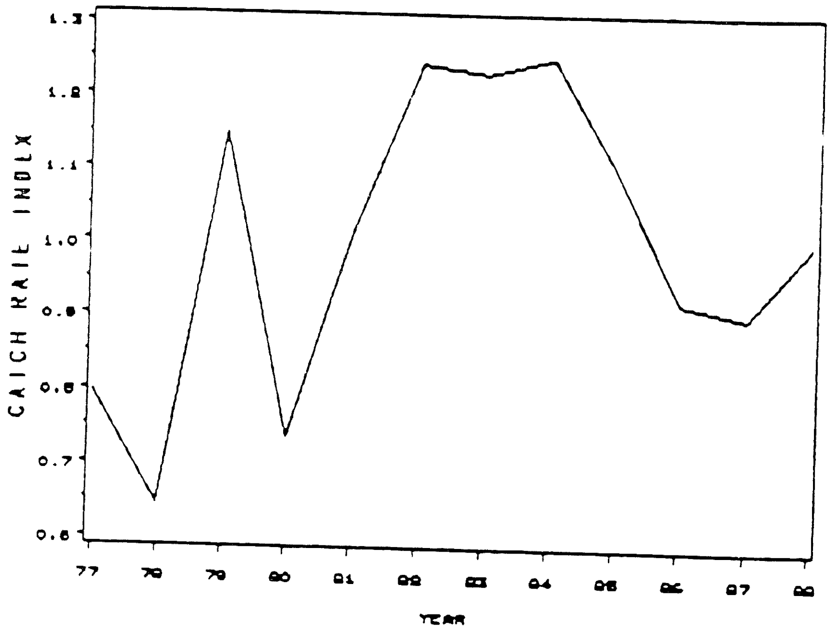


FIG. 1. Catch rate index derived from averaging Canadian OT & Spanish PT catch rates.

SUMMARY SHEET - Cod in Divisions 3N and 3O

Source of Information:

Year	1982	1983	1984	1985	1986	1987	1988	1989	Max[1]	Min[1]	Mean[1]
Recommended TAC ('000 tons)		Same as agreed							-	-	-
Agreed TAC	17[1]	17[1]	26	33	33	33	40	25	33	15	27
Actual landings	32	20	28	28	51	30	43	-	51	15	33
Sp. stock biomass	97	101	105	108	116	119	97	96[1]	119	18	79
Recruitment (age 3)	23	35	51	47	10	10	33	-	51	10	30
Mean F	0.25	0.20	0.24	0.30	0.30	0.27	0.36	-	0.62	0.16	0.29

[1] Over 1977-88 period.
[2] Excludes expected catches by Spain.

Weights in '000 tons
Recruitment in millions

Catches: Catches declined from a peak of 225,000 tons in 1967 to a low of 15,000 tons in 1978. The maximum catch since 1974 occurred during 1986 (51,000 tons) but were lower in 1988 at 43,000 tons.

Data and Assessment: Analytical assessment of catch-at-age data using Canadian and USSR survey indices in a formulation of the adaptive framework.

Fishing Mortality: Fully recruited F ranged from .17 to .36 for the 1978-88 period, with the estimate of 0.36 occurring in 1988.

Recruitment: The 1983 year-class at age 3 in 1986 estimated from ADAPT to be about 10 million fish. The Canadian RV indicated that the 1984 year-class was about the same size. These two year-classes are about one-half the next lowest year-classes observed in the 1959-88 period.

State of Stock: The mean 3+ biomass increased from 45,000 tons in 1976 to 190,000 tons in 1986 and subsequently declined to about 126,000 tons in 1988. The major reason for the decline is the size of the weak 1983 and 1984 year-classes.

Forecast for 1989: Catch 1989 is the TAC of 25,000 tons (F = 0.23).

Option Basis	Predicted catch (1990)	Predicted SSB (1.1.1991)
$F_{0.1}$ = 0.15	18,600	106,600
F_{88} = 0.36	40,700	87,500
F_{max} = 0.25	29,600	97,000

Recommendation:

Special Comments:

COD AND CLIMATE CHANGES

ii) Southern Gulf Cod (4T and 4Vn (Jan.-Apr.))

by

G. A. Chouinard and J. M. Hanson

Fishing for cod in the southern Gulf of St. Lawrence has been going on for over a century. Prior to the 1950's, landings varied between approximately 30,000 to 40,000 t caught mainly by hook and line gears (Halliday and Pinhorn 1982). Trawlers were introduced in 1947 and catches subsequently increased to attain a high of 104,000 t in 1956. Danish and Scottish trawlers were introduced in the early sixties. From 1960 to 1972, landings varied between 40,000 and 70,000 t then decreased to 22,000 t in 1977 when the stock was depleted. Catches then rebounded and have been in the order of 50,000-52,000 t in the period 1987-1989 (Chouinard et al. 1990). This stock has been under quota management since 1974. In recent years, catches by fixed gears (gillnets, longlines and handlines) have decreased. Over 80% of the landings are made by mobile gear vessels (trawlers and Danish and Scottish seiners). Cod is the most important groundfish species in the southern Gulf of St. Lawrence and this fishery is, with others such as lobster, herring and snow crab, a major component of the fishing industry in the area.

Virtual population estimates indicate that the average population biomass declined from a high of 500,000 t in 1955 to approximately 100,000 t in 1975 (Chouinard and Sinclair 1989). Good recruitment and lower fishing mortalities since 1977 have resulted in an increase of biomass to the present level of approximately 400,000 t. Although the recent biomass estimates are similar to the biomass levels of the early 1950's, total population numbers are substantially higher because of a marked decrease (as much as 50%) in average weights at age.

In summer, most of the population is found in waters off the Gaspe Peninsula and northeastern New Brunswick coast and banks offshore (American, Bradelle, Orphan, etc)(Koeller and Legresley 1981). In the fall (October-November), cod begin their annual migration from the shallow waters of the southern Gulf to the deeper waters of the Laurentian Channel and the Sydney Bight area (NAFO 4Vn) where they overwinter. The return migration in the spring occurs in April-May just before spawning. Tagging studies (Powles 1957; McCracken 1959; Martin 1962; Jean 1963) have indicated that the stock appears to be relatively discrete. There appears to be some mixing with the northern Gulf stock (3Pn,4RS) on the lower north shore of Quebec in summer and with a resident stock in Sydney Bight in winter. There is no strong evidence for the presence of sub-stocks.

Fishing patterns generally follow the annual migration of the stock. In winter, ice precludes fishing in 4T and the fishery is almost exclusively conducted by otter trawlers in 4Vn. In recent years, several management measures (gear-time period allocations and enterprise allocations) have been introduced and have restricted fishing at certain times in the year. Fishing mortalities on the stock since 1987 (0.24) are estimated to be the lowest since the early 1950's and are close to the target fishing mortality of $F_{0.1}$=0.2. In previous years, the stock was being exploited at a level corresponding approximately to F_{MAX}.

The environment in the southern Gulf of St. Lawrence is considered to be the main cause of the extensive annual migration. Most of the area of the southern Gulf where cod are found in summer is relatively shallow (less than 100 m). In winter, this area is covered with ice and temperatures are at or just above the freezing point (-1.5 °C) (Strain 1988) making it unfavorable for adult cod. Juveniles appear to be more tolerant of cold temperatures. In summer, surface temperature can reach 20°C but generally the warm surface layer (10-30 m) reaches 15°C. Salinity can range from 27 to 33 (Strain 1988).

The general circulation in the southern Gulf is mostly influenced by the strong Gaspe Current generated by the outflow from the St. Lawrence Estuary. The Gaspe Current sweeps over the Magdalen Shallows in a southeasterly direction (Trites 1972; Strain 1988). Gyres are present in the Miramichi Bay-Shediac Valley areas and in eastern Northumberland Strait. Sediments are mostly composed of gravels and coarse to fine sands containing some gravel and mud (Loring and Nota 1973; Strain 1988). As an indication of primary productivity, particulate organic carbon (POC) and nitrogen (PON) reach a maximum in April-May, decline in early summer (June-July) then increase again in August. These concentrations decrease again in November to reach a minimum in January. The concentrations observed in the period April to August are as high as in waters off the northwest African coast during the months of upwelling; one of the most productive areas of the world oceans (Pocklington 1988).

Cod in the southern Gulf of St. Lawrence spawn from May to September with the peak occurring from late-May to mid-June (Powles 1958; Lett 1980). The principal spawning areas are the area between the mouth of the Mirimichi River and the northern tip of Prince Edward Island, east of the Magdalen Islands, and (in some years) the Baie-des-Chaleurs (Powles 1958; Lett 1980; Tremblay and Sinclair 1985). The water depths in these areas is between 35 and 90 meters and egg densities do not appear to vary with water depth (Lett et al. 1975). Egg numbers were surveyed from 1965 to 1975 and were found to be correlated with water temperature and stock size (Lett et al. 1975; Lett 1980). In the centers of distribution (at the mouth of the Mirimichi River and east of the Magdalen Islands), average egg densities were over 2.5 eggs/m^3. Surface temperatures during peak spawning periods were 3.5 to 6.6 C. Larval cod were reported from water 0 to 40 m deep in August 1962 in Baie-des-Chaleurs (Bergeron and Lacroix 1963). Mackerel (Scomber scombrus) may be an important predator of 4T-Vn cod eggs and larvae (Lett 1980).

The distribution of juvenile cod, which includes ages 0 to 3, is partly separated from that of adults as young cod do not migrate out of the Gulf in winter (Jean 1964; Paloheimo and Kohler 1968). Ages 1 and 2 cod are mostly concentrated near the mouth of the Mirimichi River, inside of the Baie des Chaleurs, near the Magdalen Islands, and at the southeast end of Prince Edward Island (Tremblay and Sinclair 1985). These areas are shallower and warmer than the areas where most adult cod congregate. Some large cod are found in these areas and small cod have been found in their stomachs (Kohler and Fitzgerald 1969; Lett 1980; Waiwood and Majkowski 1984).

Lett (1980) and Beacham (1981) suggested that age-1 cod show density dependent growth. However, Lett (1980) also noted that size of age-1 cod in the Baie-des-Chaleurs appeared to be affected by water temperatures.

Based on limited data, young cod (11 to 30 cm) feed primarily on euphasids, amphipods, mysids, and small decapods (Pandalus and Crangon). Fish (small capelin and American plaice) comprised <5% of the diet (Powles 1958; Kohler and Fitzgerald 1969; Waiwood 1981). Small (16 - 30 cm) cod in the Baie des Chaleurs do not show the same nocturnal vertical feeding migrations as adult cod (Brunel 1972).

Adult 4T-Vn cod (>39 cm) show a pronounced seasonal migration. They overwinter along the edge of the Laurentian Channel off of the northeast coast of Cape Breton, sometimes reaching as far as Banquereau Bank, and are found mostly in the area east of the Magdalen Islands to the Gaspe Peninsula and south to the Baie-des-Chaleurs during summer (Jean 1964; Paloheimo and Kohler 1968). Adult cod are seldom found in water > 6 C and are usually found in water > 70 m deep (Tremblay and Sinclair 1985). Adult cod in the Gulf show pronounced nocturnal vertical migrations, presumably for feeding (Beamish 1966; Lacroix 1967; Brunel 1972).

Powles (1958) reported that 50% of female cod were mature at a length of 52-57 cm but Lett (1980) found that 50% of females were mature at a length of 45 cm and that some females < 35-cm long were mature. Fecundity is strongly correlated with fork length. Average relative fecundity was 379 eggs per gram of fish (Buzeta and Waiwood 1982). Based on data from research cruises from 1971 to 1989, males comprise 49.9% of the population (Chouinard and Hanson, unpublished data).

The age- and size-structure of the Gulf cod population has changed markedly from 1971 to 1989 (Chouinard et al. 1990; Hanson 1990). During the early 1970's, cod of ages 8 to 12 declined from 7% to < 2% of the population and younger fish (ages 3 or 4) dominated the age-distribution. By 1988 and 1989, the age-distribution was more even and cod 8 to 12 years old comprised >16% of the number of fish age-2 or older. Very small (30 - 35 cm) fish dominated the size-distribution in the mid-1970's, whereas, cod 45-50 cm long dominated the size-distribution in 1989. However, the proportion of fish > 65 cm long in the population has declined from 5.3 to 0.48% since 1972. The number of cod > 65 cm long has also declined in this period. This implies a change in growth. Average length-at-age (based on research surveys) illustrate these changes:

Time/Age	3	4	5	6	7	8	9	10	11	12
1972-74	34.6	42.6	49.7	54.7	59.0	63.0	66.4	74.0	76.7	82.8
1986-88	31.7	37.6	41.6	44.8	47.0	49.8	54.9	57.6	62.6	62.8

The changes in growth appear to be related at least in part to intra-specific competition (Kohler 1964; Crabtree and Ware 1975).

Preliminary studies indicate that size-selective fishing mortality and interspecific competition need to be examined further as potential factors (Hanson 1990).

The food habits of 4T-Vn (Jan.-Apr.) cod were investigated during the late 1950's and early 1960's (Powles 1958; Brunel 1962; Kohler and Fitzgerald 1969) and again in 1979 and 1980 (Waiwood 1981; Waiwood and Majkowski 1984). Diet analyses for the late 1980's are not as yet completed. As with cod elsewhere, they are very flexible in their diet. In general, the diet of cod 30 to 50 cm long is still dominated by crustaceans but fish are becoming important (> 20% by weight). Cod > 50 cm prey more heavily on fish and cod > 70 cm long are primarily piscivores. The primary fish prey has been herring but capelin has been important in some places and times and significant numbers of small American plaice and young cod are eaten. Large cod (>50 cm) also eat significant numbers of molluscs. In areas where snow crabs occur, they are an important part of the cod diet. Cod eat primarily the smaller size-classes of crabs and were not thought to have a significant impact on the snow crab population during the late 1970's (Bailey 1982; Waiwood and Elner 1982).

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iii) Climate change and the Gulf of St. Lawrence Cod Stocks

Both cod stocks in the Gulf of St. Lawrence exhibit extensive migrations in response to annual large-scale variation in environmental conditions. The cold water temperatures in winter and the warm temperatures in summer (particularly in the southern Gulf) are clearly a limiting factor affecting the distribution of the species and triggering the annual migration. Because of the semi-enclosed nature of the Gulf of St. Lawrence, effect of climate changes are likely to be more noticeable in this area. A general cooling of waters would likely result in an earlier exit from the Gulf and a later return in the spring while global warming would likely displace the species completely from many areas especially in the southern Gulf.

Climate changes may also result in significant changes in rainfall and consequently could affect the Gaspe current which is driven by the outflow of the St. Lawrence river. Changes in the velocity and/or direction of this current would likely affect cod egg and larvae transport and recruitment processes in general especially in the southern Gulf. Climate change would also likely affect prey species and predators. Because the northern and southern Gulf cod stocks, while in close geographic proximity, inhabit waters of different bathymetry and influenced by different current regimes, the effect of climate changes on these stocks would not necessarily be similar. The effects of climate change would likely be more dramatic for these stocks and similar ones and studies designed to study these effects should consider these stocks.

Norther Gulf of St. Lawrence Cod
3Pn 4RS

by Alain Fréchet

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2.2 The Regional Perspective.

Canadian Atlantic cod.

3Pn, 4RS Cod Stock.

The 3Pn, 4RS cod stock inhabits the Northeastern part of the Gulf of St. Lawrence in what may be considered as a semi enclosed sea. Two straits separate the Gulf from the Atlantic ocean, the largest being only 60 nautical miles wide. Despite this, the overwintering migration leads this stock outside the Gulf into NAFO Subdivision 3Pn, where a very important fishery takes place in the first few months of the year. As the ice cover progresses in winter, large concentrations of fish can be found at the ice edge. Strong mixing caused by upwelling at the ice edge is thought to force cod to move into deeper waters. A strong thermal gradient close to the bottom in those areas may cause an increase in catchability of cod to the otter trawls.

In April-May, as the cod are returning inside the Gulf, spawning takes place. This preceeds the summer inshore migration where fixed gear catches occur. Availability of cod to these gears has been shown to be heavily dependant on upwelling of deeper waters close to shore induced by favorable winds. This particular fishery has declined substantially in recent years. Investigations are ongoing on factors contributing to this including reduced cod abundance, reduced fishing effort, slower growth of cod, unfavorable wind conditions.

Little is known about larval distribution and dynamics for this cod stock. Growth rate for this stock have declined substantially in the last decade, as is the case for the majority of cod stocks from the Canadian Atlantic. For most of these stocks, evidence supporting density dependance has been shown.

The Gulf of St. Lawrence water masses are influenced by three important currents. The Gaspé current is a surface current outflow of relatively fresh waters from the St. Lawrence estuary. Waters from the Labrador current can be found in the cold intermediate water mass. Finaly, deep waters in the Laurentian Channel are formed by an estuarine type of circulation that brings warmer Atlantic waters into the Gulf. Temperature from this water mass (200-300 meters) have been monitored since 1955. Temperatures have risen by two degrees in 1966-1967 to reach slightly over 6 degrees in 1987. The impact of this change on distribution, migration patterns, food supply, predators and productivity of cod stocks are unknown. The impact of such a change is likely to be different for both cod stocks present in the Gulf. The 4T-Vn [Jan-Apr] cod stock inhabits the southwestern part of the Gulf, this is a relatively shallow area mostly influenced by the Gaspé current. Bottom topography for the 3Pn, 4RS cod stock is made up of deep water channels (Esquiman and Jacques Cartier) with a more typical estuarine circulation.

Government of Canada / Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

TO / À: R. O'Boyle, Chief
Marine Fish Division
Biological Sciences Branch
Scotia-Fundy Region

FROM / DE: P. Fanning
Marine Fish Division
Biological Sciences Branch

SECURITY - CLASSIFICATION - DE SÉCURITÉ

OUR FILE — N / RÉFÉRENCE

YOUR FILE — V / RÉFÉRENCE

DATE 18 June 1990

SUBJECT / OBJET: **M. Sinclair's Requested Stock Summary for 4VsW Cod**

The Eastern Scotian Shelf cod (NAFO Div. 4VsW) is comprised of a complex of inshore and offshore spawning groups. Offshore spawning is associated with individual banks while inshore spawning is spread along much of the nearshore area. There is spring spawning in all component areas, however there is also fall spawning in the western part of the inshore and on most of the shelf edge (offshore) banks.

This population has been exploited since at least the 1800's with catches since 1958 ranging from 10,000 to 80,000 t and averaging over 49,000 t in the 1980's.

Tagging programs have been carried out intermittently since the 1930's and have indicated that linkage to the southwest Nova Scotia (NAFO 4X) cod stock is relatively weak, however there is some seasonal interchange with the Sydney Bight (NAFO 4Vn) and Southern Gulf of St. Lawrence (NAFO 4T) stocks.

Research vessel surveys have been conducted in July using a stratified random design since 1970. The survey estimates of the population size declined to a minimum in 1976 and climbed to a maximum in 1984 and have declined since then.

P. Fanning

SUMMARY OF 4Vn COD FISHERY

At present the Sidney Bight (4Vn) fishery is managed as two units, the catch being partitioned between two stocks. Catch taken between January 1 and April 30 is considered comprised mainly of Gulf of St. Lawrence (4T) cod overwintering in the area; whereas, a resident stock is presumed to supply most of the cod to the fishery carried out during the remainder of the year, May to December. Catch attributed to 4Vn cod is relatively small, but stable, and has averaged about 10,000 tonnes over the past 10 years. Despite the present scheme of catch allocation to two statistical areas, assessments continue to be plagued by the problem of stock mixing.

Information from tagging and meristic studies indicated that inshore cod were distinct from those of the offshore which appeared identical to cod found in adjacent areas to the south. Formerly, small longliners exploited this inshore stock almost exclusively, while larger otter trawlers concentrated their activities offshore. Thus the fortunes of the resident 4Vn stock could be followed by monitoring longliner catch. However, since the implementation of Canadian extended fishery jurisdiction and the exclusion of foreign vessels from the Scotian Shelf fishing patterns have changed. Larger longliners were built which ventured further from shore and there has been an increase in smaller trawlers which drag inshore waters, thus blurring the association of cod stock with gear type.

Although it is safe to say that the proportion of 4T cod in Sidney Bight is large at the height of winter, it is much less easy to estimate this proportion at other times of the year. The timing of the migration is variable and in some years 4T cod begin their movement out of the Gulf as early as November. Sometimes too, the return migration is late. Thus so-called 4Vn catch can be badly 'contaminated' with 4T cod at the beginning and end of the May-December fishing season. In addition, tagging studies show that some Gulf cod do not undertake the return migration but remain in 4Vn for the summer. Thus it appears the summer catch in Sidney Bight consists of a mix of 4Vn, 4Vs and 4T cod in annually varying proportions.

Cod in the Gulf of St. Lawrence and on the Scotia Shelf are predominantly spring spawners. The most recent plankton sampling in the Sidney Bight area indicated spring spawning alone, but coverage was sparse and limited to offshore waters. Another, earlier series of samples showed concentrations of cod eggs in the autumn as well as in the spring. It is entirely possible this fall spawning is by the resident inshore stock. If so, quantitative egg surveys might provide a means of assessing the spawning biomass of this cod population.

Proposed research (OPEN & ESP) on cod in this and adjacent areas of the Scotian Shelf should shed considerable light on the dynamics of these populations; particularly in explaining patterns of distribution and movements in relation to physical oceanography.

Timothy Lambert

Government of Canada / Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

TO / À: R. O'Boyle, Chief
Marine Fish Division
Scotia-Fundy Region

FROM / DE: S. Campana
Marine Fish Division

SECURITY - CLASSIFICATION - DE SÉCURITÉ

OUR FILE — N / RÉFÉRENCE

YOUR FILE — V / RÉFÉRENCE

DATE: June 13, 1990

SUBJECT / OBJET: 4X Cod Contribution to ICES Study Group on Cod Stock Fluctuations

As per M. Sinclair's request for regional input into the Cod and Climate program, the following summarizes the current state of affairs for cod off Southwestern Nova Scotia (4X). As a result of FEP, much more is known about this stock than has been reported here; however, this should do for now. Note also that literature citations have largely been omitted.

STOCK SUMMARY FOR 4X COD

The cod off southwest Nova Scotia have been fished commercially since at least the 1800's. Landings since 1948 have varied between 11,000 and 36,000 t, with a mean of 20,000 t. While managed as a unit stock (NAFO Division 4X), the cod in this region most likely form a stock complex. Numerous, small inshore stock components are known to mix extensively with an offshore component, which is primarily centred on and around Browns Bank. There also appears to be substantial immigration from Georges Bank.

There are both spring and fall spawners in this region. The spring spawning component is the larger of the two, and is largely restricted to Browns Bank between February and April. Fall spawning is believed to be restricted to coastal waters during October and November. Both spawning periods may be associated with plankton blooms; however, a sympatric haddock stock spawns only in the spring.

Offshore spawning occurs in the presence of a tidally-dominated circulation which results in a permanent gyre around Browns Bank. Episodic breakdowns in the gyre circulation release large numbers of eggs and larvae to the northwest, where they become entrained in a coastal current and drift towards shore. The remainder of the ichthyoplankton is retained on the bank, resulting in a drift-retention dichotomy for individual plankters spawned on the bank.

Eggs hatch in 15-20 days; both egg development and the subsequent larval growth are largely temperature-mediated. Pelagic juveniles range in age between 70-120 days by May, and settle to the bottom approximately 1 month later. At the end of their first year, the young cod are approx. 20 cm in length. Sexual maturity begins at age 2 and is largely completed by age 4. Maximum age is about 18 years, corresponding to a length of about 125 cm.

Yearclass strength has varied by a factor of 6 between 1948-1989. In an intensive 3-year field program (Fisheries Ecology Program; Can. J. Fish. Aquat. Sci. 46: Suppl. 1 (1989)), the abundance of the pelagic juveniles proved to be the earliest reliable indicator of yearclass strength. Mortality between the larval and juvenile stages appeared to be most influential in determining yearclass strength, but the sources of the mortality could not be identified. Despite previous reports of large-scale physical forcing of recruitment patterns (Koslow et al. 1987), the results of the FEP analysis indicated that local spatial and/or temporal effects could be at least as important to the recruitment process (Campana et al. 1989).

Steven Campana

cc: M. Sinclair

The Georges Bank cod stock is the most southerly cod stock in world. Commercial fisheries have existed since the 1700's and modern landing statistics are available since the late 1800's. Annual commercial catches during the 1960-88 period have ranged between 11000 and 57000 t and averaged 33000 t. Recreational fisheries are also important and have averaged about 6000 t in recent years. Based on apparent segregation of the fish in the Northeast part of the Bank, Canada has introduced a new management unit which encompasses the eastern-most part of the Bank. Results of tagging studies suggest variable interaction with adjacent stocks in the NAFO 4X area. Preliminary analysis suggest divergent patterns in stock biomass between the Northeast peak area and the remainder of Georges Bank.

Cod spawning occurs between December and May with peak activity in February-March. Spawning takes place throughout the bank but is often concentrated on the Northeast Peak. Eggs drift in a clockwise gyre around the Bank and hatch in about 2-3 weeks. The transition from pelagic to demersal life occurs by 4-6 cm in length or about 3 months. Recruitment has been variable in recent years with a bi-annual pattern in abundance since 1981. Recent fishing mortalities have exceeded Fmax without apparent impact on recruitment success.

Growth is rapid and age 0 fish attain an average size of 26 cm within their first year of life. Sexual maturity commences at age 2 (40-60 cm) and is completed by age 5)70-80 cm). Size at age and rate of maturation may represent the extremes for North Atlantic cod stocks. Cod on Georges Bank are opportunistic feeders, feeding on a variety of benthic and fish species as adults. Maximum age is about 18 years and maximum size may exceed 140 cm.

DOREPORTS 1

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POPULATION NUMBERS

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967
3	60296	62429	54196	50477	43865	70907	81244	85763	99337
4	113869	48460	50599	43965	40201	35044	56329	64423	69358
5	42341	80615	34703	36373	29888	28843	23457	37399	40383
6	24396	27857	44553	19041	21633	18054	18516	13958	18798
7	17040	13400	16732	22036	11488	12939	10096	11894	7216
8	7286	9540	7826	10427	12870	7119	7929	5321	5106
9	5183	5113	4658	2173	7300	7796	4127	4632	2922
10	7156	3111	3263	2141	1063	5164	4672	2276	2134
11	10601	4719	1799	1426	1236	606	3638	2890	924
12	1899	8108	3496	1069	999	833	190	2683	1898
13	536	1061	5270	2622	749	728	425	94	1845
14	0	399	613	4627	2025	516	547	238	48
3+	290602	264812	228709	196378	173317	188599	211168	231571	249999
4+	230306	202383	174513	145900	129453	117692	129924	145808	150662

AGE	1968	1969	1970	1971	1972	1973	1974	1975	1976
3	71121	56811	35587	60701	40195	31538	41995	55903	60823
4	78732	57195	45812	28452	47088	32247	24966	32675	44105
5	46911	53058	40405	30166	17464	34079	22143	14973	20121
6	21391	26523	32958	21394	16940	10144	17599	9092	7376
7	9607	12217	15220	18149	10941	10655	4677	8650	3335
8	3807	4633	5882	6694	7424	4793	5084	1531	1773
9	2946	1934	2204	2594	2647	3693	1933	2482	599
10	1845	1915	867	1144	970	1414	1197	543	950
11	1461	1126	919	516	447	375	691	493	349
12	412	995	867	592	345	180	151	341	246
13	1468	237	706	640	371	177	48	52	232
14	1375	1198	134	469	468	261	132	10	37
3+	241079	217842	181560	171510	145300	129555	120616	126745	139946
4+	169958	161032	145973	110809	105105	98018	78621	70842	79123

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985
3	77589	41948	25571	37878	66401	44956	77649	77044	67549
4	46079	62679	33890	20813	30679	53440	36689	62886	62895
5	25126	29441	46661	24967	15570	22505	39146	27612	47396
6	9305	13038	18589	28864	15868	9910	14417	23749	18501
7	3437	4714	7050	10635	16252	8782	5989	8112	13094
8	1550	1982	2274	3643	5650	8008	4602	3318	4632
9	1004	912	1032	1209	1848	3158	3897	2727	2188
10	364	582	534	634	694	1025	2007	2249	1742
11	730	192	315	361	416	410	619	1422	1535
12	271	546	92	210	245	280	260	425	1043
13	182	183	423	54	131	169	202	190	316
14	186	121	134	334	25	91	128	149	140
3+	165823	156337	136563	129602	153779	152735	185606	209873	221031
4+	88233	114390	110992	91724	87378	107778	107957	132828	153482

AGE	1986	1987	1988
3	29044	48806	64628
4	55118	23529	39434
5	47225	40672	16624
6	28423	29472	23528
7	9611	13155	15543
8	6131	4026	6092
9	2439	3080	2070
10	1414	1418	1447
11	1085	959	868
12	956	737	643
13	735	655	534
14	237	532	428
3+	182419	167040	171839
4+	153375	118233	107211

POPULATION BIOMASS AT BEGINNING OF YEAR

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967
3	10755	11135	9667	9003	7824	12647	14491	15297	17718
4	62801	21301	22241	19324	17670	15403	24759	28317	30486
5	36664	69591	29957	31399	25801	24899	20249	32285	34861
6	34291	37523	60013	25648	29140	24319	24941	18801	25321
7	35362	26908	33598	44248	23068	25981	20272	23883	14551
8	20693	26480	21722	28942	35723	19759	22007	14770	14172
9	19093	18547	16900	7883	26483	28282	14970	16804	10599
10	33366	14198	14891	9771	4852	23569	21320	10389	9738
11	59327	26116	9956	7894	6842	3356	20136	15996	5112
12	12394	52677	22713	6946	6488	5735	1232	17430	12334
13	4043	7968	47067	19686	5620	5465	3191	704	13846
14	0	3425	5264	39730	17388	4432	4699	2040	410
3+	328789	315868	293988	250475	206900	193847	192266	196715	189149
4+	318034	304733	284321	241471	199076	181199	177775	181418	171431

AGE	1968	1969	1970	1971	1972	1973	1974	1975	1976
3	12686	10133	6348	10827	7169	5625	7491	9971	10928
4	34606	25140	20137	12506	20697	14174	10974	14362	19386
5	40496	45802	34879	26041	15076	29419	19115	12926	17369
6	28813	35726	44394	28817	22818	13664	23706	12247	9935
7	19291	24532	30561	36444	21970	21395	9391	17368	6697
8	10568	12861	16326	18579	20605	13303	14112	4249	4921
9	10668	7015	7995	9409	9604	13397	7011	9006	2174
10	8422	8742	3955	5220	4426	6452	5461	2476	4337
11	8086	6234	5089	2855	2473	2076	3827	2728	1933
12	2679	6466	5633	3844	2244	1172	984	2214	1599
13	11022	1781	5302	4806	2788	1328	361	387	1741
14	11810	10284	1147	4026	4019	2238	1135	90	316
3+	199169	194716	181765	163373	133888	124243	103567	88025	81336
4+	186483	184583	175418	152546	126719	118617	96076	78053	70408

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985
3	37827	15706	7911	15980	25165	14807	33633	41729	39936
4	20106	38891	18329	11308	19663	32489	22557	48841	50582
5	23797	25230	39234	21397	15179	21636	39614	29943	56367
6	13188	19665	24814	37374	22631	15191	21998	38441	30411
7	7280	10064	14892	21514	31756	18101	12835	18593	29116
8	4440	5599	6827	11037	16089	20610	12764	10349	13938
9	3681	3413	3699	5390	7321	11293	12841	10731	8962
10	1638	2706	2753	3465	3843	4918	8907	10296	8541
11	4004	971	1896	2482	2984	2428	3645	7826	8428
12	1727	3566	600	1636	1987	2236	1882	3271	7827
13	1430	1321	3502	470	1120	1492	1880	1749	3286
14	1745	1062	1229	3195	236	894	1296	1524	1543
3+	120863	128195	125685	135247	147973	146095	173854	223294	258837
4+	83036	112489	117774	119267	122808	131288	140221	181565	218901

AGE	1986	1987	1988
3	13398	22120	33018
4	38187	14873	26321
5	50784	38584	14930
6	44963	42352	34095
7	20814	28101	31318
8	17239	11227	16560
9	9365	11281	7191
10	6918	6616	6825
11	6074	5554	4727
12	6570	4872	4217
13	6387	5260	3934
14	2829	4355	3433
3+	223528	195197	186569
4+	210130	173077	153550

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WEIGHTS AT THE BEGINNING OF THE YEAR

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
3	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
4	0.55	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
5	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
6	1.41	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
7	2.08	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01
8	2.84	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78
9	3.68	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63
10	4.66	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56
11	5.60	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53
12	6.53	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
13	7.55	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51
14	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59
15	0.00	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77

AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
3	0.18	0.18	0.18	0.18	0.18	0.18	0.49	0.37	0.31	0.42	0.38	0.33
4	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.62	0.54	0.54	0.64	0.61
5	0.86	0.86	0.86	0.86	0.86	0.86	0.95	0.86	0.84	0.86	0.97	0.96
6	1.35	1.35	1.35	1.35	1.35	1.35	1.42	1.51	1.33	1.29	1.43	1.53
7	2.01	2.01	2.01	2.01	2.01	2.01	2.12	2.13	2.11	2.02	1.95	2.06
8	2.78	2.78	2.78	2.78	2.78	2.78	2.86	2.83	3.00	3.03	2.85	2.57
9	3.63	3.63	3.63	3.63	3.63	3.63	3.67	3.74	3.59	4.46	3.96	3.58
10	4.56	4.56	4.56	4.56	4.56	4.56	4.50	4.65	5.16	5.47	5.54	4.80
11	5.53	5.53	5.53	5.53	5.53	5.53	5.48	5.05	6.01	6.88	7.18	5.92
12	6.50	6.50	6.50	6.50	6.50	6.50	6.38	6.53	6.51	7.78	8.12	7.99
13	7.51	7.51	7.51	7.51	7.51	7.51	7.81	7.24	8.28	8.75	8.51	8.84
14	8.59	8.59	8.59	8.59	8.59	8.59	9.37	8.75	9.17	9.55	9.44	9.78
15	9.77	9.77	9.77	9.77	9.77	9.77	8.96	13.58	8.30	12.30	9.72	9.34

AGE	1983	1984	1985	1986	1987	1988	1989
3	0.43	0.54	0.59	0.46	0.45	0.51	0.00
4	0.61	0.78	0.80	0.69	0.63	0.67	0.75
5	1.01	1.08	1.19	1.08	0.95	0.90	0.98
6	1.53	1.62	1.64	1.58	1.44	1.45	1.32
7	2.14	2.29	2.22	2.17	2.14	2.01	2.11
8	2.77	3.12	3.01	2.81	2.79	2.72	2.67
9	3.30	3.94	4.05	3.84	3.66	3.47	3.27
10	4.44	4.58	4.90	4.89	4.66	4.72	4.09
11	5.89	5.50	5.49	5.60	5.79	5.45	5.79
12	7.23	7.70	7.50	6.87	6.62	6.56	6.31
13	9.31	9.73	10.39	8.68	8.03	7.36	7.58
14	10.11	10.23	11.02	11.93	8.19	8.03	7.99
15	12.88	13.66	9.81	9.87	17.31	8.66	9.50

POPULATION BIOMASS AT BEGINNING OF YEAR

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967
3	10755	11135	9667	9003	7824	12647	14491	15297	17718
4	62801	21301	22241	19324	17670	15403	24759	28317	30486
5	36664	69591	29957	31399	25801	24899	20249	32285	34861
6	34291	37523	60013	25648	29140	24319	24941	18801	25321
7	35362	26908	33598	44248	23068	25981	20272	23883	14551
8	20693	26480	21722	28942	35723	19759	22007	14770	14172
9	19093	18547	16900	7883	26480	28282	14970	16804	10599
10	33366	14198	14891	9771	4853	23569	21320	10389	9738
11	59327	26116	9956	7894	6842	3356	20136	15996	5112
12	12394	52677	22713	6946	6488	5735	1232	17430	12334
13	4043	7968	47067	19686	5620	5465	3191	704	13846
14	0	3425	5264	39730	17383	4432	4699	2040	410
3+	[illegible]	[illegible]	[illegible]	250475	206900	193847	192266	196715	189149
4+	318034	304733	[illegible]	[illegible]	199076	[illegible]	177775	181418	171431

POPULATION BIOMASS (AVERAGE)

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967
3	15166	15766	13693	12640	11001	17735	20302	21636	24818
4	66438	28428	29736	25168	23604	19916	31892	35515	39610
5	37362	65677	28181	30637	25355	25163	19762	29204	32279
6	30832	36664	53734	25112	28417	23002	25135	17200	23003
7	31031	24875	31997	40907	21912	24552	17893	19265	12825
8	19693	21861	14161	28155	32492	17615	19689	12847	12608
9	16644	16887	13277	6365	25300	25014	12752	13215	9604
10	29733	12168	11274	8369	4133	22132	18846	7618	9023
11	56071	24583	8457	7235	6329	2162	18912	14229	3823
12	10078	50048	21268	6296	5993	4384	953	15663	11719
13	3734	6575	43525	18602	5033	5098	2594	549	12868
14	0	3190	4828	37335	16401	4165	4381	1874	383
3+	316783	306722	274130	246821	205968	190937	193111	188814	192563
4+	301618	290956	260438	234180	194967	173202	172808	167179	167745

AGE	1968	1969	1970	1971	1972	1973	1974	1975	1976
3	17894	14312	8928	15010	10101	7875	10399	13936	14871
4	44887	33337	25838	15534	27761	18547	13486	17866	23274
5	38614	45590	32290	24754	14552	26933	15835	11588	15146
6	27515	34189	41700	26187	22773	11863	21166	9644	8666
7	16369	20801	24911	28795	17877	18071	6761	10414	5591
8	8877	10495	12891	14002	17150	10109	11650	3188	4340
9	9815	5451	6626	6768	8062	9082	4486	6542	1934
10	7399	6894	3435	3767	3180	5130	4030	2229	4244
11	7316	5976	4484	2562	1771	1487	2988	2142	1859
12	2217	5898	5235	3311	1763	701	649	1980	1489
13	10694	1153	4665	4424	2517	1236	199	352	1677
14	10938	9448	1046	3634	3683	2033	1021	76	292
3+	202535	193844	172049	148749	131192	113064	92671	79960	83382
4+	184641	179532	163121	133739	121091	105189	82272	66024	68511

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985
3	38429	16999	9475	17759	28649	18307	40605	46022	39119
4	25256	37993	18981	13007	20841	35360	26826	56968	53592
5	23954	25489	37423	22685	16537	21249	40975	31854	50463
6	12557	17043	23502	36449	21560	13859	21818	35254	26198
7	7057	8200	13158	19546	26790	15265	11670	16395	23032
8	4113	4351	6203	9520	14008	16439	11680	10233	11726
9	3242	2894	3511	5010	6089	9927	11302	10440	7714
10	1328	2246	2866	3594	3064	4252	8556	10394	7023
11	3751	703	1816	2181	2544	2036	3385	7349	6627
12	1512	3469	584	1450	1848	2058	1839	3325	8249
13	1315	1217	3591	350	925	1275	1752	1781	3283
14	1782	916	1264	2786	207	906	1327	1364	1312
3+	124296	121521	122375	134337	143061	140934	181735	231378	238337
4+	85868	104522	112900	116578	114412	122627	141130	185356	199219

AGE	1986	1987	1988
3	14142	24175	36037
4	35647	14709	26989
5	44431	37586	13756
6	36466	38097	31728
7	15598	22753	26693
8	13959	9410	13534
9	8095	9209	5796
10	6446	5671	6112
11	5569	4822	4262
12	6939	4454	3883
13	5055	3945	3510
14	2425	3813	3247
3+	194773	178644	175547
4+	180630	154469	139510

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FISHING MORTALITY

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
3	0.019	0.010	0.009	0.028	0.025	0.030	0.032	0.012	0.032	0.018	0.015	0.024
4	0.145	0.134	0.130	0.186	0.132	0.201	0.210	0.267	0.191	0.195	0.118	0.218
5	0.219	0.393	0.400	0.320	0.304	0.243	0.319	0.488	0.435	0.370	0.276	0.436
6	0.399	0.310	0.504	0.305	0.314	0.381	0.243	0.456	0.471	0.360	0.355	0.397
7	0.380	0.338	0.273	0.338	0.279	0.290	0.440	0.646	0.444	0.529	0.531	0.621
8	0.154	0.517	1.081	0.157	0.301	0.345	0.338	0.400	0.350	0.478	0.543	0.619
9	0.311	0.249	0.577	0.515	0.146	0.312	0.395	0.575	0.259	0.231	0.603	0.456
10	0.216	0.348	0.627	0.349	0.362	0.150	0.280	0.702	0.179	0.294	0.534	0.319
11	0.068	0.100	0.320	0.157	0.137	0.962	0.105	0.220	0.606	0.184	0.062	0.241
12	0.382	0.057	0.087	0.156	0.116	0.531	0.505	0.175	0.057	0.353	0.143	0.103
13	0.095	0.349	0.104	0.059	0.172	0.086	0.382	0.474	0.094	0.004	0.374	0.210
14	0.065	0.078	0.110	0.059	0.051	0.059	0.075	0.108	0.072	0.090	0.107	0.123

AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
3	0.054	0.020	0.034	0.051	0.037	0.078	0.013	0.013	0.006	0.011	0.017	0.003
4	0.288	0.123	0.176	0.311	0.285	0.363	0.248	0.095	0.106	0.090	0.110	0.111
5	0.377	0.343	0.461	0.690	0.508	0.571	0.456	0.260	0.280	0.253	0.252	0.245
6	0.471	0.264	0.574	0.510	0.803	0.564	0.480	0.415	0.358	0.374	0.392	0.304
7	0.694	0.625	0.540	0.917	1.385	0.566	0.351	0.529	0.460	0.433	0.508	0.446
8	0.728	0.498	0.708	0.517	0.738	0.369	0.331	0.453	0.432	0.479	0.382	0.520
9	0.784	0.427	0.927	1.070	0.760	0.299	0.345	0.335	0.287	0.355	0.389	0.254
10	0.740	0.750	0.515	0.687	0.241	0.064	0.439	0.412	0.191	0.222	0.327	0.304
11	0.201	0.707	0.707	0.508	0.495	0.055	0.090	0.535	0.205	0.188	0.196	0.253
12	0.266	0.469	1.121	0.877	0.185	0.099	0.193	0.056	0.340	0.270	0.172	0.126
13	0.113	0.154	0.092	1.326	0.138	0.019	0.208	0.109	0.035	0.566	0.164	0.075
14	0.144	0.112	0.131	0.153	0.236	0.094	0.067	0.095	0.086	0.086	0.092	0.088

AGE	1983	1984	1985	1986	1987	1988
3	0.011	0.003	0.003	0.011	0.013	0.016
4	0.084	0.083	0.087	0.104	0.147	0.147
5	0.300	0.200	0.311	0.271	0.347	0.379
6	0.375	0.395	0.455	0.570	0.440	0.346
7	0.391	0.360	0.559	0.670	0.570	0.435
8	0.323	0.216	0.442	0.489	0.465	0.419
9	0.350	0.248	0.236	0.342	0.555	0.428
10	0.144	0.182	0.273	0.189	0.291	0.240
11	0.177	0.110	0.274	0.188	0.200	0.165
12	0.171	0.095	0.149	0.178	0.121	0.118
13	0.104	0.050	0.088	0.125	0.226	0.118
14	0.071	0.061	0.099	0.113	0.109	0.081

Appendix III of ICES C.M. 1990/G:50
Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

WEST GREENLAND COD

Prepared by E.Buch, H.Hovgaard

West Greenland.

Physical environment.

Observations of the physical environment along the west coast of Greenland have been performed regularily since 1950 on the standard sections agreed upon within ICNAF/NAFO.

The data, primarely temperature and salinity data, have been analysed with the aim of establishing timeseries reflecting the seasonal and interannual variability of the physical environment of West Greenland waters. The causes to the observed variability have been investigated, looking into the relative importance of the processes of air-sea interaction and advection. The dependence on the variability of the large-scale atmospheric circulation pattern over the North Atlantic have also been touched upon.

A detailed description of the physical oceanography of the Greenland waters have resently been published by Buch (1990).

The West Greenland ocean area is dominated by the inflow of water masses from two currents:

a) **The East Greenland Current**, which carries cold and low salinity water from the Arctic Ocean along the East Greenland coast to the West Greenland fishing banks. The inflow is most intense during spring reaching its maximum intensity in June.

b) **The North Atlantic Current** supplying warm and high salinity water to the West Greenland area. The major part of the atlantic component of the West Greenland Current originates from the area south to southeast of Cape Farewell, but also inflow of water having its origin in the Irminger Current do take place and is mainly found in the southern part of the West Greenland area. The intensity of inflow of water from the North Atlantic Current is highest during autumn and early winter. It is also at this time of the year the Irminger water mainly reflects itself.

The interannual variability can be illustrated by the Fylla Bank St.2 medio June temperature time serie, Fig.1., clearly revealing the great changes in the physical environment this area is exposed to.

In analysing the reasons to interannual variability good correlation between the atmospheric temperatures and the upper ocean temperatures have been demonstrated. Likewise have a correlation between the ice cover in the Greenland Sea in December and the temperatures in the upper 400 m at Fylla Bank the following June and July been found documenting the importance of the East Greenland Current.

Further analysis have shown that much of the interannual variability of the ocean temperatures off West Greenland can be correlated to variations in the North Atlantic Oscillation index

(NAO-index) i.e. variations in the air pressure difference between the Subtrophical High and the Subpolar Low. This pressure difference rules the atmospheric circulation in the North Atlantic region and thereby the air temperatures and wind systems over Greenland.

A correlation between the temperatures of the Atlantic water component off West Greenland and the NAO-index have been demontrated.

With regard to understanding the recruitment of cod to the West Greenland area from the Icelandic spawning grounds, it is essential to understand, what physical processes in the ocean and the atmosphere, that triggers a greater than normal inflow of Irminger water to West Greenland and to investigate whether these processes were more common during the warm period from 1920 to 1970, than the last 20 years.

Due to the strong impact of climate changes on the Greenland fishery the Greenland Fisheries Research Institute follow and takes an active part in various research projects, which aims at a better understanding of the climate variability such as the Greenland Sea Project (GSP) and the World Ocean Circulation Experiment (WOCE).

References.

Buch, E. (1990). A Monograph on the Physical Oceanography of the Greenland Waters. Greenland Fisheries Research Institute publication.

Cod in Greenland

1) The history of the West Greenland cod fishery

Cod fishery is documented since the recolonization of Greenland in 1721 . In this period cactches have in general been scanty although short periods with high cod abundance are known.

In the first decade of the 20th century two attempts to develop Greenland fisheries were made ('Napoleon Andreasen' trial fisheries in 1906 and the 'Tjalfe' expedition in 1908-09). Both of these trials showed low cod abundance.

However, starting from 1917 cod catches increased from 200 tons annually to a level of 60.000 - 100.000 tons in the 1930'ies. Concurrent with the catch increase the distribution area expanded to the north (fig. 1). High catches were at first recorded in the Qaqortoq and the Paamiut areas, then near Nuuk (1919), at Manitsoq (1922) and near Sisimiut (1927). In the 1930'ies good catches were taken in the Disko Bay region and up to Uummannaq. In the end of this decade cod was also observed in the Upernavik area.

The fishery in the 1930'ies were primarily a hook and line fishery in summer and autumn concucted by foreign fleets. This fishery was brought to an end by world war II. After the war a mixed international fishery (trawlers, dories and long-liners) developed, resulting in expanded yields (fig. 2). Catches remained at a high level of about 300.000 tons annually during the 1950'ies and 1960'ies after which time the fishery collapsed and annual catches have been approximately 60.000 tons in the last two decades.

Catch-at-age information for the West Greenland cod fishery are available after 1956 and the stock collapse can therefore be studied by an analytical assessment (VPA). The spawning stock biomass (fig. 3) were reduced from 1.6 mill. tons to less than 0.1 mill. tons between 1955 and 1975 and has since then remained at this low level. Recruitment (fig. 4) expressed as numbers at age 3 has been extremely variable - ranging from less than 10 mill. to more than 500 mill. However, in the years prior to the mid 60'ies recruitment were generally good with large year-classes occurring frequently wheras the later years are characterized by low average recruitment and only two good year-classes, those of 1973 and 1984.

The decline of the cod stock coincidices with a retraction of the distribution area. In the 50'ies and 60'ies a major fishery took place at the Store Hellefiske Bank which at that time was probably the main nursery area. In the 70'ies and 80'ies the fishery has mainly taken place at the banks south of Nuuk. In the most recent years this displacement of the population center has continued further south

2) The fishery off East Greenland

The East Greenland coast is only accessible to fisheries with difficulty as the area is being dominated by the cold and icefilled East Greenland polar current. Further the bottom topography is rough and the weather conditions often harsh.

The population in East Greenland is restricted to a few hunting settlements where fishing has never been important. Information on the occurrence of cod in these areas in former periods are scanty. Cod was reported from the area in 1912 and abundance were low at that time. Abundance increased in the area during the 20'ies and 30'ies where cod were found in almost all fiord areas around Ammasalik.

A commercial trawl fishery developed in the offshore areas in the late 1950'ies. Annual catches has fluctuated between 5.000 and 35.000 tons without significant trends. The fishery takes place in shelf regions dominated by the warm Irminger current.

3) Spawning and drift of eggs and larvae.

No directed research has been carried out to locate spawning areas or to examine the periodicity of spawning. Plankton surveys has been made more or less reguarilly off West Greenland in May-July since the 1930'ies. The knowledge of the spawning is therefore based on cod egg and larvae distribution supplemented by observations on spawning or post spawning cod in the fisheries.

Highest densities of eggs are generally found off Nuuk in May and of larvae off Manitsoq in June/July. Allowing for current at an estimated velocity of 20 cm / sec this implies that the main spawning area should be in the Paamiut and Qaqortoq areas. This agrees well with the observations from the fisheries where mature cod are concentrated on the outer side of the banks in this area during spring. Few eggs and larvae are found south off Nuuk. The current is unidirectional clockwise which suggests that only limited spawning takes place off East Greenland. Spawning also takes place in many fiord areas in West Greenland.

In East Greenland cod larvae and O-group cod have been taken in Atlantic water off Ammasalik. Considering the direction and speed of the Irminger current, these cod must originate from the spawning areas off Southwest Iceland (off Reykjanes). Icelandic surveys conducted annually in August since 1971 show large variations in O-group abundance of cod in the area between Iceland and Greenland. It is interisting that the highest O-group abundance is found in 1973 and in 1984, i.e. corresponding to the two largest year-classess in the West Greenland fisheries since the mid 1960'ies. The distance between the Icelandic spawning area and Southwest Greenland is approximately 1200-1600 km which is very similar to the distance travelled by the Arctic-Norwegian cod.

4) Migrations

More than 100.000 cod have been tagged off West Greenland since 1930. Returns from these taggings indicates that :

A) Fiord tagged cod do generally not leave the areas where tagged.

B) Cod tagged on the banks shows cyclical migrations moving north during summer and south in winter. Offshore populations do not mix randomly but tend to return to the tagging areas during successive summers.

C) Almost all returns from outside West Greenland are reported from East Greenland or Iceland. Very few are reported from Canadian waters and single individuals are returned from the Faroes and Norway.

D) The vast majority of tag returns in East Greenland / Iceland are cod tagged in Southwest Greenland south of Paamiut.

E) The time pattern of tag returns from East Greenland and Iceland indicate that this migration is not a quick direct migration but rather a gradual movement from West Greenland to East Greenland and then further to Iceland. This process takes a couple of years.

5) Stock structure

Information on spawning and migration indicates that the Greenland cod stock is composed of three components.

1) West Greenland bank populations : These cod spawns off Southwest Greenland and eggs and larvae are carried northward along the coast. The 0-group settles mainly in areas north of Nuuk.

2) West Greenland coastal populations : The spawning areas are found in the fiords and the young fish probably settles in the same areas. Cod rarely migrates out of the fiords.

3) Icelandic spawners : Spawning takes place off Southwest Iceland and the offspring are carried off by the Irminger current. Some of these cod settles in the East Greenland area and some are carried further to West Greenland. When maturing, these cod, or at least a large proportion of them migrates back to the Icelandic spawning area.

The relative sizes of the three stock components have not been assessed and it is likely that their sizes have developed differently over the years. Prior to 1960 there was a large fishery in the Store Hellefiske Bank region. Almost no fishery has taken place in this area since then and surveys carried out annually since 1982 shows that the cod abundance is very low. Also, a large inshore fishery in the fiords around Nuuk took place in the 1940'ies and 50'ies but this fishery faded out in the late 50'ies. Spawning cod are still observed in the fiord but today surveys show that the fiord population is very small. Data from other fiord population are scarce but anecdotical information indicates that abundance and spawning success has been reduced in several areas. It appears as if the two true West Greenland stock components both have been severely affected by the stock collapse.

Drift of larvae/0-group from Iceland to Greenland is documented from the 1930'ies and from the Northwestlant surveys in 1963. But consistent time series are only available from the Icelandic O-group surveys carried out since 1971. In this period, large numbers of small cod have only been seen twice off East Greenland (1973 and 1984) and these year-classes are the outstanding large in the West Greenland fisheries within the last 25 years.

The general poor recruitment prevailing in the last 25 years with few outstanding year-classes (fig. 4) may be generated by reduced recruitment from the true West Greenland populations overlayed by infrequent inflows of large numbers of young cod from Iceland.

6) Feeding and growth

Various stommach content samplings have been conducted over the years mostly on adult cod. However, no consistent time series exists and the samplings do not cover all seasons and areas. As seen elsewhere cod is an opportunistic feeder prefering larger prey (mostly fish) with increasing cod size.

Many analyses of growth has been made in the past. However, these analyses are all made by size-at-age calculations and they are therefore biased as the length distribution is affected by a size selective migration out of the area. This effect is evident at present where almost no changes in size-at-age is seen in the 1984 year-class off West Greenland for the last two years. In the same period the numbers of this year-class have multiplied in East Greenland waters and these fish are all of a considerable larger size than in West Greenland.

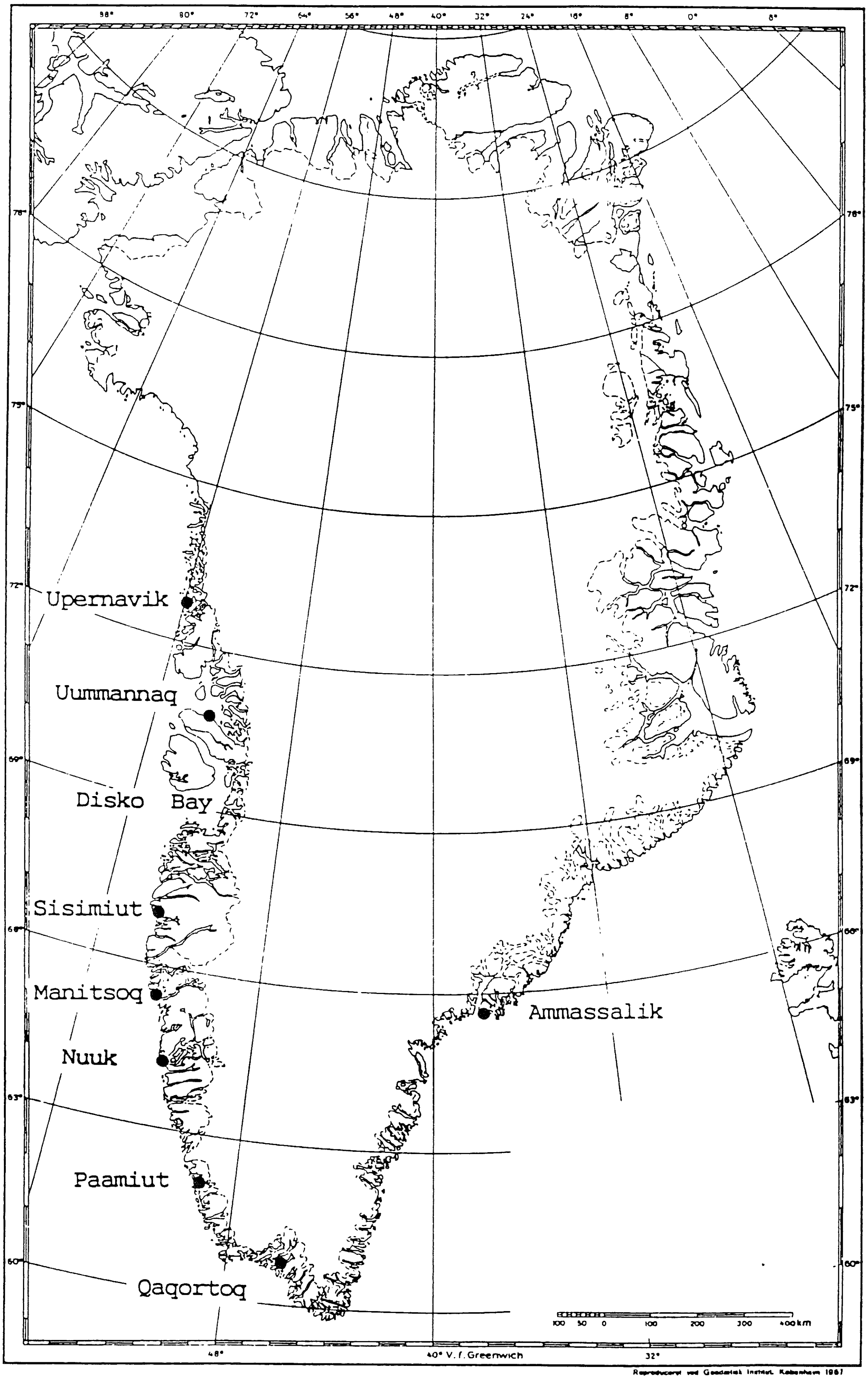

Fig. 1 : Map of Greenland.

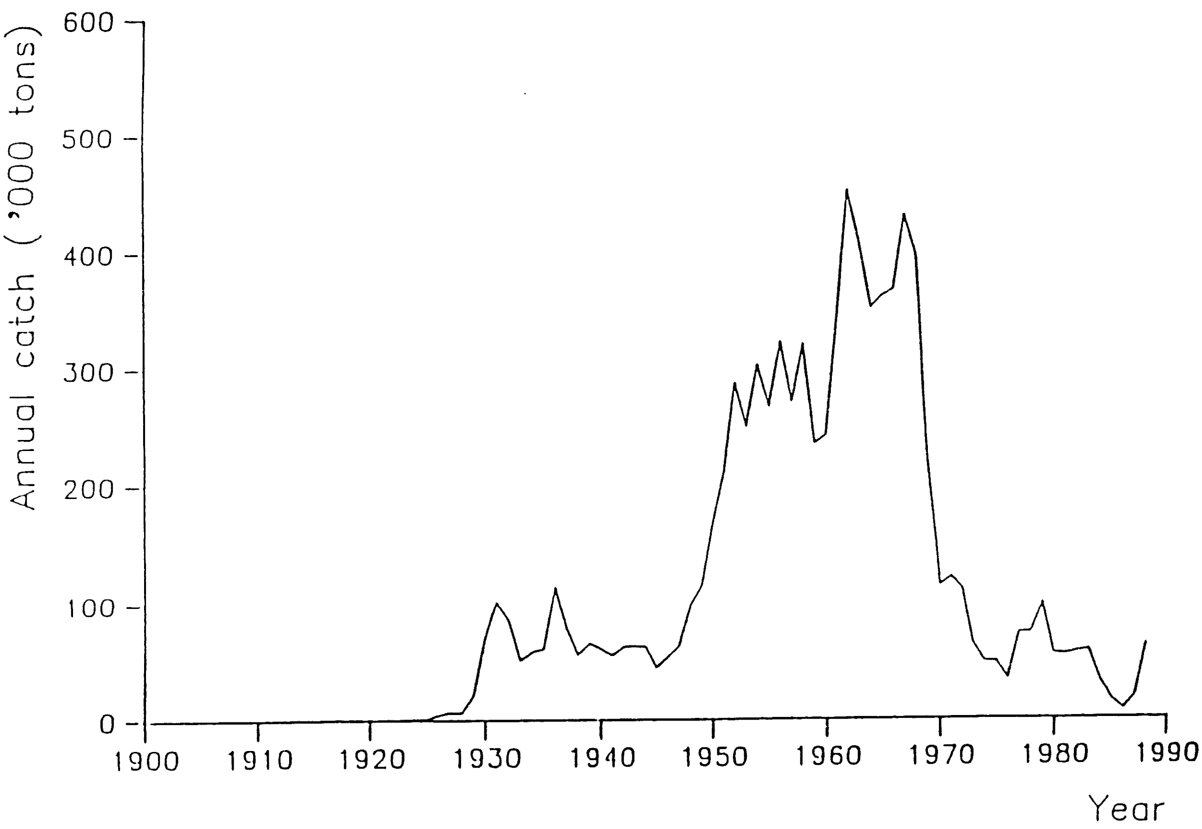

Fig. 2. : Catches of cod off West Greenland, 1900-1988.
After Hovgaard and Buch (1990).

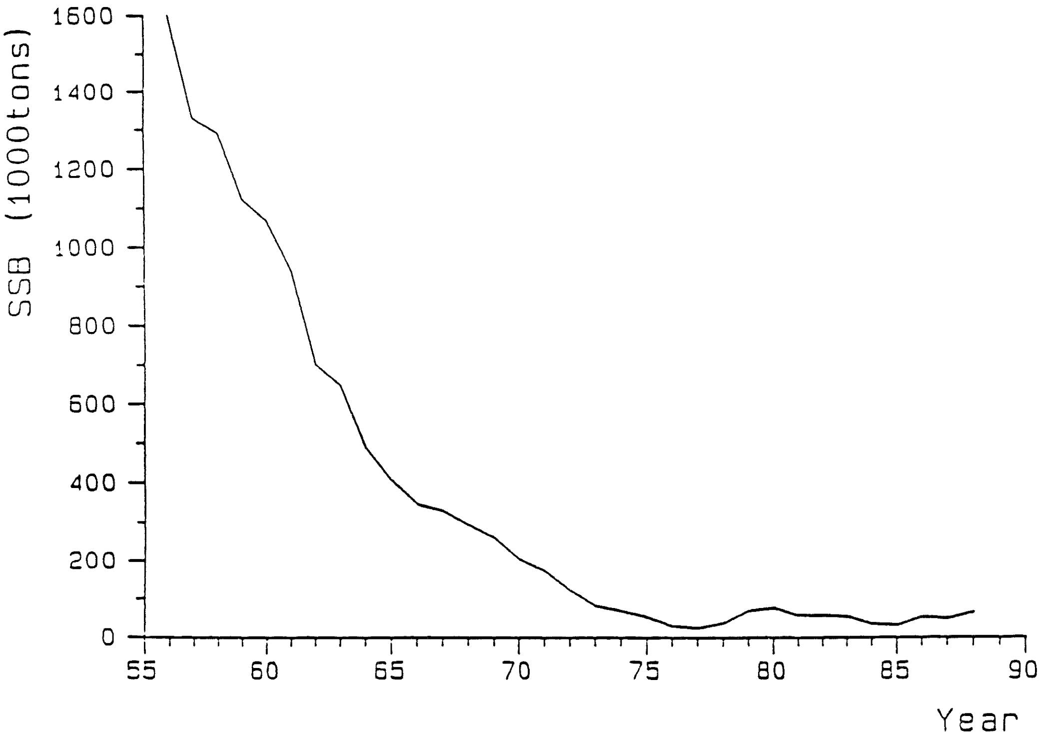

Fig. 3. : Spawning stock biomass ('000 tonnes) of the West Greenland cod stock, 1956-1988.
After Hovgaard and Buch (1990).

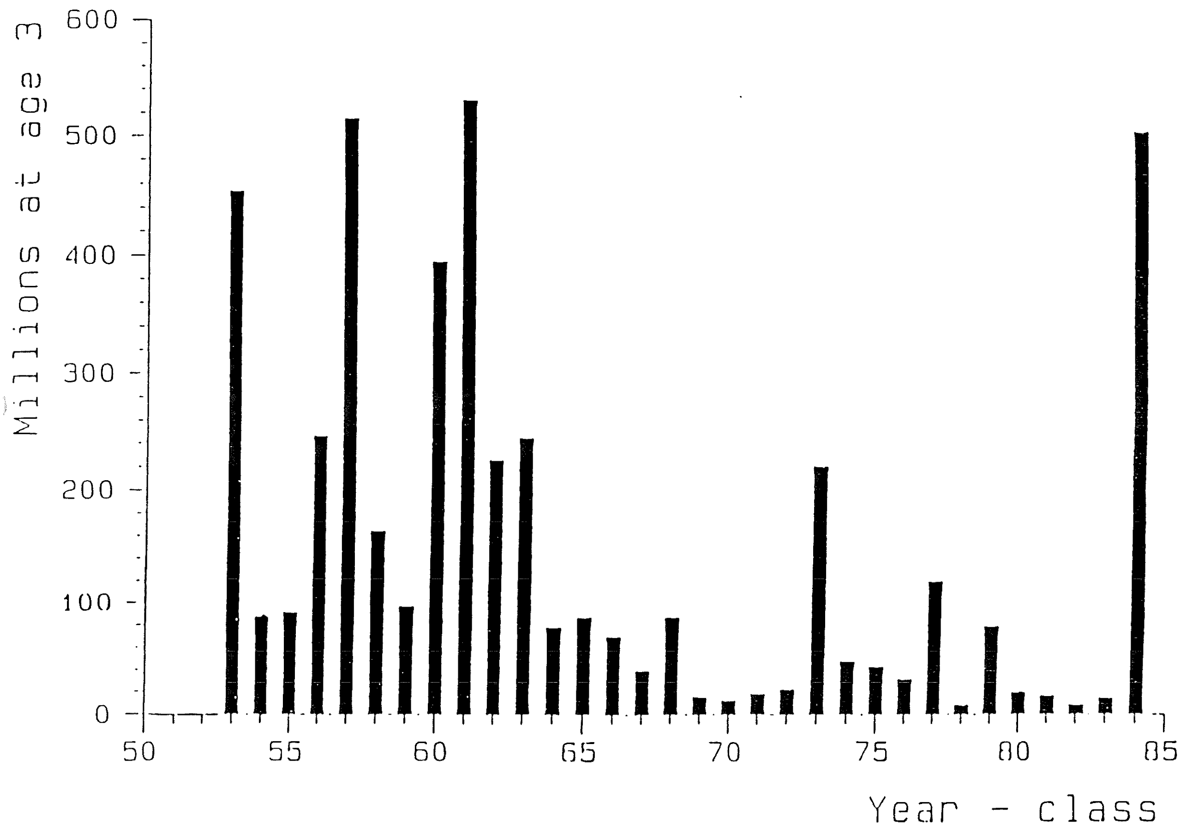

Fig. 4. : Year-class strenght, measured as numbers at age 3, at West Greenland, 1953-1984. After Hovgaard and Buch (1990).

Appendix III of ICES C.M. 1990/G:50
Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

THE WHITE SEA COD

Prepared by V.P.Serebryakov

WHITE SEA COD

White Sea cod is a subspecies (Gadus morhua maris albi Dorjugin) of Atlantic cod (Gadus morhua morhua L). This subspecies inhabits mainly shallow waters of the White Sea, it is distributed in the Kandalaksha Bay and around the Solovetsky Islands. The White Sea cod does not migrate for a long distance.

Spawning of this cod occurs in coastal zone in bays and sounds above 15-100 meter depth. The spawning starts (in the Verkhnyaya salma sound) in the middle of March under ice cover with surface water temperature -1.6 to -1.40°C and salinity as high as 30 promille. Spawning peak time is the first half of April when surface water temperature still low, -1.2 to -1.0°C. The spawning ends in the second half of May. The water temperature has risen to 4.0°C by this time, and there is no ice cover,and desalinisation were observed in the surface water at this time.

A batch spawning was observed in the White Sea cod. Usually the eggs are spawned in 5-6 batches by a female. Eggs are pelagic and with 1.45-1.70 mm of diameter. Eggs of the same batch could be of different buoyancy. Eggs spawned in March develop under almost constant temperature -1.6 to -1.4°C, but the development of eggs spawned in April realised under gradual temperature increasing from 0 to 1.0°C. Also desalinisation of surface water was observed during this time which resulted in eggs sinking to subsurface and deeper layers where the egg development continued successfully. Normal White Sea cod development as it was revealed in the laboratory experiments could go on in a wide temperature range - from -1.5°C to +8.0°C with duration of the embryonic development from 45-50 days to 12-14 days depending on temperature.

Newly hatched larvae of 4.2 - 4.9 mm TL occurs in plankton in the second half of May. Complete yolk absorption occurs by larval length of 5.5 TL, nearly ten days after emerging from the egg capsule. Larvae and postlarvae are distributed in the coastal zone while cod eggs could be obtained in the open sea.

0-group and young cod are also distributed in the shallow water coastal zone. 0-group cod attaining TL of 20-35 mm transfers from pelagic to demersal way of life usually in the second half of June. Adult cod predators on stickleback, sand lance, capelin, herring and other fish as well as on crustaceans. Growth rate of this cod is faster than that of the Barents Sea cod during first two years of life, then it become slower. The White Sea cod attains maturity at age 3-5 years and length of 25-35 cm TL. This cod lives for 10-11 years reaching 2.5 kg of weight and 60 cm TL.

Stock of this cod is not very abundant and commercial exploitation is not high. Total registered catches are from some tons to some hundreds of tons. Last decade it was not higher than 650 tons.

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Syntheses of North Atlantic Cod Stocks.

THE NORTH-EAST ARCTIC COD

Prepared by S. Sundby and K. Sunnanå

The ICES Study Group on Cod Stocks Fluctuations

DESCRIPTION OF THE ARCTO-NORWEGIAN COD STOCK LIFE HISTORY

The cod fishery history.

The spawning skrei fishery in Lofoten has been an important fishery at least since the 9th. century. The first written Norwegian history (Egils saga) refers to Torolv Kveldulvson who had fishermen at the fishing village Vågan in Lofoten catching skrei in the year 875. The importance of the fishery is indicated by what Egils saga tells about the trading with the cod: Torolvs man Torgils Gjallande sailed to England with stockfish and skins, and returned with wheat, honey, wine and clothes. Gultorers saga also indicates that the Lofoten spawning fishery must have been widely known: He tells that Icelanders who stayed in Norway during the last half of the 9th. century and the beginning of the 10th. century went to Lofoten to make money on the skrei fishery. The first history gives the impression that the fishery was quite an ordinary business, so it is reason to believe that it is much older.

Through out the centuries there are many descriptions of the variability of the fishery. However, the present authors has not managed to retrieved time series of the fisheries through out the centuries. Helland (1908) gives some indications of it from different historical sources: It was most probable good through the 14th., 15th. and the first half of the 16th. century according to the Hanseatic office in Bergen. During the last part of the 16th. and the first years of the 17th. century there seemed to be several years of poor fishery. Around 1650 the catches seemed to be back to normal, but it was less good during the last years of the 17th. century. Around 1750 the fishery was again back to the level as hundred years before. A new decline occurred in the late 1780ies, and this was probably influenced by large scale cool climate (Wyatt, 1987).

The exploitation of the Arcto-Norwegian cod has traditionally been a spawning fishery. For many hundred years (until around 1650) the gear type they used was line and hook. Then the the technical improvements started, first by introducing long line. In the 18th. century the nets came, and in the 19th. century purse seines was introduced. This must have had an substantial influence on the fishing mortality.

During the 19th. century there was large increase of the catches, only
interrupted by two minor declines in the beginning of the 1840ies and
and the late 1950ies and early 1960ies (Solhaug 1976). The Norwegian
export of stockfish and salted fish increased from around 15 mill.
fish in 1815 to 90 mill. fish in 1880 (Figure 1). This increase was 1.
most probable due to several factors like technical improvements of
the gear, the rise in consumption from a rapidly increasing European
population, and an incresing fishing effort.

<u>The history of cod research.</u>

The scientific history of the Arcto-Norwegian cod started in 1864 when Georg Ossian Sars did the first field investigations at the spawning grounds in Lofoten (Sars 1879). He observed that eggs and larvae from cod were floating in the surface layers after beeing spawned in the depth. Untill then it was assumed that all types of fish eggs developed at the bottom. The relation between cod and climate came also immediately in focus: Already that same year Sars emphasized that the temperature influenced the the distribution of the spawning cod, and he suggested that routineous deep water temperature measurements should be started to advice the fishermen of the location of the cod. However, the government did not start such measurements before 1878. In 1887 the governmental measurements stopped, but several fishermen had found the information useful and continued on their own (Sundby 1980). They were all of the opinion that the fish was located in the deep layers at temperatures of 4 - 5 ^{0}C. In 1891 the Norwegian Parliament funded an investigation aimed to reveal the relation between distribution of cod and temperature. This resulted in the first systematic investigation of the temperature conditions in the Vest Fjord (Gade 1894). He concluded that the spawning cod preferred temperatures 4 - 6 ^{0}C, and these temperatures were found in the thermocline at varying depths between 50 and 200 m.

From the turn of the century Johan Hjort exerted a large influence on the research on the biology of the cod, and particularly in the recruitment problem he was a brain stormer (Hjort 1914). However, at the same time it started to develop a schism between the physical oceanographers and the biologists, which should become an impediment to the development of the many important physical aspects of the recruitment research.

General structure of the stock.

The Arcto-Norwegian cod stock has historically been the largest cod stock in the North Atlantic. However, the stock size has been decreasing during the last 45 years from 6.7 mill. t in 1946 to 0.9 mill. t in 1989. There is a periodic variability in stock size of 6 - 9 years superimposed the decrease. The amplitude of the variability is large compared to the other cod stocks. Numbers on stock size based on virtual population analysis are available from 1946 (Figure 2). 2.

The Arcto-Norwegian cod is a relative long-lived type of cod. Typical it will mature around 7 to 8 years of age. It will recruit to fisheries at an age of 3-4 years and be out of fisheries by the age of 15. Its recruitement varies, and the influence of large yearclasses on the stock structure is quite strong. Figure 3. shows the variation of 3.
recruiting yearclasses (as 3 years old) since 1946.

Age material is avalable since 1904 in a limited form and since 1946 in an extensive form. This gives us time series of catch at age for the total stock, and divided on country and gear back to 1946. Catch at age for the norwegian catch may be constructed back to 1904. Using this material it may be possible to run a VPA back to this point.

The distribution of the Arcto-Norwegian cod is shown in Figure 4. The 4.
east and north boarder is determined by the polar front and may vary from year to year. The western boarder is the continental slope and cod is not found in deep oceanic watermasses. However, tagging experiments have shown that individuals may have migrated west to Iceland, Greenland and Newfoundland. The southern boarder is the spawning areas on the Norwegian coast, the southernmost beeing the Bremanger bay at 62 ^{0}N.

The total stock may be devided into components, one is found in the Barents sea and one in the Spitsbergen-Bear Island area. However the two components seem to have different main spawning grounds at the coast. The Barents sea component spawn mainly at the Lofoten area and the Spitsbergen-Bear Island component spawn mainly further south at the Møre region off Mid Norway. There is however substantial exchange between the two components and they are managed as one stock unit. There is also a third component of this cod, the coastal cod, which is found in the fjords and coastal regions all along the coast of Norway and the Murman coast.

Fishing pattern.

The fishing pattern is well described (by age) back to 1946 and is given as average 10-year values in Figure 5. Before this various sources of information is available. The largest change in fishing pattern is probably caused by the introduction of trawlers in the fishery. This made the exploitation on young pre-mature fishes much more extensive than earlier, and this may be an explaination of both the stock reduction and the decreased maturation age during the last 40 years. 5.*

As a commercially important fishery, throughout the 19th century the fishing took place mainly on the mature cod (the Lofoten fishery) and secondly on the migratory, prespawning cod following the capelin to the coast (the Finnmark fishery). In Figure 6 the catches in the main fisheries together with the total cod catch is given to illustrate the changes in the fishing pattern during 19th and 20th century. From this we can se that other fisheries has also been important during time periodes, in particular the fishery on spawning cod at the Møre coast. 6.*

Environment.

The feeding habitat of the juvenile and adult cod comprises the ice free parts of the Barents Sea and the narrow shelf region to the west of Svalbard, which is an area of about 0.6 - 0.7 mill. km^2, or about 40 - 50 % of the entire area of the Barents Sea. Spawning occurs mainly outside the feeding habitat, at distinct and separate locations along the Norwegian coast from Sørøya to Møre (Figure 7). The drift of eggs, larvae and early juvenile take place in the upper 50 m of the sea and mainly in the Norwegian Coastal Current, where they are passively advected from 600 -1600 km and dispersed back into the habitat of juveniles and adults. 7.*

Loeng (1989) has reviewed the ecological features of the Barents Sea with emphasize on the physical conditions and the primary and secondary production. The mean depth of the Barents Sea is 230 m. The Bear Island Channel, which intrudes eastwards from the western shelf edge, is the deepest part of the sea with depths between 400 and 500 m. Large areas of shallow depths, less than 100 m, are found between Spitsbergen, Bear Island and Hopen (Figure 8). 8.

There are two sources of warm water supply to the Barents Sea, the large and salty Norwegian Atlantic Current, which carries about 3 Sverdrups, and the less important and fresher Norwegian Coastal Current, which carries about 1 Sverdrup, (Figure 9). Both these 9.
currents run parallel towards northeast along the coast of North Norway and turn east into the Barents Sea in the region of the bank Tromsøflaket. The coastal current spreads out in a clock-wise circulation above Tromsøflaket, while the Norwegian Atlantic Current splits into two branches northwest of Tromsøflaket. One branch flows around the bank and into the Barents Sea, the other continues north towards Spitsbergen along the shelf edge. The scalar speed of the Coastal Current is 10 - 30 cms^{-1}, while the maximum speed is 80 - 100 cms^{-1}. The speed of the Atlantic Current is about 50 cms^{-1} along the shelf break off the Norewegian coast, but decreases when it turns into the Barents Sea and get wider.

The cool water enters the Barents from the Arctic Basin through the straits between Svalbard and Franz Josefs Land (The East Spitsbergen Current) and Franz Josefs Land and Novaya Zemlya (The Persey Current)(Dickson et al. 1970). Very few current measurements have been carried out in this northern region and the volume fluxes are not known.

Even though the Norwegian Atlantic current is much larger than the Norwegian Coastal Current, the latter is the most important conveyor for eggs and larvae from the coast of Norway to the Barents Sea. The Coastal Current extends above the continental shelf of Norway, and its circulation is strongly influenced by the bottom topography, creating numerous stationary and quasi-stationary eddies and bends. Particularly, the influence of bank topography on the circulation has been studied (Eide, 1979), and it has been demonstrated how the bank topography influence the distribution of eggs and larvae (Sundby, 1984, Bjørke and Sundby, 1984). The bank Tromsøflaket in the southwestern Barents Sea (Figure 10) is a key region for the early juveniles. The 10.

clock-wise circulation above this bank creates an interim retention of early juveniles in July on the drift route from the spawning fields at the Norwegian coast to the central parts of Barents Sea. During the early juveniles survey in July 40 - 90 % of the year class is found within this bank (Bjørke and Sundby, 1987), The area of Tromsøflaket is no more than 25.000 km^2, while the total area of early juveniles distribution ranges from 100.000 to 200.000 km^2.

The habitat of the Arcto-Norwegian cod is influenced by four water masses, The Atlantic Water, The Coastal Water, the Arctic Water and the Norwegian Sea Deep Water. The first three of these water masses are present in the in the habitat, while the fourth, the Norwegian Sea Deep Water is only present as a mixing product with the Atlantic Water. Figure 11 shows the positions of the first three water masses 11.*
along a north-south hydrographical section at the entrance of the Barents Sea. Figure 12 shows the positions of all four water masses 12.
in a temperature-salinity plot.

1. The Atlantic water occupies the deep layers at the Norwegian continental shelf, the entire water column above 500 m depth off the shelf break and the central parts of the Barents Sea. The salinity in the core is 35.0 - 35.2 and the temperature is ranging from 6 - 8 ^{0}C. The temperature and salinity are decreasing as the water mass flows northwards along the shelf edge and eastwards into the Barents Sea. At the entrance of the Barents Sea the mean salinity and temperature in the core in the autumn was 35.13 and 6.2 ^{0}C respectively (Blindheim and Loeng, 1981). This water mass is the main habitat of the juvenile and adult Arcto-Norwegian cod

2. The Coastal water flows parallel to the Atlantic water close to the coast and is wedge shaped. The t-S characteristics have a large yearly amplitude, beeing fresh and warm in summer, cool and more saline in winter. The extreme values are typically 10 - 12 ^{0}C and 33.2 - 33.6 in August and 2 - 4 ^{0}C and 33.7 - 34.4 in March/April. As this water mass flow north and eastwards the temperature decreases due to heath loss from the surface, and the salinity increases due to mixing with the saline Atlantic Water. During the eggs, larvae and early juveniles stages the coastal water is the habitat of the Arcto-Norwegian cod.

3. The Arctic Water origins from the inflow of water through the straits between Svalbard and Franz Josefs Land and Franz Josefs Land

and Novaya Zemlya. It flows southwest through the Barents Sea along the northern slope of the Bear Island Channel. In this region ice is formed during winter and melts again during summer. Its average temperature and salinity is -1.8 ^{0}C and 34.5 respectively. The position of the Arctic Water limits the northern extension of the Arcto-Norwegian cod. Increased mortality due to low winter temperatures has been reported for 0-group and 1-group cod. However, there are also examples of adult cod that intrude water of -1^{0}C in summer when chasing capelin.

4. The Norwegian Sea Deep Water occurs only as a mixing product with the Atlantic Water in the habitat of the cod. This mixing product is found i the deepest troughs of the Norwegian continental shelf and i the Bear Island Channel. It has a very constant salinity of 34.92 and a temperature ranging from -0.5 to -1.0 ^{0}C.

There are considerable variations in the sea ice conditions from year
to year in the Barents Sea. Figure 13 shows the variation in the 13.
position of the ice edge, based on satellite images from a period of
10 years, 1971-1980, for 6 months of the year. The seasonal extremes
are found in March-May and August-September (Loeng, 1979). Figure 14 14.
show the distribution of ice during April-August for three periods 1898-1922, 1929-1939 and 1971-1980. There was a distinct decrease of the ice in the Barents Sea from the first to the second period. This decrease was a result of alterations in the atmospheric and oceanic circulation (Hesselberg and Johannessen, 1958) (Zubov 1943).

Spawning.

The mature cod aggregate off the coast of Finnmark during late autumn, start the spawning migration along the Norwegian coast in December and arrives the Lofoten spawning grounds from late January (Bergstad, Jørgensen and Dragesund, 1987). The spawning migration is counter current along the coast and takes mainly place in the thermocline between the upper cool Coastal water (2-4 ^{0}C) and the warmer Atlantic water (7 ^{0}C) below. This implies that the cod have the opportunity to select the ambient temperature within the range of 2-7 ^{0}C. Sætersdal and Hylen (1959) decribed the migration. The spawning route along the coast seems to be the same each year, southwards along the shelf break and along specific troughs from the shelf break in to the near shore spawning grounds. The average migration speed of the schools is 8 - 10 n.m. per day, or 17 -20 cm s^{-1}. The highest concentrations are recorded within eddies along the route. In regions of strong current the concentrations are low. The largest and oldest specimens arrive the spawning grounds first (Rollefsen and Hylen, 1981).

The spawning areas of Arcto-Norwegian cod are patchy, located in the Norwegian coastal current off mid and north Norway, along a 1200 km coastline. The spawning areas are the same sites every year, although the magnitude of the spawning at the sites may vary. Most of the eggs are spawned along a limited part of the coastline, in Lofoten and Vesterålen, between 67^0 30' N and 69^0 N (Figure 15). From 1983 to 15.
1985, 60-70 per cent of the total egg number were spawned here, when the production varied between 3.1×10^{13} and 4.7×10^{13} eggs (Sundby and Bratland 1987). Especially in Lofoten the spawning schools are very dense, the peak egg concentration may exceed 10.000 eggs per m^2 surface (Wiborg 1950, Sundby 1980). Such high concentrations are not only caused by dense spawning, but are also due to higher retention at the Lofoten spawning grounds than at the other spawning sites (Sundby and Bratland 1987). A characteristic feature of all the larger and most of the medium size spawning fields is that they either are found in bays close to the coast (the Lofoten fields), or that they are found on offshore banks where the bottom topography induces a clockwise circulation (Sundby 1984). Both in the bays and on the banks where spawning takes place, the residence time of the water masses is prolonged, and consequently this will also be the case for eggs that develop in these areas, an analog to retention areas (Iles and Sinclair 1982). However, not all of the major spawning grounds are found in areas of high residence time of the water masses. Especially at some of the Vesterålen offshore spawning grounds, cod eggs are subjected to rapid transport and dispersion (Sundby and Bratland 1987). Altogether, about 20 - 30 percent of the eggs are spawned at sites where there is short residence time of the water masses. Most of these eggs are spawned close to the offshore front between the coastal water and the Atlantic water. In this region both water masses move rapidly northwards along the shelf edge.

The influence of the changing winds on the spawning behaviour and the distribution and spreading of eggs in Lofoten has been described (Ellertsen et al. 1981a, Ellertsen at al. 1981b, Furnes and Sundby 1981, Sundby 1981). Northeasterly winds in Vestfjorden increase the egg transport out of the fjord, while southwesterly winds increase the spreading within the fjord. Calm wind conditions give a low rate of both transport and spreading.

The spawning occurs in March and April. In Lofoten, where the largest spawning sites are found, the spawning intensity has been monitored each year since 1975 (Solemdal 1982 , Ellertsen et al. 1984). There is a remarkable constancy between years of how spawning proceeds, starting during the first days of March, reaching maximum intensity during the first week of April and petering out within the first half
of May (Figure 16). The spawning intensity has also been monitored at 16
several other major spawning fields (Anon. 1983), revealing a tendency towards later spawning at the grounds farther north. The spawning period is delayed by about 2 weeks at the northernmost spawning field relative to the Lofoten area (Sundby and Bratland 1987).

Pedersen (1984) examined the long term changes of the maximum spawning intensity in Lofoten based on cod roe investigations from fish catch statistics since 1929. He found a tendency towards later spawning, approximately 7-15 days, during the period from 1930 to 1960.

The Arcto-Norwegian cod spawn in the thermocline between the cold Coastal water and the warmer Atlantic water, at temperatures between 4 and 6^0 C, both pelagically and where these layers intersect the bottom (e.g. Gade 1894, Sund 1925). The depth of the thermocline may vary considerably from year to year (Eggvin 1932), but short term variations caused by wind effects may also be of great importance for the depth of the thermocline causing upwelling or downwelling at the spawning fields (Furnes and Sundby 1981, Ellertsen et al. 1981a).

Egg and larval stages.

Ellertsen et al. (1989) summarized recent research on the early life stages of the Arcto-Norwegian cod.

The eggs are buoyant compared to the natural environment, and hence tend to rise towards the surface layers (Solemdal 1970, Solemdal and Sundby 1981). The neutral buoyancy and the egg diameter for the entire egg population are Gaussian distributed, and range from 29,5 to 33,0 p.s.u., and from 1,2 to 1,6 mm, respectively. From these values the ascending speed of the eggs was calculated to range from 0,2 to 1,8 mms^{-1} (Solemdal and Sundby 1981, Sundby 1983). Solemdal and Sundby (1981) showed that neutral buoyancy is correlated to the weight of the eggshell, whose thickness may vary between 5 and 9 µm (Davenport et al. 1981). The specific weight of the eggs increases through the development (Sundnes et al. 1965).

The eggs are found in the entire upper mixed layer, but the concentration increases towards the surface. During calm conditions high concentrations are found at the surface, and most of the eggs are found above 20 m depth. During rough weather the eggs are mixed downward due to the influence wave action and turbulence, Figure 17. When the 17.
wind speed exceeds 15 ms^{-1} the vertical concentration profile of cod eggs shows only a very slight increase towards the surface, and may be found in relatively large concentrations down to the bottom of the mixed layer. Models for how the vertical distribution of pelagic and bathypelagic eggs in general are influenced by buoyancy and turbulence are described by Sundby (1983), Sundby (1990) and Westgård (1989). The vertical spreading of the pelagic Arcto-Norwegian cod eggs is mainly determined by the wind induced turbulence, and only to a very small extent by the buoyancy distribution.

The years 1981 and 1983 represent two extreme years with respect to temperature during the incubation, with mean March/April temperatures in the upper 30 m in the Vestfjord, 1,3 and 3.6^{0}C, respectively. The peak of hatching varied by approximately 2 weeks between 1981 and 1983 (Solemdal 1984, Ellertsen et al. 1987), hatching time for the earliest spawned eggs in 1981 was ca. 35 days.

Egg mortality estimates for the years 1983 and 1984 have been made in Lofoten where the retention is high (Ellertsen et al. 1987, Fossum 1988), based on population fecundity estimates (Sundby and Solemdal 1984, Sundby and Bratland 1987) and subsequent measurements of late egg stages. In both years the mortality from spawning to hatching was 90 per cent (Fossum 1988). The causes of the mortality are not well known, but there is evidence that the predation by herring may be considerable (Melle and Ellertsen 1984, Melle 1985). The stock fecundity estimates are assumed to have a high precision, since they were in very good agreement with acoustic measurements of the biomass of spawning fish (Godø, Nakken and Raknes 1984, Godø, Raknes and Sunnanå 1985).

The cod larvae in the Lofoten area are, like the eggs, trapped in the mixed water masses of the cold coastal current, and consequently the distribution is determined by the dynamics of the coastal current. The maximum recorded concentration of larvae is approximately 200 per m^2 surface, which is about 5 % of the maximum recorded concentration of newly spawned eggs. The number of larvae estimated during one survey varied between years from $2x10^9$ to $1,2x10^{11}$ (Ellertsen et al. 1987). The horizontal distribution of larvae has been recorded since 1979. The horizontal distribution of larvae for the two years 1981 and 1983 are shown in Figure 18. 18.

Investigations on the vertical distribution of cod larvae, carried out with large pumps (Solemdal and Ellertsen 1984), found that the majority of first feeding larvae in the Lofoten waters are distributed in the upper 30 m of the water column (Ellertsen et al. 1979, Wiborg 1948). The peak concentration occurs between 10 and 20 m, and the concentrtation above 5 m depth is very low. Diurnal vertical migration depends on the ability of the larvae to move and the vertical turbulence. During extremely calm conditions larvae seem to "control" their vertical position in the water column, and show diurnal migration (Ellertsen et al. 1984).

Like most marine fish larvae, cod larvae are visual feeders (Ellertsen et al. 1980), and select their prey on the basis of size (Ellertsen et al. 1979). Larval gut content analysis from the Lofoten area shows that nauplii of Calanus finmarchicus are the most dominant prey item (Ellertsen et al. 1984, Wiborg 1948). A larval bioassay technique (Lasker, 1975) tested in Lofoten showed that the cod larvae were able to capture nauplii at rather low concentrations (Ellertsen et al. 1979), and that larvae were feeding on copepod fecal pellets. Fish larvae have been frequently reported with green food remains in the gut (Lebour 1919). Wiborg (1948) reports the same findings in cod larvae from the Lofoten area. Nordeng and Bratland (1971) have identified the phytoplankters Peridinium pellucidum and Coscinodiscus sp. in the gut of cod larvae from the same area. Analysis of polyunsaturated fatty acids in the cod larvae from Lofoten shows influence of specific fatty acids from phytoplankton (Tilseth et al. 1987). The significance of this observation from a nutritional point of view is not yet fully understood. The first feeding larvae were active feeders on larger plankters like Peridinium sp. (50-80 µm).

Active feeding in fish larvae usually occurs only above a certain light intensity (Blaxter 1966). Cod larvae fed *Artemia salina* were able to capture *Artemia* nauplii at 0.4 lux, but not at 0.1 lux, and highest feeding incidence was observed at 1.4 lux (Ellertsen 1976, 1980). Providing that the light intensity threshold for visual feeding of cod larvae on nauplii is close to 0.1 lux, there are 22-24 hours available for feeding per diurnal period in May in the Lofoten area (Blaxter 1966).

Ellertsen et al. (1987) examined the prey density and larval distribution in different regions of the Lofoten area and found higher prey densities, higher larval feeding incidence and higher number of larvae with full gut in the areas of Vestfjorden where the retention is large. In the surrounding areas these parametres were much more variable. Comparison of the gut fullness of stage 7 larvae caught in the upper 40 m during daytime, and the integrated nauplii concentration in the water column showed that maximum gut fullness was reached when the nauplii concentration exceeded 10 per litre. The empirical data indicate a critical prey density of 5-10 nauplii per litre. However, the wind generated turbulence was demonstrated by Sundby and Fossum (1990) to have a substancial impact on the contact rate between the cod larvae and their prey, as outlined in the theory by Rothschild and Osborn (1988). When the average wind velocity increased from 2 m s^{-1} to 6 m s^{-1}, the contact rate increased by 2.8, which corresponds fairly well with the theory. In Figure 19 the 19.
relation between the number of nauplii in the larval gut and the nauplii concentration in the sea are drawn for three different wind situations.

Ellertsen et al. (1987) and Fossum (1988) examined survival of cod eggs and larvae within the Lofoten spawning area in 1983 and 1984, when strong year classes were produced. Only 2-3 per cent of the eggs spawned in 1983 and 1984 reached the stage of first feeding larvae. Larval length/ dry weight results for the first feeding periods in 1982 - 1985, indicate that the first feeding larval condition is correlated to the year class strength.

In investigating the vertical distribution of copepod nauplii different plankton pumps and particle rate meters have been used (Ellertsen et al. 1976, 1979, Mohus 1981, Tilseth and Ellertsen 1984a). The highest concentrations of nauplii usually occur at 5 - 15 m depth, occasionally at the very surface (Ellertsen et al. 1979, Tilseth and Ellertsen 1984a), and the general impression is that very high concentrations of nauplii at the surface usually occur in the evening during very calm weather (Ellertsen et al. 1979).

Almost all C. finmarchicus nauplii in the Lofoten occur within the upper 50 meters due to spawning close to the surface, the sinking velocity of eggs and the incubation time. However, the vertical distribution of copepod nauplii is not constant throughout a 24-hour period. Numerous 24-hour stations in 1975-87 have revealed an increasing concentration in the upper 0-5 m in the evening versus a daytime maximum at 5-15 m (Ellertsen et al. 1979, Tilseth and Ellertsen 1984a, and unpublished data). It can be concluded that the medium and larger sized nauplii show a diurnal vertical migration, while the smallest ones, (<120 µm carapace length) do not seem to migrate.

The first feeding cod larvae are seldom observed to make vertical migration, and such migration has only been observed during very calm weather conditions. Usually, they have their maximum concentration at 10-20 m depth throughout the 24 hour period (Ellertsen et al. 1979, Tilseth and Ellertsen 1984a), or undertake a vertical migration over a few meters. Cod larvae show a reduced feeding intensity at night (Ellertsen et al. 1979, Tilseth and Ellertsen 1984b), coinciding in general with a period of reduced nauplii concentrations at 10-20 m. The smallest nauplii which are prevailing at cod larval depths at nighttime are in general to small to be eaten by the cod larvae, which seem to select food organisms over a certain size (Ellertsen et al. 1979).

The horizontal distributions of copepod nauplii in the Lofoten area 1980-1985 are shown in Figure 20. These maps, together with series of 20.
previously published (Ellertsen et al. 1984, Tilseth and Ellertsen 1984a) data give an impression of the Lofoten as a variable area with regard to naupliar distribution. In general there are higher concentrations of nauplii within the smaller fjords like Austnesfjord, while the lowest densities are usually found outside the Lofoten archipelago. Ellertsen et al. (1989) showed that the production of nauplii is highly dependent of the temperature of the upper layer where the mature C. finmarchius spawn. Figure 21 shows the date of maximum 21.

occurrence of C. finmarchicus copepodite stage 1 as a function of the average temperature of the uppper layer during March-April. The time of maximum occurence varies by more that 1 1/2 month, beeing late in cold years and early in warm years.

For the Arcto-Norwegian cod, temperature seems to be a very important parameter related to recruitment. Only small year classes are produced when the temperatures in the early larval distribution areas are low (Figure 22), while year classses of all strengths are produced under 22.
higher temperatures. The most prominent environmental feature of the year 1983 was the high temperature of the coastal water masses during spawning, of 3.6^0C, the highest recorded since 1961. Only two years earlier, in 1981, eggs and early larvae experienced the lowest environmental temperature (1.3^0C) ever recorded since the temperature measurements started in 1936, and became a very poor year class. The relationship between year class strength at age 3 years and the temperature during the egg/early larval stages indicates that temperature is a necessary condition for the formation of strong year classes, it also implies that other processes are important, since far from all years with high temperatures produced a strong year class.

Temperature dependent recruitment is found in other cod stocks living on the border of their distribution area, for example the cod stock at West Greeland (Hansen and Buch, 1984). They suggested that it could be caused by variable advection of juveniles from warmer Icelandic waters. Obviously, many processes related to recruitment are temperature dependent. For the Arcto-Norwegian cod the temperature-dependent spawning of C. finmarchicus in Lofoten, causing a delay in spawning of 1 1/2 month in the coldest year compared to the warmest, may be a very important process to cause variable larval survival (Ellertsen et al. 1989).

The significance of temperature is supported by the work of Sætersdal and Loeng (1987), who found that strong and medium year classes occurred most frequently in years with high temperatures along the Kola section. Since most of the temperature variations in the Norwegian Sea/Barents Sea are of a geographically large scale (Dickson and Blindheim 1984, Blindheim, Loeng and Sætre 1981) the same variations also appear in the Lofoten spawning area.

Juveniles.

There is a gap of information and research on stages around metamorphosis, when the fish is about 8 - 15 mm long. This is due to lack of adequate gear types. During these periods the concentrations are too low and the mobility of the creatures are too high to get good samples by low speed plankton nets or large pumps. However, a Norwegian early juveniles survey has been carried out each July since 1977, when the juveniles have reached a size of 20 - 50 mm. From this survey maps of distribution and an abundance index are worked out. The gear type is a mid water trawl with an opening 29 x 29 m, the same gear as is used during the subsequent International 0-group survey of the Barents Sea in August-September when the juveniles have reached a size of 50 - 80 mm and obtained their terminal pelagic distribution before they settle to the bottom. Figure 23 shows two examples of the distributions during early larval stage in July and the 0-group stage in August - September (Sundby et al. 1989). 23.

The spatial distribution of early juveniles (20 - 50 mm) is described by Bjørke and Sundby (1984, 1987). As for the larvae, they are mainly found above 30 m depth, but their vertical distribution within this column is different from the larvae. While the larvae have their maximum concentration between 10 and 20 m depth and seem to avoid the upper 5 m of the sea, the early juveniles are often found in high concentrations in the upper 5 m. The horizontal distribution is strongly influenced by the mesoscale circulation which in turn is strongly influenced bottom topography steering. This results in high concentrations above the two banks Tromsøflaket and Nordkappbanken in the southwestern Barents Sea (Figure 10). 10.

As during the early larval stages, the main prey organism of the early juveniles is still C. finmarchicus, but now they increasingly take the adult stages. They also start feeding on krill (Sysoeva and Degtereva, 1965). Bjørke and Sundby (1987) found that the early juveniles in the southern and western parts of the area of the early juveniles distribution is considerably larger than in the eastern part, even though it is to be expected from consideration of the circulation that the larvae in the eastern part are older. It is assumed that this appearent paradox is due to the combined effect of higher temperature and food supply in the southwestern region (Suthers and Sundby in prep.).

The international 0-group survey in the Barents Sea has been conducted each year since 1965. They give maps of distribution and an abundance index. The survey is carried out during three weeks in August-September which is prior to when the juveniles settle to the bottom.

Randa (1984) studied the relation between the 0-group abundance index and the abundance at age three based on virtual population analysis for a period in the 1970-ies. He found that there was a good correlation indicating that the year class strength is mainly determined at the 0-group stage. Sundby et al. (1989) studied the early juveniles data and found that the year class strength is largely determined already at this stage. However, it was concluded that during periods of large ecological changes, the year class strength may change considerably after the stages of early juveniles and 0-group. This happened in 1983-85 when the production of the extremely strong 1983 year class of cod was succeeded by a break-down in the recruitment of the important prey organism capelin. The 1983 year class of cod then switched predation to the 1984 and 1985 year classes of cod (Mehl, 1988). This reduced these two year classes from relatively strong at the early juveniles stage to weak-average at the stage of 1-group. Ponomarenko (1984) found that another factor for the mortality of 1-group and 2-group cod is low winter temperatures in the northeastern Barents Sea.

The population mortality during three periods from hatching to the 3-group stage was studied by Sundby et al. (1989). The instantaneous mortality declined from an average value of 42 y^{-1} during the period from hatching to early juveniles (2-3 months old), to a value of 8 y^{-1} during the preceeding period from 2-3 months old to 4-5 months old (0-group survey). During the third period from 4-5 months old to 3-group fish the instantaneous mortality was on the average 0.6 y^{-1}. Also the range of variation in the total mortality during these three periods was considerably larger during the first period, 67, while during the following period (from 2-3 months to 4-5 months) the range of variation was reduced to 3. Besides, most of the variation during this second period could be ascribed density dependent mortality, and hence it is predictable. Even though the instananeous mortality is as low as 0.6 y^{-1} during the third and long period from 4-5 months to 3 years, the range of variation of the total mortality is relatively high, 2.8, due to the much larger duration. There is no indication of density dependent mortality during this period. The results of Sundby et al. (1989) demonstrates that the first three months is the most important period in the formation of year class strength, and they conclude that the mortality during this period most probably is caused by the combination of predation and starvation.

Adults

As the cod mature, it takes on a different migratory pattern than the juveniles. The migration is aimed at reaching the spawning grounds at the coast in February-March. This also determines the food available to the mature part of the stock. Two important feeding periodes may be described. The first one is in late summer/autumn when the fish is building up its storage for developing spawning products. The second, and perhaps most important, is the feeding in spring when returning from the spawning grounds. In this period the losses due to spawning must be compensated and also the intake of energy for most of the growth of the fish takes place. If not sufficiently food is found in this period, low growth and perhaps no maturation will occure.

The main food items found in cod stomacks during the later years are capelin, redfish, shrimps, other crustaseans and other fishes. In earlier years herring also was a very important food item. The relative importance of capelin and herring in the food of cod are determined by the size of the herring stock. The migration pattern of cod together with the distribution and migration pattern of herring and capelin is given in Figure 4. The cod returning from the southern 4.
spawning grounds may find a lot of herring on their way back to the Barents sea. There are also observations of cod eating herring before spawning and this may indicate that the southernmost spawning migration may be influenced by the amount of herring at the coast. Cod spawning at the northen spawning grounds are very dependent of capelin as food after spawning. However, young herring may be found in the Barents sea, espesially the large yearclasses and this may be important for the cod during spring.

The age at first maturation of Arcto-norwegian cod may vary considerably, from 4 years to 10 years of age. The median age at maturity is about 7 years. Observations of changing average size in the Lofoten fisheries during the years after 1815 indicate that median age at first maturity must have varied considerable.

Changes in growth may account considerable to this change in average size but can not account for all of it. Growth of the individuals is very close to linear conserning length. The growth in the first year of living may typical be 15 cm. The avarage annual length increment beeing between 10 and 11 cm. However the variation in this increment is substantial, typical low values beiing 7 cm and high values beiing 13 cm. The weight is best decribed using the cubic of the length multiplied by a "condition-factor". The formula $W = a L^3$, where a = 0.009 and L is lenght of fish in cm, gives weight in grams. The variability in the condition factor is between 0.008 and .0095 typically.

The mean individual population fecundity is about 1.4×10^6 eggs (Sorokin, 1961, Kjesbu, 1988).

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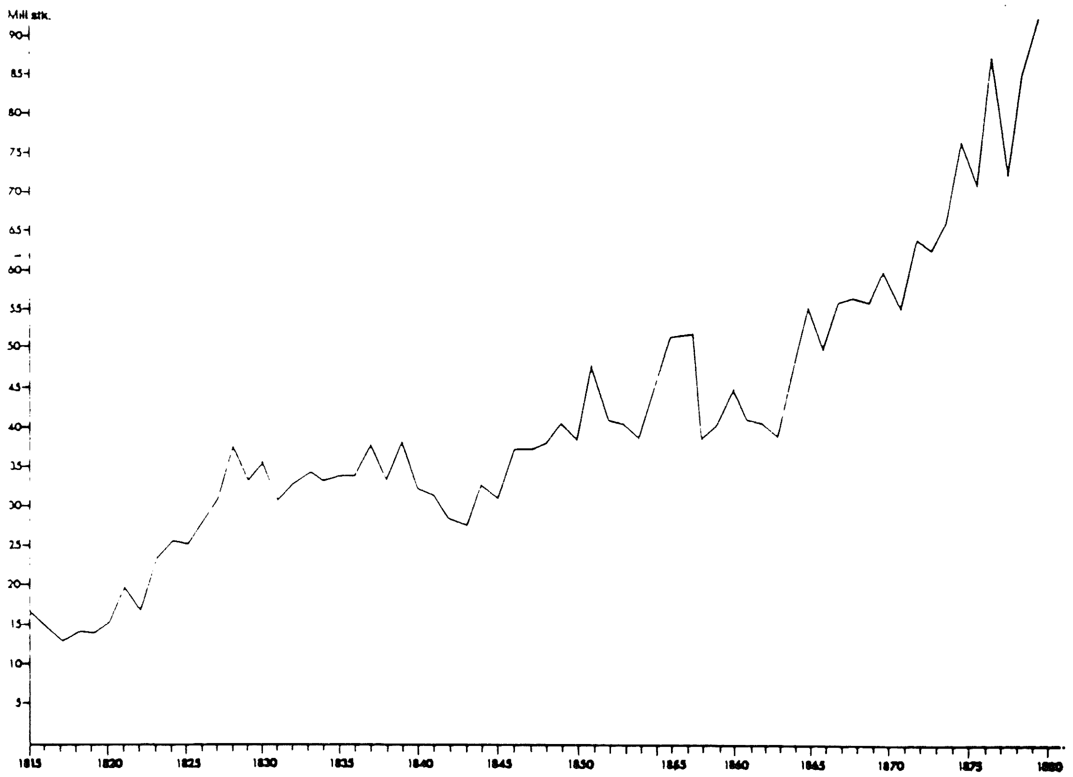

Figure 1. The export of cod in numbers of mill. from Norway during the period 1815 -1880. (After Solhaug (1976)).

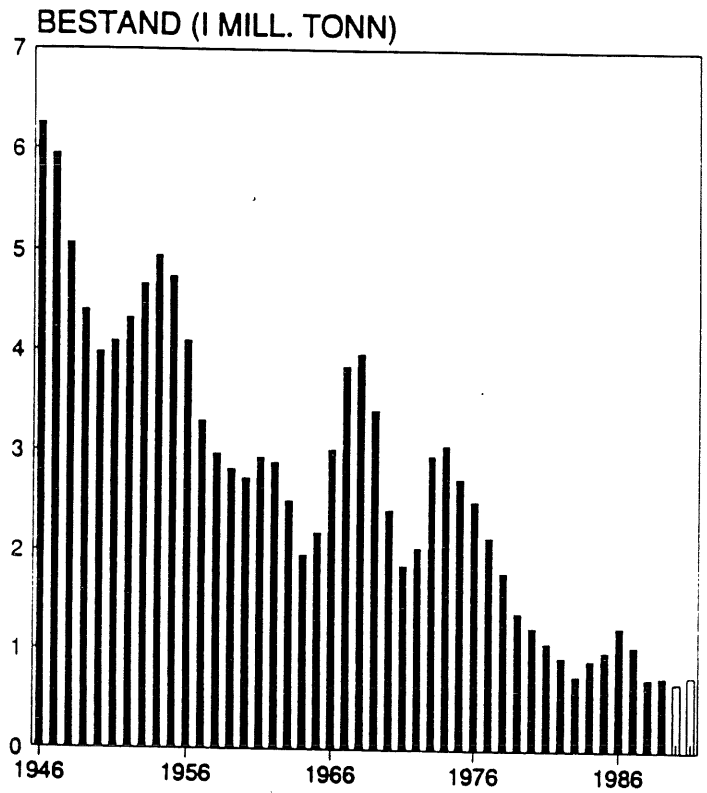

Figure 2. Total biomass (mill. tons) of the Arcto-Norwegian cod stock since 1946. (Fisken og Havet 1990, Særnummer 1).

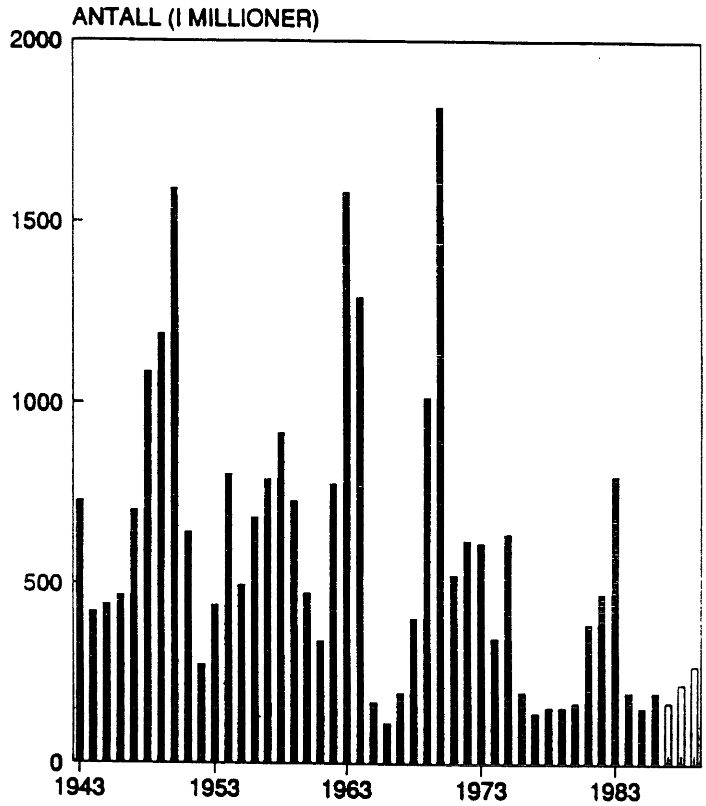

Figure 3. Year class strenght in numbers of mill. at age 3 of the Arcto-Norwegian cod since 1943. (Fisken og Havet 1990, Særnummer 1).

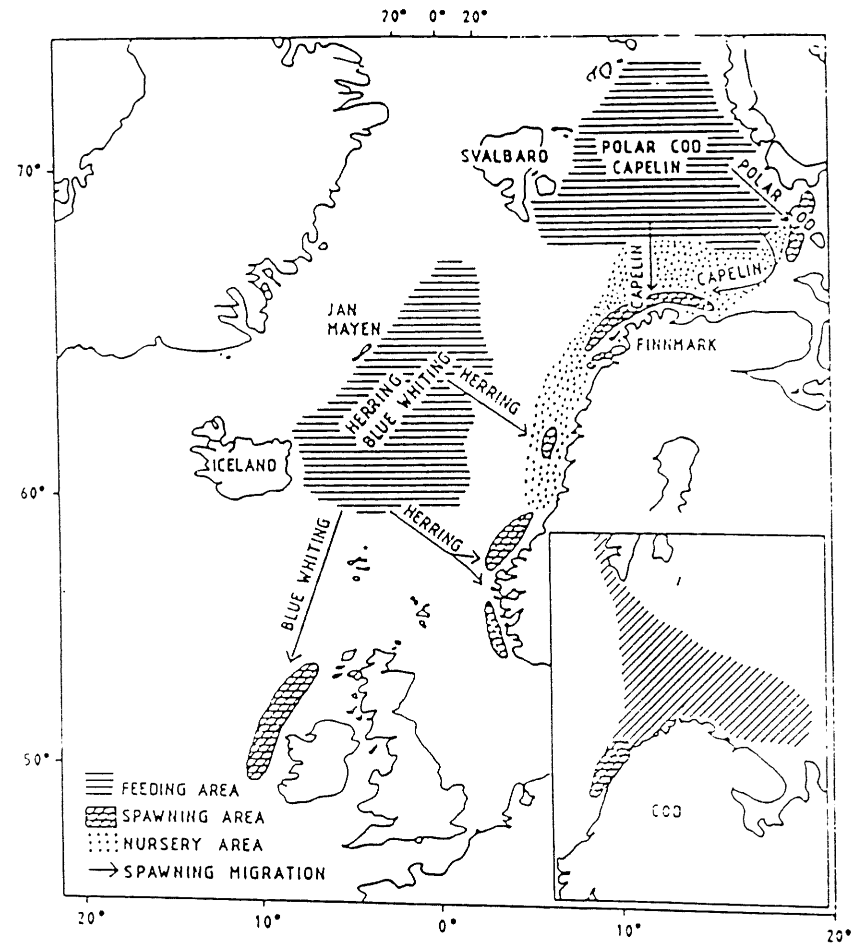

Figure 4. The general distribution of herring, capelin and cod in the Norwegian Sea- Barents Sea ecosystem. (Hamre, 1988)

Figure 5. The fishing pattern given as average 10-year values from 1946.

Figure 6. Catches in the main fisheries together with the total cod catch during 19th and 20th century.

Figure 7. Spawning areas of the Arcto-Norwegian cod.

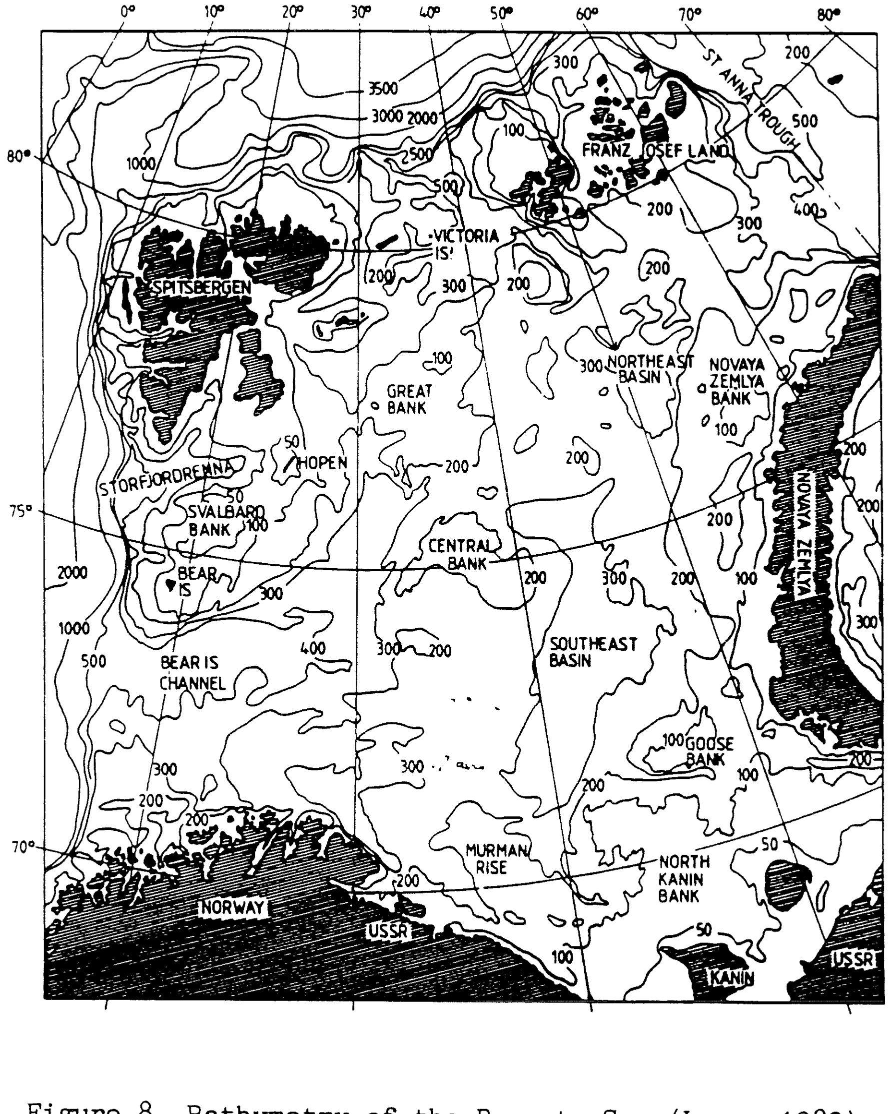

Figure 8. Bathymetry of the Barents Sea (Loeng 1989).

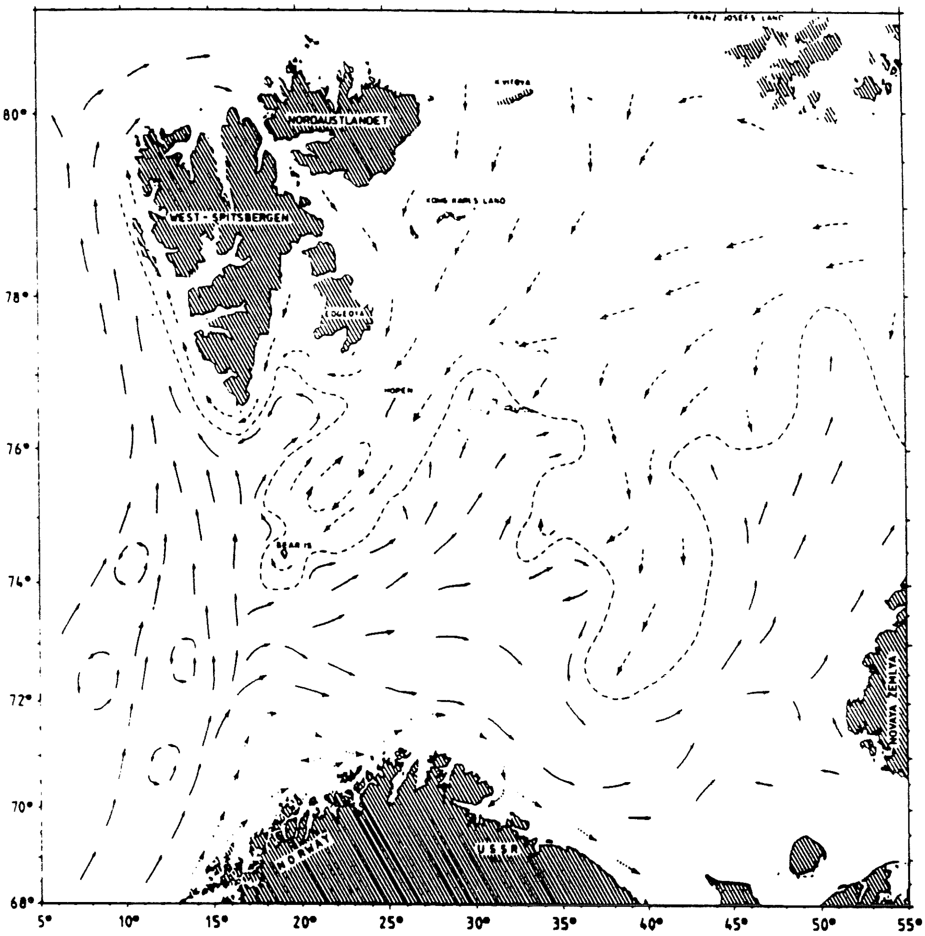

Figure 9. General circulation of the Barents Sea (Loeng 1989).

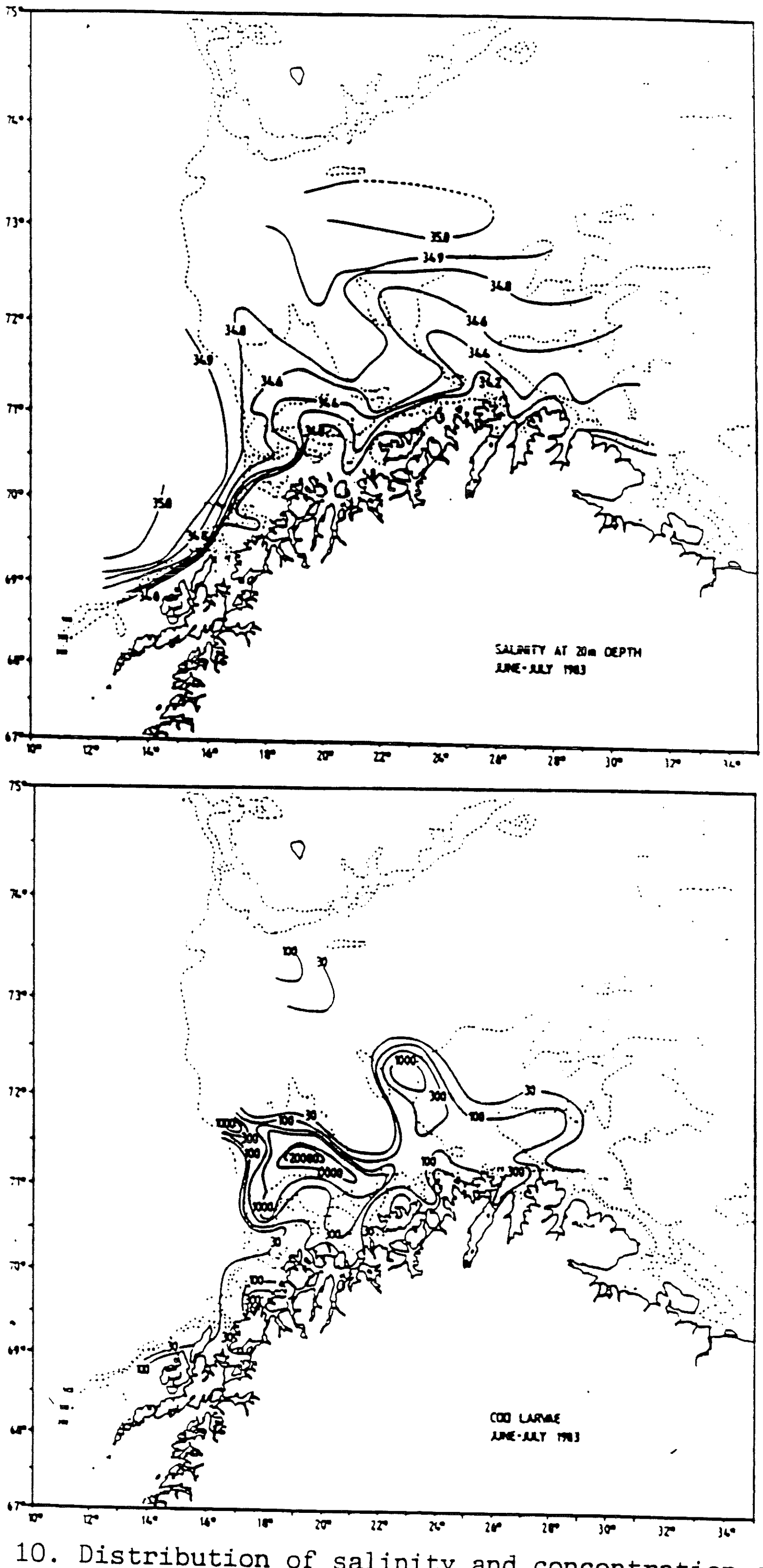

Figure 10. Distribution of salinity and concentration of early juveniles cod at the banks Tromsøflaket end Nordkappbanken in 1983. (Bjørke and Sundby, 1986).

Figure 11. Water masses in a North-South section at the entrance (the western boundary) of the Barents Sea.

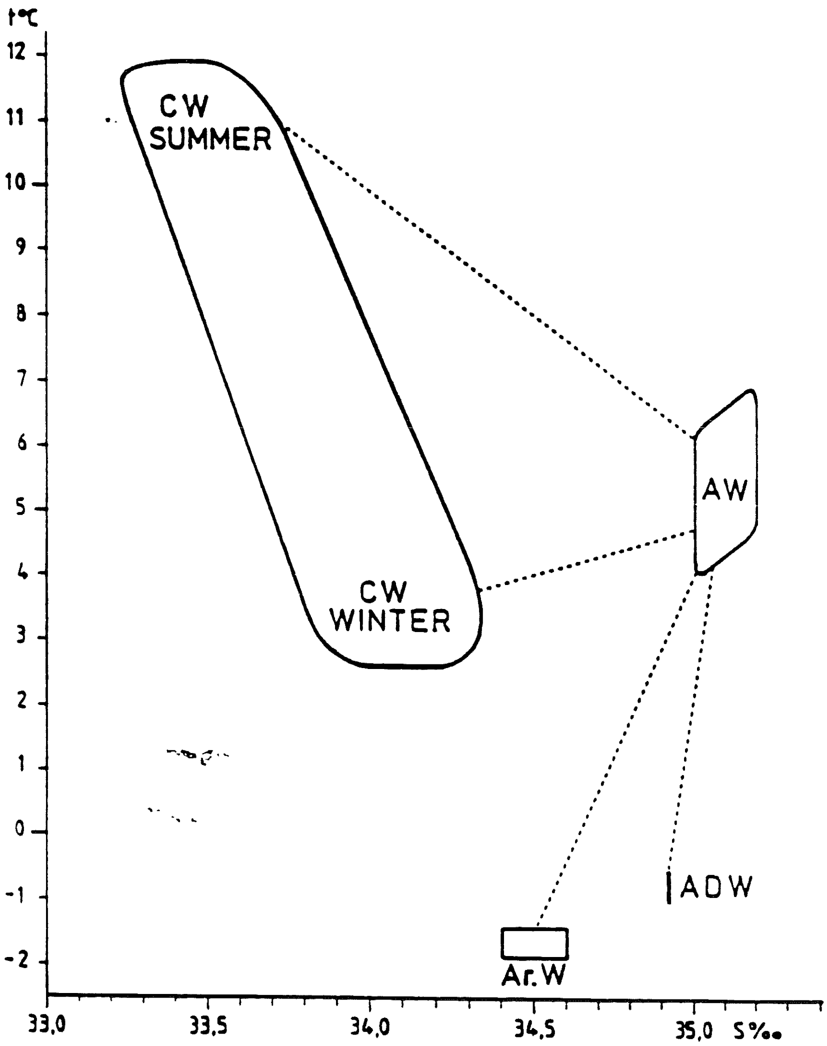

Figure 12. Temperature-salinity characteristics of the ambient water masses of the Arcto-Norwegian cod. (Loeng and Sundby 1986)

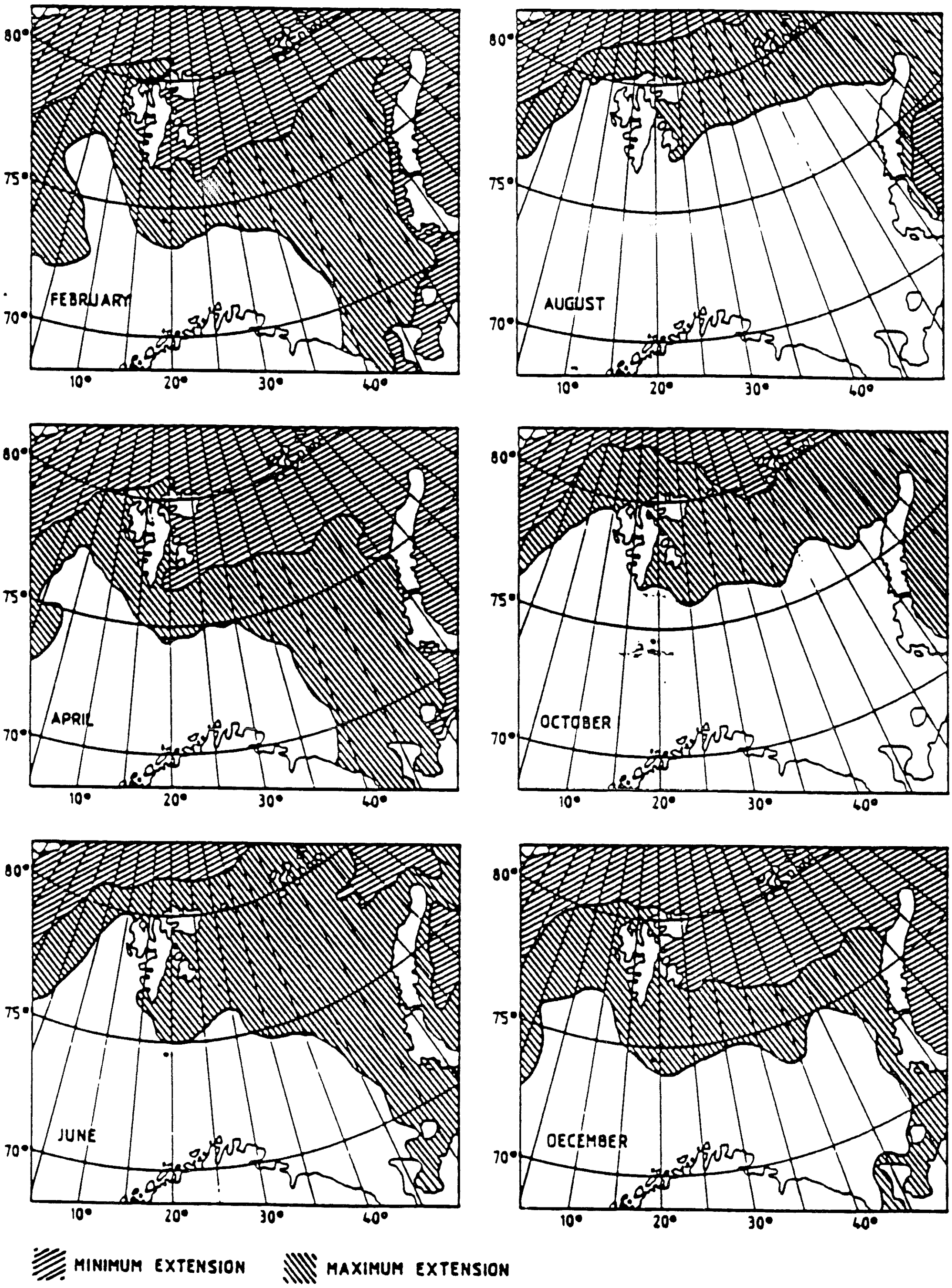

Figure 13. southern limits of sea ice at the end of the months February, April, June, August, October and December for the period 1971-1980. (Vinje 1983).

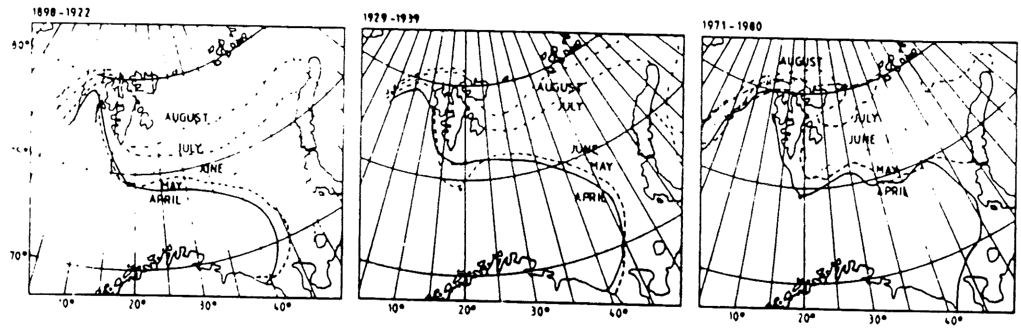

Figure 14. Mean position of the ice border at the end of the months April, May, June, July and August for three different periods. (After Loeng 1989)

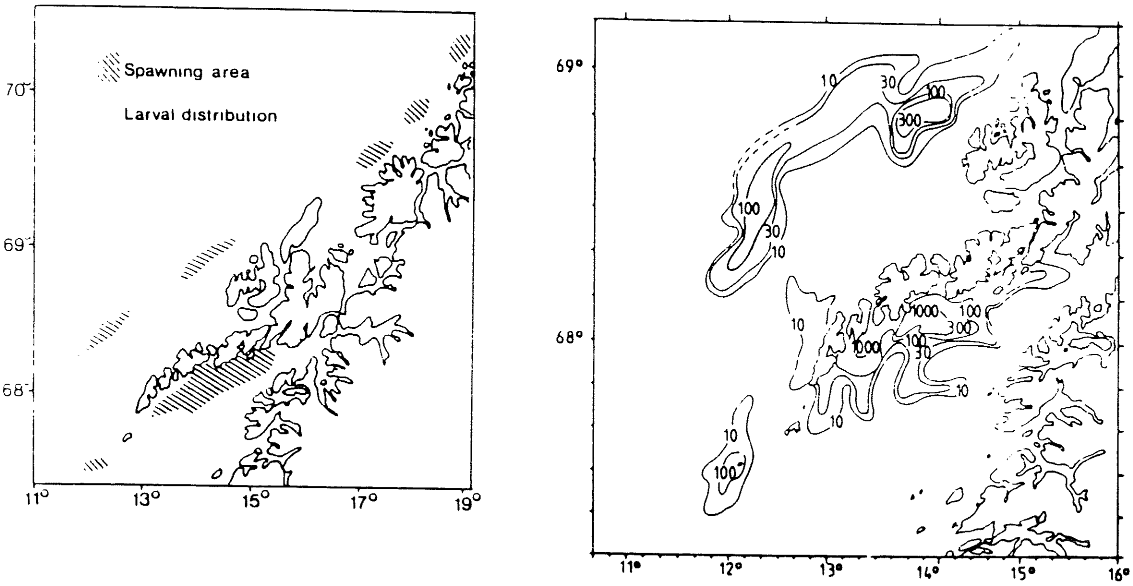

Figure 15. Main spawning areas of the Arcto-Norwegian cod, and the distribution (number m^{-2}) of 3-5 day-old eggs 3-10 April 1985. (Ellertsen et al. 1989)

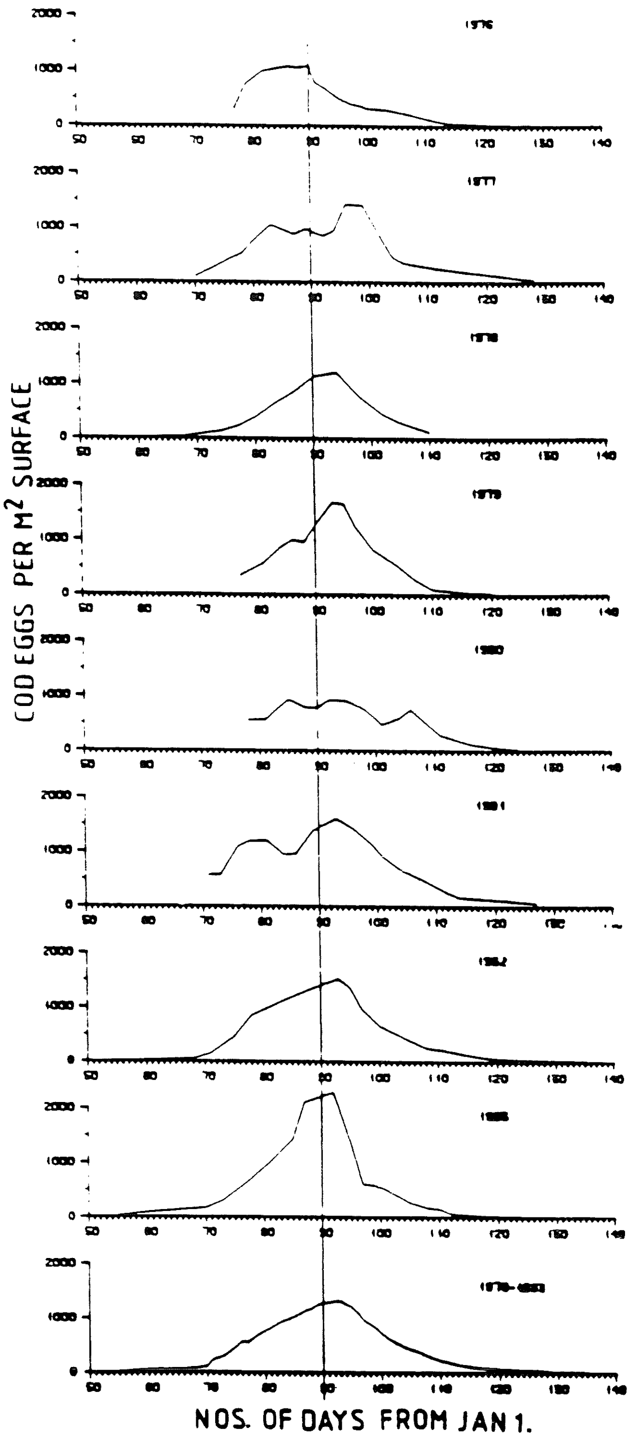

Figure 16. Spawning period of cod in Lofoten represented as the average concentration (numbers m^{-2}) of newly spawned eggs for the years 1976-1983. (Ellertsen et al. 1989)

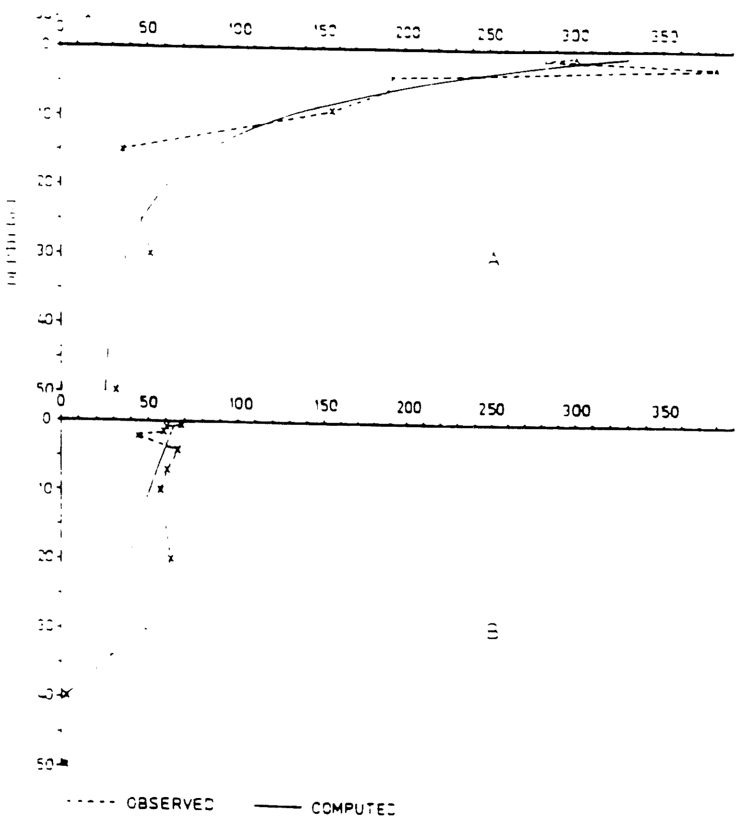

Figure 17. Observed and computed vertical distribution of cod eggs during A) low wind speed and B) higher wind speed. (Sundby 1983)

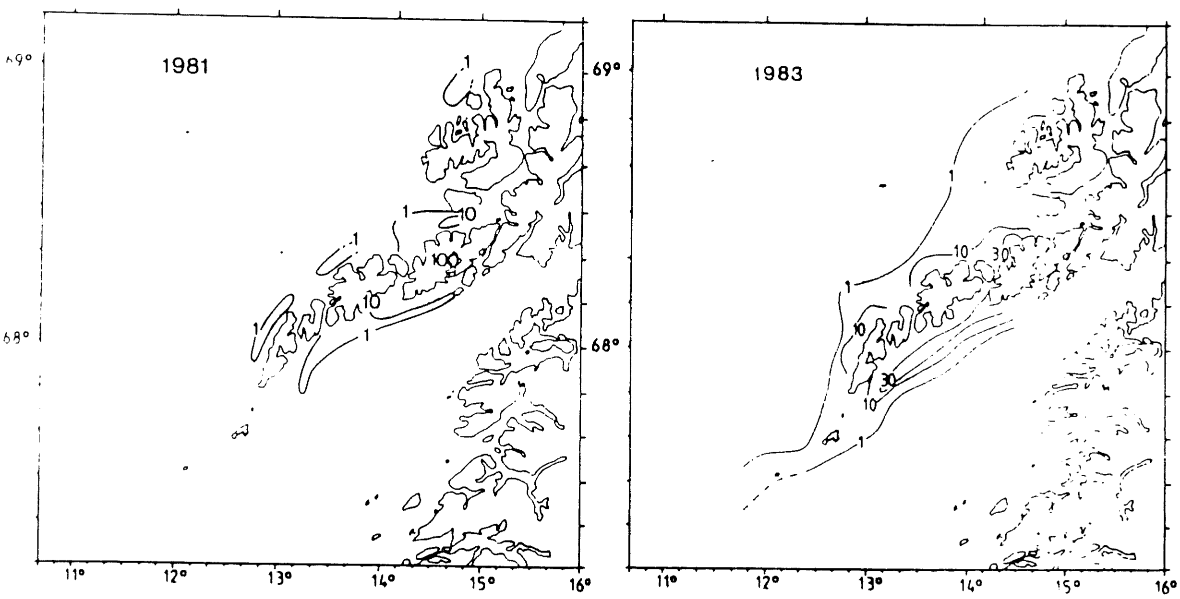

Figure 18. Distribution of cod larvae in early May (number m^{-2}) in 1981 and 1983. (Ellertsen et al. 1989)

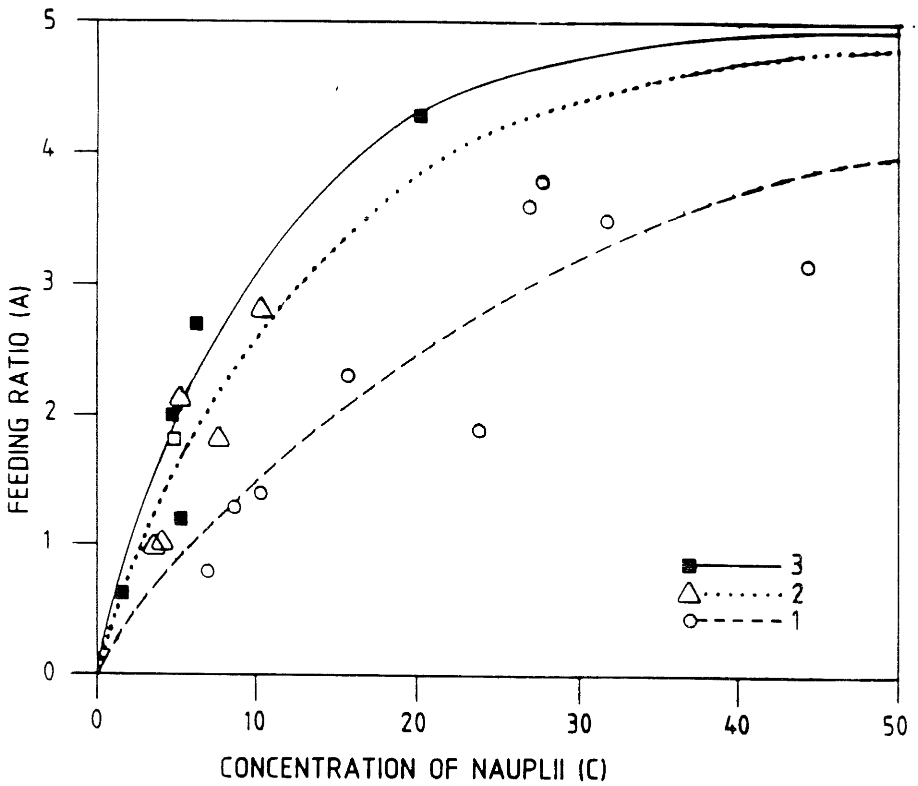

Figure 19. The feeding ratio (number of nauplii per larval gut) of about 7 days old larvae from Lofoten as a function of the nauplii concentration in the sea for 3 different wind speeds. 1) 2 ms^{-1}, 2) 4ms^{-1} and 3) 6 ms^{-1}. (Sundby and Fossum 1990).

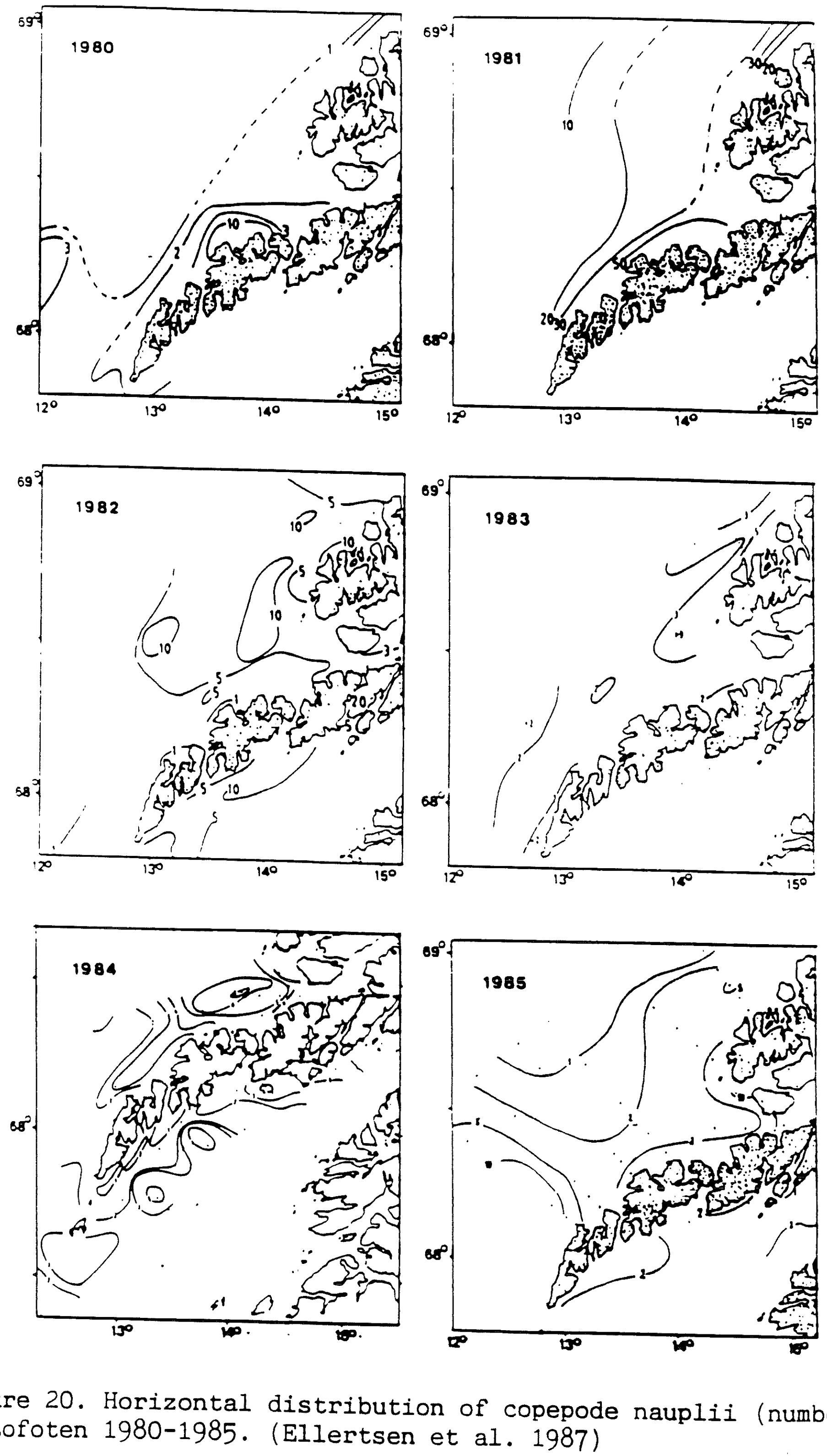

Figure 20. Horizontal distribution of copepode nauplii (number l^{-1}) in Lofoten 1980-1985. (Ellertsen et al. 1987)

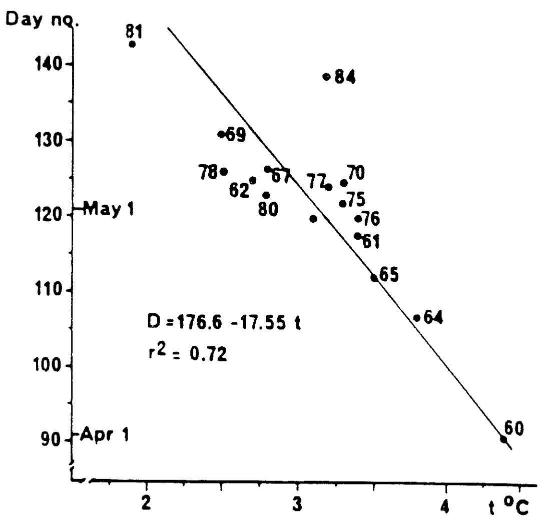

Figure 21. Time of maximum occurrence of C. finmarchicus copepodite stage I versus the average temperature of the upper layer in April. (Ellertsen et al. 1989)

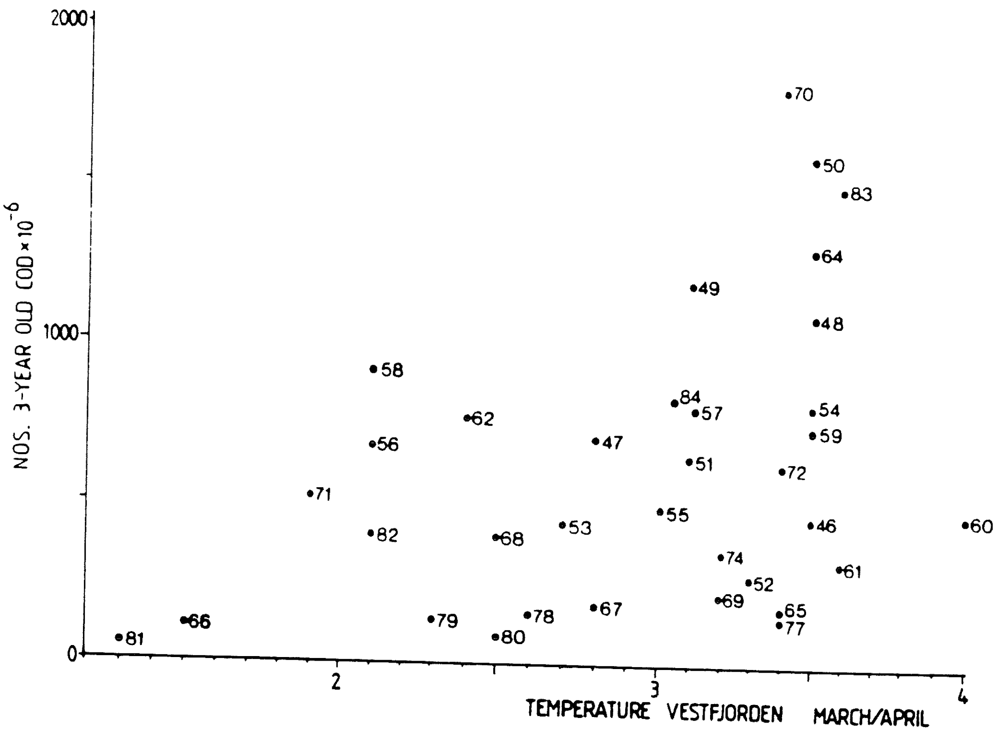

Figure 22. Relation between the year-class strength at 3 years and the mean temperature of the upper layer in March-April in Lofoten. (Ellertsen et al. 1989).

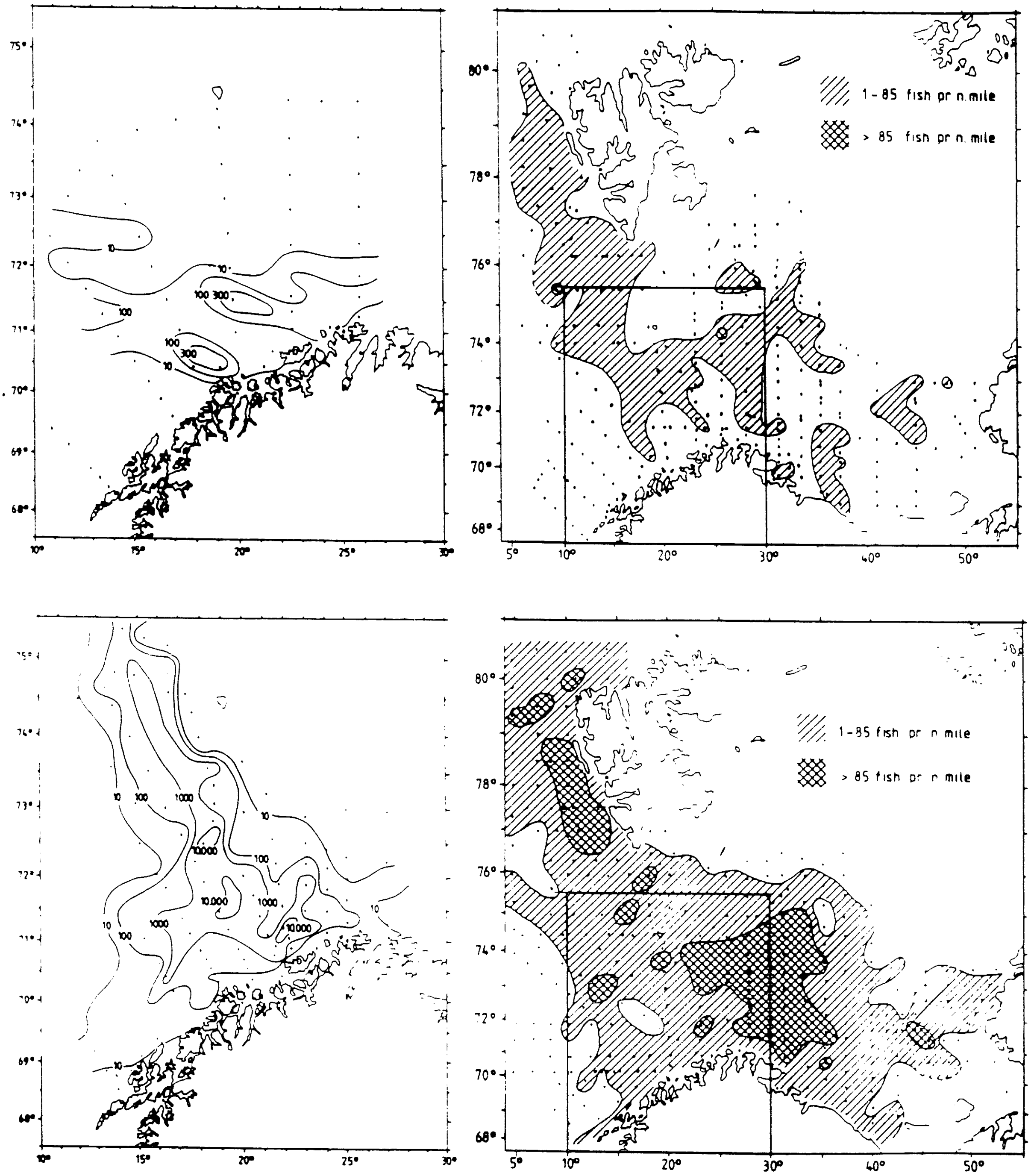

Figure 23. Distribution of early juveniles (2-3 months old), left, and 0-group (4-5 months old), right, for a typically weak year class, 1987 above, and for a typically strong year-class, 1985 below. (Sundby et al. 1989)

Appendix III of ICES C.M. 1990/G:50
Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

THE FAROES COD

Prepared by A. Kristiansen and B. Hansen

COD IN FAROESE WATERS

Cod is the commercially most important demersal species in the catches from the Faroe area. Catches back to 1903 are shown in Fig.1. Total catches have fluctuated between 20.000 and 40.000 tonnes. With the exception of the World War periods the proportion caught by the Faroese was rather low until 1970 but then increased. During the last 10 years Faroese vessels have taken more than 98 % of the total catch.

The habitat of cod as well as the whole ecology of Faroese waters is dominated by the location of the islands on the submarine ridge system between Scotland and Greenland separating the warm Atlantic waters from the cold waters north of the ridge. In the northern part of the area the Iceland-Faroe Ridge (IFR) has sill depths around 500 meters while the southern part of the ridge system, the Wyville-Thomson Ridge (WTR), has sill depths around 600 meters (Fig.2). These two ridges are separated by the Faroe-Shetland Channel (FSC) and the Faroe Bank Channel (FBC) with sill depth around 850 meters. This channel separates the Faroe Plateau from the banks in the northeastern corner of the Rockall-Hatton Plateau of which the most important one is the Faroe Bank (FB).

Stock structure and assessment

Extensive tagging experiments have demonstrated the existence of two cod stocks in the Faroe area, one on the Faroe Plateau and one on Faroe Bank (Strubberg 1916,1930; Tåning 1940; Joensen 1956; Jones 1966). Schmidt (1930) has shown that cod on the Faroe Bank has a lower number of vertebrae than cod on the Plateau and concluded that the stock on Faroe Bank and that on the Plateau are two different stocks. Analysis of serum protein Jamieson (1967) supports this thesis. In the assessment of cod in the Faroe area the cod on the Faroe Bank and that on the Plateau are therefore treated as two different stocks.

The catch figures shown in Fig.1 are for the total Faroe area. The catches on Faroe Bank back to 1965 are shown in Fig.3. They reached a maximum of 5.000 tonnes in 1973. Since 1985 the catches have decreased and in 1989 only 460 tonnes were caught.

Data to assess the cod stock on the Faroe Plateau are available back to 1962 while no attempts have been made to assess the Faroe Bank cod stock. Mean fishing mortalities for the age groups 3 to 7 estimated by virtual population analysis are shown in Fig.4. From 1962 to 1974 the fishing mortality decreased from 0.8 to 0.4 and has since then fluctuated within the range: 0.4-0.7. With the present exploitation pattern F_{max} is estimated to 0.39 and $F_{0.1}$ to 0.17. The estimated recruitment as one year old and the estimated spawning stock biomass are shown in Fig.5. With the exception of the 1972, 1973 and 1982 yearclasses the recruitment has flutctuated between 10 and 30 mill. The longterm recruitment is estimated to 22 mill. The spawning stock biomass increased from 1962 up to 1977 and then decreased again due to increased fishing mortalities (Fig.5). Due to high fishing mortality the very good 1982-yearclass did not contribute so much to the spawning stock as it would have with a more moderate fishing mortality. The low recruitment in the three following years 1984 to 1986 has caused a drop in the spawning stock biomass. It is estimated to be at a very low level at present.

Environment

The upper layers of the waters surrounding the Faroes are dominated by the "Modified North Atlantic Water" (MNAW) deriving from the North Atlantic Current (Becker & Hansen 1988). This water has typical temperatures around 8 °C and salinities around 35.25. The general circulation pattern of the area (Fig.6) transports this water past the Faroes on all sides; but in the Norwegian Sea north of the Faroes the "Subarctic Front" separates it from the "North-Icelandic/Arctic-Intermediate" (NI/AI) water of the East Icelandic Current. The NI/AI water is much colder (temperature around 4 °C) and fresher (Salinity below 34.8) and in the upper layers it is only found north of the Subarctic Front; but at deeper levels this water may be found mixed into the MNAW in increasing amounts down to depths of 300 to 500 meters to the north and east of the Faroes. Below 500-600 meters the "Deep Norwegian Sea Water" (DNSW) takes over, and this water mass ($T < 0°C$, $S = 34.92$) dominates the deeper regions north, east and south of the Faroes, that is east of the ridge system defined by the Iceland-Faroe Ridge (IFR) and the Wyville-Thomson Ridge (WTR). Thus only the region north of the Faroe Bank and west of the IFR is in the deeper parts dominated by Atlantic water, and even in that region one finds colder water deriving from Overflow of DNSW through the Faroe Bank Channel and of NI/AI water over the IFR.

There is some evidence that during the "Little Ice Age" in previous centuries the Subarctic Front was displaced fairly much to the south; but during this century it seems to have been so far north of the Faroes, that the waters on the Plateau and on the banks have had comparatively small variations in temperature and salinity although cold intrusions from the frontal region may occasionally reach the shelf region (Hansen & Meincke, 1979). Contributing to this stability are the almost closed anticyclonic circulation systems which are known to dominate the shallower regions at least on the Faroe Bank (Hansen & al., 1986) and on the Faroe Plateau (Hansen, 1979). The persistence of these flows results in large retention times for the water and planktonic organisms over the shallower regions and the fact that the circulation over Faroe Bank is separate from the circulation over the Plateau may explain how the two cod stocks can remain distinct. On the Faroe Plateau there are indications that there may be more than one gyre; but detailed knowledge on this is lacking as is knowledge on the vulnerability of the gyre systems towards storms or abnormal weather conditions.

In the shallow regions there are strong tidal currents which mix these waters very efficiently. This results in a difference between the vertically almost homogeneous shelf water and the offshore waters which in the warmer seasons become stratified. The border between these two regimes is seen as a distinct front on infrared satellite pictures both on Faroe Bank and on the Plateau. During summer the temperature difference is of the order of one degree for the front on the Plateau and somewhat less on Faroe Bank. These three regimes (well-mixed, frontal and stratified) have different conditions for primary production; but little is known on production cycles in Faroese waters and much more work is required to establish an understanding of these cycles and their dependence on the very variable weather conditions in the region.

From the beginning of the century hydrographic investigations have been made in Faroese waters, but irregularly. In the late eighties three standard sections have been established which are occupied at least four times a year. These sections were designed to coincide as well as possible to sections often occupied in the historical data set. A much more regular timeseries is the shorebased series of daily temperature measurements initiated in 1875 in Tórshavn and moved in 1914 to Mykines where it continued until 1969. A critical analysis (Hansen & Meincke 1984) has shown that the measurements in Tórshavn have probably been influenced by local effects during summer; but the later part of the series seems to give a fairly representative picture of the seasonal variation (Fig.7) of sea surface temperature of the Plateau waters and for the winter season the whole series gives a climatic signal (Fig.8). In 1989 an automatic temperature recording station has been established close to the Mykines site abandoned in 1969 to continue the series.

Spawning

Tåning (1943) and Joensen & Tåning (1970) state that spawning takes place from February to May, April being the important month. Analysis of roe-landings (Hoydal & Reinert 1977) and length distributions of pelagic larvae and juveniles (Reinert 1979) verified this spawning period but indicated a mean spawning in second half of March. Data from the Faroese Groundfish Surveys 1982-89 have now been used to estimate the timing of gonadal development and spawning. The results are shown in Fig.9. Gonadal development has been determined on a scale from 1 to 7 with 1 as immature, 2-5 as maturing, 6 as spawning and 7 as spent. According to this data spawning on the Plateau starts in February on a low level. In the second half of March most of the sampled cod have been spawning. No data is available for the first half of February for the Faroe Bank but in the second half the proportion spawning is at the same level as that on the Plateau. The lower proportion of spawning cod and higher proportion of stage 5 in March on the Faroe Bank compared to the Plateau may indicate either a larger interannual variability in timing or a prolonged spawning period on the Faroe Bank.

Spawning takes place all around the Faroe Plateau at depths about 80-180 m and temperatures of 6-7 °C. By far the most important spawning grounds are to the north and west of the islands (Fig. 10). It should be mentioned that there seems to be a delay of about one month between the main spawning of the three main demersal gadoids in the area, with main spawning time of saithe in second part of February, of cod in second part of March and of haddock in mid April (Joensen, 1953 and Joensen & Tåning, 1970).

Eggs, larvae and juveniles

After the fertilization the eggs ascend towards the upper layers, where the development up to hatching occurs. The incubation period is about 16-20 days (Joensen & Tåning 1970). No other information is available on the duration of the embryonic period, but the start of exogenous feeding seems to coincide at least in most years with the onset of primary production. The youngest larvae taken are about 4 mm, and data from 1978 seem to indicate a dispersal of embryos and larvae by the anticyclonic current systems around the islands

(Reinert 1979). Later on the larvae seem to be distributed horizontally all over the Plateau by the circulation and the strong tidal currents. In June and early July the distribution of juveniles shows a very characteristic picture on the Plateau, with heavy concentrations near the islands to the north and more scattered in other areas (Fig.11). The Faroe Plateau seems to be a retention area for eggs and larvae, created by the anticyclonic current system and a subdivision of this system into several minor gyres could be responsible for the characteristic distribution of the juveniles in June and early July. The current system around the Faroe Bank creates a retention area there as well (see above).

The information on growth in the pelagic phase is scarce; samples from Bongo, Gulf III and capelin trawl in the late seventies indicated a logaritmic growth in agreement with Saville (1956): $L = L_0 * 10^{0.012\,t}$, t = no of days (Reinert 1979).

At lengths about 3.5-4.0 cm the juveniles leave the pelagic phase and most of them migrate into the littoral zone of the fjords; this happens usually after the first week of July. On the Faroe Bank, however, the juveniles are settling on the Bank proper, i.e on relative deep water.
In late July the demersal stages are found in the seaweed in the littoral zone, now about 4.5 cm long. In the middle of august the meanlength is about 5 cm, in medio september about 7 cm (Joensen & Tåning 1970). The growth of cod from 1-year and onwards is shown in Fig.12.

After 1-2 years in the littoral zone of the fjords the cod are migrating towards deeper waters. Tagging experiments show, however, that the cod is rather stationary while sexually immature i.e. up to about 3 years (Joensen & Tåning 1979). The food in the littoral zone is mainly crustaceans and the young of other fish species, e.g. saithe and sandeel.

Adults

When sexually mature most of the Faroe Plateau cod migrate to the spawning grounds especially north of the islands. After spawning the fish disperse all over the Plateau (Joensen & Tåning 1970).

Data on feeding and predation is scarce. Joensen & Tåning (1970) describe the cod as feeding on nearly everything they come across and mention fish, crustaceans, worms, mussels, echinoderms, ascidians and hydroids. Of the fish species in the food the most favoured are probably sandeel and herring but also norway pout. The abundance of these fish species and their migrations may at times be decisive for the cod migration.

In Fig.12 the mean lengths at age for the two cod stocks in the Faroe area are shown. The figure is based on ages determined from otoliths collected over the period 1973-1982. The Faroe Bank cod grows more rapidly than the Plateau cod. At an age of 3 years the average length of cod on the Faroe Bank is around 75 cm while on the Faroe Plateau it is around 55 cm. Cod on the Faroe Bank is one of the cod populations with the fastest growth.

Very little data has been published on the maturation of cod at the Faroes. Tåning (1943) and Joensen and Tåning (1970) state that, in the average, the cod on the Faroe Plateau becomes mature at an age of 4 years while the Faroe Bank cod reaches maturation as 3 years old. Since 1982 samples have been collected during the Faroese groundfish surveys in February and March to estimate maturity ogives. The results are shown in Fig.13. According to these investigations there is no difference in the maturity ogives by ages for cod on the Plateau and the Faroe Bank cod. In both cases 50% of the cod became mature at an age of 3 years, i. e. one year younger than stated by Tåning (1943) and Joensen and Tåning (1970). The rapid growth of cod on the Faroe Bank and the similar maturity ogives by ages must imply that cod must become mature at a larger length on the Faroe Bank compared to the Plateau and this is demonstrated in Fig.13b. The 50% maturation length of the Plateau cod was around 40-45 cm while it was around 65 cm for the Faroe Bank cod.

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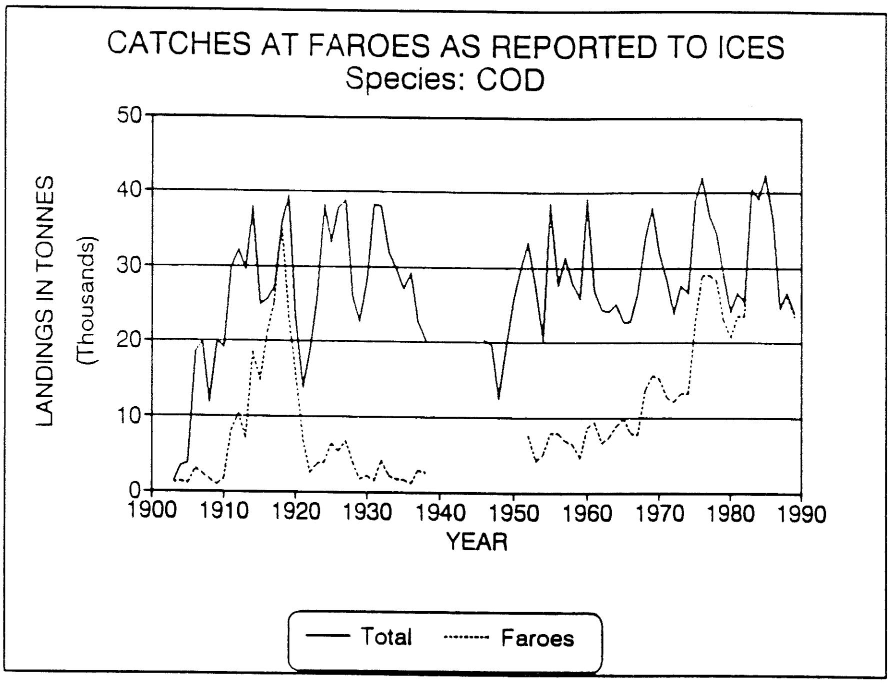


Fig. 1.

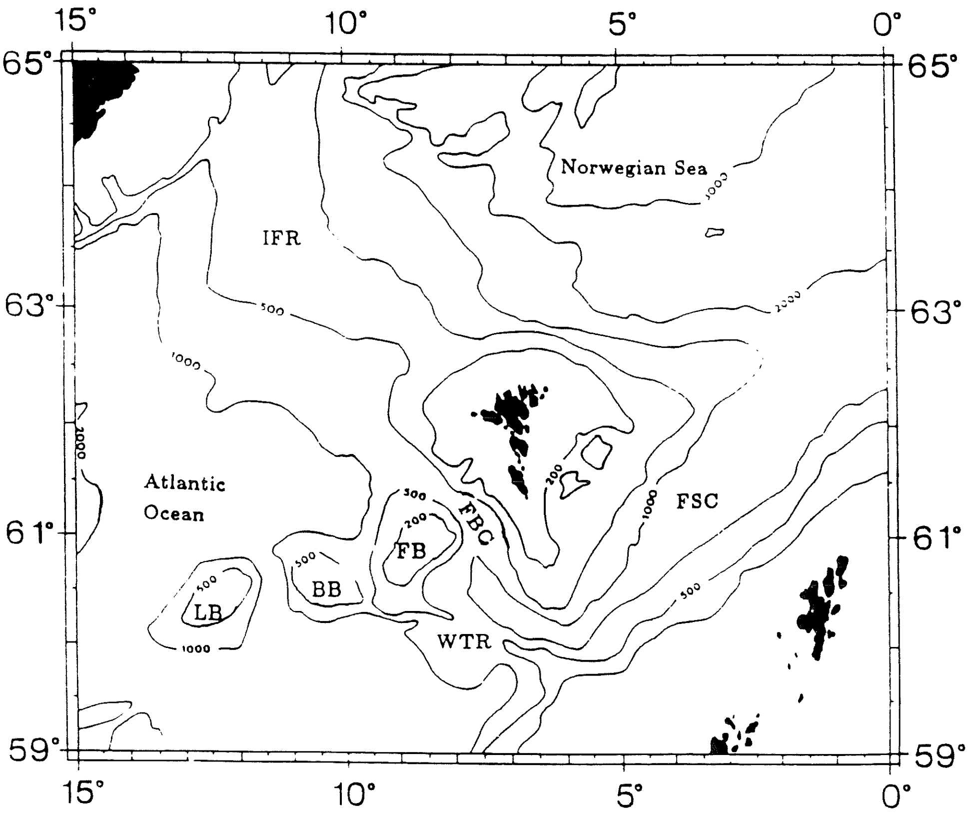


Fig.2. Topography of Faroese waters.

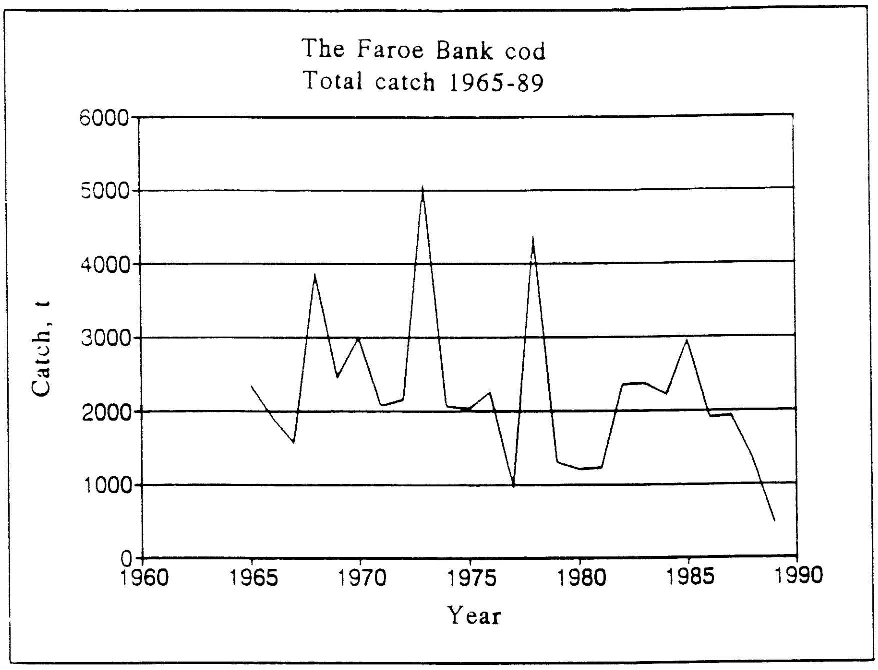

The Faroe Bank cod
Total catch 1965-89
6000
5000
4000
3000
2000
1000
0
Catch, t
1960
1965
1970
1975
1980
1985
1990
Year

Fig. 3.

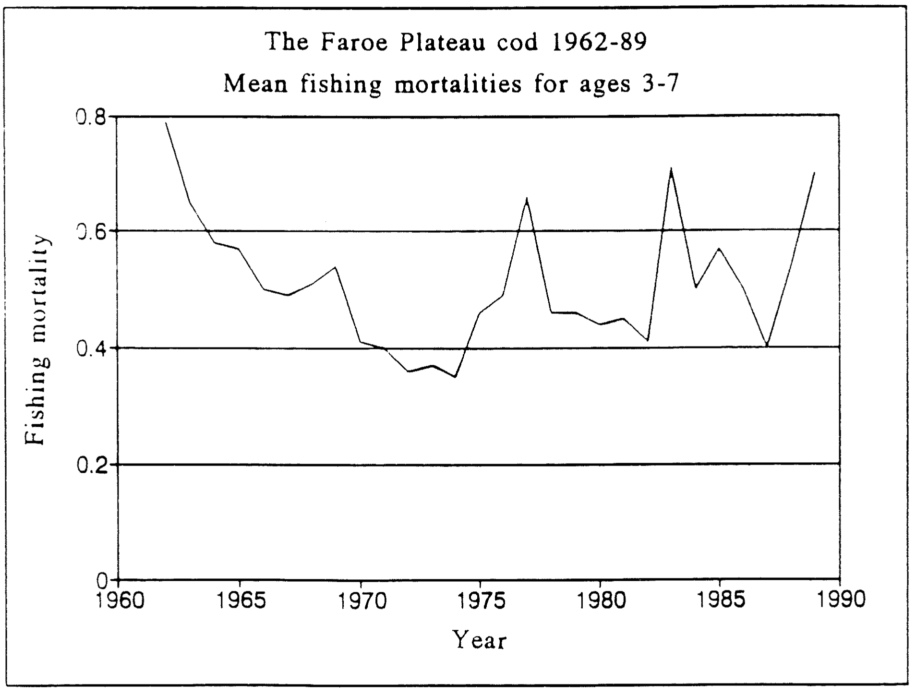
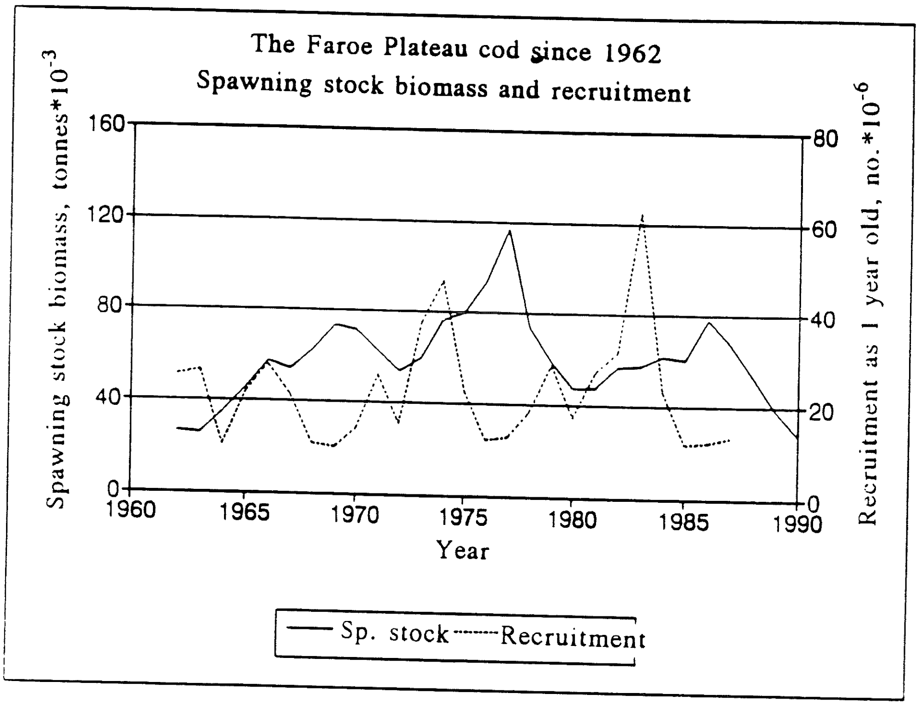

The Faroe Plateau cod 1962-89
Mean fishing mortalities for ages 3-7
0.8
0.6
0.4
0.2
0
Fishing mortality
1960
1965
1970
1975
1980
1985
1990
Year

Fig. 4.



The Faroe Plateau cod since 1962
Spawning stock biomass and recruitment
Spawning stock biomass, tonnes*10^-3
Recruitment as 1 year old, no.*10^-6
160
120
80
40
0
80
60
40
20
0
1960
1965
1970
1975
1980
1985
1990
Year
Sp. stock
Recruitment

Fig. 5.

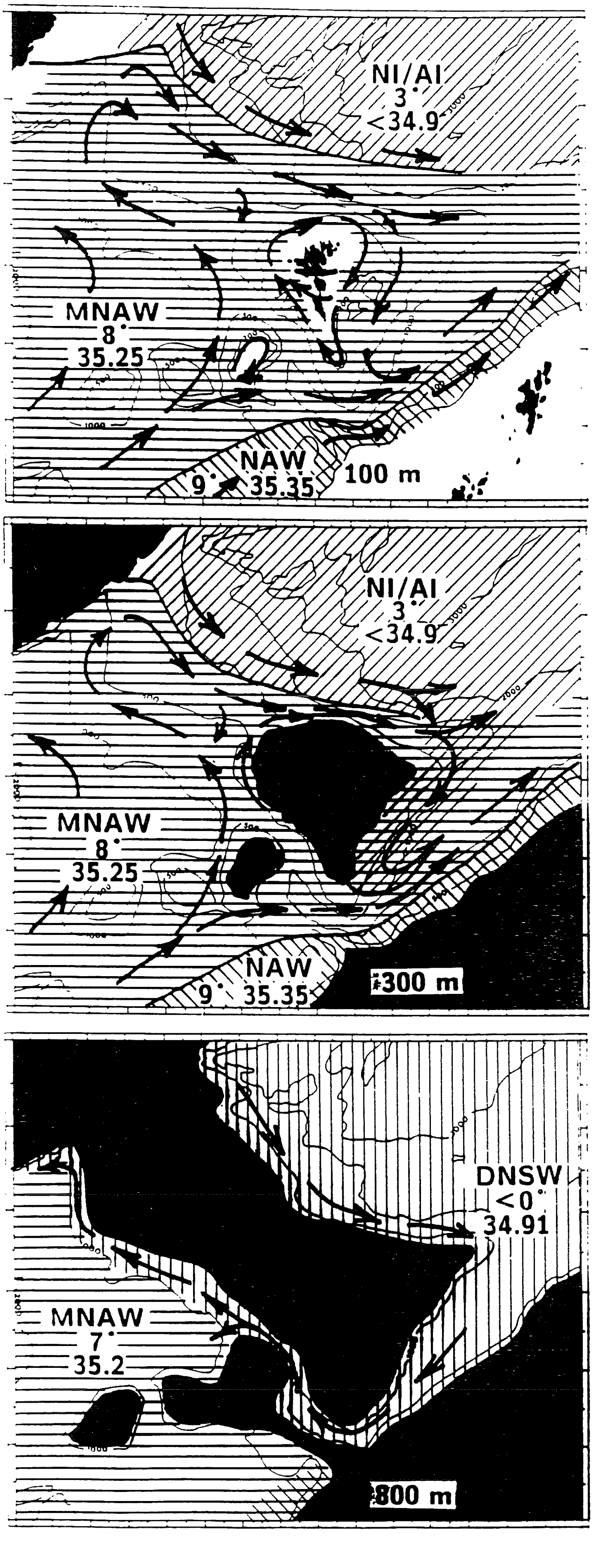


Fig.6. Distribution of main water masses and circulation patterns of Faroese waters at three different depths.

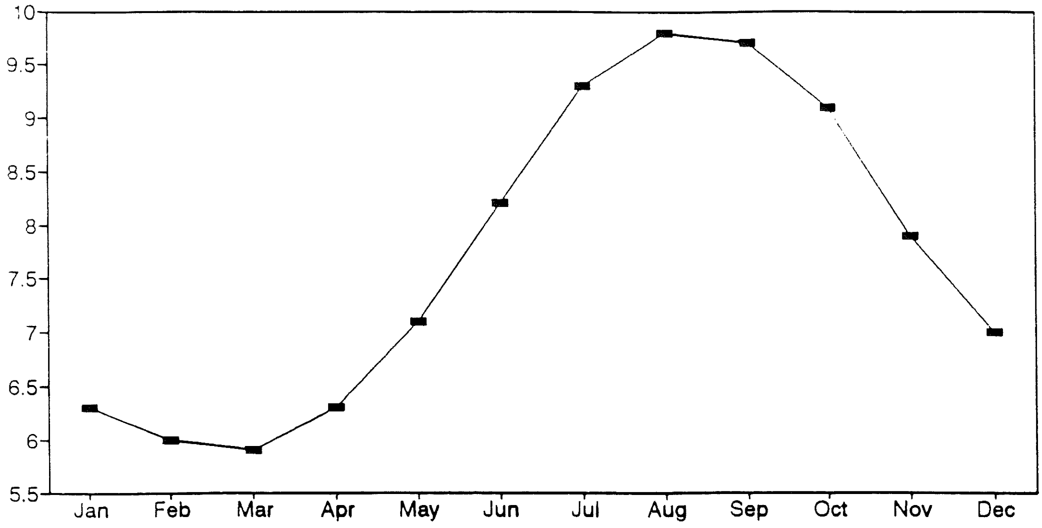


Fig.7. Seasonal variation of sea surface temperature of the Plateau waters based on monthly means for period 1914-1950, (Smed, 1952).

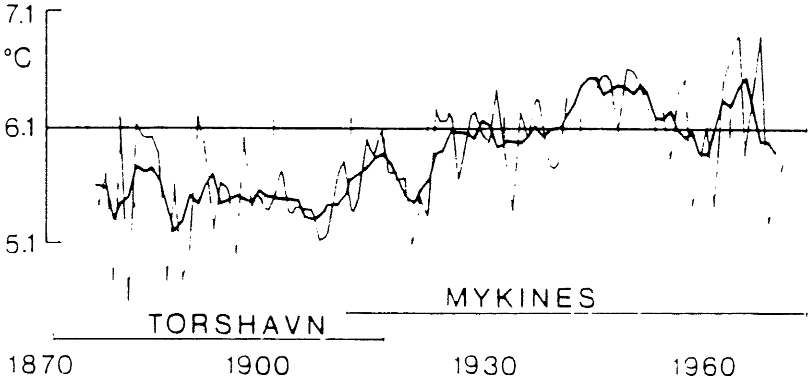


Fig.8. Yearly (light curve) and 5-yearly running mean (heavy curve) of sea surface temperature of the Plateau waters for the Jan-March period. (Hansen & Meincke 1984).

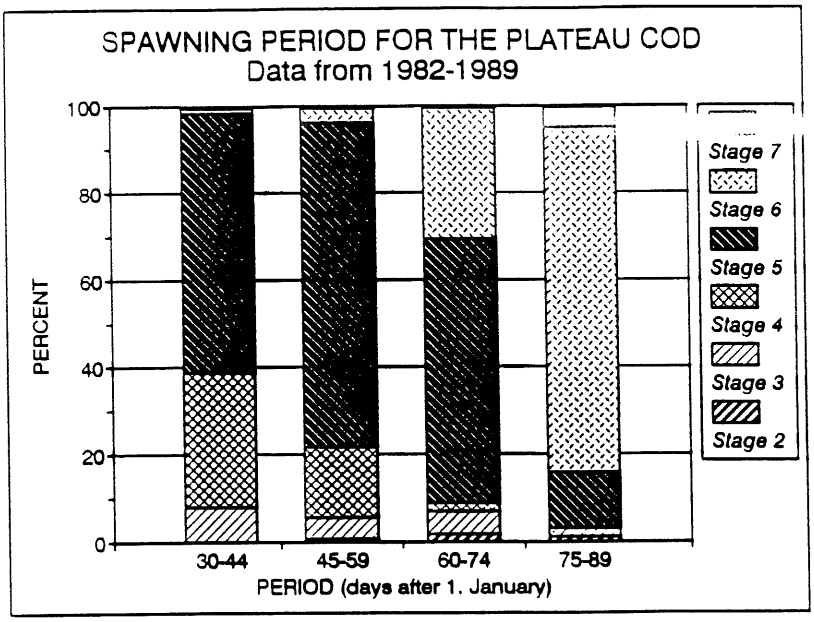

SPAWNING PERIOD FOR THE PLATEAU COD
Data from 1982-1989
PERCENT
100
80
60
40
20
0
30-44
45-59
60-74
75-89
PERIOD (days after 1. January)
Stage 7
Stage 6
Stage 5
Stage 4
Stage 3
Stage 2

Fig. 9a.

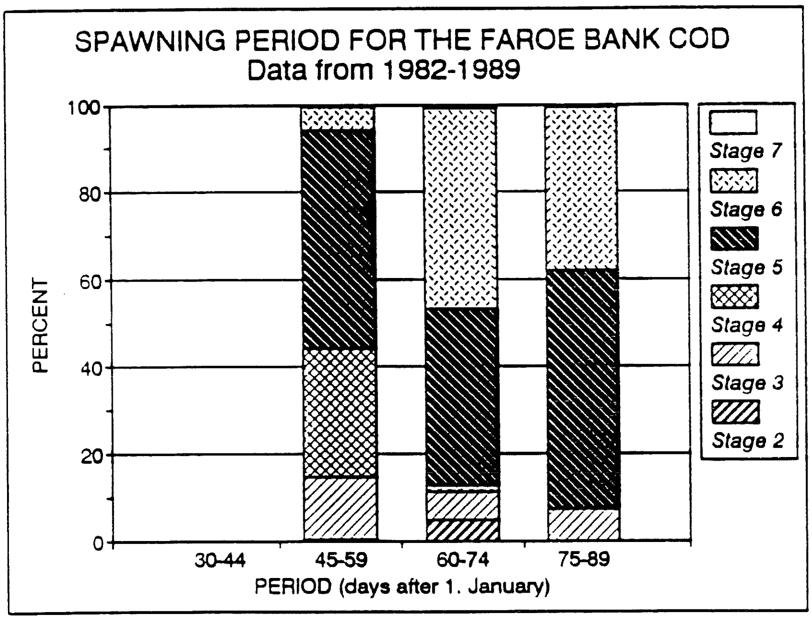

SPAWNING PERIOD FOR THE FAROE BANK COD
Data from 1982-1989
PERCENT
100
80
60
40
20
0
30-44
45-59
60-74
75-89
PERIOD (days after 1. January)
Stage 7
Stage 6
Stage 5
Stage 4
Stage 3
Stage 2

Fig. 9b.

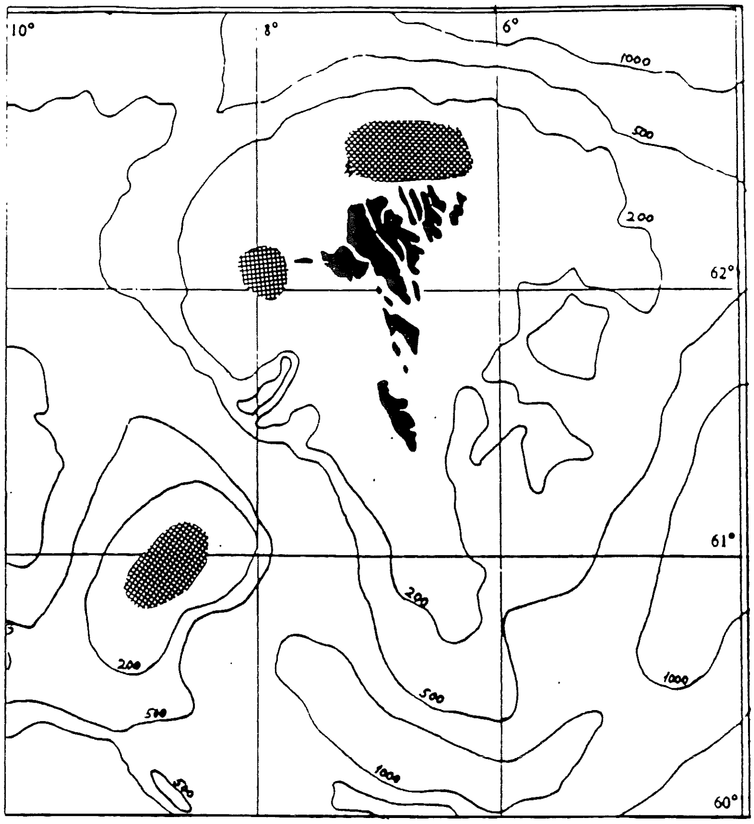


Fig 10. The main spawning areas for cod in Faroese waters (Reinert 1988).

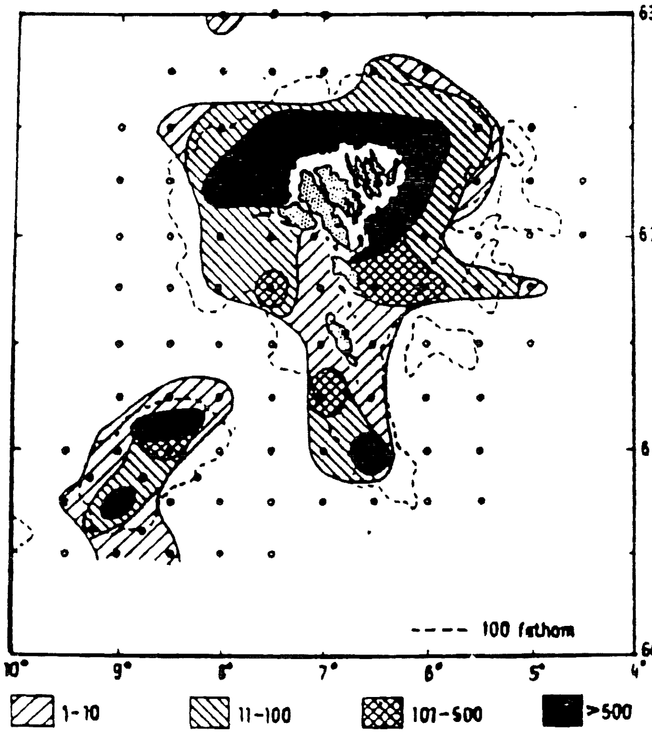


Fig. 11. A typical distribution of O-group cod in late June (Anon 1976).

Appendix III of ICES C.M. 1990/G:50
Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

THE NORWEGIAN SKAGERRAK COASTAL COD

Prepared by J. Gjøsæter

DESCRIPTION OF COD STOCKS, THEIR BIOLOGY AND ENVIRONMENT.

THE COASTAL COD AT THE NORWEGIAN SKAGERRAK COAST.

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History

The coastal cod used to be the most important resource for the fishermen at the Skagerrak coast up to recently when its importance (at least from an economical point of view was surpassed by deep sea shrimp (Dannevig and van der Eynden 1986). The cod was fished in nets, various types of pots and by hook and line.

General structure of the stock.

The coastal cod seem to be clearly separated from the cod of the open Skagerrak. This is indicated by tagging experiments (e.g. Danielssen 1969, in prep) and by differences in recruitment patterns (Gjøsæter and Danielssen 1990). Genetical studies show that the Skagerrak coastal cod are different from the cod of other parts of Norway at least in some characters (Nævdal, Gjøsæter and Gjørstad in prep).

Dannevig (1954) suggested that the Skagerrak coastal cod could be subdivided into three groups:
1. "Deep cod" living at deep water in the fjords and in the skerries,
2. "Kelp cod" living at shallow waters in the skerries, and
3. "Fjord cod" living at shallow waters in the fjords.

These groups were based on pigmentation, but some differences in body proportions were also suggested. The separation in these three groups has not been verified, and nothing is known about the stability of the groups and about their genetical basis.

Tagging experiments (Dahl 1906, Løversen 1946, Moksness and Øyestad 1984, Danielssen 1969, in prep.) has shown that the coastal cod is very stationary. Most recaptures are made less than 1 nautical mile from the tagging location, and according to (Danielssen in prep.) more that 93% are caught less than 15 n.miles from the tagging location. These tagging experiments and also studies showing that the growth rate may be different in different fjords and coastal areas (Dannevig 1933, Løversen 1946, Gjøsæter and Danielssen in prep), suggest that the fjords can have separate populations. However, it is likely that they partly are recruited from a common pool of eggs (Dahl 1906), and they can not be regarded as separate stock units.

There are evidence of a vertical migration. As the surface water gets warm during summer the cod go deeper, and it come back to shallow waters at autumn when surface water gets colder. During winter cod go down again to avoid the cold surface water, but come back to the upper layers in spring (Dannevig 1966, unpublished data, Flødevigen marine research station).

Fishing pattern.

The coastal cod are partly fished by professional fishermen, and partly for leisure and for private consumption. There are no data to say which are most important. Neither is it possible to give any reliable catch quanta. Fishing mortality is not known, but based on tagging experiments a total mortality around 1.7 ($year^{-1}$) has been suggested (unpublished data, Flødevigen marine research station).

Environment

The environment of the cod on the Skagerrak has been described by several authors, and will not be dealt with here.

Spawning

The cod at the Skagerrak coast spawn from middle of February till May, usually mainly in March - April (Dahl 1906, Dannevig 1966, Dahl et al. 1983). Spawning takes place at temperatures between 4 and 6^{o}C, and apparently the temperature is the main factor regulating the time of spawning.
Data on where the cod spawn is sparse, but apparently spawning takes place in many (most?) fjords along the coast, and probably in the skerries too (Dahl 1906, Dannevig 1966, Dahl et al. 1983).

Dahl (1906) described spawning migration from Søndeledfjorden in the Risør area: During autumn adult fish are found in the skerries off the fjords entrance. From September an migration towards the inner parts of the fjords starts. They stay in the inner parts of the fjords during winter, and there the spawning starts in February - March while the fjord is still covered with ice. After spawning most of the spent fish starts an outward migration towards the fjord entrance. It is not known how representative this pattern is for other fjords.

Egg- and larval stages

The eggs are pelagic and are mainly found in the upper 50 m. The depth distribution varies, however with the hydrografic conditions, and when there is much freshwater, they may go deeper. Experiments has shown that cod eggs from the Skagerrak coast has a density of 1.0238 - 1.0271 g cm^{-3} (Moksness unpubl.).
Dahl (1906) argues that eggs and larvae float with the current and that eggs from different spawning sites can mix.
At temperatures around 6 ^{o}C the eggs hatch after 14 days (Iversen and Danielssen 1984).

Juveniles

Distribution and growth
Larvae are pelagic till they reach an age of 2 - 3 months and a length of about 30 mm. Then they settle in shallow waters. Apparently few settle deeper than 20 m (Dahl 1906). The first juveniles settle in April - May, and generally they stay in the littoral zone till October - November, but in warm years they can stay even longer before they go deeper (Gjøsæter et al. 1989).
A study in the Risør area showed the density of 0-group cod was highest in protected fjord areas (exposure 4) and decreased gradually towards the most exposed areas (exposure 1)(Fig. 1) (Gjøsæter and Danielssen 1990).

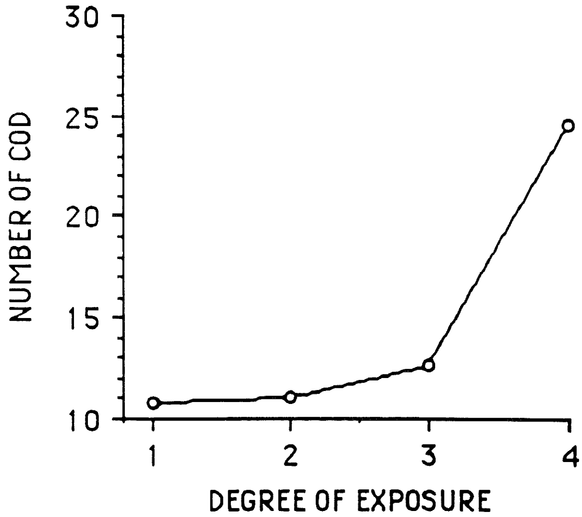

Fig. 1. Relation between number of 0-group cod pr. haul and degree of exposure. 1 most exposed, 4 most protected (Data from Gjøsæter and Danielssen 1990)

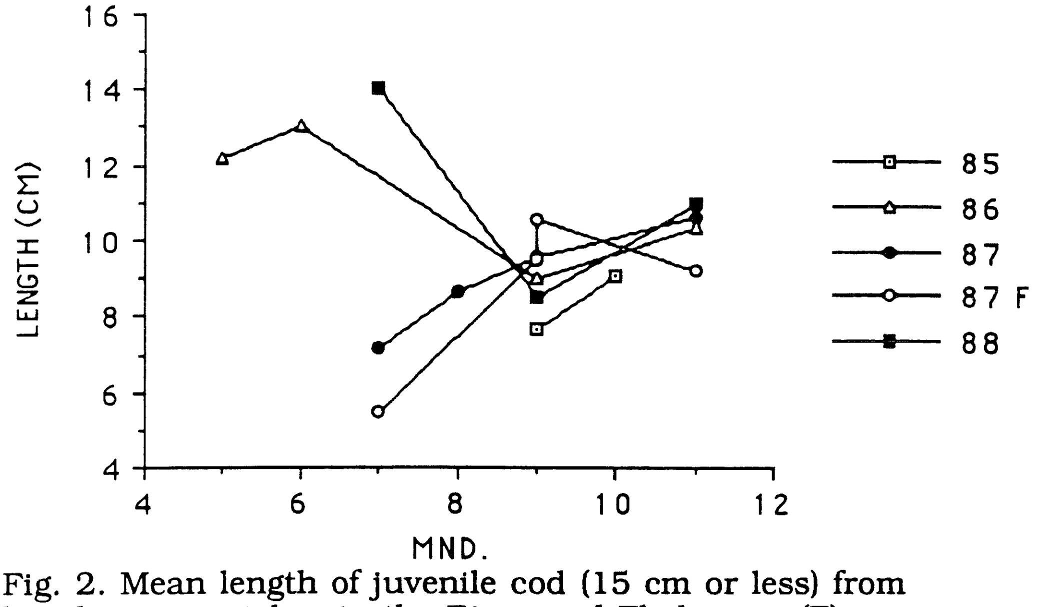

Fig. 2. Mean length of juvenile cod (15 cm or less) from beach seine catches in the Risør and Flødevigen (F) areas. The figures in the legend indicate years(Gjøsæter and Danielssen in prep)

From the cod settles at a size of about 3 cm in May - June it grow rather fast, but simultaneously new recruits settle (Dahl 1906, Gjøsæter and Danielssen in prep.). Therefore, the increase in mean length in the catches (Fig. 2), gives a underestimate of growth. It should also be noted that the smallest fish are not caught representatively with the beach seine used. During autumn the 0-group reach a mean size of about 12 cm and a maximum size of 15 cm.

Interactions

A list of the most abundant species occur together with cod in shallow waters are given in Table 1.

Table 1. Species caught in beach seine in the Arendal area 1985 -87. Only species giving an average of more than 1 fish houl^{-1} are included (Gjøsæter et al. 1989).

Species	Number pr haul
Gobiculus flavescens	40.51
Gasterosteus aculeatus	26.58
Ctenolabrus rupestris	20.26
Gadus morhua O-group	16.56
Merlangus merlangus O-group	12.90
Gobius niger	11.33
Platichthys flesus	9.39
Gadus morhua I-group	6.32
Sprattus sprattus	4.44
Zoarches viviparus	4.24
Pomatoschistus minutus	3.82
Spinachia spinachia	3.57
Siphonostoma typhle	3.26
Pollachius virens	2.90
Pholis gunellus	1.82
Acanthocottus scorpius	1.67
Pleuronectes platessa	1.13

The correlation between abundance of 0-group cod and abundance of some other species caught in the littoral zone was studied by Gjøsæter and Danielssen (1990). They used a material from 22 stations in the Risør area, sampled each year from 1945 till 1985. No significant correlations were found (Table 2).

Table 2. Spearman rank correlations , ρ, between annual mean number of 0-group cod and abundance indices of other species (N = 41). P = probability (Gjøsæter and Danielssen 1990)

Species		ρ	P
Goldsinny wrasse	*Ctenolabrus rupestris*	0.072	>0.50
Other labridae	*Labridae*	-0.017	>0.50
Gobidae	*Gobidae*	-0.001	>0.50
Stickleback	*Gasterosteus aculeatus*	0.307	0.10>P>0.05
Flounder	*Platichthys flesus* (L.)	0.309	0.10>P>0.05
Herring	*Clupea harengus* L.	0.063	>0.50
Sprat	*Sprattus sprattus*	-0.305	0.10>P>0.05
Mackerel	*Scomber scombrus* L.	-0.188	0.50>P>0.20
Sand eel	*Ammodytes lancea* Yar	-0.255	0.20>P>0.10
Pipe fish	*Siphonostoma typhle*	-0.044	>0.50
Other fish		-0.13	0.50>P>0.20
Crab	*Carcinus meanas*	-0.203	0.50>P>0.20

Interactions between juveniles and older cod and between juvenile cod and other fish from the littoral zone, have been studied by Gjøsæter (1987a, 1987b, 1988, 1990). He showed that 0-group cod avoid habitats occupied by older cod. If they cannot avoid the larger cod, they prefer to stay close to algae where they can hide. Presence of alga seem to reduce the predation from larger cod considerably, although large cod prefer small cod to most other littoral fishes, at least under experimental condition.

It was also shown that 0-group cod and 0-group whiting generally prefer the same habitats, but they have different feeding habits. The whiting take pelagic food more efficiently then cod, while cod is better in finding food at the bottom or hidden among algae.

0-group abundance and recruitment

Tveite (1971) has shown that there is a close correlation between the number of O-group caught in the littoral zone during autumn and subsequent abundance of that year-class along the Norwegian Skagerrak coast.

Beach seine hauls has been taken annually since 1917 (except 1940 - 44) in September at more tha 100 stations from Kristiansand to the Swedish border. Average number of cod in these haul has been taken as an indication of recruitment. Tveite (1971, 1984) presented data for the period 1917 till 1983. He concluded that there was a period with relatively low recruitment in all areas from 1930 to 1950. The best period for the open areas was from 1950 till 1970, while for the more landlocked areas the abundance of 0-group was highest before 1930 and after 1970.

Gjøsæter and Danielssen (1990) studied data from the Risør area 1945 - 1985 in more details, and found no general trend in abundance (Fig. 3). They found no correlation between the abundance of 0-group cod and other gadoids from the same area. The correlation between abundance of 0-group cod in the Risør area and on the Skagerrak coast in general was strong.

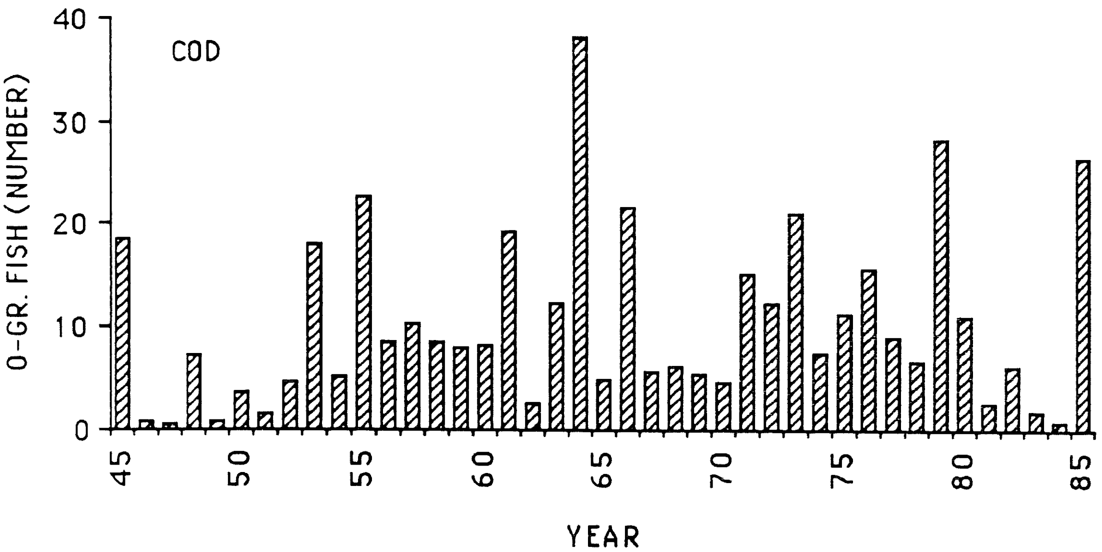

Fig. 3. Average number of 0-group cod in 22 beach seine hauls in the Risør area 1945 - 1985. (From Gjøsæter and Danielssen 1990)

Johannessen and Tveite (1989) studied the relationship between abundance of 0-group and environmental factors, and concluded that the wind direction and the stability of the water masses was the most important factors.

Adults

Feeding

Some preliminary data on food content of stomachs from cod from the Risør area caught during winter were given by Hop, Danielssen and Gjøsæter (1988). Fish, mainly Gobidae, was an important part of the diet (Fig. 4, 5), and so were shrimps, crabs and other crustacea. The diet is, however, highly variable both geographically and with season, and a more derailed analyses of these variations is in progress.

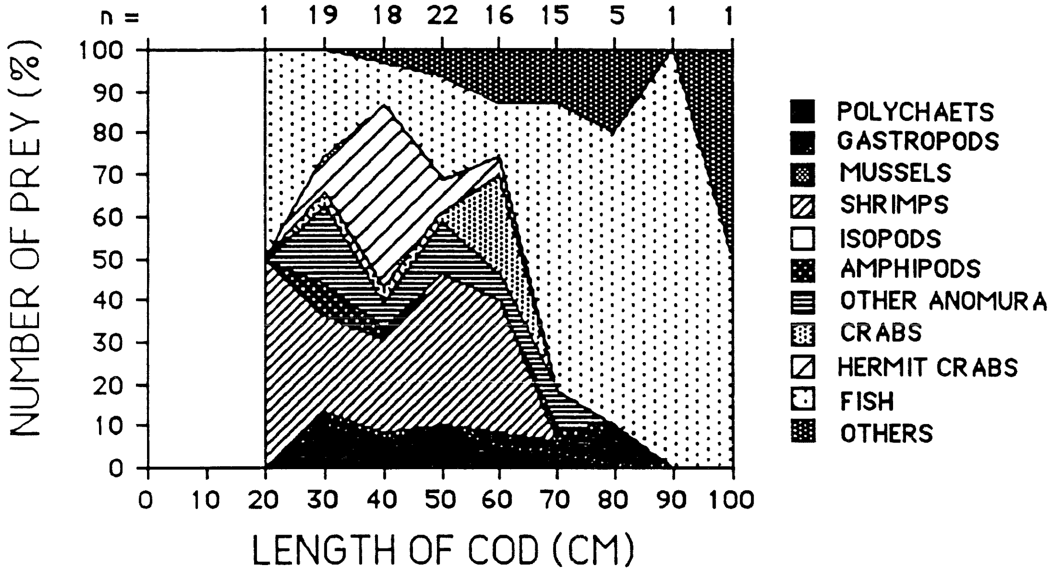

Fig. 4. Stomach content of cod from the Risør area during winter (From Hop, Danielssen and Gjøsæter 1988).

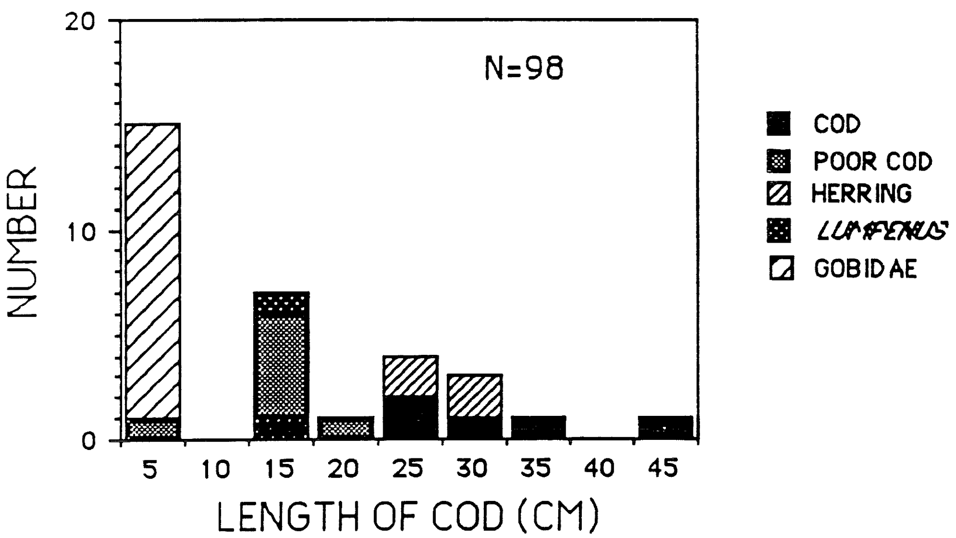

Fig. 5. Fish species in the stomach content of cod from the Risør area during winter (From Hop, Danielssen and Gjøsæter 1988).

Growth

Age and growth of the cod from the Norwegian Skagerrak coast have been studied by i.a. Dannevig (1933, 1953), Løversen (1946) and Gjøsæter and Danielssen (in prep). They showed that growth was generally fast compared to other areas, and that it varied between different fjords and coastal areas (Fig 6). The average growth for the areas studied by Gjøsæter and Danielssen (in prep.) is

$$l_t = 76.01(1 - \exp[-0.30(t - 0.26)]).$$

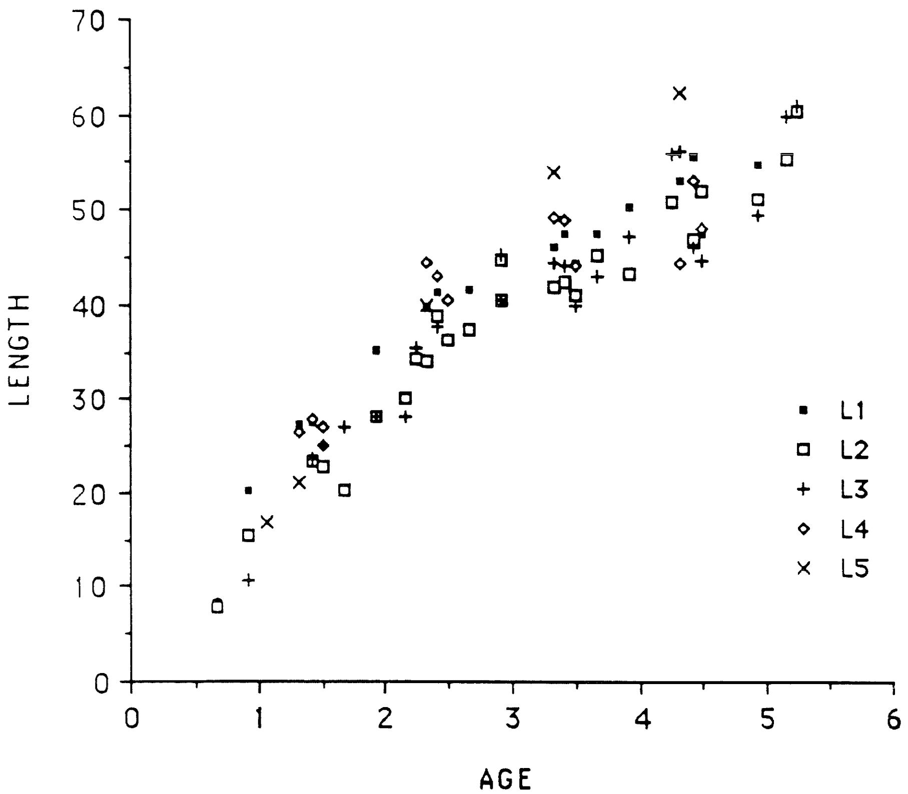

Fig. 6. Length at age of cod from the five areas: L1, Risør skerries, L2, Outer part of Søndeledfjord, L3 Inner part of Søndeledfjord, L4, Sandnesfjord, L5, Flødevigen. The symbols give average length for each age. Only lengths based on five or more observations are shown. (From Gjøsæter and Danielssen in prep.).

To analyse possible density dependence in the growth rates, otolith diameters were measured and used as an indicator of length at age (Gjøsæter and Lønnhaug 1990). The results suggest that there is no correlation between the length increments and year-class strength (Fig. 7) (Gjøsæter and Danielssen in prep.).

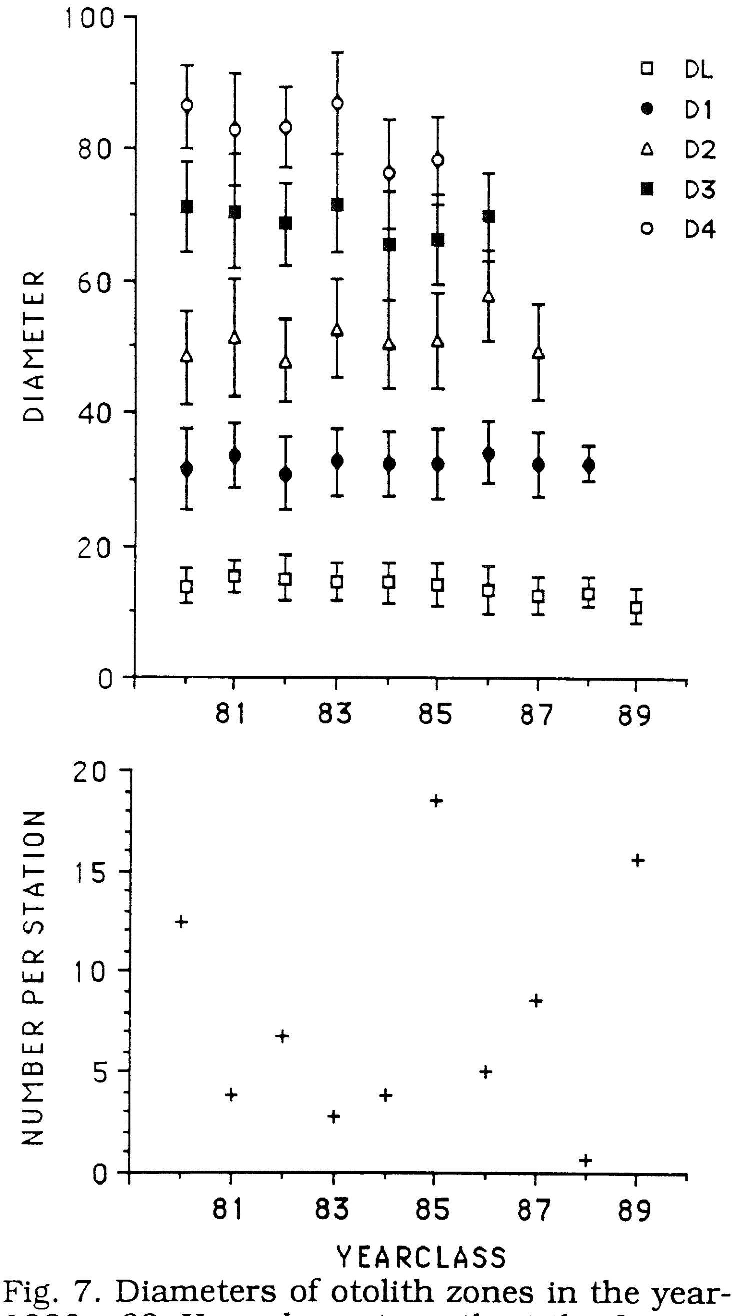

Fig. 7. Diameters of otolith zones in the year-classes 1980 - 89. Year-class strength at the 0-group stage is also indicated. (From Gjøsæter and Danielssen in prep.).

Age composition

Few data are available on age composition, but results from a series of surveys with trammel netts in the Risør area suggests that few cod live for more than five years, and catches are usually dominated by 2 years old fish (Fig. 8) (Gjøsæter and Danielssen in prep.).

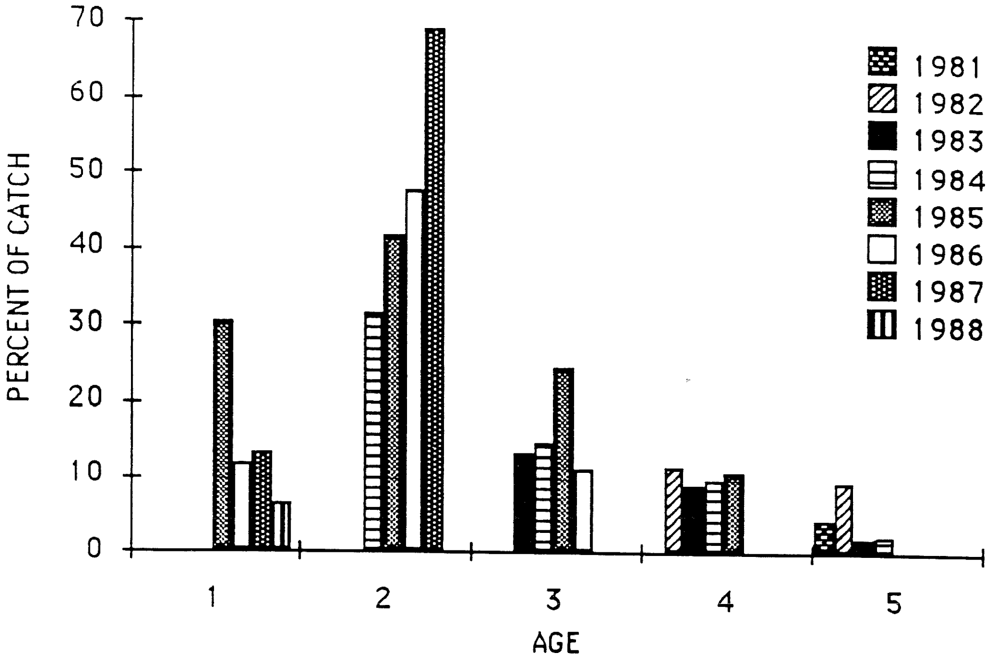

Fig. 8. Relative abundance of year-classes 1981 - 1988. The legend indicate year-class. (From Gjøsæter and Danielssen in prep.)

Maturation, fecundity and sex ratio.

The Skagerrak coastal cod mature at an age of 3 - 6 years. There seem to be some geographical variations and the fish from the inner parts of the fjords mature at a lover age and a smaller size than fish from the open areas (Dannevig 1954). Off Flødevigen Sivertsen (1935, 1937) found that few cod were mature at an age of 3 years while 85 - 90% of the 4 and 5 year old fish were mature. According to Dannevig (1954) about 505 of the 3 years old fish mature.

Sivertsen (1937) found 337 males and 548 females in a material from the Flødevigen area during 1934-35, while unpublished data from 1985-88 gave 341 males and 326 females.

The fecundity has not been studied.

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Syntheses of North Atlantic Cod Stocks.

THE BALTIC SEA COD

Prepared by P. O. Larson

DESCRIPTION OF COD STOCKS, THEIR BIOLOGY AND ENVIRONMENT

THE BALTIC

1. History

In historical time cod has occured in the Baltic maximum some 7500 years. Before that the Baltic had a freshwater stage, but as the land uplift was higher in the northern than in the southern part, a new connection with the ocean was established through the Danish sounds. In the initial phase of this latest sea stage the water was more saline than at present in the Baltic Sea (Voipio, 1981).

At present cod are regarded as two well separated stocks, a small stock SW of Bornholm (the western stock) and a large one inhabiting almost all the rest of the Baltic Sea (the eastern stock). As reviewed by the Working Group on Assessment of Demersal Fish in the Baltic (WGADFB) in 1990 (Anon., 1990) these two stocks seem to be separated quite distinctly from each other and from the Division IIIa (Kattegat) stock as well.

Before the World War II the exploitation of cod in the Baltic Sea was very limited but increased rapidly during and just after the war (Table 1). The increased fishing intensity caused a reduction in the cod stock and a decrease of the mean age but also an increase in growth rate (Table 2). In Table 1 the catch for at least one country (FRG) is given as gutted weight, and discards are not included (Bagge, 1981). Table 3 is from the 1990 report of the WGADFB and shows the total catch in Subdivisions 22-32 (Figure 1) in round fresh weight including discards for at least some countries. In Figure 2 the catch is shown together with fishing mortality the latest 20 years. It is obvious that the present fishing mortality is much too high, by far exceeding F_{Max} (ca. 0.3) (Anon., 1990).

The peak catch in 1984, almost 450.000 tonnes, is the result of several good year-classes but still impressing. For some countries the cod fishery is the most important one, e.g. for Sweden the value of the cod catches (95% in the Baltic) was 46% of the value of the total landings (Baltic and the west-coast).

In 1975 quotation of cod was introduced by the International Baltic Sea Fishery Commission together with a minimum landing size of 30 cm and a minimum mesh size of 90 mm in cod trawls. It has not been possible to agree on a TAC every year and when an agreement was reached it has always been on a higher level than the advice from ICES. The minimum landing size and mesh size were raised to 33cm and 105 mm January 1, 1990.

From the peak in 1984 the catches have gradually decreased to an average level, in 1989 well below a long-term average. This is in accordance with the predictions by the WGADFB and a result of a sequence of poor year-classes. Due to environmental conditions the reproduction areas have been severally reduced in the latest years, resulting in still poorer year-classes and consequently further reductions of catches to be expected in the years to come (Larsson, in press).

2. General structure of the stock

Reliable time series on stock abundance are available only from about 1970. As reflected in the catches (Figure 2) there was a peak in abundance in the early 1980s as an effect of rich year-classes especially in 1976, 1977, 1979 and 1980.

The western stock has a small area of distribution and seem to be more randomly distributed over that area as adults, apart from aggregations during spawning.

The eastern stock has a limited area of reproduction (Figure 3) but from that area cod spread over almost the whole Baltic Sea. In the Bothnian Sea and Bay the density is however much lower. With average size of year-classes total catches in that area are a few hundred tonnes, but e.g. the good year-classes mentioned above (1976-80) gave rise to a stock permitting about 10.000 tonnes a year for a few years (Modin, 1987). Three such episodes are known from this century, 1915-16, 1940-42 and 1987-88. Spawning occurs in the Bothnian Sea but in that low salinity (<7‰ in the bottom water) the eggs do not survive. Some adults migrate to the main spawning areas in the southern Main Basin (Otterlind and Norberg, 1988). The relatively small area where succesful spawning is possible has prevented the development of sub-stocks.

3. Fishing pattern

From the increase in fishing intensity 1940-50 the main gear used for cod fishing has been trawl, with a small and gradually decreasing proportion taken by set-nets and long-lining. At first only bottom-trawls were used but from the mid 70's pelagical trawling has become more and more important, partly because the deteriorating oxygen-situation in the bottom water has made spawning more pelagic.

As mentioned above fishing mortality has for long been far too high, F varying from 0.5 to 1.2 during the latest 20 years (Figure 3).

4. Environment

The Baltic Sea is brackish with a surface salinity increasing from almost freshwater in the north to 8-9 ‰ in the south. In the Main Basin there is a halocline at 60-70 m depth and below that the salinity normally is 10-16 ‰. The outflow from the Baltic Sea, forming the Baltic current in the Kattegat, is entirely made up of low salinity surface water. The water masses below the halocline are rather stagnant causing frequent oxygen deficiences in the deeper basins. Periods with oxygen deficiency and formation of hydrogen sulphide have occured more often and with longer duration in the latest decades, presumably as a result of eutrophication (Fonselius, 1977; Grasshoff and Voipio, 1981).

The salinity is maintained by frequent inflows of oceanic (deep) water from the Kattegat. In 1977 there was a major such inflow raising the salinity and the oxygen concentration in the deep basins of almost the whole Baltic Sea. Since then there has been only one average inflow in 1980 and a small one 1983. The development of the salinity since 1975 can be seen in Figure 4 (After Juhlin, 1990) .

The combined effect of low salinity from the surface and no or low oxygen concentration from the bottom creates a "reproduction volume", where both parameters have sufficient levels. In the latest two or three years there seems to have been no such volume in the two eastern of the three main spawning areas in the Baltic Sea (Anon., 1990).

The regional climate is characterized by warm summers and cold winters creating high surface temperatures in summer and ice-cover of substancial parts of the Baltic Sea in winter, normally at least the Bothnian Sea and Bay, in some years the whole of the Baltic Sea.

The Baltic Sea has a very low species diversity. Apart from cod there are no gadoids, except occasional vistors from the Kattegat of haddock and whiting. Other visitors are e.g. mackerel, garpike (also spawning in the Baltic, but not staying there permanently as adults) and a number of species in very low numbers. The most important resident fish species in addition to cod are herring, sprat, salmon, trout, flounder, plaice, dab, turbot, sticklebacks, gobids, sandeel and eel. Also a number of freshwater species inhabit at least the coastal areas of the Baltic Sea (Voipio, 1981).

Other biota are also represented by few species but the total bio-mass is large, and primary production in a very effective way transferred to the top predators. In a comparison with the ecosystem in Cheasapeake Bay the production of fish in relation to primary production the Baltic Sea system proved to be 3-5 times as efficient (Wulff and Ulanowicz, 1989). A large proportion of the total biomass is made up of *Mytilus edulis,* which does not grow as large as in the oceans, but covers vast areas of cliffs not inhabited by seaweeds normally doing so in the oceans. Another common invertebrate is *Mesidothea entemon*, a crustacean (Isopoda) specialized on brackish water and growing to about 12 cm in length (Voipio, 1981).

Apart from a low number of seals cod has no natural enemies in the Baltic Sea as adults.

5. Spawning

Spawning is restricted to areas where there exist "reproduction volumes" as described above. For the western stock the main spawning area is in the Arkona Deep just north of Rügen at a depth of 40-50 m.

The eastern cod stock has three main spawning areas, the Bornholm Deep (minimum spawning depth 60 m), the southern part of the Gotland Deep and the Gdansk Deep (minimum spawning depth 80 m) and a minor area in the Slupsk Furrow (Figure 3).

To compensate for the sometimes critical abiotic conditions, the spawning season of the eastern stock in the Baltic Sea is very long. It begins in March and ends in August. In the Bornholm area it begins in February. The western stock has a more normal period, February - April. There is quite a variation from year to year and between areas probably depending on temperature, salinity and oxygen conditions. The variation is exemplified in Table 4 (From Bagge, 1981).

From a large number of tagging experiments the migrations of cod in the Baltic Sea are rather well known. Even from long distances cod migrate to the main spawning grounds. In the Bothnian Sea spawning occurs (without result) but a number of cod (at least 10%) migrate all the way to the southern Main Basin (Bagge etal., 1974; Otterlind and Norberg, 1988).

6. Egg and larval stages

Marine fish species in the Baltic Sea are slowly growing but have a higher fecundity. In the North Sea a female cod 75 cm long produces an average of 1.830.000 eggs but in the Baltic Sea 3.660.000 eggs, in spite of the eggs being larger in the Baltic cod, 1.7-1.8 mm compared to 1.45 as an average for the North Sea cod (Bagge, 1981).

A part of the Baltic cod mature at an age of 2 years and all when 3 years old. In the northern parts they mature later.

The eggs of the eastern stock have a neutral buyoyancy at a salinity of 11-14‰ and of the western stock at 13-16‰. That means the eggs will stay at the spawning depth or sink to the bottom or down in oxygen-free water and die. The same applies to the newly hatched larvae but when they are able to swim and regulate the swim-bladder pressure (10-15 mm) they approach the surface. At that time they are normally moved by the main surface current. That current has an anticlockwise direction and most of the larvae are transported to the Polish and Soviet coasts (Bagge, 1981).

The larvae and juveniles stay close to the coasts but not in as shallow waters as in the oceans, probably because the water has too low salinity in shallow coastal areas of the Baltic Sea (Bagge, 1981).

7. Juveniles

Very little is known about the biology of juvenile cod in the Baltic Sea. In young cod surveys juveniles (8 months - 1 year) are found almost everywhere in the Baltic Sea, but predominantly at depths between 30 and 50 m.

To improve the knowledge about this stage an *ad hoc*Working Group on Young Fish Surveys in the Baltic was set up by ICES, after two meetings transformed to a Study Group, which has had another two meetings. The group has so far concentrated on young cod rather than real juveniles.

8. Adults

The von Bertalanffy growth parameters which are considered relevant for the Baltic cod are: L_∞=105.0 cm, k= 0.15, t_0= 0.5 (Bagge, 1981).

The cod is feeding all the year, except in very severe winters. The feeding of mature female cod is especially intensive under maturity stage IV. During stages V and VI the feeding decreases but never ceases. For males feeding decreases during the stages IV-VI.

Food composition has in several investigations been very similar. Cod <30 cm feed mainly on crustaceans like *Mysis spp., Pontoporeia spp., Mesidothea entomon* and the polychaete *Harmothoe sarsi.*Fish play a minor roll as food except in spring when 20-30 cm cod eat 15-30% sprat by weight.

For cod >30 cm fish are more important as food, especially sprat, which during the first 6 months of the year constitute 30-40% of the cod food, herring 9-25% and other fishes 2-10%. The corresponding figures for the second half year are 6-9%, 3-25% and 2-7% respectively. The invertebrates are still important as food. The first 6 months *Mesidothea* constitute 19-21%, Mysidacea 2-8%, other crustaceans 2-6% and *Harmothoe* 12-23% of the food. The corresponding figures for the second half of the year are 28-44%, 11-37%, 2-7% and 6-13% respectively (Bagge, 1981).

Cannibalism is rarely registered.

The food and feeding of cod in the Bothnian sea is less well known but it is clear that fish are less important and *Mesidothea* totally dominating in the food.

Several attempts have been done to calculate the annual consumption by cod. Uzars (1975) estimated it to be 2.995.000 tonnes of which 276.000 tonnes of herring and 408.000 tonnes of sprat. Danish investigations (Bagge, 1981) resulted in an estimate of 1.112.000 tonnes (315.000 tonnes of herring and 266.000 tonnes of sprat).

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Table 1. Total catch of cod in the Baltic 1935, 1943, 1951 and 1965-1977.

Year	Denmark	Finland	German Dem. Rep.	Fed. Rep. Germany	Poland	Sweden	U.S.S.R.	Total
1935	1 700	—	3 000		500	5 000	1 000	11,200
1943	9 900	—	53 100		—	11,900	6 100	81,000
1951	11,700	—	8 000	3 200	51,200	20,500	46,900	141,500
1965	21,450	23	8 186	5 203	41,498	19,523	22,420	118,303
1966	22,658	26	6 671	3 297	56,007	20,415	38,270	147,344
1967	25,839	27	16,839	2 520	56,003	21,367	42,980	165,575
1968	28,320	70	19,381	4 808	63,245	21,895	43,610	181,329
1969	29,371	58	21,802	7 217	60,749	20,888	41,580	181,665
1970	28,014	70	13,604	6 954	68,440	16,467	32,250	165,799
1971	30,000	53	7 375	4 562	54,151	14,251	20,910	131,302
1972	42,000	76	9 160	4 985	57,093	15,194	30,140	158,648
1973	44,650	95	10,404	15,873	49,790	16,734	20,083	157,629
1974	39,510	160	7 948	12,226	48,650	14,498	38,131	161,123
1975	46,543	298	11,271	12,465	69,318	16,033	49,289	205,217
1976	57,094	287	7 260	14,313	70,466	18,388	49,047	216,854
1977	55,749	310	9 990	19,899	47,702	16,061	23,767	173,478

Table 2. Mean age and length of Baltic cod in various periods.

Period	Kiel Bay	Bornholm Deep	Gdansk Deep	Gotland Deep
Mean age				
1929–1938	4.77	4.51	4.74	5.95
1939–1944	2.77	4.22	3.48	4.48
1946–1957	2.02	3.58	3.71	4.33
1960–1967	1.59	3.60	3.68	3.78
1965–1977	2.34	3.57	3.94	4.00
Mean length — age group III				
1931–1938	38	35	35	34
1953–1956	44	42	41	41
1962–1965	44	38	38	—
1974–1977	44	41	36	—

Table 3. Total catch of Baltic cod (Subdivisions 22-32) 1965-1989. (Working Group on Assessment of Demersal Fish in the Baltic).

Year	Denmark	Finland	German Dem.Rep.	Germany, Fed.Rep.	Poland	Sweden	USSR	Faroe Islands	Total
1965	35,313	23	10,680	15,713	41,498	21,705	22,420	-	147,352
1966	37,070	26	10,589	12,831	56,007	22,525	38,270	-	177,318
1967	39,105	27	21,027	12,941	56,003	23,363	42,980	-	196,446
1968	44,109	70	24,478	16,833	63,245	24,008	43,610	-	216,353
1969	44,061	58	25,979	17,432	60,749	22,301	41,580	-	212,160
1970	42,392	70	18,099	19,444	68,440	17,756	32,250	-	198,451
1971	46,831	53	10,977	16,248	54,151	15,670	20,910	-	164,840
1972	59,717	76	13,720	15,516	57,093	16,471	30,140	-	192,733
1973	66,050	95	14,408	28,706	49,790	18,389	20,083	-	197,521
1974	57,810	160	10,970	22,224	48,650	16,435	38,131	-	194,386
1975	62,524	298	14,742	24,880	69,318	17,965	49,289	-	239,016
1976	77,570	287	8,552	26,626	70,466	20,188	49,047	-	252,736
1977	73,505	310	10,967	30,806	47,702	18,127	29,680	-	211,097
1978	50,611	1,437	9,345	15,122	64,113	16,793	37,200	-	194,621
1979	59,704	2,938	8,997	19,375	79,754	23,093	75,034	3,850	272,745
1980	75,529	5,962	7,406	18,407	123,486	33,201	124,350	1,250	389,591
1981	92,648	5,681	12,936	18,281	120,901	44,330	87,746	2,765	385,288
1982	91,927	8,126	11,368	21,860	92,541	46,548	86,906	4,300	363,576
1983	107,624	8,927	10,521	25,154	76,474	53,740	92,248	6,065	380.753
1984	113,701	9,358	9,886	42,031	93,429	65,927	100,761	6,354	441,447
1985	107,627	7,224	6,593	31,798	63,260	54,723	78,127	5,890	355,242
1986	98,464	5,633	3,179	22,422	43,236	49,572	52,148	4,596	279,250
1987	83,844	3,007	5,114	18,816	32,667	47,429	39,203	5,567	235,647
1988	74,742	2,904	4,634	18,295	33,351	54,968	28,137	6,915	223,946
1989[1]	65,935	1,843	2,147	15,342	31,815	52,397	14,722	4,520	188,771

[1]Provisional data.

Table 4. Variation in spawning time as reflected by number of eggs found per sq.m in 1969, 1971 and 1973.

	February	March	April	May	June	July	August
Bornholm Deep:							
1969	—	29	59	71	82	87	8
1971	—	10	57	50	13	23	6
1973	2	60	129	48	37	54	—
Southern Gotland Deep:							
1969	—	0	23	18	24	20	—
1971	2	0	4.5	5	4	6	3
1973	—	4	16	10	13	0	—

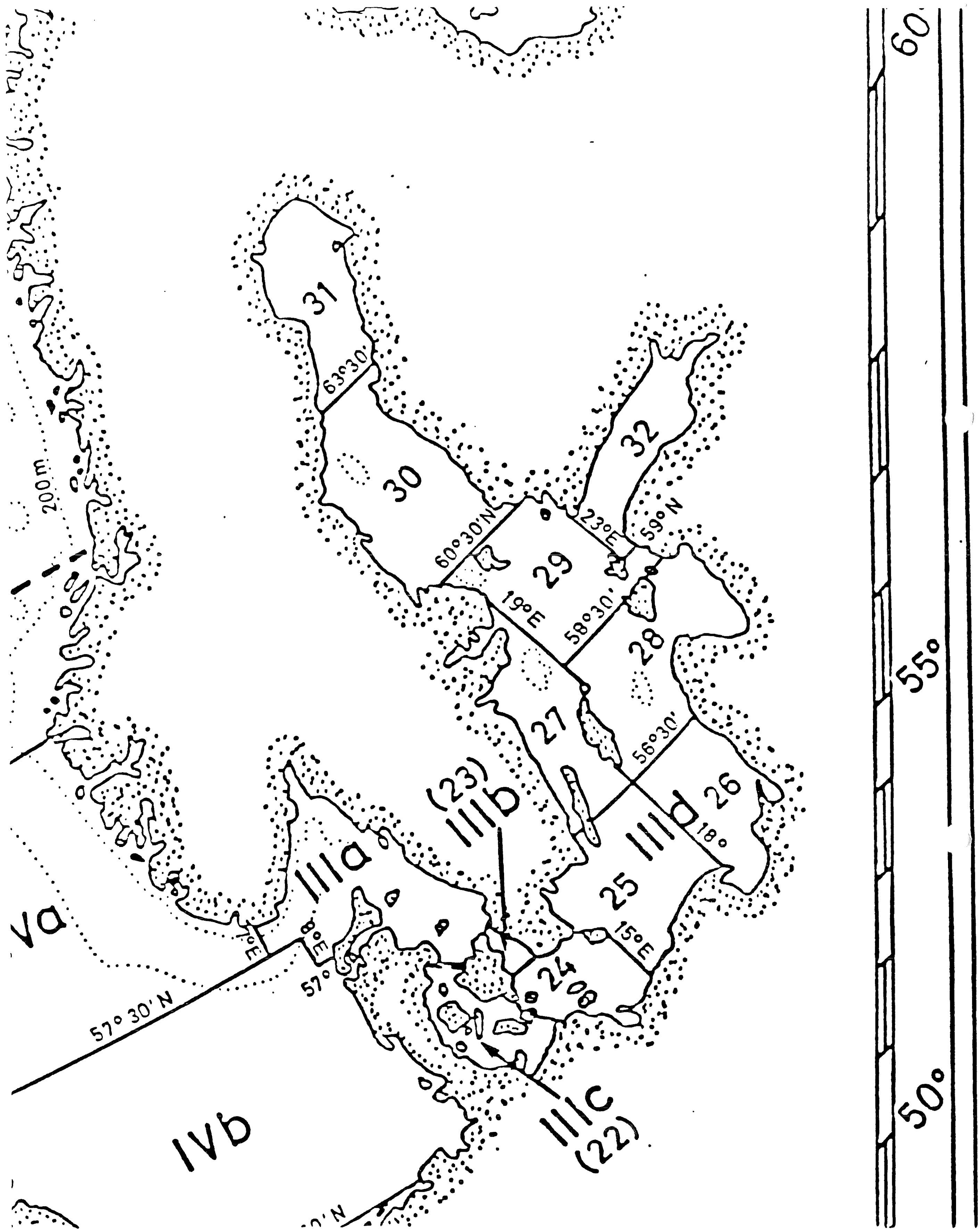

Figure 1. The Baltic Sea (IIId). Subdivision 24-29: Main Basin, SD30: Bothnian Sea, SD 31: Bothnian Bay, SD 32: Bay of Finland

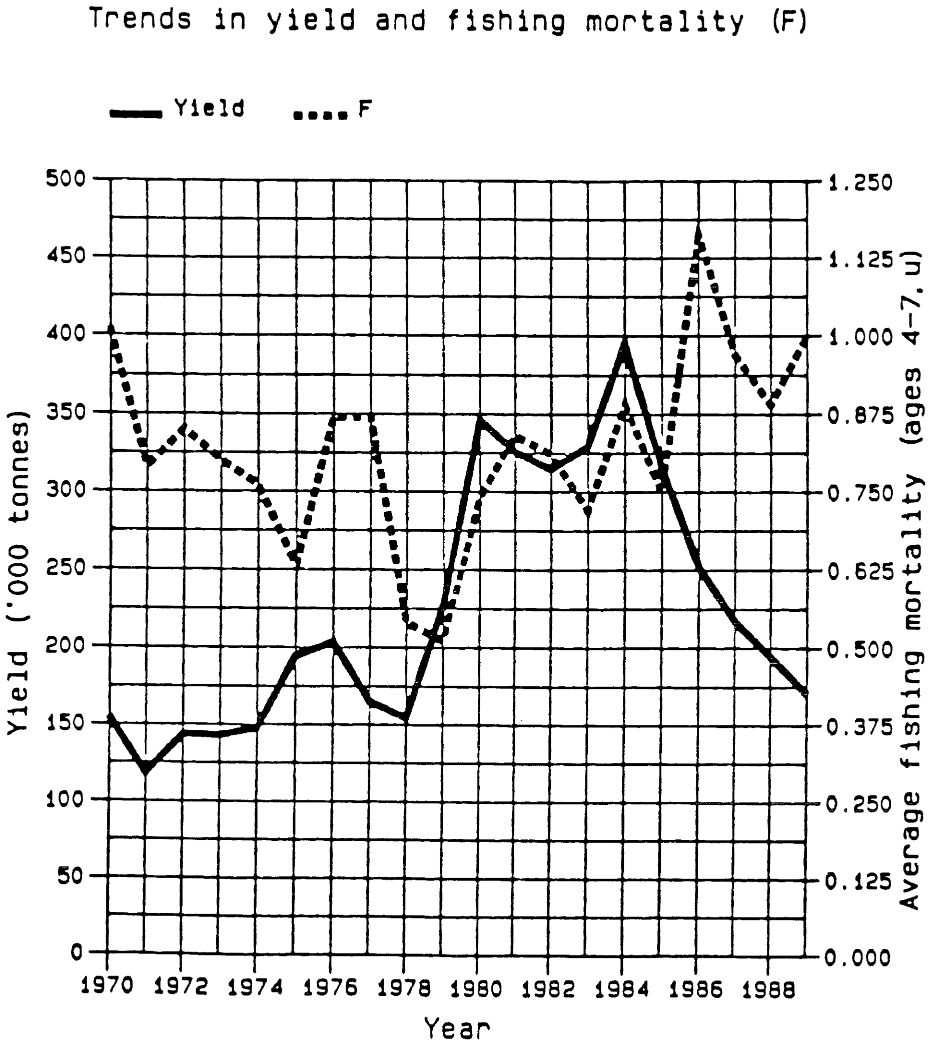

Figure 2. Trends in yield and fishing mortality of Baltic cod, eastern stock.

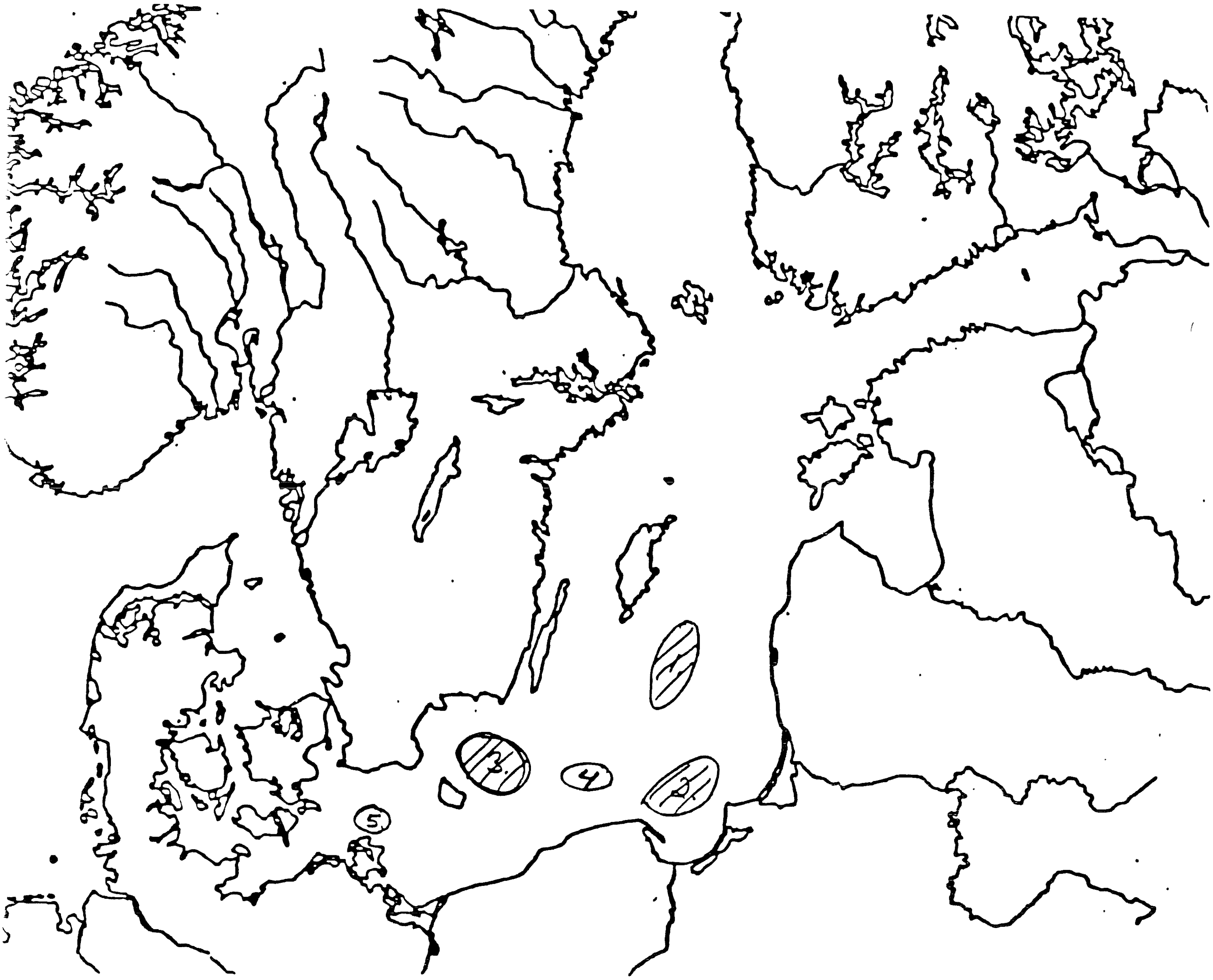

Figure 3. Spawning areas of Baltic cod. 1,2 and 3 (Gotland deep, Gdansk Deep and Bornholm Deep) main areas for the eastern stock, 4 (Slupsk Furrow, eastern stock), 5 (Arkona Deep) main area for the western stock.

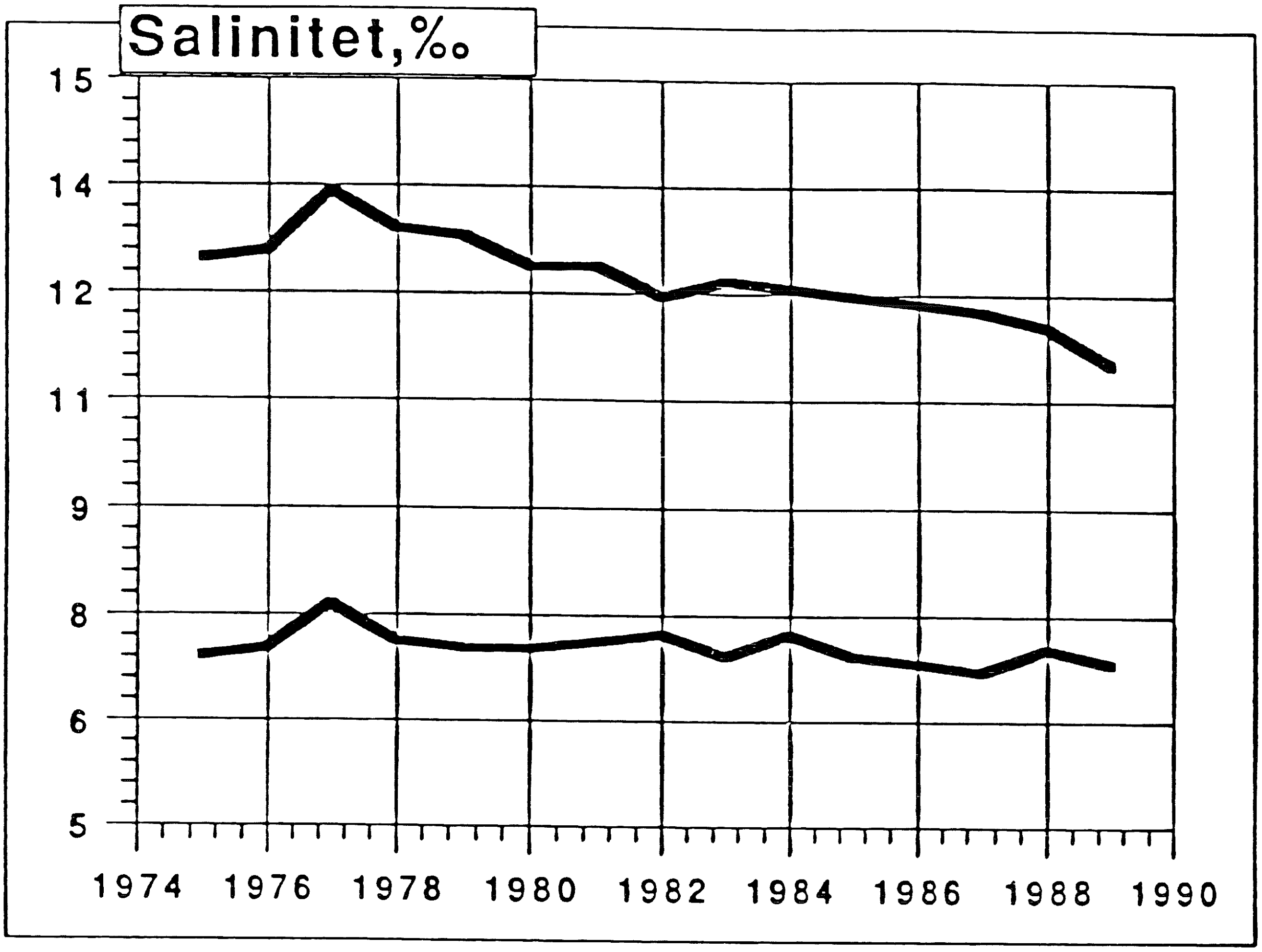

Figure 4. Salinity in the Gotland Deep 1975 - 1989.
Surface (lower) and 225 m (upper)

Appendix III of ICES C.M. 1990/G:50
Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

THE NORTH SEA COD

Prepared by H. Heessen

COD and CLIMATE CHANGES in the North Atlantic

North Sea Cod

History

Catches
Data on landings of North Sea cod for years prior to 1906 do possibly exist in some form or another as national statistics. In 1906 ICES started to collect detailed information on total international landings.

Social/economic influence
Not known.

Break-downs/ increases of the stock
Not known.

Interaction with other stocks
Not known.

General Structure of the Stock

Time series on stock abundance/catches
Prior to the early 1960s, landings fluctuated between about 60 000 and 160 000 tonnes, with a marked fall during the two war periods. Landings peaked immediately after each war. In the 1960s there was a remarkable increase and a peak of about 340 000 tonnes was reached in 1972. Although there have been wide fluctuations subsequently, landings have remained at a high level compared to the period before 1960. One reason for the increase in landings in the past 20 years is that recruitment has been at a much higher level than before. VPA-estimates of the size of the spawning stock are available since 1963. From 1963 spawning stock biomass increased steadily up to 1970 when a maximum of 270 000 tonnes was reached. Since than the spawning stock has declined and is estimated to be around 90 000 tonnes at present.

Distribution
Cod has a widespread distribution throughout the North Sea. For recent years survey data are available which give distribution by age in winter (the International Young Fish Survey) and in summer (e.g. the English Groundfish Survey). Furthermore some countries collect detailed statistics on catches per ICES rectangle.

Evidence of sub-stocks
Extensive tagging data have been reviewed by the North Sea Roundfish Working Group (Anon., 1970 and 1971). On the basis of many tagging experiments it was concluded that cod do not disperse uniformly throughout the North Sea but remain more or less within one region. As an approximation the following regional grouping was suggested:

a) the Norwegian side of the Skagerrak,
b) the Danish side of the Skagerrak,

c) one or possibly several coastal regions, from Flamborough to the Scottish east and north coasts,
d) the central North Sea,
e) the Southern Bight, from the Straits of Dover to latitude 54° N,
f) the English Channel, south and west of the Straits of Dover.

See also studies on the genetics of cod by Jamieson (e.g. J. Fish Biol. 35, Suppl. A, pp 193-204).

Although North Sea cod is certainly not one homogeneous stock, sub-stocks with clear boundaries can not be discriminated.
The region off the north and north-west coasts of Scotland is an important spawning area for cod and it is likely that their eggs and larvae are also transported into the North Sea. It might be expected that this one-way drift of eggs and larvae into the North Sea would be counterbalanced by a return migration of adolescent or mature fish to the westerly spawning grounds (Daan et al., in press). Also at the other end of the North Sea there is an interchange of spawning fish and spawning products: cod leave the North Sea to spawn in the Channel (Daan et al., in press).

Fishing Pattern

Changes of fishing pattern, fishing mortality
Cod is caught by a great variety of gears, often as the main species in a mixed fishery. Fishing mortality estimated from VPA is steadily increasing since 1963. Data from Daan (1969) on the composition in market-categories of the Dutch landings show a clear increase in the proportion of small cod in the landings since 1949. For most countries data exist on total landings and their age-compositions. For some countries these data are disaggergated by fleet.

Environment

Water masses

General circulation

Variability

Regional climate
See Århus Symposium, 1975?

Times series

Production regions (primary and secondary)
Data on fronts in Texel Symposium.

Other important species

Spawning

Spawning period
Spawning occurs from the beginning of January to April. In the Southern Bight peak spawning falls in February, whereas in the more northerly regions, maximum spawning

activity shifts to March. On a very limited scale autumn spawning occurs in the northern North Sea, but this was more regularly observed between 1900 and 1930 than in the most recent period.

Spawning areas and their physical conditions
Spawning areas are widely distributed over the North Sea. In the northern North Sea spawning occurs close to banks, but whether cod actually spawn on or just close to these banks is unknown. A difficulty in the location of spawning areas in the northern North Sea is that cod and haddock spawn in the same areas, so only late stage eggs can be used to provide information about the location of spawning areas. The spawning area off the Dutch coast was studied in several egg surveys since 1970.

Spawning migration
Information on spawning migration is available from tagging experiments. Since spawning areas are to be found throughout the North Sea, there are only local, short migrations.

Variability
The importance of certain grounds may shift to some extent from year to year but the available data do not indicate that since the beginning of this century major changes have taken place in the spatial distribution of spawning (Daan, 1978). Variation in number of eggs and spawning time: data for the Southern Bight (Daan, 1980; Heessen and Rijnsdorp, 1989) and for the west central North Sea (Harding et al., 1978).

Spawning behaviour
Not known.

Spawning depth
Not known.

Egg and Larval Stages

Physical and biological properties

Development and growth
Egg and larval development at different temperatures is described in Thompson and Riley (1981). The development rate of eggs is given for the temperature range 1.7° to 11.59° C. For larvae the development rate has been described at 6.5° C.

Vertical distribution
Not enough information is available to draw general conclusions.

Predators
Several species are known to predate on eggs and larvae. For the southern North Sea Daan et al. (1985) studied the predation by herring. The estimated fraction consumed of the initial numbers of eggs produced varied from 0.04 to 0.19%.

Prey
In the southern North Sea yolk-sac stage larvae begin to feed on diatoms, dinoflagellates and tintinnids, but the principal food is the nauplii and copepodites of calanoid copepods, particularly of *Pseudocalanus minutes*. More details are given in Last (1978).

Mortality

For the southern North Sea mortality data are available for 7 years (1970-1974 and 1978-1988). The observed instantaneous daily mortality rates varied between 0.027 and 0.404 (Daan, 1980; Heessen and Rijnsdorp, 1989). For the west central North Sea a value of Z of 0.14 was observed in 1976 (Harding et al., 1978).

Timing in relation to production cycle
Spawning of cod is rather early in relation to the production cycle (see Harding et al., 1978)

Horizontal spreading/ retention
In the southern North Sea eggs of cod drift in a northerly direction.

Juveniles

Predators
Data on predation of juvenile cod in quarter 3 and 4 of 1981 are given in Daan (1989). Among the predators of juvenile cod are cod, whiting and saithe. In a recent study (Daan and Heessen, unpublished) predation was also shown in grey gurnard and greater sandeel.

Prey
Copepods dominated the food of pelagic juvenile cod in the northern North Sea (Robb and Hislop, 1980; Robb, 1981). The copepod species most commonly taken were *Para/Pseudocalanus* spp.
In demersal juveniles the food is dominated by crustaceans (Daan, 1989).

Growth
Some data on growth during the pelagic phase of O-group cod can be found in the annual reports of the International O-group Gadoid Survey, carried out annually in the central and northern North Sea in June/July in the period 1974-1983 (see e.g. Daan et al., 1981).

Mortality
not known

Distribution
Data on distribution of pelagic O-group are also available from the survey mentioned above. In the pelagic phase O-group cod is almost absent in the southern Bight. The distribution of demersal O-group in the autumn is only known for the southeastern North Sea. The distribution of 1-group fish is well known for the total North Sea from the International Young Fish Survey in February and a number of national summer surveys. Mean distribution of pelagic O-group and demersal 1-group is shown in Hislop (1984).

Physiology

Behaviour

Vertical distribution
Some data on vertical distribution were collected in 1975 as a cooperative exercise during the International O-group Gadoid Survey. Pelagic cod in the northern North Sea was found to be mainly confined to the upper 0-40 m stratum (Holden, 1981). Recently some work was done by England and Netherlands the results of which will be available in due course.

Settling

Juveniles start their demersal stage of life somewhere between June and autumn. In pelagic trawls no fish bigger than 7 cm is caught (Hislop, 1973).

Adults

Feeding
The most comprehensive data on feeding of North Sea cod were collected in 1981 during an international stomach sampling project (Daan, 1989). In juvenile (0- and 1-group) cod crustaceans are the dominant prey items but in older cod, fish comprise an increasingly important part of the diet. Most of the fish species consumed are of commercial importance and they include cod itself.

Migration
Migration of adult cod is restricted to limited areas, they do not disperse throughout the North Sea (Anon., 1970 and 1971). The distance between summer feeding grounds and winter spawning grounds varies between 20 and 120 miles. In general the spawning grounds lie to the south of the feeding areas.

Growth
Growth of North Sea cod was analyzed in several papers, e.g. Daan (1974), Macer (1983) and Van Alphen and Heessen (1984). The growth rate varies slightly throughout the North Sea and cod in the southern North Sea grow faster than those in the north (Van Alphen and Heessen, 1984).

Mortality
Data on fishing and natural (predation) mortality can be derived from VPA (Anon., 1990) and from multispecies VPA (Anon., 1989). In the multispecies VPA in all 11 commercial species are taken into account.

Physiology

Behaviour

Interaction with other species
See MSVPA (Anon., 1989).

Maturation and fecundity
Data on maturity are available from the International Young Fish Survey. Some North Sea cod become mature in their second year of life, but it is not before they are 6 years old that they are all mature (Oosthuizen and Daan, 1974; Van Beek et al, 1989). There is a tendency that cod in the southern North Sea become mature at a slightly younger age than in the northern North Sea.
Fecundity estimates are available for a small number of years in the early 1970s and late 1980s (Oosthuizen and Daan, 1974; Heessen, unpublished). The relative fecundity appears to be significantly higher in recent years (in the order of 20%) than during the earlier studies.

Age, Size and Sex ratio
Data for age and size distributions and sex ratio are also available from the International Young Fish Survey.

Literature

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Syntheses of North Atlantic Cod Stocks.

THE IRISH SEA COD

Prepared by K. Brander

Irish Sea cod stock

1. History

Catches from this stock have remained between 6000 and 15000 t yr^{-1} since 1968 and fishing mortality has been between 0.5 and 0.9. Total catch statistics are available since 1920. Cod is the major demersal fish species landed from the Irish Sea in value, but the area is one of mixed fisheries and several other species are also important. The management strategy for cod (using TAC) allows for the biological interaction between cod and Nephrops, which has a greater total value than cod.

2. Stock structure

The evidence for stock discreteness comes mainly from the results of tagging experiments carried out during the 1970s. These show that mature fish tagged on spawning grounds in the northeast and northwest Irish Sea (and in the Bristol Channel) are recaptured from the same sites in subsequent spawning seasons. During the rest of the year there is some migration out of the Irish Sea to the south, but virtually no recaptures of fish which have crossed the 5 deg W longitude in either direction. Immature fish tagged in various parts of the Irish Sea (including Belfast Lough) are recaptured over a much wider area than are the mature fish and this is evidence of substantial migration into the Celtic Sea and round the north and west of Ireland. Once these fish mature however they are recaptured mainly on Irish Sea spawning grounds. Extensive tagging of cod West of Scotland has produced no recaptures from the Irish Sea at all.

The genetic evidence is equivocal (Jamieson and Birley, 1989), showing allele frequencies which are for the most part similar to those elsewhere around the British Isles, but with a few unusual samples.

3. Environment, egg and larval stages

About 50% of spawning occurs in the cool, less saline water mass of the northwestern Irish Sea, close to the mouth of Carlingford Lough in the first two weeks of March. Primary production starts early in this water mass because it is shallow. Spawning also occurs two or three weeks later in the northeast Irish Sea, where water temperatures are one or two degrees lower and where primary production gets underway later. The precise location of spawning in relation to the fronts separating the water masses and the timing and nature of the production cycle in them is currently being investigated, as is the growth and survival of cod larvae. Other species spawning in the same general area as cod include sprat, dab and whiting, but cod may start to spawn before the others. Cod larvae occur in the part of the NW part of the Irish Sea which becomes stratified and where copepod abundances are highest. Within this area the numbers of cod larvae per m^3 are not related to the density of copepods, but there is a significant relationship between numbers of all species of fish larvae and copepod abundance. In the NE Irish Sea spawning occurs close to the position of the front separating the less saline coastal water from higher salinity offshore water. The circulation in both areas is complex, but larvae do not appear to be transported very far from where the eggs were spawned. It is not clear whether larvae from the two halves of the Irish Sea become mixed.

4. Adults

On spawning grounds during the spawning season 62-83% of 2-year old cod and all older fish were mature. However in order to estimate population maturity it is necessary to know what proportion of each age group is on the spawning ground, because almost all 2- and 3-year old cod caught away from the spawning grounds were immature. A rough estimate, which takes account of the differences in size-at-age, indicates that about 17% of 2-year old cod and about 85% of 3-year old cod are mature.

Table 3.9 Irish Sea COD. Summary of some VPA inputs and results, 1968-1987

Year	F on oldest true age (6)	$F_{1-6,u}$	1-yr-old recruits ($N \times 10^{-3}$)	SOP (%)	SSB[2] (t)	Landings (t)	Landings/ SSB ratio
1968	0.80	0.65	3,684	87.3	7,701	8,541	1.11
1969	0.86	0.76	5,500	81.3	6,285	7,991	1.27
1970	0.71	0.60	7,133	94.1	5,720	6,426	1.12
1971	0.57	0.54	12,309	96.8	7,113	9,246	1.30
1972	0.50	0.48	4,116	86.2	8,522	9,234	1.08
1973	0.83	0.70	11,348	91.1	10,240	11,814	1.15
1974	0.62	0.58	2,662	85.8	8,642	10,251	1.19
1975	0.90	0.73	9,172	92.6	8,794	9,863	1.12
1976	0.70	0.69	2,927	97.1	7,443	10,247	1.38
1977	0.87	0.71	4,339	98.6	7,110	8,054	1.13
1978	0.57	0.50	4,523	112.9	6,655	6,271	0.94
1979	0.76	0.64	9,779	112.7	6,743	8,371	1.24
1980	0.74	0.64	11,615	102.3	6,719	10,776	1.60
1981	0.77	0.68	6,519	107.6	9 873	14,907	1.51
1982	0.97	0.82	2,896	99.1	10,030	13,381	1.33
1983	0.88	0.74	4,334	98.4	8,361	10,015	1.20
1984	0.86	0.73	6,391	101.3	6,322	8,383	1.33
1985	0.87	0.77	6,493	100.4	6,132	10,483	1.71
1986	0.93	0.80	5,361	100.3	5,764	9,852	1.71
1987	1.01	0.86	18,996	100.2	6,106	12,894	2.11
1988	1.05	0.83	(8,202)[1]	100.0	6,977	13,958	2.00

[1] From recruit indices.
[2] SOP corrected.

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MISCELLANEOUS DATA AND TIME SERIES

COD IN THE NORTH SEA

ICES IV

	MAX.	MIN.	MEAN	1989
LANDINGS YEAR	341 (1972)	90 (1962)	213 (62 - 88)	
SPAWNING STOCK YEAR	269 (1971)	88 (1988)	177 (66 - 88)	91
RECRUITMENT AGE 1 YEARCLASS	847 (1970)	105 (1984)	407 (65 - 87)	

TIME SERIES:			
LANDINGS	1903 +		
VPA	1963 +		
SURVEYS	1970 +	IYFS	INTERNATIONAL
	1977 +	EGFS	ENGLAND
	1979 +	DGFS	NETHERLAND
	1982 +	SGFS	SCOTLAND
TAC	1978 +		

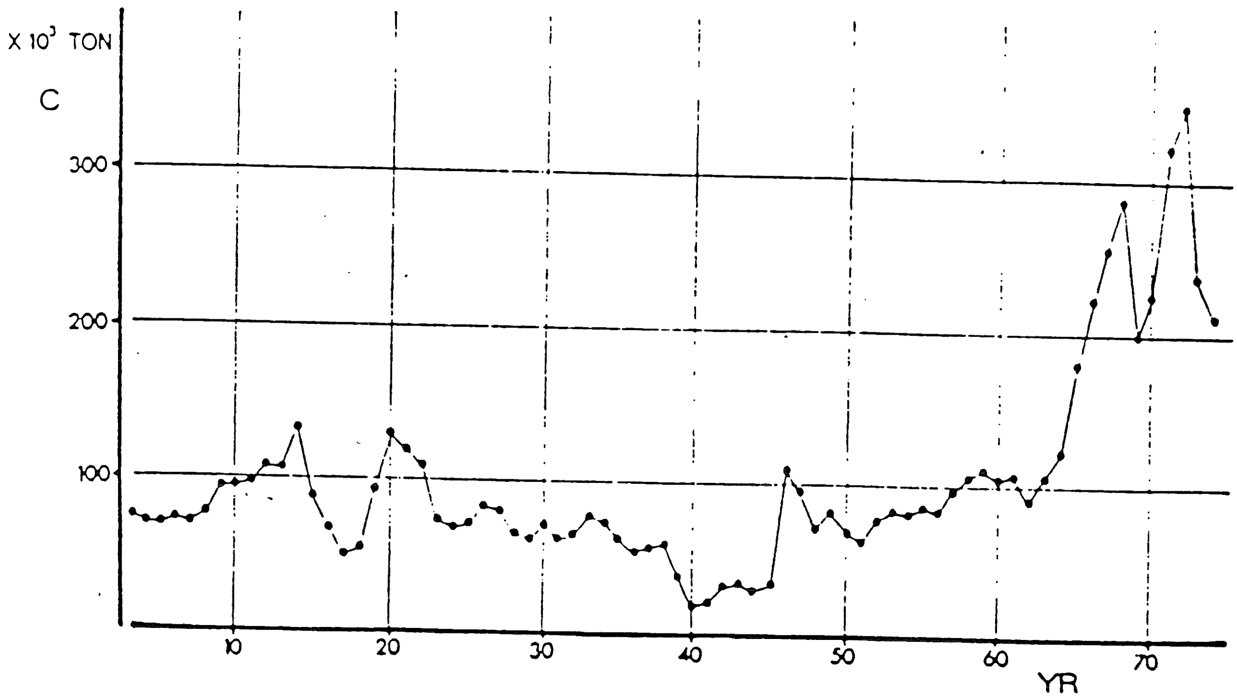

Figure 52. Nominal international catch of cod from the North Sea (*Bulletin Statistique*).

Prepared by O.M. Smedstad, Inst. Mar. Res., Bergen

Table 1. Principal Atlantic cod stocks in the Northwest Atlantic. Prepared by Dr. F M Serchuk, NEFC, Woods Hole Jan 1990.

Stock	NAFO Area	Landings (1000s t) Max	Landings Min	Landings Mean	Landings 1989	Spawning Stock Biomass (1000s t) Max	SSB Min	SSB Mean	SSB 1989	Recruitment (No. in Millions) Max	Recruitment Min	Recruitment Mean	Recruitment Current	Time Series Landings	Time Series VPA	Time Series Surveys	Time Series TACs	References
West Greenland	1	451 (1962)	7 (1986)	197 (52-88)	90	710 (1962)	9 (1985)	182 (62-88)	71 (OGV)	525 (1964)	13 (1973)	124 (62-82)	20 (Age 3)	1952+	62-82	1982+ (FRG)	1974+	NAFO SCR 83/60 ICES 1988/Ass. 11 NAFO SCS 89/17
Northern Labrador	2GH	94 (1966)	0.1 (1987)	17 (60-88)	0.4	-	-	-	-	-	-	-	-	1960+	-	1986+ (CAN)	1974+	ICNAF 73/106 CAFSAC Res 89/43 CAFSAC Adv 89/12
So. Labrador/ No. Grand Banks	2J3KL	810 (1968)	139 (1978)	377 (59-88)	190?	1069 (1962)	77 (1977)	431 (62-88)	489 (7+)	1195 (1966)	137 (1974)	488 (62-88)	214 (Age 3)	1959+	62-88	1978+ (CAN)	1973+	CAFSAC Res 89/6 CAFSAC Adv 89/1
Flemish Cap	3M	60 (1965)	1 (1988)	25 (60-88)	1	216 (1964)	5 (1978)	72 (59-80)	<2? (6+)	134 (1961)	3 (1979)	44 (59-80)	? (Age 3)	1960+	59-80	1977+ (USSR)	1974+	NAFO SCR 80/28 NAFO SCR 81/12 NAFO SCR 89/05 NAFO SCS 89/17
So. Grand Bank	3NO	227 (1967)	15 (1978)	71 (53-89)	41	121 (1965)	12 (1976)	78 (59-88)	96 (6+)	210 (1966)	10 (1986)	66 (59-80)	33 (Age 3)	1953+	59-88	1971+ (CAN) 1977+ (USSR)	1973+	NAFO SCR 89/35 NAFO SCR 89/05 NAFO SCS 89/17
St. Pierre Bank	3Ps	84 (1961)	27 (1978)	52 (59-87)	57	142 (1959)	28 (1976)	83 (59-87)	100 (OGV)	98 (1967)	22 (1979)	58 (59-87)	51 (Age 3)	1959+	59-87	1972+ (CAN) 1978+ (FRA)	1973+	NAFO STACFIS 1988 NAFO SCR 88/72 NAFO SCR 88/75
N.&E. Gulf of St. Lawrence	3Pn4Rs	106 (1983)	47 (1988)	81 (59-88)	80	264 (1988)	117 (1977)	185 (74-88)	258 (6+)	178 (1981)	57 (1974)	114 (74-88)	61 (Age 4)	1959+	74-88	1978+ (CAN)	1977+	CAFSAC Res 89/55 CAFSAC Adv 89/12
W. Gulf of St. Lawrence	4TVn (Jan-Apr)	104 (1956)	22 (1977)	57 (50-88)	54	396 (1986)	75 (1976)	231 (71-88)	380 (4+)	250 (1983)	34 (1972)	128 (71-87)	128 (Age 3)	1950+	50-88	1971+ (CAN)	1974+	CAFSAC Res 89/51 CAFSAC Res 83/51 CAFSAC Adv 89/12
Sydney Bight	4Vn (May-Dec)	13 (1981)	4 (1975)	9 (60-88)	8	-	-	-	-	-	-	-	-	1960+	-	1970+ (CAN)	1975+	CAFSAC Res 89/44 CAFSAC Adv 89/12
Banquereau & Sable Island	4VsW	80 (1968)	10 (1977)	52 (58-88)	35	275 (1985)	60 (1975)	168 (58-89)	210 (3+)	167 (1966)	26 (1984)	103 (58-87)	40 (Age 1)	1958+	58-88	1970+ (CAN)	1973+	CAFSAC Res 89/57 CAFSAC Res 84/78 CAFSAC Adv 89/12
W. Scotian Shelf	4X	36 (1968)	12 (1958)	22 (48-88)	13	89 (1966)	38 (1959)	61 (48-88)	52 (3+)	43 (1964)	9 (1952)	26 (48-88)	19 (Age 1)	1948+	48-88	1970+ (CAN)	1982+	CAFSAC Res 89/30 CAFSAC Adv 89/12
Gulf of Maine	5Y	17 (1983)	3 (1963)	9 (60-88)	10	37 (1982)	9 (1988)	18 (82-88)	10 (OGV)	7 (1984)	2 (1985)	5 (82-86)	5 (Age 1)	1960+	82-87	1963+ (USA)	-	NEFC Ref.89-04
Georges Bank	5Z+6	57 (1982)	11 (1960)	33 (60-88)	40	92 (1980)	31 (1988)	64 (60-88)	31 (OGV)	42 (1981)	6 (1985)	22 (78-86)	23 (Age 1)	1960+	78-87	1963+ (USA) 1986+ (CAN)	-	NEFC Ref. 89-04 NEFC Ref. 86-12 CAFSAC Res 88/73

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APPENDIX IV

SYNTHESES OF ATLANTIC COD STOCKS.

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Synthesis of North Atlantic Cod Stocks.

GEORGES BANK COD

Fredric M. Serchuk and Edward B. Cohen

GEORGES BANK COD

In USA Atlantic waters, three major groupings of cod have generally been recognized: (1) Georges Bank; (2) Gulf of Maine; and (3) Southern New England- Middle Atlantic (Wise 1962; Serchuk and Wigley 1986). Tagging studies (Smith 1902; Schroeder 1930; North American Council on Fishery Investigations 1932; 1935; Wise 1962), parasite infestation research (Sherman and Wise 1961), spawning time data (Colton et al. 1979), and growth rate analyses (Penttila and Gifford 1976; Serchuk and Wood 1979) indicate that minimal interchange occurs between the Gulf of Maine and Georges Bank groups, but that extensive mixing prevails between cod on Georges Bank and in the Southern New England-Middle Atlantic region. A seasonal southwesterly movement of cod from the South Channel area of Georges Bank occurs in autumn followed by a northeasterly return in spring. Wise (1958) postulated that the autumn movement was not a migration of Georges Bank fish (as concluded by Schroeder (1930)) but rather a return of Southern New England-Middle Atlantic fish to their native grounds for winter spawning. The presence of ripe spawning individuals off the New Jersey coast (Smith 1902; Schroeder 1930; Wise 1958) and the occurrence of cod eggs and larvae as far south as North Carolina (Schroeder 1930; Berrien et al. 1978) suggest the possibility that cod in the Middle Atlantic may comprise a genetically distinct subpopulation, separate from those groupings found further north. However, the origin and fate of Middle Atlantic cod eggs and larvae have yet to be delineated, and hence the existence of the Middle Atlantic subpopulation remains to be confirmed. Serchuk and Wood (1979) found strong affinities between Georges Bank and Southern New England-Middle Atlantic cod based on growth rates, research vessel survey abundance patterns and catch composition, recruitment patterns, and commercial catch size/age distributions. The relative absence of juvenile cod in inshore and offshore research vessel surveys in the Southern New England-Middle Atlantic region (Serchuk and Wood 1979) suggests that either the southerly populations are not self-sustaining or that offspring from the southern spawning move north as ichthyoplankton or larval nekton and subsequently return south several year later as adults.

The demographic similarities of Georges Bank and Southern New England-Middle Atlantic cod are so pronounced that the two groups are presently considered to comprise a single stock (i.e., Georges Bank and

South; commonly referred to as the Georges Bank stock).

The Georges Bank cod stock is the most southerly cod stock in the world. Georges Bank cod are omnivorous feeders and commonly attain lengths up to 130 cm (51 in) and weights up to 25 to 35 kg (55 to 77 lbs). Maximum age is in excess of 15 years, although young fish (ages 2-5) generally comprise the bulk of the catch. Sexual maturity is attained between ages 2 to 6; spawning occurs during winter and early spring. Commercial fisheries for cod on Georges Bank have existed since the 1700s and modern landings statistics are available since the late 1880s. Annual commercial catches since 1960 have ranged between 11,000 and 57,000 metric tons, and have averaged about 33,000 tons per year. The commercial fisheries are conducted year-round with otter-trawls and gill nets as primary gear. Recreational fishing is also important and recreational landings have averaged about 6,000 tons in recent years.

Cod in spawning condition are found on Georges Bank nearly year-round but peak spawning normally occurs between February and early March (Colton et al. 1979). Spawning occurs over the entire Bank, but is frequently concentrated on the northeastern part (Northeast Peak). The pelagic eggs drift to the southwest and hatch in about 2-3 weeks at typical spring temperatures (Lough and Bolz 1989). A semi-persistent clockwise gyre on Georges Bank acts as a retention mechanism for cod eggs and early-stage larvae (Smith and Morse 1985; Lough and Bolz 1989). Lough and Bolz (1989) have found that the cross-shelf distribution of larvae is consistent with estimated dispersion rates and observed and predicted near-bottom, cross-isobath currents. Larval retention is probably also enhanced by the proximity of larvae to the bottom in areas less than 70 m deep (Lough and Bolz 1989).

The transition from pelagic to demersal life normally occurs in late May-early June when larvae are about 4-6 cm in length or about 3 months old. Juveniles are typically associated with pebble-gravel substrates; the gravel beds probably reduce predation (due to the coloration of the cod on the gravel), and furnish an abundance of prey items. (Lough et al. 1989). Year-class strength appears to be set by the time cod become demersal juveniles. Growth of Georges Bank cod is rapid - age 0 fish attain an average size of 26 cm by the end of their first year of life. Sexual maturity commences at age 2 (40-60 cm), and by age 5 (70-80 cm) virtually all cod are sexually mature.

Assessments of the Georges Bank cod stock have been conducted since the early 1970s but virtual population estimates (VPA) only go back to 1978 (Serchuk and Wigley 1986; Hunt 1988; NEFC, NMFS 1989). Commercial CPUE indices for the USA otter trawl fleet exist since 1964 and Canadian CPUE data are available from 1967 to the present. Stock abundance and recruitment indices derived from autumn (1963 onward) and spring (1968 onward) USA research vessel surveys have been used to monitor changes and assess trends in population size and recruitment of the Georges Bank cod stock. Abundance indices are also available from Canadian research vessel surveys of Georges Bank (since 1986), and inshore spring and autumn bottom trawl surveys conducted by the State of Massachusetts since 1978.

VPA results indicate that fishing mortality on Georges Bank cod doubled between 1978 and 1985 (F=0.39 to F=0.84) and reached a record-high level in 1987 (F=0.95). Spawning stock biomass at the beginning of 1988 was a record-low, about half of that in 1978. Although strong year classes have been produced with regularity (1975, 1978, 1980, 1983, 1985, 1987), significant rebuilding of the spawning stock has been hampered by a strong dependence by the fishery on mostly young fish (ages 2 and 3).

VPA results for the period 1978-1987 indicate that variability in year class strength is rather modest - the smallest and largest year classes differ by a factor of 7. The range in spawning stock biomass is more limited; the highest and lowest SSBs differ by only a factor of 3. Age 1 indices from the autumn USA research vessel surveys appear to accurately reflect relative year class strengths suggesting that year class size in determined during the first year of life. Patterns in recruitment of the Georges Bank stock are generally different from those observed in the Gulf of Maine cod stock.

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Synthesis of North Atlantic Cod Stocks.

ICELANDIC COD

S.A. Schopka, S.Å. Malmberg and O.S. Astthorsson

ICELANDIC COD (DIV. VA.)

1. Historic yields

Cod has been by far the most important commercial species in the waters around Iceland ever since the country was settled 1100 years ago. Little is known about the fishing activities in previous centuries but already in the 13th century foreign fishing vessels started to fish for cod at Iceland. Since 1905 detailed catch statistics are available.

With increase in fishing effort landings of cod from Icelandic grounds increased steadily from 1905 to a peak of almost 520 000 tonnes in 1933. Catches then declined down to 300 000 tonnes in 1939. During the World War II foreign fishing came to an end in this area which lead to a great drop in fishing effort resulting in a tremendous recovery of the stock. By increase in fishing effort after the war landings of cod increased again and reached a peak of almost 550 000 tonnes in 1954. In spite of increased fishing mortality, catches have since then gradually declined with some fluctuation due to changes in effort, year class strength and/or immigration from Greenland waters. In 1984 landings reached a minimum of 280 000 tonnes. In most recent years catches have been on the level of 300 000 - 400 000 tonnes annually.

The importance of the cod stock for the Icelandic economy is illustrated by the fact, that cod alone makes more than fifty per cent of the annual demersal catch at Iceland. As cod is more valuable than most other demersal species its importance is therefore greater than reflected by the catches.

2. Stock components

Generally speaking the codstock at Iceland can be considered as a unit stock. Tagging experiments of more than one hundred thousand cod have shown that both mature cod tagged on the spawning grounds as well as immature cod tagged on the nursery grounds have with only few exceptions been recaptured in the Icelandic shelf area all around the island. On the other hand however, there has been an immigration of mature cod from East- and West-Greenland waters to the spawning grounds at Iceland. These immigrants admix the Icelandic spawning population and are believed to be components of the Icelandic stock which originally drifted as larvae to Greenland from the Icelandic spawning grounds (Jamieson and Jonsson, 1971).

On the average about 25% of the mature cod at East Greenland migrate yearly to Icelandic spawning grounds (Anon, 1976). Changes in environment and the size of different year classes at Greenland can, however, affect the immigration from Greenland greatly. In some years this immigration has been on a large scale, and has been of great importance to the Icelandic winter fishery (also called the spawning fishery). From tagging experiments it has been estimated that in the period 1930-1933 up to 60% of cod tagged at West Greenland were reported at Iceland. Again in the years 1953-1955, 1970-1971 and 1980-1981 immigration of strong year classes of cod from Greenland waters took place. In 1991-1992 it is expected that the strong 1984 year class at Greenland, which drifted as larvae from Iceland, will show up again on the spawning grounds along the S- and SW-coasts of Iceland.

3. Stock fluctuation and fishing pattern

Information on stock size and recruitment (VPA estimates) is available since early fifties, and these have been published in ICES assessment working group papers (Anon, 1976) and annually in Icelandic stock status reports (e.g. Anon 1990). Older data are available back to 1928 (Jonsson 1954 a) and may possibly be enhanced for VPA. For the most recent years indices of biomass and recruitment have also been estimated based on stratified groundfish surveys in Icelandic waters (e.g. Palsson et al. 1987).

In 1955 the total fishable stock (4 years and older) was about 2.2 million tons, and was much larger in the late forties (Schopka, unpublished). The size of the fishable stock has fluctuated due to the changes in recruitment and fishing and is at present of about 900 thousand tons. Spawning stock size has shown similar trends, varying from 1.2 million tons in 1955 to 340 thousand tons in 1990.

By increase in effort fishing, mortality has gradually been increasing, however, with some fluctuations. Fishing mortality decreased notably on younger age groups by introduction of larger meshes (155 mm) in 1977 (Schopka 1980). However, this change in fishing pattern was not only because of the increase in mesh size as other means were also taken to protect the nursery areas of cod. Some areas were closed permanently against trawling, while in other areas fishing can be banned at a short notice if the number of small and undersized cod exceeds a certain minimum of the catch. Such a box closure is a temporary measure, valid for seven days but can be prolonged if necessary. Due to decline in the adult stock fishing pressure on younger age groups has nevertheless been increasing in recent years.

Since 1984 the Icelandic cod fisheries has been managed by a quota system.

4. Environment

Iceland is surrounded by a relatively wide shelf of 115.000 km^2 within the 200 m depth limits. This continental plateau is connected with some neighbouring countries by several submarine ridges, i.e. the Greenland-Iceland Ridge (620 m depth), Iceland -Faroe Ridge (<400 m), Kolbeinsey Ridge and Iceland Jan Mayen Ridge (<1000 m), as well as the Reykjanes Ridge (<1000 m), extending southwestward into the North Atlantic as part of the Mid Ocean Ridge System. Below these submarine ridges, depths reach 2000-3000 m. These topographic features divide Icelandic waters into different oceanographic regions such as the Iceland Basin, the Irminger Sea, the Denmark Strait and the Iceland Sea.

The bottom topography influences the mixing and circulation and thus water mass distribution, and leads to very high productivity. According to Thordardottir (1976) annual production is 150-170 gC m^{-2} or 30-37 millions tons of carbon in the shelf area.

Icelandic waters are located at the boundary zones, between warm Atlantic water and cold water from the Arctic, i.e. the oceanic polar front in the northern North Atlantic. The Irminger Current flows northwards and splits into two branches west of Iceland. The western branch meets the East Greenland current and flows southwards into the Irminger Sea. The eastern one flows north- and eastwards off northwest Iceland into North Icelandic waters, or the Iceland Sea, and dissipates off the eastern coast of Iceland (Stefansson 1962). The cold low salinity water masses are those of the East Greenland (Polar)

Current, flowing southwards through the Denmark Strait, and the East Icelandic Current flowing southwards north and east of Iceland (see Malmberg 1984, 1985, 1986). This circulation is complicated by north-south fluctuations of the boundary zone from year to year, mainly expressed by the presence of Atlantic, Polar or Arctic water in North and East Icelandic waters. These shifts in the location of the oceanic polar front have their impact on climate and ecology in Iceland as well as in the surrounding waters.

The main water masses in Icelandic waters can in general be defined as follows:

1. Atlantic Water (NA) of the North Atlantic Drift and the Irminger current ($t = 4\text{-}8\ ^{0}C$, $S > 35.0\ ^{0}/_{00}$).

2. Polar Water (PW) of the East Greenland Current ($t < 0\ ^{0}C$, $S < 34.0\ ^{0}/_{00}$).

3. Artic/Polar water (AW/PW) of the East Icelandic Current ($t < 0\text{-}2\ ^{0}C$, $S < 34.7\text{-}34.9\ ^{0}/_{00}$).

4. North Icelandic Winter Water (NI) on the North Icelandic shelf ($t = 2\text{-}3\ ^{0}C$, $S = 34.8\text{-}34.9\ ^{0}/_{00}$).

5. Bottom Water (NS) in deeper layers north and east of Iceland ($t < 0\ ^{0}C$, $S = 34.92\ ^{0}/_{00}$).

6. Coastal Water (CW) on the shelf around Iceland, diluted by run-off (t variable, $S < 34.0\ ^{0}/_{00}$).

Since 1970 hydrobiological investigations have been carried out in Icelandic waters on standard sections on a seasonal basis. Similar investigations started on a more or less annual basis in the spring of 1948 in connection with herring surveys in North Icelandic waters (see Stefansson 1962, Jakobsson 1980) The present investigations include physical (t,S) and chemical (nutrients, O_2) parameters, primary production and composition of phytoplankton, zooplankton densities and composition, 0-group abundance and destribution of cod, capelin and other species. Fishery-biological studies include recruitment estimates, information on maturity and weight, stock size and migration patterns, and food selection. At present, the possible influence of fresh water run-off together with winds and time of spawning and feeding conditions of larvae south of Iceland are of special interest (Olafsson 1985, Thordardottir 1986, Jonsson and Fridgeirsson 1986). Also the drift of larvae or 0-group fish into North Icelandic waters, where hydrographic and feeding conditions are under consideration i.e. as regards recruitment and growth (Malmberg 1986, 1988, Palsson and Astthorsson 1985).

5. Spawning

During late autumn and early winter the mature cod migrates towards the spawning areas which are mainly along the SW-coast of Iceland. The main spawning grounds are rather close to shore by Selvogsbanki and off Reykjanes, however the spawning area does extend along most of the S- and SW coasts but the exact location of the main spawning varies somewhat from year to year but detailed information is limited (Fridgeirsson 1982, Jonsson 1982). Some spawning occurs off the west coast and appears to begin somewhat later than on the more southerly spawning grounds.

Usually spawning starts on the main spawning grounds in late March, reaches the peak in the second week of April and is over in early May. The beginning of the season may be two weeks earlier or later than the long term mean (Jonsson 1982).

In some years some spawning also takes place in the fjords along the north coast of Iceland. This spawning starts in late May or early June depending on the water temperature. In the years 1977, 1979 and 1980 eggs found in the coastal waters north of Iceland made up to 3-4% of the eggs collected during larval studies in those years (Jonsson 1982).

The main spawning area are located close to the shore at the boundary of the low salinity coastal current and the more saline Atlantic Water further offshore (Fridgeirsson 1983).

Limited information is available on the location of the main spawning grounds with respect to other species and possible predators. However, it can be stated that in the coastal area where the spawning is usually most intensive the largest densities of zooplankton are usually also encountered (Astthorsson and Gislason, unpublished data).

The spawning appears closely related to the onset of the phytoplankton spring-bloom and the spawning of the zooplankton in the area. Further, in the coastal area the onset of the spring phytoplankton bloom occurrs earlier than in the waters farther offshore, and appears mainly to depend on stratification due to the outflow of freshwater from several large rivers dissipating there (Fridgeirsson et al. 1981, Thordardottir 1985, Olafsson 1985). The extension of the low salinity water, from the coast and on to the shelf, is highly variable and depends very much on the direction and strength of winds.

6. Egg and larvae stages

On the main spawning grounds numbers of newly spawned eggs commonly observed are 100-500 per m^2 in the uppermost 50 m layer, but at hatching, the numbers are 10-50 eggs m^2. The eggs and larvae drift clockwise with currents to the colder waters off the north and east coast of Iceland where the 0-group fish seeks bottom in early autumn. Southerly winds will tend to favour this transport and confine the drifting larvae close to the west coast and within the shelf area. On the other hand, northerly winds will distribute the low saline water onto the western shelf (Stefansson and Gudmundsson 1978) and probably lead to more extensive distribution of larvae at lower densities. The smallest larvae feed on euphausiids nauplii and small copepods. Larger larvae eat _C. finmarchicus_ and other copepods. Also euphausiids and capelin larvae are found in the diet. (Thorisson 1989).

7. Juveniles

0-group surveys in the waters around Iceland and in the Irminger Sea have been carried out since 1970. The survey takes place in August before the young cod seeks the bottom. The distribution of 0-group cod varies very much from year to year. In some years 0-group cod is also found over Dohrn Bank and along the East Greenland coast and these have likely drifted to there from the spawning areas at Iceland. Also the calculated abundance index of 0-group cod may vary by a factor of 10^3.

Helgason and Sveinbjornsson (1987) found a significant relationship between VPA estimates at age three and 0-group abundance, condition (size) and environmental parameters. Further, high abundance and extensive geographical distribution are considered to be important indications for a possible strong year class, however, actual size of a year class on the basis of the 0-gr. survey results alone can not be forecasted.

The pelagic 0-group cod (40-80 mm) feed mainly on euphausiids, capelin larvae and C. finmarchicus (Palsson 1973). When the juveniles have reached the bottom phase euphausiids is the most important food during the first winter but when the cod is growing older the importance of juvenile capelin and shrimp (P. borealis) as food increases (Palsson 1980).

When the young cod has found bottom in late August and early September it can be very abundant in fjords on the NW-peninsula and along the N-coast. In some years the shrimp fishery in these fjords has to be closed during autumn. When the influx of the costal water increases at the end of the year, the 0-group cod disappears from the fjords to deeper and warmer waters outside. Rather little is known about the distribution of 1 year old cod but taggings on 2 and 3 years old cod show that immature cod is rather stationary on the nursery grounds off the NW-, N and E-coast until they reach maturity. Migration pattern is more linked to available food and not as pronounced as the spawning migration of the adult cod.

8. Adults

The age at first maturity varies considerably depending on the area where the fish has been living. Thus cod living in the Atlantic water off the southwest and west coast of Iceland matures at an younger age than cod which inhabit the colder waters off the north and east coasts. For cod living off the north and east coasts the 50% maturity is reached at 8 years of age, but comparable figure for cod from the southern regions is 6 years. Also the age at first maturity varies from year to year.

Onset of maturity is also linked to the rate of growth which again depends largely on the water temperature and the available food.

The main food of the adult cod is capelin, redfish and shrimps, sometimes euphausiids and other fish species (Palsson 1983). The importance of capelin as food for cod seems to be linked to size of capelin stock (Magnusson and Palsson 1989).

During late autumn and early winter the mature cod starts migrating to the main spawning grounds off the south and southwest coasts. Cod grown up off the east coast migrate the shortest way, i.e. southwards along the east coast to spawning grounds, sometimes linked to the spawning migration of capelin, but cod grown up off the north and northwest coast migrate westwards counterclockwise south to the spawning areas (Jonsson 1954 b, 1965).

After spawning the main bulk of the mature cod migrates westwards to the summer feeding grounds off the NW- coast but a small part of the mature fish migrate eastwards to southeast and east of the island (Jonsson 1986).

Studies on fecundity (Joakimsson 1969, Schopka 1971) show that numbers of egg per female are between one and fifteen million depending on the size of the fish.

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