A Narrative of NAFO Divs. 2J3KL Cod Assessments from Extension of Jurisdiction to Moratorium

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Abstract

The cod stock in NAFO Divs. 2J3KL has been assessed annually since the early 1970s, a period over which the stock size has fluctuated substantially. Results have been presented annually to scientific Committees or Subcommittees of NAFO and CAFSAC. Throughout this period the stock assessment process has undergone considerable change as new methods, data and technologies have become available. The stock is currently in a severely depleted state and the determination of reasons for the decline has been controversial. This report provides a narrative of the assessment process for this stock from extension of jurisdiction to moratorium (1977-1992). Details of the annual assessments conducted are presented and the data and methods used to determine stock status and the results including TAC projections in terms of the standard requested reference points are described. The origin and evolution of the important databases such as catch at age, catch rate indices, and research survey data are discussed. Topics related to the assessments, such as the various committees and commissions that have been struck to provide advice on scientific aspects of the assessments, and important issues such as the "retrospective problem", are also given attention in this report.

Résumé

Le stock de morue des divisions 2J3KL de l'OPANO a été évalué chaque année depuis le début des années 1970. Pendant cette période, son effectif a fluctué notablement. Les résultats de ces évaluations ont été présentés tous les ans aux comités et sous-comités scientifiques de l'OPANO et du CSCPCA. Durant le laps de temps considéré, le processus d'évaluation des stocks a subi des changements considérables, dus à l'apparition de nouvelles méthodes, données et technologies. Le stock est actuellement gravement épuisé et la détermination des causes de son déclin a soulevé des controverses. Le présent rapport décrit le processus d'évaluation du stock depuis l'extension de la zone de juridiction jusqu'au moratoire (1977-1992). On y présente des renseignements détaillés sur les évaluations annuelles effectuées ainsi que sur les données et méthodes utilisées pour déterminer l'état du stock, et on y décrit les résultats obtenus, notamment les projections de TAC par rapport aux points de référence standards établis. On y discute également de l'origine et de l'évolution d'importantes bases de données, comme celles qui portent sur les prises selon l'âge, sur les indices de taux de prises et sur les données des relevés de recherche. Enfin, le rapport traite aussi de sujets reliés aux évaluations, notamment des divers comités et commissions qui ont été constitués pour fournir des conseils sur les aspects scientifiques des évaluations et de questions importantes comme le "problème de rétrospective".

1.0 Introduction

The importance of the cod fishery to Newfoundland's history, economy and social structure, or more succinctly - to it's existence - is unquestioned. The recent dramatic decline in abundance of the major contributing cod stock, namely the NAFO Divs. 2J3KL or Northern Cod stock (Fig. 1), has received much attention in recent years. A number of articles have been written describing aspects of the history and management of this resource (e.g., Lear and Parsons 1993). The present paper provides information concerning the biological assessments of the 2J3KL cod stock from 1977 to 1992. It includes background information on the process from the initial requests for advice to the incorporation of the advice into Management Plans. Its purpose is to consolidate published and unpublished information and to provide a clear narrative of the events surrounding these assessments. The report is not a statement of advocacy but of fact concerning the whole scientific assessment process during the time period. This is aimed to assist those interested in learning more about the process and, as well, to reduce some of the confusion and inaccuracies that appear to persist regarding the role that science has played in the assessment of 2J3KL cod from extension of jurisdiction to moratorium.

The chronology of the assessment process for this stock has been described previously in varying degrees of detail (Parsons 1993, Lear and Parsons 1993). There have also been several criticisms of the assessments or the assessment process (e.g. Steele et al. 1992, Finlayson 1991, Hutchings and Myers 1993, Walters and Maguire 1996). The present document is not intended as a response to these criticisms or a rebuttal, but will provide information about the assessments and the assessment process for the 2J3KL cod stock over the period from extension of jurisdiction to moratorium, as well as the rationale behind interpretation of data and results at the time the assessment was done. It is up to the readers to draw their own conclusions regarding the strengths and weaknesses of the process, given a detailed description of the facts.

2.0 The Assessment Process

It is important to realize that stock assessments for commercial groundfish species in the northwest Atlantic have been conducted as part of a specific process. This process included: i) a request for scientific advice on a particular stock (with respect to requests to NAFO); ii) a meeting involving assessment scientists to analyse all information available from countries prosecuting the fisheries; and iii) the production of a report addressing the specific requests. Groundfish assessments in the northwest Atlantic have always been conducted by scientific bodies, usually on an annual basis.

Assessments of the 2J3KL cod stock were conducted by Standing Committees of The International Commission for the Northwest Atlantic Fisheries and its successor, the Northwest Atlantic Fisheries Organization (ICNAF/NAFO) during the years 1977 to 1986 and 1992. Under the NAFO process the annual TAC was set by the Fisheries commission. For the period 1987-1992 assessments of this stock were conducted by the Groundfish Subcommittee of the Canadian

Atlantic Fisheries Scientific Advisory Committee (CAFSAC). Under the CAFSAC process the annual TAC was set by the Federal Fisheries minister. After 1977 most stocks within the Canadian zone were assessed by CAFSAC with NAFO considering those stocks in both the overlapping and Regulatory (outside of 200 miles) areas. After 1986, Canada, as coastal state did not request advice for 2J3KL cod from NAFO until 1992. The Fisheries Commission of NAFO continued to request advice from the Scientific Council relative to the "portion of the stock in the Regulatory Area" (nose of the Bank - the portion of Div. 3L outside of 200 miles) after 1986. This was addressed each year but did not have a big impact on the assessment of the stock as a whole. The dates and locations for assessment meetings are given in Appendix 1.

As stated above, these Subcommittees responded to specific requests. In the ICNAF/NAFO forum the requests were made by the Fisheries Commission comprised of individuals from Member countries. Requests were also made by coastal states for stocks within their territorial waters. In response to this, the Scientific Council of ICNAF/NAFO and its Standing Committees (STACRES/STACFIS - Standing Committee on Research and Statistics / Standing Committee on Fisheries Science) would meet, normally in June of each year unless otherwise requested, and a stock assessment would be carried out.

The Standing Committees (STACRES/STACFIS) are scientific bodies whose membership included scientists from many of the member countries. Members from countries with active fisheries and/or research programs were required to provide documentation with respect to their activities (length frequencies and age compositions of their catch, catch and effort data for their fleets, survey biomass and abundance data, etc.). All available data, including that of a general biological nature, were considered in the assessment with regard to impact on stock status. The task of compiling the data for use in statistical analyses for the determination of stock size generally fell to one country, and for 2J3KL cod this was accomplished by the Canadian participants. However, there were no restrictions and any individual or group was free to present analyses. There was open debate as to the interpretation of the data and results and generally a consensus was reached with regard to the proper analysis and interpretation of the data.

This is not to suggest that there were no heated debates or disagreements. With the imprecise nature of fisheries science, inherent variability in data can lead to varied interpretations. Both NAFO and CAFSAC allowed for dissenting views in the form of 'minority reports' but these were rare or non-existent for assessed stocks. None were produced for the 2J3KL cod stock.

The situation with CAFSAC was similar to NAFO in that participants in the Groundfish Subcommittee meetings where assessments were carried out included a considerable number of researchers from other Department of Fisheries and Oceans (DFO) Regions with expertise in stock assessments and related disciplines. At assessment meetings most commercially fished groundfish stocks were assessed, enabling peer review by a relatively large scientific group. Attendees at the CAFSAC Groundfish Subcommittee meetings also included fishery scientists from the USA and in more recent years non-governmental representatives such as University scientists and fishermen.

Each assessment had two major components: the determination of stock status up to and including the last full year for which data were available and catch projections with respect to requested management options so that Total Allowable Catches (TAC's) could subsequently be established by fishery managers.

3.0 The 2J3KL Cod Assessments

3.1 Stock Structure

Cod from NAFO divisions 2J, 3K and 3L have been assessed and managed as a single unit since 1972. The description and rationale for separation of the individual stocks was reviewed by Templeman (1962), although at that time the stock unit also included cod in Div. 2G and 2H. The issue of definition of the stock unit has since received additional attention. In 1974 STACRES, in response to an ICNAF Commission request (Comm. Doc. 74/15), reviewed available information relative to the interrelationships of inshore and offshore catches and concluded (ICNAF 1974, p80) that catches by one component were affecting the other. A further review in 1977 reiterated the 1974 advice and concluded that the inshore and offshore fisheries were exploiting the same stock.

The most recent comprehensive review of stock structure by the NAFO Scientific Council in 1986 was in response to a Commission request (NAFO Sci. Coun. Rep. 1986, p121). This review considered factors such as genetic variation, migrations, meristics, infestation by parasites, growth rates, ages, lengths at maturity, and spawning time. Although there was some evidence for genetic differences, there was a significant degree of mixing between divisions, especially in summer during the inshore feeding migration, and it was concluded that the current practice of assessing cod in Divisions 2J, 3K, and 3L as one stock complex should be continued. Up to the time of moratorium there were no studies to indicate that this practice should have been changed. The issue of the existence of substocks in the coastal bays has received attention in recent years, particularly following moratorium. These studies will not be reviewed here.

3.2 Assessments and Management prior to 1977

As indicated, the purpose of this report is to provide an in depth review of Assessments since the extension of jurisdiction (1977). This Section provides some background information on assessment efforts prior to 1977.

While the fishery on the northern cod stock has been conducted for several centuries, attempts at stock assessment have been substantive only over the past two decades. Over this period, there have been large changes in the types and quality of data available, the methods and technologies for analysis, and the resultant interpretation of stock size.

Early regulatory efforts were toward the control of catches by the establishment of mesh size regulations. The fishery had seen a rapid expansion of effort in the 1960s and it was recommended by ICNAF in 1965 that direct control on the amount of fishing was necessary. It was agreed that the least difficult way to do this was by means of catch quotas. However the authority to propose national quotas did not come into effect until December of 1971. The first attempt at controlling fishing through national catch quotas for this and most other groundfish stocks commenced in 1973 following recommendations from the June 1972 ICNAF meeting.

The establishment of annual catch quotas as a management tool necessitated the knowledge of stock size and hence the development of assessment methods to determine stock size on an annual basis. Catches of 2J3KL cod had peaked in 1968 (Table 1, Fig. 1) and had declined substantially by 1972 when catch quotas were first considered. The major objective of the assessments conducted from 1972 to 1975 was to estimate the F_{max} catch (the catch corresponding to the fishing mortality which maximises the yield in a yield per recruit calculation) for each of the subsequent years. As can be seen, the TAC's were well above the reported catches from 1973-76. TAC's were high from 1973-75 and the failure of the fleets to take these quotas was generally related to severe ice conditions. The TAC for 1976 was reduced substantially (46%) because there were indications of stock reduction (declining survey catch rates and reduced levels of recruitment).

Although TAC's were set at F_{max}, it is of interest to note that Canada proposed (to the Fisheries Commission; ICNAF Comm. Doc 72/12) that the first quota (666,000t for 1973) should have been no more than 400,000t which was more in line with the $F_{0.1}$ level, a more conservative fishing mortality level than F_{max}. The latter measure, which was to become a basic reference point, was discussed at the 1972 NAFO meeting (Gulland and Boerema, 1972) and reported as a management option (ICNAF, Redbook, 1972 p.41-42). Canada again proposed at the 1975 meeting that the TAC's be set to produce F's lower than F_{max}. The Fisheries Commission did not accept this as an option for the 1976 TAC's as there had already been a downward revision of the F_{max} level based on a revised assessment and the $F_{0.1}$ level would have represented an additional reduction (May et al , 1981). However, at the 1976 meeting, STACRES proposed the use of $F_{0.1}$ as a management objective and it was accepted by the Commission.

The first $F_{0.1}$ TAC of 160,00t was set for 1977. The agreement to change to this management option may have been heavily influenced by the fact that Canada, which strongly favoured its adoption, had announced it's intention to extend fisheries jurisdiction just prior to the 1976 Annual Meeting of NAFO.

3.3 Overview of Management Procedures

Assessments and management are interrelated to the extent that some of the results from stock assessments are used for management purposes. The basic aim of the assessment process is the estimation of stock size at age. Any subsequent predictions or projections of future stock size and possible catch are determined by the specific objectives that fishery managers consider appropriate (eg. $F_{0.1}$, F_{max}, etc.). For this reason it is considered informative to describe in this section some of the more important or influential management procedures that have been in effect over the period being considered.

This section summarises some of the more important procedures in the management of the stock. Descriptions can also be found in publications such as Parsons (1993) and Lear and Parsons (1993).

As stated above, the first management procedure used to establish TAC's was based on F_{max}, the fishing mortality that gives the maximum yield per recruit. This was in place for the assessments done in years 1972 to 1975. TAC's for the years including 1978 to 1983 were set below the $F_{0.1}$ level (F=0.16 in 1978 to 1982 and between 0.16 and 0.20 in 1983) to promote more rapid rebuilding of the stock, while those for 1984 to 1988 approximated the predicted $F_{0.1}$ level. The decision to set TAC's below $F_{0.1}$ was partly the result of recommendations from a Northern Cod Seminar (see Section 7.1) in 1979. After 1988, the period when the perception of stock status changed significantly, TAC's were set with the expectation that the population would show little or no growth.

Another change in management procedure that appeared in the late 1980's was the so called "50% rule". Industry had requested a change in the management practice of setting annual TAC's so as to reduce the impact of large variations in the annually recommended catch levels at $F_{0.1}$ for some stocks. Their preference was that annual catch projections be replaced by long term projections based on a phased-in effort reduction strategy. The Groundfish Subcommittee of CAFSAC (see Subcommittee Report 86/14) had reservations about providing long term advice. However, it realized that for some stocks an abrupt change from high F's to the $F_{0.1}$ level would be disruptive to the fishing industry and proposed an interim practical solution. This formula for setting TAC's for the coming year became known as the 50% Rule and was calculated as follows:

$$F_{NEXT} = F_{CURRENT} - \frac{(F_{CURRENT} - F_{0.1})}{2}$$

It was also recommended that if F_{NEXT} resulted in catches within 15% of the $F_{0.1}$ catch, then F_{NEXT} would be set at $F_{0.1}$ and if above twice $F_{0.1}$ then F_{NEXT} would be set at twice $F_{0.1}$ to prevent growth overfishing. It was stressed that it was a stop-gap proposal until a more comprehensive management procedure could be developed.

The TAC's from 1973 to 1976 were allocated to Canada as the coastal state (a portion based on the estimated required catch) and to the other participating nations based on their historical catch performances. The Canadian allocation in 1973 amounted to about 24% of the TAC. There was a decline to about 17% in 1974-75 followed by increases to 25% in 1976 and 44% in 1977, the year in which Canada extended its fisheries jurisdiction. After 1977 the Canadian portion of the TAC was much higher and after 1988 there was very little foreign catch allocated in Canadian waters. This was not the case in the area of the Nose of the Bank outside of Canadian jurisdiction in Div. 3L. After 1977 there was persistent overfishing, in excess of assigned quotas, particularly by Spain and Portugal. The problem worsened in the mid 1980's and in trying to find a solution Canada was able to obtain approval from NAFO for a moratorium on cod fishing in the area. Spain and Portugal ignored the moratorium and for some years the 'illegal' fishing produced substantial catches. After the stock declined and Canada imposed its own moratorium, the EEC finally agreed, in 1992, to cease fishing for cod.

Other management decisions that likely impacted on stock assessments included the introduction of Enterprise Allocations (EA's) for the Canadian offshore fleet in 1982 and the proportional allocation of catches by division in 1987. Before EA's, the annual Canadian allocation was obtained on a first come, first served basis. Fishing skippers were encouraged to return with large catches and as quickly as possible. With EA's, each fishing company or enterprise was allocated a specific portion of the total annual allocation, which could also be taken at any time during the year. Maximization of catch rates was no longer necessary and in some cases discouraged (for example, the use of windows in trawls). The EA's were coupled with an improved quality control consciousness which enabled a more rational approach to harvesting. Proportional allocation of catches was introduced to counteract the occurrence of excessive fishing pressure on specific components of the stock. Fishing fleets had been concentrating on areas which were closest to home port and which provided relatively good catch rates. It was considered that this practice might have lead to depletion of offshore components (specifically in Div. 3K) and have detrimentally influenced fisheries in inshore areas supported by the summer inshore migration of these components. The proportional allocation (1/3 by division) was based on the divisional distribution of cod biomass observed during autumn research vessel surveys. It was considered that cod distribution at the beginning of the following year, when the offshore fisheries commenced, would be similar. Proportional allocation could have impacted on commercial catch rates in that fishing had to be attempted in areas where catch rates may have been expected to be lower.

Estimates of monthly and annual catch rates by offshore otter trawlers were an important component of the assessment database (Sections 4.3, 5.0). Maintaining comparability between yearly estimates was important though difficult to accomplish. The impact on catch rates of changes in fishing methodologies and technology, and management decisions were difficult to determine.

4.0 The Database for Stock Assessments

Stock assessments using established procedures can only be conducted if an adequate database has been maintained from year to year. Although a variety of data types can be involved in the assessment, there are some data which are considered essential to the models in use. These include catch and average weights-at-age, commercial catch rates, and research vessel survey results. The mathematical model most frequently used for the assessment of this and many other stocks throughout the world is the Sequential Population Analysis (SPA) model (see Section 5.0)

4.1 Catch-at-age

The basic input data required for a SPA model include annual age by age estimates of the numbers of fish caught for a number of years. SPAs conducted for the 2J3KL cod stock since 1977 have used annual catch at age estimates available since 1962. Most of the offshore catch in the 1960's and early 1970's was obtained by foreign fleets. The Canadian fishery was pursued almost exclusively by inshore fixed gears (Table 1; Fig. 1). Catch at age information for these fisheries was derived using sampling data obtained by participating countries. As members of ICNAF/NAFO each country was required to obtain samples (lengths and ages) from their catches in compliance with a minimum sampling requirement, and to use the sampled data to provide estimates of their catch at age for use in stock assessments. The aim was to sample all catches by Division and gear type throughout the entire year. Length frequency samples were combined on a monthly basis and those for ages on a quarterly basis. Details of the sampling scheme used in the Newfoundland area are described by Stevenson (1983).

The procedure used to derive the age by age estimates is fairly standard and well documented (Pinhorn 1971, Gavaris and Gavaris 1983). The question of adequacy and reliability of sampling methods and the consequent reliability of the catch at age estimates has been a concern for some time. Its importance was recognized by ICNAF in the early 1950's (ICNAF, 1953), and further addressed at a special meeting (ICNAF, 1958). The issue was again addressed by ICNAF in 1974 (ICNAF, 1974) and at this time a minimum level of sampling was recommended as follows:

> "that an ICNAF sampling requirement should be specified at one sample per 1000 tons of fish caught for each division, quarter of year and gear. As an approximate guideline, such samples should consist of 200 fish from the entire length range for length composition and one fish per centimeter length group for age composition".

With regard to desirable levels of sampling, it was considered that levels leading to a 10% coefficient of variation for the estimates of numbers caught at each age would be appropriate.

As might be expected, the reliability of the estimates of catch at age for 2J3KL cod has varied. Age compositions were first produced for the periods 1959-69 for Div. 2J (Pinhorn 1971) and 1961-70 for Div. 3KL (Wells 1972). A combined (2J3KL) age composition (1961-70) was first used in a SPA in a 1972 assessment (Pinhorn and Wells 1972). Details regarding the annual input data used to develop these catch at age estimates were not documented but Pinhorn (1971) concluded that "these age compositions are probably accurate enough for our purposes".

However, by current standards the sampling available from most countries for the 1960's and to the mid 1970's was well below minimum acceptable standards. A review of the sampling information available for this period (ICNAF annual "Sampling Yearbooks") indicates that there was considerable sampling for most years although sampling was chronically lacking for some countries. During the 1960s and early 70s sampling was extensive by the USSR. However, in all cases it was described as being research and/or exploratory, being obtained by "scouting" vessels rather than the main fleet. Canadian catches were mainly from the inshore fixed gear fishery and sampling was generally in excess of minimum requirements. However, sampling by some countries obtaining large catches was totally lacking for most years (Baird and Bishop 1991). As an example, a summary of the catch and sampling provided by non Canadian countries in 1965 was as follows:

Country	Sample Type	Catch/ Landings	Mesh Size	Landings (tons)	Lengths Samp	Lengths Meas	Ages Samp	Ages Aged
Germany (E)				23143				
Spain				92909				
Faeroes				7660				
Iceland				1349				
Norway				3786				
Poland	Res.	C	40	12026	-	468	-	278
Portugal	Comm	C	114	102784	-	15250	-	1782
USSR	Explor.	C	110	64328	-	184695	-	600
Germany (W)				36824				
France				59928				
UK				22397	108	19715		

In this situation, the estimated age composition of the non-sampled catch was based on the age compositions of the catch by other countries for the closest corresponding division and quarter.

The use of sampling from a small portion of the catch to estimate other catches also assumed some consistency with codend mesh sizes in use. Mesh size regulations for groundfish stocks were first introduced in 1961 (ICNAF, 1978, p45). The minimum mesh size of 114 mm was increased to 130 mm. in 1970 and has continued to the present. Mesh sizes used by the foreign otter trawl fleets during the early period were variable. In 1964 Spain reported a mesh size of 160 mm and the USSR 110 mm while in 1965 that reported by Poland was 40 mm. Although the latter was designated as research, it was the only sampling available for that fleet.

Documentation for the early period does not indicate how sampling was used to determine exactly how catch at age was obtained when such conditions existed. For the 1986 assessment, the existing sampling data for the 1971-76 period was reviewed, mainly in response to a recommendation from the 1985 assessment, which had questioned the abrupt change in average weights at age (see below) from 1976 to 1977. There was also a re-analysis of sampling data for the period 1977-84 to account for some changes in reported catch for those years, to portion data by division and gear, and to generally make estimation procedures consistent over the time period. The revised catch at age (Baird and Bishop 1986) differed from the original estimates mainly for 1976. The original catch at age had used sampling from small mesh research gear without a selectivity adjustment for the commercial mesh size in use at the time.

The adequacy of catch and weight at age estimates for the early years has been expressed as a concern at assessment meetings, particularly with reference to their impact on estimates of biomass and abundance for that period. The issue was most recently addressed by CAFSAC in 1991 when a review of the foreign catch at age from 1962 to 1971 was requested. It was noted that the data for this period would have no bearing on the results of the current assessment, which was based on data from 1978 and later, but would be useful in evaluating historical trends. Sampling for the period was considerable but not available for all countries. Some data were obtained from research or exploratory gear and hence not suitable for adjusting reported catches. This issue remains unresolved.

Although catches by foreign fleets were reduced after the extension of Canadian jurisdiction to 200 miles in 1977, sampling from this sector was increased with the introduction of a Canadian Observer program for fisheries in the Canadian zone in 1978.

Documentation since 1977 pertaining to assessments of the 2J3KL cod stock have generally included lists of the data and methods used in estimation of catch at age. Beginning in 1982, catch at age tables also included estimates of the variance (Gavaris and Gavaris 1983) in the numbers caught at age. Estimates obtained for all years since that time have shown that variances were generally less than 10%, the minimum acceptable level proposed by ICNAF/NAFO.

4.2 Average Weights at Age

Average weights at age have been estimated using average length at age data along with a length - weight relationship. Adequate quantities of weights of individual fish were not obtained from age samples in the most years as the equipment to obtain these weights in the field was lacking. The length -weight relationship used was first presented in Hodder (1964).

A single vector of average weights at age was used as an estimate for each year in the early part of the time series (1962-71) as suitable annual sampling data were not available. This estimate was obtained using weight at age data for 1964-68 from Div. 2J and 1965-70 from Div. 3KL, weighted by divisional catch (Baird et al., 1992). Assessments conducted prior to 1986 used these constant values for the entire 1962-76 period. For the 1986 assessment, catch and average weight at age data for the 1972-76 period were re-analysed (see above) and as a consequence annual estimates of weights at age for each of the years were obtained based on annual sampling. Values used during each annual assessment since that time have been listed in the assessment documents.

4.3 Commercial Catch Rates

Catch and effort data for otter trawl fleets fishing in the Northwest Atlantic have normally been reported to NAFO and this database has been the source for 2J3KL cod catch rate analyses. Data were originally recorded in vessel logs but were not submitted to NAFO on a tow by tow basis. Only the accumulated monthly catch and effort values were made available. For the assessments these were combined to produce a value (tons/hour) for the stock area. Until 1980 the reported data were accumulated by country, division, gear, and month to produce an annual estimate. In 1980 a multiplicative model (Gavaris 1980) was used for the first time to standardize catch rates. This method provided a more objective method for combining the data from different fleets, tonnage classes, months, and NAFO divisions to produce a single annual estimate for the stock. Since the early 1980s this method has been the 'standard' for catch rate analyses.

Catch and effort data for the inshore fishery have not been recorded in a manner similar to that for the offshore otter trawl fishery and consequently were not available from the usual statistical databases. This gap has long been recognized as being a major problem by those conducting the stock assessments. For the 1986 assessment, information recorded on individual purchase slips was used as a proxy for catch/effort, with each slip being considered a unit of effort. Inshore data from 1981-87 were analysed in a multiplicative model in the 1988 assessment. There were concerns about the quality of the data, especially in the later years, and it was concluded that it was useful only as a crude approximation of a measure of inshore effort. In 1985 logbooks were instituted for all vessels 35 ft. and greater. However, these data were not considered to be useful as a calibration index in subsequent assessments.

4.4 Research Vessel Surveys

Research vessel surveys have been conducted by four different countries at different times over the 1977-92 period:

Country	Season	Div. 2J	Div. 3K	Div. 3L
Canada (N)	Autumn	1977-1992	1978-92	1981-92
"	Winter	1986	1976	1985-86
"	Spring	-	-	1971-82,85-92
Federal Rep. Germany	Autumn	1972-83,85	-	-
USSR/Russia	Spring/Summer	-	1972-90	1972-91
France	Winter	1976-82	1976-82	1976-82

Canadian surveys were conducted using a stratified-random sampling design for fishing set selection (Doubleday and Rivard(ed) 1981). Sets were allocated to strata in proportion to their area. However, for the autumn surveys after 1989 this procedure was varied in an attempt to reduce the variance of survey biomass and abundance estimates. In 1989 and1990, an adaptive procedure was adopted whereby, during the survey, extra sets were assigned to strata having the greatest variation (Francis 1984). However, after a review of the procedure by the Statistics, Sampling, and Surveys (SSS) Subcommittee of CAFSAC, it was concluded that the method could introduce a higher than expected bias in the survey estimates and it was discontinued. In its place another method aimed at reducing the variance (Gagnon 1991) was used for 1991 and 1992, in which extra sets were selected, prior yo the survey, in strata which had, in some previous years, shown the largest variation. In 1991 and 1992 surveys, data from the previous 5 years were used.

5.0 Methods

Sequential Population Analysis (SPA) is the basis for the analytical assessments of 2J3KL cod as well as most other cod stocks in the North Atlantic. This analysis estimates population numbers at age from catch at age data and an index of stock size or fishing mortality used to "calibrate" the magnitude of cohorts that have not yet passed beyond the oldest age considered in the analysis. For 2J3KL cod these calibrations have included relationships of fishing mortality (F) from SPA on effort (E), biomass (total or fishable) from SPA on catch rate (C/E), and population numbers or biomass from SPA on survey abundance or biomass. Age aggregated data were used over much of the period under consideration, although in some instances age ranges (e.g. fully recruited ages only, fishable biomass) were used. Age disaggregated analyses were conducted from 1988 onwards as suitable data and methodology became available. Thus the form of the analytical assessment evolved over time as better data and methodologies became available. These developments would have had little or no effect on estimates of population size from the "converged" part of the SPA (i.e. that part of the analysis dependent only on year classes that have passed beyond the oldest age considered in the analysis) but did result in quite frequent revisions of the estimated population trajectory for more recent periods relative to the time of the assessment.

Within the relatively short time span of assessments considered in this report (1977-1992) there was a dramatic improvement in computational capabilities. The equipment available for assessments in 1977 was quite different from that in the late 1980s and early 1990s. Consequently, this period saw the development of new and improved methodologies and more rigorous analyses. In many cases these improvements enabled us to better determine the inadequacies as well as the limitations of the database and methods being used.

In the early years, assessments were not as rigorous because independent indices such as research surveys and adequate catch rate data were not available. From 1972, when SPA was first applied to the entire stock, to 1976, F in the terminal year was estimated from general relationships such as the ratios between F and catch, assuming that fishing effort and catchability were approximately constant.

Calibrations of the 2J3KL cod assessments from 1977 to 1987 were accomplished using one or a combination of the general calibration relationships indicated above. The acceptance criterion was usually the value of the correlation coefficient although in the latter part of this period the pattern of residuals in the most recent years as well as closeness of the intercept to the origin were also used as diagnostic features in deciding whether or not to accept the SPA. The data and relationship(s) used for calibration varied depending on the reliability of the inputs and the acceptability of the results. Results varied to some degree depending on the exact methods applied and this introduced some subjectivity into the assessments and some inconsistencies from one year to the next. Nevertheless, the procedures provided a framework which allowed for a much higher level of objectivity than is often the case with non-analytical stock assessments.

The assessment process did not occur in a static environment. New techniques were developed and tried as alternates to those in "standard" usage. The issue of standardization and consistency in the assessment process was recognized early on by CAFSAC as an important issue and the topic for a meeting of Subcommittees (Pelagic and Groundfish) in 1981 was "Standardization of Assessment Procedures". It was also addressed by CAFSAC in 1984 when the Steering Committee charged the Surveys, Sampling, and Statistics (SSS) Subcommittee with the responsibility for reviewing new techniques prior to their use in assessments.

In 1987 the SSS subcommittee reviewed and recommended the use in assessments of a more objective calibration tool known as the Adaptive Framework or ADAPT (Gavaris 1988).

ADAPT provided the "ability to examine, in an objective and systematic manner, the statistical fit of various model formulations to a set of catch and abundance index data"(CAFSAC Ann. Rep. Vol. 10). The method was first used in 2J3KL cod in the autumn 1988 assessment, the second assessment by CAFSAC, and has been used in all assessments conducted since that time. The only other method that has been used for calibration in recent assessments is that termed the Laurec-Shepherd (L/S) Method (Pope and Shepherd, 1985). This method was commonly used for stocks assessed by the Inter national Council for the Exploration of the Sea (ICES). It was first reviewed by CAFSAC in 1988 (SSS Subcommittee Report 88/4) at which time some reservations were expressed. However, formulations of the L/S method were used by the Task Group on the Newfoundland Inshore Fishery (TGNIF), the Harris Panel, and in the 1992 assessments.

In addition to the SPA which provided an estimate of numbers at age at the beginning of the year in which the assessment was conducted, population projections to the end of the following year, or sometimes further ahead, were carried out to evaluate alternative fishing mortality options. Weight at age and partial recruitment at age vectors pertaining to the commercial fishery were input for these projections.

Although the 2J3KL cod assessments were conducted solely within NAFO up to and including 1986, and then within CAFSAC from 1987 onwards (with review by NAFO in 1992), developments within ICES, NAFO, CAFSAC and other stock assessment bodies did not occur in isolation. There was considerable interchange within the international fish stock assessment community so that similar or equivalent methods were often in use. Not all methods were directly transferable because of differences in databases as well as in management objectives. Methods in use for the assessment of the northern cod stock between extension of jurisdiction and moratorium were therefore similar, and in no way inferior, to methods in use on fish stocks in Canada and Europe over the same period.

6.0 Annual 2J3KL Stock Assessments 1977-92

The following sections will describe only the major events surrounding and results from assessments conducted during the period 1977-92. Documentation associated with the assessments was much less descriptive in the earlier years and in some cases the following description represents a combination of reported fact and personal recollection by the first author, but only where no suitable reference documentation exists. The main sources of information relative to the assessments are: the ICNAF Redbooks from 1977-79, the NAFO Scientific Council Reports from 1980-86 and 1992, the ICNAF/NAFO Research Documents for each year, CAFSAC Annual Reports from 1987-92, CAFSAC Research Documents for the same period, ICNAF/NAFO and CAFSAC Working Papers, and CAFSAC Groundfish Subcommittee reports. The latter represent the deliberations of the Subcommittee during each assessment meeting (see Appendix 1) and generally represent a synthesis of the assessment. These were not intended as public documents but were developed for consideration by the

Steering Committee of CAFSAC and were labeled "Protected". The results of Steering Committee deliberations were CAFSAC Advisory Documents which were included in the Annual Reports of CAFSAC. The Advisory Documents were public documents and the main purveyors of scientific advice under the CAFSAC process.

Because the audience for the Advisory Documents was non-scientific, the content had to be free of technical jargon without sacrificing content. For the most part the content of the Subcommittee Reports and Advisory Documents were the same although the wording differed. The Working Papers were documents produced during the assessment meetings for presentation to the scientific group to aid in the determination of stock status. These were often made up of a single page and often handwritten, particularly in early years in NAFO, showing a table or figure. They were not considered to be formal documents that could be referred to and thus are not generally available as NAFO or CAFSAC documents. In later years there was a greater effort to have all information relevant to an assessment included in research documents for future reference (NAFO Sci. Coun. Rep. 1979-80, p. 108). This practice was not in place to the same extent in the earlier years and consequently some of the old information related to the stock assessments is difficult to locate. In 1979 information relative to the 2J3KL assessment was produced only as Working Papers. A document was eventually produced in 1980 which briefly described the 1979 assessment. In the 1988 assessment of 2J3KL cod only a working paper was produced in the CAFSAC Groundfish Subcommittee. In general very good documentation exists describing the details of the assessments and these are listed in Appendix 2.

In all the assessments since 1977 the basic input data, including catch and average weights at age, were available from 1962 to the year preceding the assessment year and these were included in the SPA analysis. For all 2J3KL cod assessments it was assumed that instantaneous rate of natural mortality (M) was 0.2 for all ages, a commonly used value for cod stocks in the north Atlantic. The outcome of each assessment was dependent on the available index or indices that could be used for calibration. These were varied to some degree from one assessment to the next, and even within the same assessment, different combinations and permutations were examined. Table 2 summarizes the assessments by year in terms of the management objective that was accepted in the assessment process, the F equivalent to that objective, the equivalent TAC, the corresponding $F_{0.1}$ TAC, the actual TAC that was implemented, the catch that was recorded as taken and the retrospective estimate of F (see Section 7.1 for a description of the retrospective problem).

1977-79 Assessments

Assessments in these years were similar in that the same method of calibration of the SPA was used: the relationship of fishing mortality (F) on fishing effort (E).

1977: Catch per unit effort (CPUE) data were only available to 1975. Data from both the Spanish and USSR otter trawl fleets were used to calibrate SPA. Estimated F's for 1975 ranged from 0.27 to 0.66 and an average value for 1975 was assumed at 0.50. Using the estimated catch of 216,000t in 1976 and the TAC of 160,000t in 1977, population sizes and Fs were estimated for these years and projected to 1985. As requested by the Canadian Government, projections were conducted with three options of annual F in 1978 and subsequent years (0.20 ($\approx F_{0.1}$), 0.15 and 0.10). Recruitment estimates for the 1972-74 year classes were obtained from relationships of USSR survey abundances at ages 2 and 3 in Div. 3K and 3L with SPA estimates of age 4 numbers, while those for the 1975 and later were assigned an average value from SPA age 4 estimates. Recruitment values (age 4) for each year class estimated in each assessment year are shown in Table 3. Recruitment estimates are updated within the SPA over time as more data accumulate on the year class strength.

In the report (Redbook 1977), the results from projections at three levels of F and at an annual recruitment estimate of 500 million, were presented. Projections presented in Res. Doc. 77/26 (Addend. 1) also included calculations for a lower level of recruitment (250 million) which was nearer to those estimated for the 1969-71 year classes. However the results using the higher recruitment value (500 million) were considered more appropriate by ICNAF and were presented in the report.

The 1977 assessment was the first where a series of options were requested and long term projections provided. With respect to the latter it is interesting to note that the assessment report "stresses that the long term forecasts should be considered as indicating trends, as the actual recruitment in future years may be much better or worse than the average". This 'warning' was to be repeated in later years whenever long term projections were requested and conducted. The Commission accepted an option promoting more rapid rebuilding of the stock and set the TAC for 1978 at 135,000t corresponding to a F of 0.16.

Perhaps the most significant outcome of this assessment was the estimation of a target spawning biomass. Because of concerns about the low stock levels and the poor recruitment in the early 1970's, it was felt that the spawning stock size might be at a level which would result in wide fluctuations in recruitment. Using a relationship between SPA spawning stock (ages 7 to 14) biomass and age 2 and 3 abundances from USSR surveys in Div. 3K and 3L, it was determined that an adequate spawning stock biomass might be in the range from 1.2 to 1.8 million tons with the average of 1.5 million being chosen as the reference point. The report from that meeting (Redbook 1977, p54) noted that "stock recruit relationships generally show a good deal of variation" and that "poor recruitment may result from a large spawning stock and very good recruitment from a small spawning stock". The relationship was not well documented but the data used is presented in ICNAF Res. Doc 77/26, p.11. Although the basis for establishing this 'target biomass' is subject to interpretation (relatively short time series and variable data) the resulting suggested target was not re-examined and therefore remained unchanged until 1986 when it was revised based on the analysis of Rice and Evans (1986).

1978: In the SPA, the relationships of F on effort from USSR and Spanish commercial fisheries (1963-73) as well as USSR research surveys (1971-76), along with estimates of effort in 1977, were used to estimate F in 1977. These values of F ranged from about 0.3 for the commercial fisheries to about 0.5 from research vessel data. An intermediate value of 0.4 was considered appropriate and was used in the final SPA. Partial recruitment for 1977 was estimated using the F at age from 1976 in the SPA. The sizes of the 1973-75 year classes were estimated from the relationship of USSR catch numbers per tow at ages 2 and 3 in Div. 3K and 3L with SPA numbers at age 4 for year classes from 1959-72 (Table 3). Surveys from the Federal Republic of Germany (FRG) in Div. 2J indicated similar trends in year class strengths but the estimates were not used to predict subsequent values. Average weights at age were determined from the commercial fisheries in 1977 and were used in the assessment as well as for subsequent projections. For the 1977 assessment an average value (see Section 4.2) was used for all years to 1976 which was substantially lower than that obtained from 1977 sampling.

From the projections, the estimates of biomass were higher than those in the 1977 assessment and it was estimated that the target spawning stock biomass (in this assessment ages 7-13) would be reached by 1982 with F's as high as 0.2. There was no indication in the assessment as to the effect of the new higher average weights used on the revised rate of improvement. As in 1977, catch and stock biomass projections were provided based on three options of fully recruited F (0.2, 0.16 and 0.1). The agreed upon TAC for 1979 of 180,000 t would be expected to produce an F less than $F_{0.1}$(=0.2). The projected $F_{0.1}$ catch was 197,000t.

<u>1979:</u> In the SPA the relationships of F on effort from USSR and Spanish fleets derived in the 1978 assessment (Res. Doc. 78/66) were used to estimate F in 1978. These relationships used data from 1963 to 1973. The estimated F ranged from 0.27 to 0.29 with the former being considered most appropriate and used in the final SPA. Average weights were based on Canadian sampling and partial recruitments were the same as those used in the 1978 assessment, except that values for ages 4 and 5 were adjusted to account for revised estimates of stock abundance at age 4 in 1977 and 1978. It is of interest that the report noted that the SPA results indicated that the fully recruited F for 1977 was slightly higher than that estimated during the 1978 assessment. This is probably the first time that the occurrence of an upward revision in the estimates of F for a given year in a subsequent assessment was described. This will be discussed later under the subject of "retrospective" analysis (see Section 7.1).

Recruitment strengths for the 1973-75 year classes were estimated using the relationship of abundance at age 3 from the USSR surveys in Div. 3K and 3L with corresponding SPA year class abundance at age 4 for the 1959-72 year classes. These values (Table 3) were used in projections to 1982 with three options of fully recruited F for 1980-82. Once again, it was estimated that the target spawner stock biomass (SSB) range (age 7+) would be reached by 1981. It was estimated that the accepted TAC for 1980 of 180,000t would produce an F of approximately 0.16 while the $F_{0.1}$ catch would be about 212,000t.

1980 to 1987 Assessments

Assessments conducted during this period were similar in that calibrations of SPA were accomplished using relationships between standardized offshore trawler commercial catch rate and age-aggregated SPA biomass and/or an aggregate research vessel abundance estimate with age-aggregated SPA abundance. The 1980-82 assessments used mean SPA biomass at age 4+ (numbers of cod present half-way through the year multiplied by average weights at age) for calibration with commercial catch rate. For 1983-87 assessments mid-year exploitable biomass (average SPA biomass multiplied by partial recruitment) was used.

1980: This assessment was the first to use a standardized catch rate index (see Section 4.3). Fully recruited F in 1979 was estimated from regression analysis of standardized fishing effort on F and, as well, from that of mean age 4+ SPA biomass on standardized catch rates for the period 1962 to 1977. Values for 1974-76 were not included in the analyses as they appeared to be outliers when all the data were included in the regression. A fully recruited F of 0.20 in 1979 was considered to be most appropriate and was incorporated in the final SPA. The partial recruitment vector used was similar to that derived in 1978 (from the 1979 assessment).

The results from two general production model analyses were reviewed, one based on Portuguese trawler CPUE from 1958 to 1977 and the other on standardized effort for the 1958-80 period. These gave substantially different indications of potential MSY levels for the stock.

Catch curve analyses for RV data from French surveys in 2J, 3K and 3L from 1976-1980 indicated an annual average F of 0.47. Although the 1980 STACFIS report (p.77) states that these values are consistent with estimates from SPA analysis, the available documentation including a SPA analysis is not supportive, as the SPA values were substantially lower for most years. It is not clear if this issue received much attention at the time of the meeting. However, the French surveys from 1976 to 1980 were not extensive, generally conducting less than 50 sets for the entire stock area. They may not have been considered to adequately represent the stock status.

Using SPA population estimates at age for 1980, projections of catch and SSB were made for 1980-87, again with 3 options of fully recruited F (0.2, 0.16 and 0.1). Recruitment estimates were not obtained from a relationship of survey abundance with SPA abundance, as had been done previously. All research survey information (USSR, FRG, Canadian and French) indicated that the abundance of the 1976 and 1977 year classes were very low and for projections, an arbitrary value of 125 million fish was chosen for these two year classes. An average value of 500 million was used for subsequent year classes. To indicate caution STACFIS stressed the dependency of the projections on the assumed sizes of the year classes.

A TAC of 200,000t was set for 1981 which corresponded to fishing at F=0.16 under the assumptions of the projections. Similarly, the $F_{0.1}$ catch would be about 250,000t.

<u>1981:</u> The data and methodology for this assessment were very similar to that used in 1980. A regression of mean stock biomass (age 4+) on standardized commercial catch rates for 1962-78 (values for 1974-76 were once again excluded as outliers) was used to predict stock biomass from the catch rates for 1979 and 1980. The best agreement between the predicted biomass values and those estimated in SPA was achieved with a terminal year F value of 0.17. Partial recruitment was calculated by dividing the fishing mortality at age by total fishing mortality for ages 8-11 in each year. Partial recruitment for the final year was derived from the average for the 1972-78 period.

Projections were conducted to 1983 with the same three options of F as in 1980. Research survey data once again indicated weak 1976 and 1977 year classes and arbitrary values of 125 million and 200 million respectively were taken as being appropriate for their abundance at age 4 for projections. An average of 500 million recruits was used as the size of each subsequent year class. A TAC of 230,000t was set for 1982 which corresponded to fishing at F slightly in excess of 0.16.

<u>1982:</u> An assessment was attempted in June of 1982 but STACFIS was unable to determine stock status and give subsequent advice, mainly because of difficulty in interpreting the catch rate series. Increasing catch rates suggested an increasing biomass but there was conflicting evidence as to the extent of this increase. The major difficulty was the interpretation of the high catch rates for the most recent years as absolute indicators of stock increase. It was considered that the increases from 1980 to 1981 in both catch rates and survey results (Canada, France and FRG), may have resulted from an increase in availability. There was some indication that catchability had changed after 1973 and it was uncertain whether it was more appropriate to use the total time series or only values since 1973. The interpretation of stock status was quite different depending on the choice. The later series was also relatively short and consequently subject to the influence of extreme values. Because of these uncertainties, advice concerning the stock was deferred to the September meeting when additional information from surveys and the commercial fisheries might be available.

For the September assessment catch rate data were analysed in a different manner. Data from 1962 to 1979 reported in NAFO Statistical Bulletins for Portugal and Canada were analysed separately from similar data for 1979 to 1982 obtained from the Canadian Observer Program and the Economics Branch of DFO. The two series were standardized and then combined by scaling them to a common factor for 1979. Survey data (weight per tow) from Div. 2J by FRG (1972-81) and Canada (1978-81), adjusted for the area surveyed, were averaged to produce one index. An index of mean weight per tow in Div. 3L from Canadian surveys was obtained by combining strata by depth zone. Other survey data were not used because they were either highly variable or had limited spatial coverage.

Fishing mortality in the terminal year was estimated from regressions of commercial catch rate (excluding data for 1974-76 considered outliers) versus mid-year exploitable biomass and Div. 3L research survey index (excluding values for 1976 and 1981 considered outliers) versus 4+

biomass. Exploitable biomass was obtained as the product of matrices of annual SPA biomass at age and annual partial recruitment estimates at age. The use of exploitable biomass was thought to be the more appropriate index to relate to catch rates as it was this portion of the population on which the catch rates applied. The regression analyses indicated that the fully recruited F in 1981 ranged between 0.1 and 0.2.

It was not possible to derive satisfactory regressions between survey estimates and SPA estimates of year-class size for projections. However, based on comparisons of the relative strengths of the 1978 and 1979 year-classes with those of the 1973-75 year classes in Div. 2J and 3L from research vessel surveys, a value of 500 million age 4 fish (approximately equal to the geometric mean number of age 4 fish estimated in the SPA for 1962-81) was used as the strength of the 1978 and 1979 year classes in projections. Sampling data had indicated a decline in average weights at age in the commercial fishery for all ages between 1980 and 1981. It was concluded that there was no basis for deciding whether the differences represented real changes or sampling variability. For projections, an average of values for the two years was used. This practice of averaging the recent weights at age for input into projections was first used in this assessment but became the standard practice in subsequent years. Projections were conducted to 1984 with the same three options of F as the previous two years (0.2, 0.16, 0.1). A TAC of 260,000t for 1983 was set which corresponded to fishing at F between 0.16 and 0.2. Catch at $F_{0.1}$ was projected at about 270,000t.

1983: Fully recruited F in 1982 was estimated from the relationship of the commercial catch rate index with mid-year exploitable biomass. Catch rates were obtained for two periods (1962-79 and 1979-82) with the resulting combined index being scaled to the 1979 value. The 1974-76 values were still considered outliers and were not included in the relationships. SPA results indicated that the fully recruited F in 1982 was between 0.2 and 0.25 and a value of 0.225 was chosen as an approximation. The partial recruitment estimates for 1982 were obtained by averaging values estimated for the 1975-80 period. Comparisons of plus group (age 4+ to 6+) numbers per standard set from Canadian surveys in 2J3KL from 1977 to 1982 with the SPA (fitted to the catch rate index) plus groups (age 5+ to 7+) gave significant relationships for the 1977/78 - 1981/82 period.

Projections were conducted only to 1984 (compared to the practice in the previous assessments of projecting two years beyond the assessment year) at the same three options of F as the previous years (0.2, 0.16, 0.1). Recruitment at age 4 in 1983 and 1984 were taken as the long term geometric mean of 1962-81 SPA estimates (400 million). This represented a reduction in the 'long term' mean used in previous assessments of 500 million. The mean weights at age used were averages of values from the fisheries in 1981 and 1982 and partial recruitment was the same as that used in the SPA. The TAC for 1984 was set at 266,000t which was estimated to correspond to fishing at $F_{0.1}$=0.2.

The report from this assessment noted that the previously projected F for 1982 (0.19) in the 1982 assessment was lower than that estimated (0.225) for 1982 in the 1983 assessment. It was considered that the discrepancy could only in part be explained (by reductions in average weights at age). This was the second manifestation (first was in 1979) of the so-called ‘retrospective problem’ which is discussed in more detail below (Section 7.1).

1984: As before, this assessment used the relationship of mid-year exploitable biomass and standardized commercial catch rate to estimate F in 1983. However, in contrast with previous year’s assessments, the values for 1974-76 were included in the regression analysis. The reasons are not documented but it is recollected that STACFIS concluded that it would be more prudent to use all available data and to determine the influence of outliers in the diagnostics. The regression indicated the best fit based on minimization of residuals for 1981-83 at a fully recruited F of 0.20 in 1983.

A survey biomass index was obtained using data (mean weight per tow) from Canadian (Divs. 2J and 3K) and FRG (Div. 2J) surveys. Canadian Div. 3L survey data were omitted because there was no survey in 1983. The Canadian series for the two divisions were added and the combined series scaled to its mean. The FRG series was scaled to its 1977-83 mean and then averaged with the Canadian series to produce the index of biomass used in the SPA. A regression of SPA age 4+ biomass with this survey biomass index (lagged one year) gave the best fit (r^2) at F=0.25. Because the estimates from the calibrations with the catch rate index and the survey index differed, and there was no basis for accepting one over the other, an average fishing mortality of F=0.225 was accepted.

Recruitment estimates for projections were obtained from a regression relationship of age 3 abundance from USSR surveys (Divs. 3KL) and age 4 abundance from SPA. The 1979 and 1980 yearclasses were estimated at 312 and 388 millions but were both set at the long term (1962-82) geometric mean of 400 million for projections. For the first time a short term (1973-82) mean recruitment estimate (250 million) was used for the additional projected years. It had been recognized that recruitment levels of yearclasses in the 1960s were high and that with few exceptions, a new lower level was persisting. In previous assessments, the size of the relatively large 1978 yearclass at age 4 was set or estimated at values from 500 to 550 million. In the 1984 assessment a value of 591 million as estimated from SPA was accepted.

The projected catch at $F_{0.1}$ in 1985 was 268,000t and the TAC was set at 266,000t, chosen because the $F_{0.1}$ estimate was not considered different from the 1983 TAC. Partial recruitment used in the projections was the same as that used in the SPA and average weights were derived from 1982-83 commercial sampling.

The assessment report also noted that the SSB was somewhat less than that predicted in the 1983 assessment although the projection suggested that the target of 1.5 million tons of spawners would be reached in 1986. The reason for the difference in projections was considered to be partly due to declines in weight at age in recent years.

1985: Survey and catch rate data were used to calibrate the SPA. Standardized catch rates had been calculated previously for two periods (1962-79 and 1979-83) and combined by scaling to the 1979 values. For the 1985 assessment it was decided that there was enough information available for 1978 to include it in the catch rate analysis for the later period and as well to use both the 1978 and 1979 values for scaling the two time series. This change produced a reduction in the catch rate indices for the 1979-84 period relative to pre-1979 indices when compared to those with one year as a reference. The relationship of this new catch rate index to an offshore exploitable biomass for two time periods (1962-84 and 1977-84) suggested that F in 1984 ranged from 0.175 and 0.25. The shorter time series (1977 and later) was examined because concern was expressed about using the entire catch rate time series which overlapped the time of extended fisheries jurisdiction in 1977. Changes in the fleet and season may have influenced the comparability of the series in the pre-1977 and post-1977 period. Consequently only the period from 1977 to 1984 was considered appropriate for calibration. Offshore exploitable biomass was obtained from offshore partial recruitment and the SPA average biomass. Offshore partial recruitment was obtained from the fishing mortalities estimated in the SPA after this matrix was adjusted for the proportion of the catch taken offshore. Offshore exploitable biomass was considered to be more representative when relating to offshore catch rates.

Survey biomass and abundance indices were obtained using Canadian (2J3K) and FRG (2J) fall surveys. A geometric mean regression between countries for the period 1977-83 was used to estimate values for years when there were no surveys (2J:1972-76, 3K:1977 - Canada and 2J:1984 - FRG). The Canadian and FRG estimates were then averaged to give the resultant index. Calibration using the survey biomass index and age4+ SPA biomass in the following year implied a high F (0.4-0.5) in 1984. Calibrations using the survey age 6+ abundance with SPA 7+ numbers in the following year for three time periods (1972-83; 1977-83 and 1977-84) implied F's in 1984 of 0.25, 0.35, and 0.45 respectively.

STACFIS considered that the likely range of fully recruited F's in 1984 was 0.2 to 0.25 and agreed upon 0.23 as a representative value for 1984. It is interesting to note that the rationale for selecting this value rather than a lower value included the uncertainties surrounding the indices and "because terminal fishing mortalities have been consistently underestimated for this stock" (NAFO,1985).

Recruitment estimates were obtained using Canadian RV data from 1977 to 1984. Abundance at ages 3 and 4 from the surveys for 1977 to 1981 were each regressed against SPA age 4 abundance and the resulting relationship used to estimate values for the 1978-80 year classes at age 4 in 1982-84 of 250 million, 300 million and 350 million respectively. The estimate for the 1978 year class was considered low based on the partial recruitment pattern and was subsequently adjusted to 400 million. The relationship using only age 3 values gave 400 million for the 1981 yearclass and a geometric mean (for years 1973 to 1982) of 250 million was used as the strength of the 1982 year class. Acceptance of these recruitment estimates implied SPA partial recruitment values with full recruitment at age 6 which contrasted with that of previous assessments (age 8). Despite these changes, the method of estimating recruitment was considered superior to that previously used as it more fully utilized data from the later years and did not rely on the accuracy of the SPA for the period prior to 1977.

For the projections average weights were from 1983-84 and the partial recruitment vector assumed full recruitment at age 6. Projections were conducted to 1986 only at the $F_{0.1}$ option which indicated a catch of 244,000t . However, because of the uncertainties discussed, the meeting report states that , "STACFIS was unable to discriminate between the calculated catch at $F_{0.1}$ and the 1984-85 TAC of 266,000 tons" and advised that ".. the 1986 TAC (266,000t) would approximate exploitation at the $F_{0.1}$ level in 1986". The TAC for 1986 was set at 266,000t.

It was also noted that the SSB estimates were about 30-40% lower than those estimated in the 1984 assessment and below the 'target' level of 1.5 million t. The lower estimates in this assessment were related to revised (higher) estimates of F for 1983, lower estimates of the strengths of recruiting year classes, and a decrease in weight at age values since 1980.

<u>1986:</u> The 1986 assessment was the last that NAFO conducted at the request of Canada until 1992. For the assessment, SPA was calibrated with RV abundance and commercial catch rates. Two RV survey indices were used. An abundance index for ages 6+ was obtained by combining results from Canadian autumn surveys in Div. 2J, 3K and 3L. Values for autumn 1978-80 in Div. 3L were estimated from the ratio of age 6+ autumn values to age 7+ Div. 3L spring values in the following year for two overlapping years (1981 and 1984). Calibration using this survey abundance index and age 7+ population numbers from the SPA at the beginning of the following year gave an estimate of fully recruited F in 1985 in the 0.45-0.50 range. The high 1981 spring 7+ value was influential in this determination and it was noted that, if adjusted to the level of adjacent values this would reduce the 1985 F estimate (0.35 -0.40). The relationship of total abundance from FRG surveys in Div. 2J with SPA age 4+ population numbers at the beginning of the following year suggested F in 1985 in the range of 0.20 to 0.30. SPA calibration based on commercial catch rates and SPA offshore exploitable biomass for the 1979-85 period gave an estimate of fully recruited F in 1985 of between 0.15 and 0.20. A value of 0.18 was considered likely. Calibration with either index was considered to be uncertain and STACFIS concluded that it was not able to precisely estimate F in 1985, but agreed that the most likely value would be 0.25.

Estimates of recruitment at age 4 for the 1979-81 yearclasses as well as the strengths for the 1979-80 year classes at age 5 and the 1979 yearclass at age 6 were obtained using the relationships of Canadian survey abundances for the 1973-77 yearclasses at ages 3-6 against corresponding SPA abundances (F=0.25) at age 4. The SPA at F=0.25 was subsequently adjusted with respect to the partial recruitment vector used, to approximate the yearclass strengths that were estimated from the above relationships.

A projection was conducted to 1987 at $F_{0.1}$ using the SPA partial recruitment vector, weight at age as averages over the 1983-85 period, and the 1983 yearclass (age 4 in 1987) being set at the

1977-82 geometric mean of 250 million. As in the 1985 assessment, the resulting $F_{0.1}$ catch in 1987 (246,000t) was less than the previous years' TAC (by 7.5%) but because of variation in the data and reservations about the relationships used to estimate parameters STACFIS again advised.." that a catch of 266,000t would approximate exploitation at the $F_{0.1}$ reference level in 1987". The TAC was eventually set at 256,000t.

It was also noted that the spawning biomass (age 7+) from SPA and projections was lower than that calculated in the 1985 assessment and was lower than the accepted target range. This target range of 1.2 to 1.8 million tons was also reviewed at the 1986 assessment (Rice and Evans, 1986). It was concluded, that in deriving the target, data from an SPA had been used which included 14+ as the terminal age group (compared with no plus group in current assessments) and this had produced larger estimates of spawning stock sizes. Re-analysis of SPA data without this age group (i.e. compatible with current assessments) led to revised target range estimates of 0.85 to 1.3 million tons. Even at this level, the estimated spawning stock in 1987 was slightly below the lower end of the range.

Inshore effort data obtained from individual purchase slip records for 1984 and 1985 were reviewed at this assessment. Purchase slips recorded only landings and gear type without any indication of the amount of gear or length of time fished, and consequently, an index developed from this source might be of limited value. Nevertheless, these were the only information available with at least some measure of inshore effort. Inshore catches declined from 1984 to 1985 although catch per purchase slip remained fairly stable for most gears.

The results from the June NAFO assessment were also reviewed during a special meeting of the Groundfish Subcommittee of CAFSAC in November of 1986 (Advisory Document 86/25, In: CAFSAC Annual Report Vol. 9, p.287-318). This meeting was called to consider questions posed (see Subcommittee Report 86/16, Annex 1) as a result of lower than expected catches in the inshore cod fishery in the preceding years. Inshore fixed gear catches had declined from about 113kt in 1982 to about 72kt in 1986. Because the status of the stock was important in formulating answers to the questions, CAFSAC, for the first time, reviewed the assessment of the stock carried out by the Scientific Council of NAFO. As one of the questions dealt specifically with stock status, only the CAFSAC deliberations with respect to this issue will be addressed here. The review found no basis upon which to disagree with the assessment carried out by NAFO. With respect to the inshore fishery issue it was also stated that there was "no reason to suppose that the decline in inshore catch after 1982 reflected a decline in the overall stock biomass".

As noted above, the basis for the assessment were the commercial catch rates and the RV surveys with indicating different trends in the size of the resource. The uncertainties associated with both of these indices were addressed in the CAFSAC review. The RV estimates were questioned with respect to the possible influence of a dramatic decline in water temperatures on availability to the research gear. With regard to catch rates, an analysis was presented (Winters, 1986) suggesting that the commercial catch rates obtained from the multiplicative analysis used in the assessment were highly dependent on the weighting factors applied (the weighting factor, introduced in the 1984 assessment, gave more weight to data with higher catches and greater effort) and that the assumptions of the multiplicative model (no interaction between division and year) may have been violated by different divisional trends in catch rates. The analysis by Winters suggested that weighting by RV divisional biomass estimates would produce a declining trend after 1983 in contrast to the increasing trend indicated by that the model used. It was recommended that further analyses were necessary to determine if model assumptions had been violated and to determine if there were alternate methods for treating the data to provide a better index. In summary, CAFSAC noted that the level of uncertainty in the NAFO assessment estimates of stock size and fishing mortality was "...not unusual in comparison with the assessment of other cod stocks in the Northwest Atlantic".

1987: The 1987 assessment was the first conducted for this stock by the Groundfish Subcommittee of CAFSAC. Although conducted under a different structure, the methodologies used were similar to previous assessments. Offshore catch rates were developed for the 1962-79 and 1978-86 periods and, for the latter series, by division. As recommended during the November 1986 CAFSAC review of the stock, other analyses were explored with respect to divisional weighting. The divisional catch rate estimates were weighted by the average percentage RV biomass in each division. The resulting stock index agreed quite well with the standardized index normally used (Baird and Bishop 1987). A multiplicative model of the form previously used was considered the most appropriate method of combining the divisional catch rates in spite of the concern previously expressed regarding violation of some model assumptions.

For calibrating the SPA, only the later (1978-86) catch rate series was considered appropriate because of fleet changes between the two time periods and the lack of adequate information to link the two series. Calibration of the SPA with the catch rate index compared with SPA estimates of offshore exploitable biomass for the 1978-86 period suggested an F=0.17 in 1986.

Information on catch per purchase slip for the inshore fishery for 1981-86 was examined by gear type and vessel size category. There were no trends in catch rate for vessels between 35-64 ft. while there was a decline in 2J and 3K catch rates and relative stability in catch rates in 3L for vessels less than 35 ft. It was observed that inshore catch rates had not shown the increase that had been observed in the offshore otter trawl fishery. However, there were a number of factors which could affect the availability of cod to the inshore gears. It was also noted that the method of recording data on slips had changed in 1986 (a single catch could be ascribed to several purchase slips) but the extent of this problem could not be quantified. It was emphasized that the lack of reliable inshore effort data had been a major impediment to the assessments.

Only survey data from Canada were considered at this assessment as additional data were not available from the USSR surveys and the FRG surveys had been discontinued. An abundance index for ages 6+ was obtained for 2J3KL for the 1978-86 period. Estimates for autumn 3L for 1978-80 were obtained from the ratio of ages 6+ autumn values to ages 7+ spring values in the following year for the three overlapping years (1981,1984-85). An overall abundance index was obtained by averaging the three divisional indices after weighting by division area. This index indicated that there was a large increase in 1986. In the SPA calibration the age 6+ survey abundance index was regressed against SPA 7+ population numbers in the following year. The minimization indicated that F in 1986 was about 0.25. The estimates of F from the two calibrations were given equal weight and a value of 0.21 was considered appropriate for F in 1986.

The relationship between age 3 survey index and SPA age 4 at the beginning of the following year for the 1975-79 year classes predicted the size of the 1982 year class at 473 million fish. The predicted sizes of the 1980-81 year classes were higher than the range of the values used in the relationship and consequently were set equal to the size of the 1982 year class. These predicted values were about 20% higher than the long term geometric mean of 365 million. There was concern that, while the relationship between survey age 3 abundance and SPA estimates of age 4 numbers was significant, it was not between survey ages 4 and 5 and SPA estimates for ages 5 and 6. It was suggested that the relationship at age 3 was potentially spurious.

Catch projections were conducted to 1988 using the 1987 SPA population numbers adjusted for the above recruitment estimates and with the 1983 and 1984 year classes estimated at 300 and 265 million respectively, the latter being the 1977-83 geometric mean. Weights at age were averaged over the 1984-86 period and the partial recruitment vector was the same as that used in SPA. The 1988 $F_{0.1}$ catch was estimated at 293,000t. About 63% of this catch weight would be from the 1980-82 year classes. The TAC for 1988 was set at 266,000t.

The results from this assessment gave a more optimistic interpretation of stock status than the previous assessment. Some of the increase resulted from the high abundances observed in the fall 1986 survey. The 1986 age 4+ biomass was estimated to be 1.5 million tons and the fully recruited F had declined from 0.37 in 1983 to 0.21 in 1986, the lowest in the period analysed (1962-86). The estimated declines in fishing effort supported this decline although the declines in F were larger. The Groundfish Subcommittee report (87/9) noted that the low F value should be viewed with caution as it was extrapolated beyond the range of historical values.

The Subcommittee also indicated that annual population sizes since 1977 had been overestimated in previous assessments although the magnitude of the discrepancies were only considered reliable in the earlier part of the SPA estimates (prior to 1982). This type of "retrospective" problem was also noted in the 1983 assessment with respect to F and assessments from 1984-86 with respect to spawning stock biomass. The CAFSAC Steering Committee provided a virtually identical prognosis (Advisory Doc. 87/17) to the Groundfish Subcommittee Report.

1988-89 Assessments

The 1988 assessment should be considered a milestone or turning point in assessments for 2J3KL cod. The optimistic results from the 1987 assessment produced considerable controversy as the results were at odds with the opinion and perceptions of inshore fishermen. Inshore catches had declined from about 113kt in 1982 to about 72kt in 1986 (Fig. 1) and there was some evidence (Pinhorn 1986) of a relationship between inshore catches and the stock abundance of the major age groups (4-5) caught by the inshore fisheries.

CAFSAC postponed the normal spring assessment of 2J3KL cod in 1988 to later in the year to allow time to address as fully as possible all the recommendations made by the Task Group on the Newfoundland Inshore Fishery (TGNIF) (see Section 7.5). Thus the assessment was conducted at a September 1988 meeting of CAFSAC.

1988: In the autumn assessment an estimate of the stock size in 1987 was obtained using the standard calibration techniques of previous years (commercial catch rates regressed against SPA estimates of exploitable and survey abundance regressed against SPA estimates of numbers). In addition to the methods previously used for calibration, an "adaptive framework" was used to provide a more rigorous and objective approach (Gavaris 1988). The Laurec-Shepherd (L/S) version of SPA was also applied.

Commercial catch rate data for the 1977-87 period were analysed in a multiplicative model by division as well as stock area . The resulting standardized index showed an increasing trend from 1978-85 followed by declines in both 1986 and 1987. Analysis by division indicated that the decline began earlier in 2J (1983) and later in 3L (1987).

Catch per purchase slip data for the inshore fishery from 1981-87 were analysed using a multiplicative model. Catch per slip for the stock area was highest in 1982 followed by a decline, while divisional trends showed a declining trend (2J3K) or were stable (3L). There were concerns about the quality of these data, especially since 1986 (there was some evidence that single catches had been reported on several purches slips to take advantage of an unemployment insurance plan), and about the appropriateness of combining in the analysis gears having quite different selectivities. Year class strengths could have a differential effect on the catch rates by the different gears. It was concluded that the data would not be used for calibration but would be considered a crude approximation of a measure of inshore effort.

Offshore exploitable biomass was estimated somewhat differently than in previous assessments (see 1985 assessment). There was an indication that the pattern of mortalities had changed between 1981 and 1982 in that selectivities were reduced on the younger age groups and the age at full recruitment to the fishery had increased. Offshore exploitable biomass was estimated from selectivities assuming fully recruited F's in 1978-81 at ages 6-7 and in 1982-87 at age 8-10. The relationship between catch rate and SPA estimates of exploitable biomass showed no significant relationship. However, by assuming zero intercept in the calibration, a comparison of ratios between catch rate and offshore exploitable biomass between 1978-82 and 1983-87 suggested F in 1987 of about 0.20.

Biomass and abundance estimates for the 1987 Canadian autumn RV surveys showed a decline from the high level in 1986 to a value similar to those estimated for the early 1980s. Annual abundance indices for ages 6+ and ages 3-9 were obtained after adjustments for the missing autumn surveys in Div. 3L. The regression between age 6+ survey abundance and SPA estimates age 7+ numbers suggested a fully recruited F approximating 0.45.

The ADAPTIVE framework was applied to the age disaggregated (ages 3-9) survey index and the age aggregated catch rate index in the same formulation, even though they indicated different trends. In this formulation, the RV index effectively received considerably more weight (7 times) because it was age-disaggregated, whereas the catch rate index was not. This differs from previous assessments in which separate calibrations with each were performed and the results evaluated, effectively giving each index equal weight. The results of the analysis suggested F in 1987 of about 0.40 and for 1986 at 0.43, about double the value estimated in the 1987 assessment and double the $F_{0.1}$ target. The estimates of the 1978-82 year classes were also lower.

These results presented a major change in the perception of the size of the stock compared to previous years. Some of the other available information (high offshore catch rates for the first half of 1988, high age 6+ abundance from the 1988 3L spring survey, relatively higher catches in the inshore fishery to the end of August in 1988) were somewhat at odds with the perception regarding the much higher F's. The Subcommittee decided it could not estimate the size of the stock in 1987 with any confidence until the RV and commercial fishery data for 1988 were available and analysed.

Part of the change in estimated size of the stock was related to the use of the ADAPT procedure which effectively gave more weight to the RV index as noted above. However, the main change was caused by a large reduction in survey estimates in 1987 over 1986 and the continued decline in the commercial catch rate index. Even the previous approach of separate calibrations with the RV index and the commercial catch rate index estimated F for 1987 in the 0.30-0.35 range.

The L/S method of tuning was explored at the assessment. Fully recruited F (ages 7-11) was 0.56 in 1987. The Survey, Statistics and Sampling (SSS) Subcommittee of CAFSAC had reviewed the method in March 1988 and had expressed reservations regarding its use so the results were considered exploratory.

The Advisory Documents in 1988 (88/17, 88/25) state: that the assessment was postponed in the spring of 1988 so that the recommendations of TGNIF could be included in the assessment, and that the assessment was postponed in September so that additional analyses could be conducted, specifically on the commercial catch rate data. Analysis of the available assessment related data was conducted in the September 1988 assessment (St. Andrews) and a Working Paper (Baird and Bishop, Working Paper 88/129) and a report (Subcommittee Report 88/13) were prepared, but no formal projections were carried out and no advice was provided on the 1989 TAC. As indicated above, the assessment suggested a large change in perception of stock size. The Advisory Document (88/25) stated that there were problems reconciling the 1987 catch rates with the previous series and that the assessment could not be completed. It also indicated that because of conflicting signals in the 1988 fisheries, as compared with 1987, all data for 1988, including autumn RV data, should be considered before another assessment was conducted. The 1987 catch rate data were not raised as a major issue in the Subcommittee Report (88/13).

<u>1989:</u> The first assessment in 1989 was conducted in January as soon as the data for 1988 had been analysed (Subcommittee Report 89/1 and Advisory Doc. 89/1). The methods used were similar to the 1988 assessment with indices extended to include the 1988 data.

Some additional analyses were conducted on the commercial catch rates to account for the practice of using "windows" in the codends of otter trawls. After the introduction of Enterprise Allocations in 1982, fishing Companies became more quality conscious and to this end the size of the catch per haul was limited at about 20,000 lb.(9,000kg). One way of accomplishing this was the placing of holes or 'windows' in a position on the trawl to permit escapement when the catch reached the limit. Examination of observer data for the period before the use of windows (1980-84) with the 1984-88 period indicated that the effect of this on catch rates was not large and could be ignored in the analyses.

A number of formulations of ADAPT were used to estimate stock size. RV survey and commercial catch rate indices were analysed in separate formulations. An age disaggregated (3-9) survey index indicated an average fully recruited F (ages 7-10) of about 0.57 in 1988. The age 3+ population numbers at the beginning of the year had declined since 1985 and were at their lowest level since 1980. It should be noted that this was the first assessment where age 3 estimates were included with the previously used SPA age range of 4-13.

An aggregated (age 6+) survey abundance index was used in an ADAPT calibration giving an estimate of F for 1988 of 0.75. However estimated coefficients of variation (CV's) were higher with this analysis than with the age disaggregated analysis and it was decided that the latter was the most appropriate formulation for RV survey data.

Commercial catch rates were also used in a formulation of ADAPT in which they were related to offshore exploitable biomass, as in previous assessments. Average partial recruitment vectors for two periods (1978-81 and 1982-88) were used to estimate this biomass. The results indicated patterns in the residuals suggesting a lack of fit by the model. However, the fully recruited F in 1988 was estimated at about 0.30. An additional analysis was conducted after adjustments to the catch rate data for the use of 'windows', but the results were essentially unchanged. Also, an analysis was conducted using ADAPT with the long (1962-88) time series of catch rate data. The results indicated that the residuals patterned and that calibration coefficients before and after 1977 were different. Once again it was decided that the use of the long time series was inappropriate. It was concluded that the best were two separate ADAPT formulations, one using the age disaggregated RV index and the other using the age aggregated catch rate index for 1978-88.

There were difficulties associated with both indices. The results using the RV index were variable and it was considered that this index may have been influenced by environmental conditions or variable offshore migrations of cod in Div. 2J and 3K. It was considered that the commercial catch rate index may have been underestimated since 1984 because of some operational changes in fishing activities. Because neither index was considered totally representative of stock status, the terminal fishing mortalities from the two analyses were averaged , resulting in a fully recruited F of 0.44 for 1988. It was again noted that F had been consistently underestimated in the past (the "Retrospective Problem").

Recruitment estimates for the 1984 and 1985 year classes at age 3 were obtained using a stock-recruit analysis based on nonparametric density estimation methods (Evans and Rice 1988). Using the probability ogives from this approach, values of 250 and 350 millions were estimated for these year classes, respectively.

For projections of catch and biomass in 1989, weights at age estimates were averaged over the 1986-88 period and partial recruitment vector for 1989 was derived from SPA estimates of the 1988 F's with full recruitment at age 8. Recruitment at age 3 in 1989 was assumed at the geometric mean (1978-88) value of 300 million. The projected age 3+ biomass in 1989 was 1.1 million tons and the 1989 catch at $F_{0.1}$ about 125,000t.

The assessment results were similar to those suggested in the autumn 1988 assessment and confirmed that the stock had been previously overestimated and that the age 3+ biomass had been declining since 1984. The results indicated a substantial change in perception regarding stock status. Previous assessments had consistently estimated F to be at 0.25 or below as opposed to the updated estimate of 0.44. Several factors contributed to the change. Both time series used (catch rate and RV) were relatively short and subject to the influence of extreme values. The interpretation of stock status in the 1987 assessment was strongly influenced by the high RV index for 1986. Results from the 1987 and 1988 surveys indicated that the 1986 RV index value was anomalously high. The surveys had also indicated that the 1983 and 1984 year classes were low. The catch rate index had increased from 1977 to 1985 but declined in 1986 and 1987.

In addition to a description of the substantial change in perception regarding stock status, Subcommittee Report (89/1) provided two TAC calculations under the Prognosis section. The first was the standard $F_{0.1}$ projection at F=0.2 which indicated at TAC of 125,000t in 1989. The second was the 50% rule calculation which indicated a TAC of 191,000t for F=0.32 (see Section 3.3 for a description of the 50% rule). Note that the 50% rule was proposed by the Groundfish Subcommittee back in 1986 (Subcommittee Report 86/14) as an interim solution to the problem of going from high F to the $F_{0.1}$ level, following the request from the fishing industry for a reduced variation in annual TAC's under such a situation. This was the first time the 50% calculation was provided as an option by CAFSAC for the 2J3KL cod stock.

The Steering Committee of CAFSAC met immediately after the assessment meeting. The resulting Advisory Document (89/1), under the Forecast section, provided a further TAC calculation based on keeping the F constant in 1989 at the same level as was estimated for 1988. This calculation gave a TAC of 252,000t. The Advisory Document noted that "Since, however this fishing mortality is over double the $F_{0.1}$ level, fishing at $F_{0.1}$ in 1989, and hence reducing effort by over a half, would generate a catch of 125,000 t." The constant F option had not been included in the report of the Groundfish Subcommittee. On February 8, 1989 Fisheries Minister Siddon announced a revised provisional TAC for 2J3KL cod of 235,000t and his intent to establish an independent northern cod review panel (Lear and Parsons 1993). The reasoning behind the decision to abandon the $F_{0.1}$ approach and the basis for the 1989 TAC of 235,000t were not provided with the announced TAC.

The stock status was reviewed again at the May meeting of the Groundfish Subcommittee of CAFSAC (Subcommittee Rept. 89/8; not referred to in an Advisory Doc.). There were no new data to review. Catch and biomass projections were conducted assuming a TAC catch in 1989 of 235,000 t and with the 1986 and 1987 year classes at the 1978-88 mean of 300 million. Other parameters were the same as used in the January assessment. The results indicated that a catch of 235,000t would produce F=0.41 in 1989 and that the 1990 catch at $F_{0.1}$ would be about 121,000t resulting in a age 3+ average population biomass at just over 1 million tons. A second TAC calculation based on the 50% rule was again presented in the Subcommittee Report, giving a TAC of 177,000t for 1990, associated with a fully recruited F of 0.305. The CAFSAC Advisory Document (89/12) from the May Groundfish Subcommittee did not include a section for 2J3KL cod.

The Northern Cod Review Panel (Harris Report) was established in 1989 (See Section 7.5) to review the scientific advice resulting from the January 1989 assessment. One of the recommendations from the Panel presented in its Interim Report of May, 1989 suggested that F should be reduced to a value halfway between the 1988 level of 0.45 and the F0.1 level of 0.2 (approximately 0.32) which implied a TAC for 1990 of 190,000t. This was effectively the 50% Rule although not stated as such in the report. Note that this application of the 50% rule gives a different outcome (higher TAC) to that obtained by the Groundfish Subcommittee. The TAC for 1990 was eventually set at 199,262 t (197,000t for Canada and 2,262t for France), the announcement being made by Minister Siddon on 2 January 1990 (Lear and Parsons 1993). The final report of the Panel (February 1990) was more pessimistic than the interim report, indicating that a 1990 catch of 190,000t would produce an F of 0.415, however the TAC was not changed from that recommended in the interim report.

1990: The assessment was again conducted early (January) in the year as soon as sufficient data were available for 1989, even though the TAC for 1990 was already in place at 199,262 t. The most recent (1989) catch and effort data from the commercial fisheries and Canadian RV surveys were included in the assessment.

Catch rate data for the Canadian and Portuguese fleets, each for the period 1978-89, were analysed in a multiplicative model. The results indicated that catch per unit effort increased steadily from 1978 to 1985 and was variable thereafter. Values for 1988 and 1989 were similar. This analysis included data for Canadian vessels in January and February of 1987 and 1988. These were excluded from the 1989 assessment analysis because there was concern that the requirement to harvest the offshore allocation equally by division might have affected catchability, even though analysis at the time did not indicate a large effect. Subsequent analysis also suggested that these data had little effect and it was decided that it would be more appropriate to include all the data in future analyses.

It was again noted that the catch rate analysis indicated dissimilar trends in the three divisions. Although the inclusion of all data from the divisions in one analysis would violate the assumptions of the multiplicative model, the impact of this violation was uncertain. There was no information on stock distribution coincident with the timing of the offshore fishery to weight the divisional trends and it was agreed that alternative methods for combining the divisional indices and their consequences needed to be explored.

A catch rate index was also obtained from set-by-set observer data for 1980-89 collected on Canadian vessels. Using the same technique as for the aggregated data, it was found that the resulting standardized catch rate indices showed the same trends.

An age disaggregated catch rate index was derived for the period 1978 to 1989 using catch at age from the offshore fleet along with the calculated fishing effort from the catch rate standardization. The index was derived by dividing the offshore catch at age matrix by a vector of estimated annual offshore effort. The latter was obtained by dividing the total annual offshore catch by the standardized catch rate. Previously, age disaggregated commercial catch rates were not used because both the catch at age and the catch rate at age would depend on the same proportion at age data. It was considered that this could potentially introduce a bias in the analysis. However, simulation studies were reviewed which suggested that this was not the case. Consequently, it was deemed more appropriate to use the age disaggregated CPUE data for further analyses.

The total biomass and abundance from the RV surveys increased in 1989 as the result of a substantial increase in Division 3K. Because the results from the surveys had shown considerable variation, a 2-phase survey sampling design was used for the first time in 1989 in an attempt to reduce the variance in the survey estimates. In this procedure (Francis 1984), additional tows were allocated (second stage) to strata which during the survey (first stage) had shown the largest variation. Using this procedure, the estimated variance was reduced by 43% on the abundance and 26% on the biomass. An index of RV catch at age (ages 1-13) for the stock area was derived from the RV data using the same methods as in previous years.

The ADAPT framework was applied to both the RV index and the commercial catch rate index with both disaggregated by age. The catch rate index used in the analyses included ages 5-8 for the 1983-89 period. Ages 5 to 8 comprised about 80% of the total offshore catch and residual plots for ages 9 and older indicated a lack of fit to the model. Analyses including catch rate data from 1978-82 indicated unacceptable patterns in the residuals for these years (mostly positive in the earlier years and negative in later years). Suggested causes included learning by the Canadian fleet in this period and the effect of management plans on fleet behavior. These could not be quantified and the data were excluded from further analyses even though there was little effect on the results from ADAPT.

In an effort to account for the variability in RV estimates, a formulation of ADAPT was attempted with the RV index only and with the index weighted by the inverse of the standard error of the RV estimate. Although the resulting diagnostics indicated the results unacceptable, it was considered that the technique had promise and was to be investigated further.

Another method of predicting stock biomass was reviewed in which five year moving averages of total inshore and codtrap catches were related to SPA biomass and the relationship used for predictions. The analyses showed that the reported inshore catches were related to stock biomass and could potentially provide an additional index of abundance for calibrating the SPA. The data were not used to determine stock status during the 1990 assessment but it was recommended that further analyses be pursued, particularly with respect to codtraps and, as well, to include an examination of the codtrap catch at age data for cohorts passing through the fishery.

The ADAPT formulation finally accepted for this assessment with RV catch per set for 1978-89 and commercial catch rate for 1983-89, both disaggregated by age included in the same analysis, suggested a fully recruited F (age 7-9) in 1989 of about 0.56, indicating a steady increase from about 0.30 in 1980. Age 3+ beginning of the year biomass had declined from about 1.2 million tons in 1984 to about 0.85 million tons in 1989. The decline in the late 1980s was attributed mainly to the abundances of the very weak 1983-84 year classes.

In previous assessments it had been determined that the commercial fishery imparted a partial recruitment pattern that was "flat-topped" with full (100%) recruitment for all the older ages. Preliminary formulations of ADAPT indicated that using a flat-topped pattern of partial recruitment with age produced catchability estimates for the RV which increased with age through the older ages. This was contrary to the expectation that the partial recruitment should be constant for the older ages. It was found that setting the F on the oldest age (13) at 50% of that at the fully recruited ages (7-9) produced stable catchabilities for RV ages 8+. The presence of 'dome shaped' partial recruitment had been estimated for other otter trawl fisheries and would not be unexpected for this stock.

The use of a dome-shaped PR pattern necessitated the recalculation of reference fishing levels which had been determined using a flat-topped pattern from about age 8. The re-analysis used ages from 1-16, average weights from 1987-89, and the PR pattern estimated in the ADAPT formulation. The analysis produced values of $F_{0.1}$ and F_{max} of 0.25 and 0.52 respectively.

Projections were provided only for the 1990 catch and beginning of the year (1991) biomass, using a number of options of F and catch. Projections were carried out using the 1989 population at age and partial recruitment estimated by ADAPT, weights at age averaged for the period 1987-89 and the 1987 year class assumed to be 300 million, the approximate geometric mean for the 1978-89 period. The $F_{0.1}$ catch in 1990 was calculated to be 95,000t and the F assuming the 1990 TAC catch was taken (199,262t) was calculated to be 0.59 (Subcommittee Report 90/2). It was suggested that the catch in 1990 at $2XF_{0.1}$ (the upper limit of the 50% rule) would be about 174,000t and the Groundfish Subcommittee advised that the catch not exceed this level (Groundfish Subcommittee Report 90/2). This was the first time the upper limit of the 50% rule was invoked.

The content of the Advisory Document (90/5) differed from the Subcommittee Report (90/2) in three instances. In the first, the Advisory Document states that the difference between the 1990 and 1989 assessment results was related to the increase in weight given to the RV indices in 1990. The Subcommittee report did not reach this specific conclusion. The 1989 assessment weighted the separate ADAPT results from both indices equally (average of the two estimates from separate SPAs). In the 1990 assessment, both indices were combined in a single ADAPT formulation. The RV index would have effectively had more influence in the minimization as there were more parameters to estimate (ages 3-12 as opposed to 5-8 for the catch rate index), however the extent to which this influenced the results was not determined. Secondly, the results of the projections were somewhat different in the two reports. As has been discussed, a dome shaped partial recruitment pattern was deemed appropriate in the 1990 assessment. One consequence of this partial recruitment pattern was a change in $F_{0.1}$ reference point value (0.25 instead of 0.20). It seems that the Advisory Document attempted to describe the projection results relative to the previously used reference points, i.e. $F_{0.1}$ =0.20 rather than 0.25, and, as well, it provided projections for the 1991 TAC which were not carried out by the Subcommittee. Thirdly, the Advisory Document (90/5) does not address the Groundfish Subcommittee advice contained in Subcommittee Report 90/2: "We advise not exceeding the catch corresponding to twice $F_{0.1}$ [174,000t]".

The final report of the Independent Review Panel on Northern cod was released in March 1990. The Harris Panel recommended immediate reduction of fishing mortality to 0.3 and as early as possible to 0.2. Fisheries Minister Valcourt rejected the reduction in fishing mortality recommended by the Harris Panel because of the additional hardships it would produce, following the TAC reduction already announced (from 235,000t in 1989 to 199,262t in 1990) (Lear and Parsons 1993). Instead, the Minister established a Task Force headed by the then Regional Director General of Newfoundland Region, E.B. Dunne, to develop recommendations on how best to implement the recommendations of the Harris Report (Dunne 1990). The "Dunne" Task Force Report was released in October, 1990. Under the assumption that a rebuilding strategy was desirable, it recommended that, as a minimum, age 3+ biomass should be rebuilt to 1,000,000t and that the spawning stock biomass be rebuilt to 450,000t by 1994. Reaching these levels required a reduction in catch. To accomplish this several options were considered, all having the ultimate aim of decreasing F to the $F_{0.1}$ level. It was concluded that constant-catch multi-year TAC's be introduced to reach $F_{0.1}$ and that multi-year plans be continued thereafter. The ultimate goal was a larger stock with more older fish. The Dunne Report provided comparisons of the effect of four constant catch options but did not recommend a specific TAC for 1991 and later years. It did indicate that the $F_{0.1}$ predicted catch for 1991 would have been about 100,000t.

In December of 1990 the Fisheries Minister Valcourt announced a multi-year management plan for Atlantic groundfish stocks. The TAC's for 2J3KL cod for 1991, 1992 and 1993 were set at 190,000t, 185,000t and 180,000t respectively. The rationale for these TAC steps is not known - it did not come from the Groundfish Subcommittee of CAFSAC, the scientific body responsible for carrying out the stock assessments.

The CAFSAC Advisory Document (90/5) did not include advice for 2J3KL cod relative to a multi-year plan, although the Chairperson's summary for all groundfish stocks states that "The extension of multi-year fisheries management plans to groundfish...is one of the major events of the 1990 fisheries management scene". Further, the table summarizing advice for all stocks gave a TAC for 2J3KL cod for 1991 of 190,000t (the first year of the multi-year plan).

1991: The assessment was similar to that conducted in 1990 with respect to the input data and methods. A commercial catch rate index at age was derived in a similar manner including data from 1990. Because catch rates from only1983 and later were used in ADAPT, it was recommended that for future assessments data only from those years should be included in the catch rate standardization analyses. There was no new information presented with respect to the best method for combining divisional catch rate indices. Catch rates for the 1978-90 period showed an increase to 1985 but had been relatively stable since.

The divisional RV survey estimates continued to show large annual fluctuations, particularly after 1987. The 1990 estimate for division 2J was the lowest in the time series while those for 3K and 3L were among the highest in their respective divisions. There was no indication as to the relationship of this variation to movements between divisions or to changes in availability. There was an indication that the cod biomass was found in deeper water in the later years, especially in divisions 2J and 3K. The adaptive survey design used for the 1989 survey (see 1990 assessment) was also used in the 1990 survey in an attempt to minimize variance. It was known that the design would result in some bias in survey estimates. Simulation studies to examine this bias were conducted and presented to the SSS Subcommittee of CAFSAC. These indicated that the size of the bias for over-dispersed distributions may be as large as the CV's on the survey means. This amount of bias was considered unacceptable and it was therefore recommended that the use of the adaptive strategy be discontinued. In subsequent years a method of set allocation was used based on previous years survey data, i.e. more sets were allocated to strata which had cod catches with high variances in the previous surveys.

In estimating stock status several formulations of ADAPT were used. The formulation eventually accepted used ages 3-12 from the RV index and ages 5-12 from the catch rate index, as opposed to ages 5-8 from the catch rate index in the previous assessments. The addition of the older ages was considered more appropriate as it would add more information for estimating abundance at these ages. A dome shaped partial recruitment pattern was again implemented.

In the 1990 assessment, ADAPT formulations used the commercial catch rate index for ages 5-8 with survey results from both the traditional survey design, and from the 2-phase survey design for comparison. The resulting age 3+ population estimates differed by only about 5% from the accepted formulation. As recommended in the 1990 assessment, age 2 estimates were included in the RV index in a formulation of ADAPT. The CV of the age 3 abundance in this formulation improved relative to the accepted formulation but those for the older ages increased. A high proportion (1/3) of the residuals were considered outliers and the age 3 population estimate was unrealistically high. Therefore the results using the age 2 RV index estimates were considered unreliable.

The assessment results (Groundfish Subcommittee Report 91/9) indicated that the age 7-9 mean F in 1990 was about 0.52 representing only a slight decline from 1989 (0.59). The previous estimate of the 1989 F (1990 assessment) was 0.56. The age 3+ population biomass at beginning of 1990 was estimated to be about 1 million tons. The biomass estimate for 1989 was about 10% higher than that estimated from the 1990 assessment. The sizes of the 1986 and 1987 year classes (505 and 645 millions respectively) as estimated from ADAPT, were considered appropriate. Both of these estimates were higher than any since the late 1960s.

The multi-year management plan announced by Fisheries Minister Valcourt in December of 1990 established TAC's for 1991-93 at 190,000, 185,000 and 180,000t respectively, as discussed above. This period of relatively stable TAC's was proposed in the expectation that the stock would rebuild, albeit very slowly (Lear and Parsons, 1993). These TAC's and the estimated catch for 1991 were used in subsequent projections of F and stock size by the Groundfish Subcommittee of CAFSAC. Projections used weights at age as an average of those from 1988-90 and a partial recruitment vector as derived from 1990 Fs with full recruitment at ages 7-9. The 1988-90 year classes at age 3 were set at 300 million, the geometric mean of SPA age 3 numbers from 1978-1990 (1975-87 year classes).

The results indicated that fully recruited F would decrease from 0.44 in 1991 to 0.28 in 1993, just above the $F_{0.1}$ reference level of 0.25. The age 3+ beginning of the year biomass would increase slightly from 1.085 to 1.163 million tons over the same period. This reduction in F and increase in 3+ biomass was driven by the estimated strong 1986 and 1987 year classes. Risk analysis (Restrepo et al, 1991) suggested that the probabilities of F's in 1991 and 1992 being higher than that in 1990 were less than 20%. The risk analysis indicated that the multi-year plan would most likely result in a fishing mortality rate approximately that which would be obtained by applying the 50% rule.

The Advisory Document (91/13) from Steering Committee presented different values of F than those found in the Subcommittee Report (91/9), but gave the same values of population biomass. The Advisory Document suggested that the stock would increase faster than was forecast in the previous year's assessment, largely because of the strength of the 1986 and 1987 year classes and that the $F_{0.1}$ target would be reached in 1993. Steering Committee recommended that the existing multi-year management plan be maintained.

1992 - Although the 1991 assessment indicated a small degree of optimism with regard to potential stock rebuilding largely because of the apparently large 1986 and 1987 year classes, events in 1991 subsequent to the assessment were much more pessimistic. The main cause for concern resulted from reduced Canadian catches in both the inshore and offshore fisheries and a substantial decline in RV indices in the autumn surveys (Fig. 2). Catches by foreign fleets fishing outside the 200 mile zone in division 3L, as estimated by Canadian surveillance, were high (49,000t) in 1991, the second highest by foreign countries since 1977. This was coincident with increased survey biomass in this area (Fig. 3), especially during the spring survey. This situation was considered serious and CAFSAC was requested to conduct a stock assessment in early (January) of 1992.

The January 1992 assessment considered the preliminary data available relative to catch, catch at age, catch and effort, as well as the results from the 1991 autumn surveys. The total Canadian catch in 1991 was about 127,000t, a decline of about 64,000t over that for 1990. The decline was greatest in the fixed gear fishery and was most pronounced for gillnets. Much of the decline resulted from a substantial decline in catches from the relatively new 'offshore' gillnet fishery in the Virgin Rocks area of Div. 3L. Some of the decline was also related to the presence of poor to average year classes at ages 6-8, the ages normally abundant in gillnet catches. Although codtrap catches declined slightly from a relatively high level in 1990, they were comparable to those in 1986-89. There were, however, concerns among inshore fishermen that landings had not increased in proportion to improved fishing power and that the stock decline was probably continuing.

The autumn 1991 survey results indicated a substantial decline (50% biomass and 33% abundance) from 1990 to 1991 with the difference observed mainly at the older (age 6+) age groups (Fig. 4) . Research into migration patterns using acoustic technology indicated densities well below those in 1990 and there was a substantial decline in the relative abundance of large (>60 cm.) fish. Offshore standardized catch rates indicated a sharp decline in 1991. The catch rate index was lower at all ages but this was most pronounced at older ages.

The formulation of ADAPT used for stock estimation was the same as that in the 1990 assessment with the additional year's data added. The 1991 RV residuals were large and negative, an indication that the 1989 and 1990 indices may have been too high or possibly that natural mortality in 1991 was higher than that usually estimated (0.20). The pattern in catch rates residuals observed in the past was more pronounced with the addition of the 1991 data. It was suggested that the catch rate index should be excluded from future assessments of the stock. The analysis indicated that F in 1991 was about 0.5 and that F's in 1989 and 1990 were among the highest in the 30 year SPA time series. It was estimated that the age 3+ biomass in 1991 had declined to about 700,000t and that for 1990 was about 25% lower than what was estimated in the 1991 assessment.

Using year class estimates from the calibrated SPA and a geometric mean of 300 million for age 3 in 1992-1994, projections of F and beginning of year biomass were conducted and were compared to the projections for the same period from the 1990 and 1991 assessments. Catches assumed for 1992 and 1993 were those of the existing management plan, including an estimate for foreign catch. Results from the 1992 assessment were more in line with those using data from the 1990 assessment and indicated that the 1991 assessment was more optimistic relative to stock growth and F reduction. It was concluded that the three year management plan would produce little, if any, reduction in F or increase in biomass throughout its duration. The 1992 $F_{0.1}$ catch was projected to be 95,000t.

Based on the Subcommittee Report (92/2), Steering Committee reported a preliminary estimate of the January 1992 age 3+ biomass estimate at 780,000t and a 1991 spawner biomass estimate at 130,000t, among the lowest observed (CAFSAC Advisory Doc. 92/2). CAFSAC indicated that the fishing mortality would remain high under the current three year fisheries management plan. The assessment was described as preliminary because the statistics on catches by Canada and by foreign countries used in the January assessment would likely be updated in the coming months and additional information on the size composition of the foreign catch might become available. Because Steering Committee considered the assessment to be preliminary, the Advisory Document did not provide the results of the projection at $F_{0.1}$ (TAC of 95,000t) carried out by the Subcommittee. However the Advisory Document stressed that CAFSAC was "very concerned about the low estimate of the adult stock biomass and that continued fishing at the current levels will result in over-harvesting of the 1986 and 1987 year-classes at an early age".

In response to CAFSAC advice, Fisheries Minister Crosbie undertook several management measurements to protect the stock. These included a reduction in the 1992 TAC from 185,000 to 120,000t (well above the Groundfish Subcommittee $F_{0.1}$ projection of 95,000t) with the offshore quota reduced to 20,000t for the first 6 months. Although a NAFO moratorium on cod fishing already existed for the Regulatory area in Div. 3L, Canada also requested that other foreign countries adopt similar measures in their management of cod fisheries outside of 200 miles. Before taking any initiative on management, one group of countries, the European Economic Community (EEC) convened a Group of Experts in March of 1992 to examine the scientific background of the issue and to give preliminary advice to the EEC. The results of this review were documented in NAFO SCS Doc. 92/16. A summary of these results is as follows:
1) For their review, the Group considered the 'official' catch statistics as more appropriate than the Surveillance estimates of Canada and also used EEC countries sampling to estimate removals at age in 1991. The Surveillance estimate was about 17,500t higher than the official statistics(about 32,000t).

2) The decline in Canadian catch rates inside of 200 miles was not observed outside, although cod were found in deeper waters. Information from one fleet indicated a decline in 1992.
3) Fishing skippers were reporting catches of cod in poor condition.
4) The Group used the L/S method of tuning the SPA and, with data and assumptions as close to the CAFSAC assessment as possible, the results were very similar.
5) Analyses with a revised catch and catch at age for 1991 gave very similar results to the CAFSAC estimates although the revised figures were used for further analyses.
6) A flat-topped partial recruitment pattern was used which produced a slightly higher F but little change in biomass.
7) Analysis using divisionally separated RV indices was considered but it was concluded that the combined index was more appropriate.
8) A maturity ogive was used to calculate spawning stock biomass (SSB) but there was little difference from that obtained using a knife-edged pattern (ages 7 and older considered to all be mature).
9) The results of retrospective analyses were similar to those obtained by CAFSAC with the main feature being the large discrepancy between the results obtained in the 1991 and preliminary 1992 assessments, caused by the effects of highly variable RV indices.
10) Analyses with both the RV and commercial catch rate data indicated that the two series were not very compatible.
11) The effect of changes in effort by the Canadian and EEC fleets on SSB per recruit and yield per recruit appeared to be influenced by a change in distribution of the stock making it more available outside the 200 mile zone. It was concluded that the major decline in the stock was not related to increased fishing effort.
12) Their main conclusion was that the results were extremely dependent on the "noise" in RV data rather than the SPA method used or the input parameters. They were unable to produce a definite picture of the stock status and to produce the basis for a catch forecast. Consequently, they were not "...in a position to recommend any change in the management strategy adopted so far". It was considered unlikely that the decrease in abundance was caused by overfishing by either the Canadian or foreign fleet and that changes in distribution and natural mortality could had have a role.

The stock was assessed again by the Groundfish Subcommittee of CAFSAC (Subcommittee Report 92/10) in May of 1992. Data presented at the preliminary assessment in January were updated and new information was reviewed. Changes to input data since the January assessment included a revision of the total catch and catch at age estimates for 1991. In January sampling from the foreign fleets was available only from Portugal while the new age composition included sampling from Spain and Germany. The revised age composition indicated fewer cod at ages 3-5 in 1991. Age composition data were also available for Spain and Portugal for 1990 and these were used to revise the catch at age. The revised age composition of the catch for 1990 indicated more younger cod than previously estimated.

Environmental information relative to 2J3KL were reviewed in the May Subcommittee meeting. These data indicated that: water temperatures were below normal in 1991 with negative anomalies over the whole area; the spatial extent of ice coverage was greater than normal and persisted for a longer period of time; and the cold intermediate layer of the Labrador current was at or near its long term maximum. The influence of these and other factors on the cod stock and fisheries could not be determined by the Subcommittee. It was considered that the more pronounced declining trend in cod abundance in the north may have resulted from long term and large scale environmental changes. It was noted that there was also evidence of reduction of biomass of other groundfish species for which there was little or no commercial exploitation.

Results from a February 1992 acoustic survey indicated that mean densities were lower in 1992 than 1991. The general distribution and size of cod encountered throughout the survey area during 1991 and 1992 were similar to those determined during the previous autumn. In 1992 cod were generally more dispersed throughout divisions 3K and 3L with concentrations being smaller than those encountered in previous years.

In addition to the standard catch rate index, other indices of catch rate were considered. A spatial analysis technique (SPANS) was used to convert estimates of catch rate and area fished from observer data into a biomass index. The index showed a decline from 1988 to 1991. The analysis was considered preliminary and was not used for calibrating an SPA. A codtrap catch at age index was also examined. The index indicated higher levels of abundance than all the other indices and it was considered that additional analyses were necessary before it could be used for calibration purposes.

In the determination of stock status several formulations of the ADAPT framework as well as the L/S calibration were used. The accepted versions were those using only the RV indices. The ADAPT analysis with the catch rate index produced strong patterns in the residuals. These patterns, which indicate lack of fit between the SPA estimates of biomass and the index, was observed in the past. For the May 1992 assessment they were considered sufficient to warrant excluding the catch rate index from the calibrations.

The results from ADAPT indicated all positive residuals for 1989 and 1990 and all negative for 1991. Information from the offshore fishery in early 1992 (reduced catch rates and preponderance of small fish) as well as from RV, acoustic and commercial scouting surveys (lower densities and smaller fish) suggested that the lower RV index in 1991 was more likely the result of mortality than availability. The unweighted mean F in 1991 was estimated from ADAPT at about 0.70, the age 3+ biomass at 640,000t tons and the SSB (age 7+) at 110,000t (Figs. 5 and 6). The L/S calibration had a similar formulation to that of ADAPT. The results were more pessimistic with the age 7-9 F at about 1.4, the age 3+ biomass and SSB in 1991 of 500,000t and 72,000t respectively (Figs. 5 and 6).

Both analyses indicated a sharp increase in F from about 0.5 in the mid 1980s to between 0.7 and 1.0 (ADAPT) or greater than 1.0 (L/S) in 1989-91. As well, the ADAPT calibration indicated a decline in F in 1991 whereas that from L/S continued to increase (Fig. 6). The difference in the results were attributed to differences in the degree of influence each method placed on each survey year. Results from the L/S are strongly influenced by the index value in the terminal year while those from ADAPT are influenced by the survey index over a longer time period. The low survey index in 1991 would consequently have produced a more pessimistic outcome in the L/S method.

Retrospective analyses were conducted back to 1985 using both calibration techniques (Fig. 7). In general the ADAPT estimates were more optimistic that those from L/S. The L/S calibration gave more variable results when the terminal year RV indices were substantially different from previous years as was the case in 1986 and 1991. Results from both methods were very sensitive to the 1991 RV index with both indicating sharp change between 1990 and 1991. This suggested that neither model adequately accounted for the stock changes indicated by the data from 1991. However, both methods indicated that the more recent trends in F were radically different from those observed in the previous assessments of the stock. Neither formulation was considered to adequately account for a possible increase in natural mortality in 1991 although the formulation used with ADAPT was considered more sensitive to major shifts in natural mortality. It was concluded that the decline in biomass could not be ascribed to fishing alone (reported removals and surveillance estimates) and that it was likely that deaths due to natural causes was higher in 1991 than usual.

Stock status could not be determined precisely but all information indicated a very low level. Consequently, projections of catch, biomass and F were conducted using the results of both calibrations for several options of catch or fully recruited F for 1992 and SSB at the beginning of 1993 (Subcommittee Report 92/10, p17). The projected catch for 1992 at the standard reference point of $F_{0.1}$ was 79,000t with ADAPT and 50,000t with L/S. It was felt that results from the 1991 autumn RV survey were representative of stock status based on information from the fishery in 1992 as well as the results from other surveys. Consequently, results from the L/S method were considered more appropriate as it was influenced strongly by indices for the terminal year. It was concluded from the assessment that the stock was at a very low level with both total biomass and SSB at or near the lowest in the time series. The 1992 fishery would be dominated by two year classes (1986 and 1987) and the 1988 year class was estimated to be weak. The Groundfish Subcommittee recommended that the 1992 catch be restricted to the lowest possible level (Subcommittee Report 92/10).

The stock was also assessed by the Scientific Council of NAFO at a Special Session in June of 1992 (NAFO Scientific Council Reports, 1992, p.29-44). "Because of the EC failure to curtail its fishery on the Nose of the Grand Bank, Canada requested the NAFO Scientific Council to review the status of this stock" (Lear and Parsons 1993. p.84). The input data and analyses conducted for this assessment and that conducted by CAFSAC in May were essentially the same. Only new information or analyses are described below. The results from a summer hydroacoustic survey indicated that there was a substantial decline in larger (>60 cm.) cod from 1990 to 1992 and that average densities within aggregations had declined over the same period. Analyses were conducted using ADAPT and L/S, each with both the Canadian surveillance and the officially reported catch estimates for 1991. An analysis conducted relating the extent of the

Cold Intermediate Layer of the Labrador current to year class strength suggested that the 1990 and 1991 year classes might be weak and 1989 close to average. The conclusions reached were similar to those of CAFSAC. The stock had declined rapidly since 1989 and was at or approaching its lowest observed level. NAFO found the exact cause to be unclear. Projections were conducted only for 1992 because of uncertainties associated with longer-term projections. Depending on the calibration method and the level of foreign catch used for 1991, the estimated $F_{0.1}$ catch for 1992 ranged between 50,000t and 91,000t. It was recommended that the lower value would be more appropriate given the uncertainties and the obvious need for caution.

The CAFSAC Advisory Document (92/7) included results from both the May CAFSAC and June NAFO meetings and was released in early July. This report suggests that the stock declined abruptly between 1990 and 1991.. A graph was included which indicated a decline of about 50% (Fig. 8). However the graph could be misleading in that the results presented were SPA biomass for 1962-90 from the 1991 assessment along with the 1991 SPA biomass from the 1992 assessment. When assessments were updated annually it was common occurrence to have the estimates for years closest to the terminal year revised downwards. The 1992 assessment indicated that the 1990 biomass (3+) was in the order of 720,000t as opposed to the value of about one million tons estimated in the 1991 assessment (Fig. 9). The abruptness was in fact related to the difference in the estimated 1991 biomass and what it was thought to be in 1990 (i.e. the retrospective problem). A more appropriate description might have been that the previously observed decline was continuing.

The Advisory Document providing catch advice for 1992 included the advice provided by the two assessments which was that the $F_{0.1}$ catch would have been 50,000t , with the added proviso that, in view of the low stock status, the 1992 catches were to be kept at the lowest possible level. As a result of the assessments Fisheries Minister Crosbie imposed a 2 year moratorium on the 2J3KL cod fishery on July 2 to continue until the spring of 1994.

7.0 Other significant events or topics with assessment implications

7.1 Retrospective Analysis

It was recognized fairly early in the assessment process that estimates from SPA in the most recent or current assessment were different, for comparable years, from those in the previous years assessment. The trend was toward a decrease in population size and corresponding increase in F with the most recent assessment. This problem was first observed for the northern cod stock in the 1979 assessment, and then in 1983,1984, 1985 assessments (see Section 6.0). Subsequently, this problem was a main concern of the Newfoundland Inshore Fisheries Association (NIFA) in their 1986 Report (Keats et al. 1986). It was also addressed in a special meeting of CAFSAC in November of 1986 (Subcommittee Report 86/16; Advisory Doc. 86/25). CAFSAC also considered the issue at a meeting of a Working Group on Accuracy of Assessments in early 1986. This Group was struck in late 1985 to address concerns from industry relative to some abrupt changes in advice and the implications this had on the accuracy of the assessments. Retrospective analysis had revealed substantial discrepancies between the current and past views of status of some stocks and that the assessments had routinely overestimated stock size. This problem with stock assessments has been reported for other north west Atlantic cod stocks (Sinclair et al., 1991).

The overestimation of abundance and underestimation of F was greatest for the fully recruited age groups, less for the partially recruited ages, and least for the prerecruits. The pattern was found to occur in the assessments of several stocks and was found in different SPA assessment methods. The Working Group Report indicated a variety of potential sources of error in SPA which could have resulted in this bias. Further analyses were suggested by the Working Group to identify the source of the problem.

In February of 1989 the SSS Subcommittee met to evaluate the use of retrospective analysis as a tool for estimating the accuracy of past stock size estimates. In doing so it also addressed some of the recommendations of the 1986 Working Group. It was generally concluded that the precision of stock size estimates in the final year would only be as good as the accuracy of the abundance index. Age disaggregated survey indices had CV's of about 30% while commercial catch rates had lower CV's. However there was uncertainty about catchability at age for commercial gear remaining constant over time. Assessments also included assumptions relative to natural mortality (M), estimates of F on the oldest age classes and the accuracy of nominal catch data. It was stated in the Subcommittee Report that it was "clear that estimates of population size from the converged part of the SPA do not necessarily represent the true population size for those years". The development of better indices of abundance was considered essential for improving the accuracy and precision of population estimates. There were other recommendations as to further work necessary on the issue but there were none with respect to any means of adjusting assessment SPA's to account for retrospective pattern. The retrospective problem was also addressed in a November 1990 meeting of the SSS Subcommittee in the form of a progress report and future plans.

Tables 3 and 4 of the present report provide results from a retrospective analysis of changes in year class strength and F. Year class estimates were variable between assessments. The most recent large year classes (1986 and 1987) were generally revised downward while some previously observed as being large (1980-82) increased with subsequent assessments.

7.2 Northern Cod Seminar

In August 1979 DFO sponsored a seminar to focus on the development of a long range plan for harvesting the northern cod resource. Participants included representatives from Federal and Provincial governments, fishing companies, unions, and fishermen. It was a time of general optimism as Canada had recently extended jurisdiction over the majority of the stock area and stocks were expected to improve. Two items resulting from the Seminar are of special interest with regard to assessments.

1) It was recommended that future TAC' s (to 1985) be established at a conservative level, and, therefore that the approach for the preceding 2 years of a level below $F_{0.1}$ was adopted. This would enable the stock to rebuild rapidly and it would allow for the uncertainty expressed by scientists regarding knowledge about the stock and uncertainties regarding stock forecasts.
2) Long term (to 1985) catch projections for the northern cod resource were provided in a presentation to the seminar (A.T. Pinhorn, unpublished report). These indicated a catch of between 350,000t and 400,000t by 1985, depending on the reference level used. A similar catch level was projected to 1987 in a 1982 report (Kirby 1982). In both cases the reports included statements describing the great deal of uncertainty associated with the estimates as they were based on a number of assumptions, particularly with regard to recruitment levels. These projections were gradually translated into expectations, and in spite of the caveats and caution that was expressed, Science Branch was expected to deliver when 1985 and 1987 arrived. However, the stock did not grow at the projected rate and this was translated as "mistake" in the stock assessments. It was a constant source of aggravation and frustration to those involved with the 2J3KL assessment in that the context in which the projections were undertaken and the statements regarding the associated uncertainty were not acknowledged by those who wished to criticise the stock assessment process. In later years there was a reluctance to provide similar long term projections unless the potential effect on catch of the variability of input parameters was specifically included.

7.3 NIFA (Keats) Report

The Newfoundland Inshore Fisheries Association (NIFA) was formed in August of 1986 in response to increasing offshore catches coincident with a recent decline in inshore catches from 1982 to 1986. The group sponsored an investigation on the 2J3KL cod stock which questioned the results from stock assessments. A report was produced on December 3, 1986 by D. Keats of Memorial University and presented to DFO personnel. DFO criticism of the material presented was substantial and this lead to a revised report by the original author as well as by Dr.'s Green and Steele of Memorial University. The second report did not remove all of the errors made in the first report. The report was not particularly enlightening to those involved with assessments. The recommendations (a total of 15) related to stock assessments highlighted issues which were already well known problem areas and which were receiving attention with the resources available. The recommendations were responded to by the Chairman of CAFSAC (letter to the NIFA chairman in July of 1987) and to a certain extent during the 1987 assessment (CAFSAC Advisory Document 87/17). One of the major issues was the retrospective problem as presented in Advisory Doc. 86/25. It is important to note that knowledge of a retrospective problem within DFO stock assessments preceded the Keats report by several years.

7.4 TGNIF (Alverson) Report

The 1987 assessment of CAFSAC was generally optimistic with respect to estimated increasing stock size and a declining trend in F to a level in 1986 that was the lowest in the time series. However, inshore catches did not parallel the estimated stock increase as there had been a decline from 1982 to 1986. Over this period fixed gear catches from Div. 3K declined from 42Kt to 29Kt while those from Div. 3L declined from 56Kt to 31 Kt. In response to fishermen's concerns, Fisheries Minister Siddon, on 4 August of 1987, announced the establishment of the Task Group on the Newfoundland Inshore Fishery (TGNIF) to investigate the nature and reason for the recent declines in the inshore catches. The group was composed of five prominent scientists with expertise in the stock assessments (Dr. D.L.Alverson (Chair), Dr.'s F.W.H. Beamish, John Gulland, Peter Larkin and Mr. John Pope). As part of their investigation, the Group reviewed the most recent assessment of CAFSAC and, as well, conducted their own analyses with SPA. In addition to the indices regularly used, the group also did SPA by division, used a 'corrected' (by R. Myers, DFO) RV index which attempted to account for timing of the survey, and tuned the SPA using the L/S approach. Details of these analyses are not included in their Report but some were provided to assessment biologists at the North West Atlantic Fisheries Center by J. Pope, one of the Task Group experts.

In his review, Pope found that the best levels of fit obtained in CAFSAC Res. Doc. 87/42 were "disappointing suggesting that the data are not particularly well fitted and that alternate levels of terminal F could not easily be rejected" (J. Pope, pers. comm.). Because of the systematic underestimation of F that had been observed, he considered it possible that there could be some intrinsic bias caused by the methods that had been used. This pattern of underestimation was presented in Table 4 of their Report. An updated version of this Table is shown in Table 4 of the present document. Adjusting for this bias would have suggested a terminal F in 1986 of 0.4 instead of 0.21 as adopted by CAFSAC. From the results of his analyses with different data sets and methods he concluded that "... a wide range of possible values of F vector for 1986 exist and that, while the CAFSAC 86/47 assessment is within this range of variation, it lays toward the bottom end of the range". There was little doubt that Pope favoured the upper end of his range, placing F in the vicinity of 0.40.

It was reported (see Advisory Doc 89/1) that the results of the Task Group and the CAFSAC 1987 assessment were quite similar with respect to estimates of stock size and the causes for the decline in the inshore fishery since 1982. It concluded that the stock was increasing but at a slower rate than indicated by CAFSAC and that F was somewhat higher. It was indicated that conclusions of TGNIF differed from that of CAFSAC only in degree and this could be traced to their method of SPA, the time series examined, and its application to the three NAFO divisions. The report also acknowledged that predicting precise quantitative changes in stock abundance would always be difficult and that there would always be differences in the interpretations of different scientists.

The Task Group recommended a cautious approach to managing the stock to protect the inshore fishery and that as a minimum the 1988 TAC should not be higher than the 1987 TAC. The 1988 TAC was subsequently set at the 1987 level of 266,000t which was below the estimated $F_{0.1}$ level (293,000t) as determined by CAFSAC.

7.5 Northern Cod Review Panel (Harris) Report

Following the September 1988 and January 1989 CAFSAC assessments and their resultant substantial change in perceived status of the stock, Minister of Fisheries Siddon announced on 12 February 1989 the formation of the Northern Cod Review Panel headed by L. Harris of Memorial University of Newfoundland. The mandate of the Panel was to.. "consider the scientific advice provided since 1977 on Northern cod and the current state and size of the stock, and make recommendations regarding stock assessment methods and means with a view to better forecasting the size, growth potential and behavior of the stock in the future" (Harris Report 1990).

The Report covered a wide range of topics from the history of the stock to its current management. In its evaluation of the most recent stock assessment, several different methods were used which were current predominantly in the ICES forum. These included the Laurec-Shepherd, CAGEAN, and Extended Survivors analysis. The results from these analyses provided a range (0.35-0.62) of possible F values although they believed that the 'true' value was at least 0.45. Consequently, it was accepted that the CAFSAC estimate obtained from ADAPT in the January 1989 assessment of 0.44 was in the right domain. Their first recommendation was the reduction of this F to at least 0.3 and at the earliest feasible date to the level of 0.2. It was acknowledged that the methodologies used by CAFSAC were similar to those used by scientists from other countries. Because the indices used for tuning are inherently variable, it was recommended that other independent indices of abundance should be developed (such as that from inshore fisheries) and, as well, that the indices currently used for 2J3KL cod required much closer scrutiny.

There were many other issues addressed by the Harris Report which will not be discussed here. There were a total of 29 recommendations with 10 dealing directly with scientific research. In a response to the Report, Fisheries Minister Valcourt, on 7 June 1990, established a Task Force to develop recommendations as to how best to implement the recommendations of the Harris Report (Dunne 1990). The aftermath of the Harris Report also saw the establishment of the Atlantic Fisheries Adjustment Program (AFAP) which included funding for an expanded research program on northern cod, better known as the Northern Cod Research Program.

The Report states (page 2) that from 1977 to the mid 1980's we were somehow caught up in "the euphoria" that had been engendered by the declaration of " the 200 mile zone" and that "in those circumstances, scientists, lulled by false data signals and, to some extent, overconfident of the validity of their predictions, failed to recognize the statistical inadequacies in their bulk biomass model and failed to properly acknowledge and recognize the high risk involved with state of stock advice based on relatively short and unreliable data series". The Panel did recognize that their blunt criticism was itself the product of hindsight and that the data available for assessments had left a lot to be desired. However they go on to state that "if there had not been such a strong emotional and intellectual commitment to the notion that the $F_{0.1}$ strategy was working, the open and increasing skepticism of inshore fisherman might have been recognized as a warning flag demanding more careful attention to areas of recognized weakness in the assessment process". We trust that the detailed narrative of stock assessments presented above provides a factual basis on which their pronouncement can be judged.

8.0 References

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9.0 Appendices

Appendix 1

List of assessment meetings for 2J3KL cod including places and dates.

1977	- Assessments Subcommittee of STACRES.	Dartmouth. N.S.	April 19-27
	- Annual Meeting of STACRES.	Ottawa, Ont.	June 7.
1978	- Assessments Subcommittee of STACRES.	Dartmouth, N.S.	April 4-11
	- Annual Meeting of STACRES	Bonn, F.R. Germany	May 18-28
1979	- Assessments Subcommittee of STACRES.	St.John's, Nfld.	March 28- April 9
1980	- Scientific Council Meeting. of STACFIS	Dartmouth, N.S.	June 3-9
1981	- "	"	June 8-15
1982	- "	"	June 8-15
	"	"	September 8-13
1983	- "	"	June 8-21
1984	- "	"	June 6-24
1985	- "	"	June 5-20
1986	- "	"	June 4-18
	- "	"	September 8-11
	- Groundfish Subcommittee of CAFSAC	St.John's, Nfld.	November 7-9
1987	- "	Dartmouth, N.S.	May 4-15
1988	- "	St. Andrews, N.B.	September 12-23
1989	- "	St. John's, Nfld.	January 16-19
	- "	"	May 1-12
1990	- "	"	January 22-26
1991	- "	Dartmouth, N.S.	May 6-17
1992	- "	Moncton, N.B.	January 27-29
	- "	Mont Joli, P.Q	May 4-15
	- Scientific Council meeting of STACFIS	Dartmouth, N.S.	June 1-3

CAFSAC Groundfish Steering Committee Chairs

1987 - 1988 J. S. Beckett
1989 - 1992 J. -J. Maguire

Appendix 2.

List of Documents associated with assessments by year from 1977-92.
(Note: This is not intended as a complete list of all documents presented at the Assessment meetings but represents those that were used to develop the summaries in Section 6.0. The list also includes some Working Papers where no suitable research document is available to cite. As complete annual lists of these Papers were not accessible, those included only represent Papers retained by the first author.)

1977
ICNAF. Redbook, Report of STACRES. p54-55.

Konstantinov, K.G. and A. Noskov. USSR research report. ICNAF Summ. Doc. 77/VI/15, 39p.

Stein, M. Hydrographic conditions on Hamilton Bank (Div. 2J) in early November 1976. ICNAF Res. Doc. 77/VI/55, 3p.

Wells, R. Div. 2J-3KL cod predictive run. ICNAF Working Paper 77/IV/13.

Wells, R. Status of the cod stock in Div. 2J+3KL + Addendum. ICNAF Res. Doc. 77/VI/26. 14p.

Wells, R. Recaptures of cod tagged in Div. 2J, 3K, and 3L in 1962-66. ICNAF Res.Doc. 77/VI/45 3p.

1978
ICNAF. Redbook, Report of STACRES. p57-58.

Wells, R. Status of the cod stock in Divisions 2J, 3KL. ICNAF Res. Doc. 78/VI/66, 10p.

1979
ICNAF. Redbook, Report of STACRES, p69-70.

Messtorff, J. Division 2J cod: Trawlable biomass in numbers ('000) of 2 and 3 year old fish from stratified random surveys conducted by the Federal Republic of Germany in 1972-78. ICNAF Working Paper 79/IV/97.

Messtorff, J. and R. Wells. Data from Federal Republic of Germany research vessel surveys in Div. 2J. ICNAF Working Paper 79/IV/100.

Wells, R. Status of the cod stock in Divisions 2J+3KL in 1978. NAFO SCR Doc. 80/VI/63, 5p.

Wells, R. A first look at the status of the cod stock in Div. 2J+3KL in 1978 + Addendum. ICNAF Working Paper 79/IV/98.

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Wells R. and C.A. Bishop. Length frequencies and age compositions of cod from the catches of various fleets in 1978 as collected by Canadian observers. ICNAF Working paper 79/IV/66.

<u>1980</u>
Gavaris, S. Assessment of the cod stock in NAFO Divisions 2J+3KL. NAFO SCR. Doc. 80/VI/81, 5p.

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Minet, J.P., A. Forest, and J.C. Poulard. Dynamics and assessment of the Labrador-Northeast Newfoundland cod stock complex (Divisions 2J and 3KL). NAFO SCR. Doc. 80/VI/89, 21p.

NAFO. Report of the Scientific Council, p76-77.

Postolaky, A.I. State of the cod stocks off Labrador. NAFO SCR. Doc. 80/VI/61.

Wells, R., and C.A. Bishop. Some recent changes in the status of the cod stock in Divisions 2J+3KL. NAFO SCR. Doc. 80/VI/101, 15p.

<u>1981</u>
Bulatova, A., Yu., V.M. Kiseleva, K.G. Konstantinov, A.I. Postolaky, and V.A. Chekova. Preliminary assessments of some demersal fish stocks in the Newfoundland and Labrador areas. NAFO SCR. Doc. 81/VI/18, 9p.

Gavaris, S. Surplus Production analysis for the cod stock in NAFO Divisions 2J+3KL. NAFO SCR. Doc. 81/VI/65, 6p.

NAFO. Report of Scientific Council, p36-36.

Wells, R. Status in 1980 of the cod stock in NAFO Divisions 2J+3KL. NAFO SCR. Doc. 81/VI/66, 13p.

<u>1982</u>
Ad hoc Working Group. Divisions 2J+3KL cod + Addendum. NAFO Working Paper 82/VI/35.

Bishop, C.A. and S. Gavaris. Assessment of the cod stock in NAFO Divisions 2J3KL. NAFO SCR Doc. 82/VI/68, 12p.

Bishop, C.A. and S. Gavaris. Further considerations of the cod stock in DIv. 2J+3KL. NAFO SCR Doc. 82/VI/111, 24p.

Forest, A. Length and age composition and abundance indices for cod in Div. 2J+3KL from French research surveys, 1976-82. NAFO Working Paper 82/IX/47.

Halliday, R.G. Canadian surveys in Div. 3L - Survival ratios. NAFO Working Paper 82/VI/38.

Larraneta, M.G. An approach to the stock-recruitment relationship of cod (Gadus morhua) in divisions 2J and 3KL. NAFO SCR Doc. 82/IX/77.

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Messtorff, J. Survey estimates for cod in Division 2J from data obtained by RV Antorn Dohrn in autumn of 1982. NAFO SCR Doc. 83/VI/63, 4p.

NAFO. Report of Scientific Council. p37-38.

Pinhorn, A.T. Further considerations of Div. 2J3KL cod + Addendum. NAFO SC Working Paper 83/VI/49, 7p.

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Baird, J.W., C.A. Bishop, and R. Wells. Estimates of age and length at maturity for cod in NAFO divisions 2J+3KLNO. NAFO SCR Doc. 86/122, 3p.

CAFSAC. Annual Report No. 9. (Advisory Doc. 86/25), p287-318.

CAFSAC. Groundfish Subcommittee Report. 86/16, 27p.

Kulka, D.W. Estimates of discarding by the Newfoundland fleet in 1985 with reference to trends over the past 5 years. NAFO SCR Doc. 86/95, 20p.

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CAFSAC. Groundfish Subcommittee Report. 87/9, p4-12

Lear, W.H. Factors which may have contributed to the relatively lower inshore cod catches in certain areas in 1985 and 1986. CAFSAC Res.Doc. 87/1, 10p.

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Baird, J., J.M. Hoenig, V. Restrepo, and N. Payton. Uncertainties, risks and costs associated with the management options for northern cod. CAFSAC Working Paper 91/103.

Bishop, C., E. Murphy, and J. Baird. A review of cod tagging data 1978-1990 related to the various cod fisheries occurring in NAFO Division 3L. CAFSAC Working Paper 91/97.

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Table 1. Historical catches (t) of cod from NAFO Divisions 2J3KL for the period 1959-92.

	2J				3K				3L				2J3KL			
	Offshore mobile gear		Fixed gear		Offshore moblie gear		Fixed gear		Offshore mobile gear		Fixed gear					
Year	Can.	Other	Can.	Total	Can.	Other	Can.	Total	Can.	Other	Can.	Total	Total Canada	Total Other	Total	TAC
1959	0	46372	17533	63905	0	97678	56264	153942	4515	51515	85695	141725	164007	195565	359572	
1960	1	164123	15418	179542	53	74999	47676	122728	7355	63985	94192	165532	164695	303107	467802	
1961	1	243144	17545	260690	0	64023	31159	95182	4675	73899	70659	149233	124039	381066	505105	
1962	0	226841	23424	250265	0	47015	42816	89831	4383	90276	72271	166930	142894	364132	507026	
1963	1	197868	23767	221636	0	79331	47486	126817	4446	83015	73295	160756	148995	360214	509209	
1964	13	197359	14787	212159	0	121423	40735	162158	10158	142370	75806	228334	141499	461152	602651	
1965	0	246650	25117	271767	21	50097	26467	76585	7353	130387	58943	196683	117901	427134	545035	
1966	39	226244	22645	248928	13	58907	32208	91128	8253	120206	55990	184449	119148	405357	524505	
1967	28	217255	27721	245004	114	78687	24905	103706	13478	200343	49233	263054	115479	496285	611764	
1968	4650	355108	12937	372695	1849	119778	40768	162395	15784	211808	47332	274924	123320	686694	810014	
1969	30	405231	4328	409589	56	80949	24923	105928	18255	151945	67973	238173	115565	638125	753690	
1970	0	212961	1963	214924	92	78274	21512	99878	14471	137840	53113	205424	91151	429075	520226	
1971	0	154700	3313	158013	31	61506	21111	82648	11976	148766	38115	198857	74546	364972	439518	
1972	0	149435	1725	151160	7	133369	14054	147430	4380	109052	46273	159705	66439	391856	458295	
1973	1123	52985	3619	57727	108	159653	13190	172951	1258	97734	24839	123831	44137	310372	354509	666000
1974	0	119463	1804	121267	19	149189	10747	159955	880	67918	22630	91428	36080	336570	372650	657000
1975	410	78578	3000	81988	189	112678	15518	128385	670	53770	22695	77135	42482	245026	287508	554000
1976	94	30691	3851	34636	771	79540	20879	101190	2187	40998	35209	78394	62991	151229	214220	300000
1977	525	39584	3523	43632	1051	26776	28818	56645	5362	26799	40282	72443	79561	93159	172720	160000
1978	4682	17546	6638	28866	7027	6373	29623	43023	9213	12263	45194	66670	102377	36182	138559	135000
1979	9194	6537	8445	24176	21572	16890	27025	65487	14184	12693	50359	77236	130779	36120	166899	180000
1980	13592	7437	17210	38239	21920	6830	37015	65765	15523	13963	42298	71784	147558	28230	175788	180000
1981	22125	4760	14251	41136	23112	3847	23002	49961	21754	15070	42827	79651	147071	23677	170748	200000
1982	58384	8923	14429	81736	8881	4074	42141	55096	27181	9271	56490	92942	207506	22268	229774	230000
1983	37276	4158	10748	52182	31621	2815	40683	75119	39123	10920	55001	105044	214452	17893	232345	260000
1984	9231	2782	13150	25163	48114	11059	35143	94316	47668	15973	49351	112992	202657	29814	232471	266000
1985	1466	78	10211	11755	68880	12945	30368	112193	36863	31176	39306	107345	187094	44199	231293	266000
1986	5734	7859	12916	26509	62086	5781	28384	96251	57805	53946	32202	143953	199127	67586	266713	266000
1987	39344	3999	16022	59365	39686	6160	27442	73288	44612	25916	36743	107271	203849	36075	239924	256000
1988	41468	9	17112	58589	40260	50	33820	74130	57805	26748	51405	135958	241870	26807	268677	266000
1989	33626	1003	23304	57933	37350	1179	20711	59240	40958	36621	59238	136817	215187	38803	253990	235000
1990	17883	183	14505	32571	26920	504	27516	54940	31187	25488	75266	131941	193277	26175	219452	199262
1991 [1,2]	621	82	2214	2917	30112	311	13332	43755	30264	49660	45416	125340	121959	50053	172012	190000
1992 [3,4]	0	0	18	18	584	273	884	1741	13627	14610	10960	39197	26073	14883	40956	0

[1] Includes French catch and an estimate of foreign catch by Canadian surveillance in 3L.

[2] Figure for Canadian fixed gear is 4000 t less than Canadian statistics as this amount is concidered 3NO catch misreported as 3L.

[3] Other offshore catch in 3L derived from reported catch and Canadian surveillance estimate for foreign catch.

[4] Canadian fixed gear in 3L includes 5000 t catch from the recreational fishery after the moritoriam was declares.

Table 2. Summary of the northern cod stock assessments from extension of jurisdiction to moratorium.

Year	Management approach: Accepted objective	Management approach: Equivalent F	Equivalent TAC	F0.1 TAC	Actual TAC	Catch	Retrospective F
1977	F0.1	0.20	160,000	160,000	160,000	172,720	0.521
1978	Below F0.1	0.16	135,000	162,000	135,000	138,559	0.501
1979	Below F0.1	0.16	180,000	197,000	180,000	166,899	0.443
1980	Below F0.1	0.16	180,000	212,000	180,000	175,788	0.297
1981	Below F0.1	0.16	200,000	250,000	200,000	170,748	0.329
1982	Below F0.1	0.16	230,000	270,000	230,000	229,774	0.436
1983	Below F0.1	0.16<F<0.2	260,000	270,000	260,000	232,345	0.443
1984	F0.1	0.20	266,000	266,000	266,000	232,471	0.481
1985	F0.1	0.20	268,000	268,000	266,000	231,293	0.539
1986	F0.1	0.20	244,000	244,000	266,000	266,713	0.530
1987	F0.1	0.20	246,000	246,000	256,000	239,924	0.555
1988	F0.1	0.20	293,000	293,000	266,000	268,677	0.744
1989	Fstatus quo*	0.44	252,000	125,000	235,000	253,990	1.007
1990	50% rule**	0.32	190,000	95,000	199,262	219,452	1.379
1991	Multi-year***	-	190,000	100,000	190,000	172,015	2.501
1992	Multi-year	-	120,000	95,000	120,000	40,961	3.424

* Fstatus quo implies that the objective was to set the TAC so that the F value would remain at the same level as the value in the previous year.
** 50% rule implies that the objective was to let the fishing mortality exceed F0.1 under certain conditions (see text for details).
*** Multi-year implies a plan to reduce the TAC in arbitrary steps towards F0.1 (see text for more details).

Table 3. Input and estimated values for recruits age 4 (1977-87) and age 3 (1989-92) used in the stock assessments from 1977 to 1992.

Assessment Year	Year classes																		
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1977	350	550	400	500	>														
1978		530	465	432	500	>													
1979		500	510	400	200	500	>												
1980					125	125	500												
1981					125	200	500												
1982						270	500	500											
1983							550	400	400										
1984								400	400	250									
1985							400	300	350	400	250								
1986								310	375	400	390	250							
1987									473	473	473	300	265						
1988																			
1989													255	344	300				
1990														257	475	300			
1991															505	645	300	>	
1992													ADAPT		385	520	175	270	>
1992													L/S		300	450	165	250	>

> Denotes use for yearclass strengths for subsequent years in projections.

Table 4. Annual values of F (ave. ages 7-10) for each assessment year (1975-91) as well as F's estimated for each of these years in subsequent assessments (1984-92).

Fishing Year	Assessment Year								
	1984	1985	1986	1987	1988	1989	1990	1991	1992
1975	1.03	1.04	1.08	1.09	-	1.09	1.04	1.05	0.98
1976	1.14	1.12	1.23	1.17	-	1.25	1.16	1.18	1.17
1977	0.63	0.64	0.53	0.54	-	0.59	0.54	0.55	0.52
1978	0.45	0.50	0.51	0.53	-	0.53	0.46	0.5	0.53
1979	0.45	0.49	0.48	0.5	-	0.51	0.44	0.48	0.47
1980	0.26	0.29	0.31	0.32	-	0.35	0.29	0.32	0.32
1981	0.24	0.28	0.32	0.35	-	0.37	0.32	0.35	0.35
1982	0.27	0.34	0.35	0.39	-	0.47	0.42	0.47	0.47
1983	0.23	0.29	0.32	0.37	-	0.48	0.44	0.49	0.46
1984		0.23	0.27	0.32	-	0.50	0.46	0.48	0.51
1985			0.25	0.28	-	0.56	0.52	0.56	0.55
1986				0.21	-	0.51	0.47	0.49	0.52
1987					-	0.46	0.46	0.47	0.56
1988						0.44	0.59	0.59	0.72
1989							0.58	0.61	0.91
1990								0.51	0.96
1991									0.68

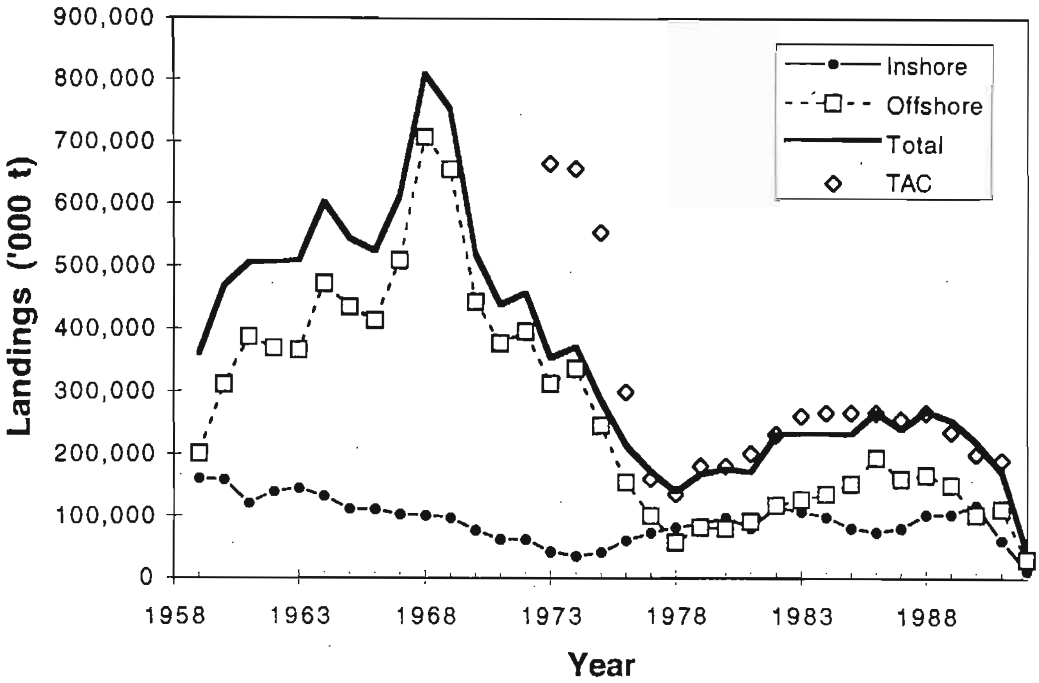

Figure 1. Northern cod landings from 1959 to 1992 compare to the TAC in effect from 1973 onwards.

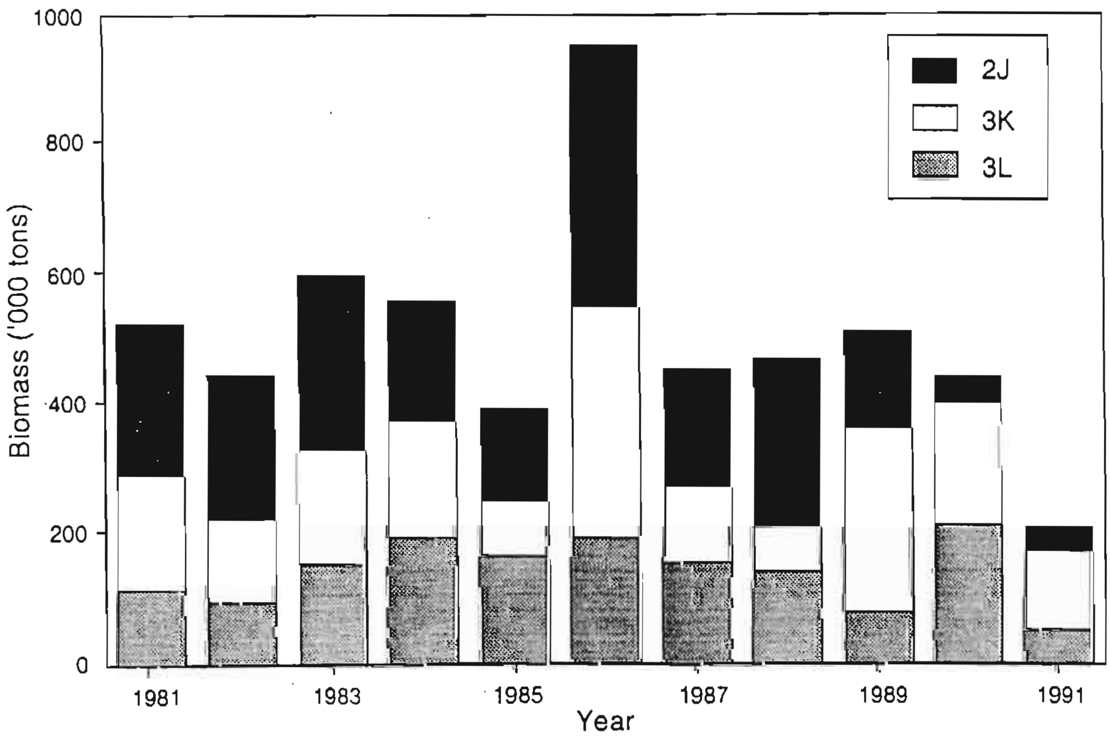

Figure 2. Canadian research vessel survey minimal trawlable biomass by Division: 1981-91.

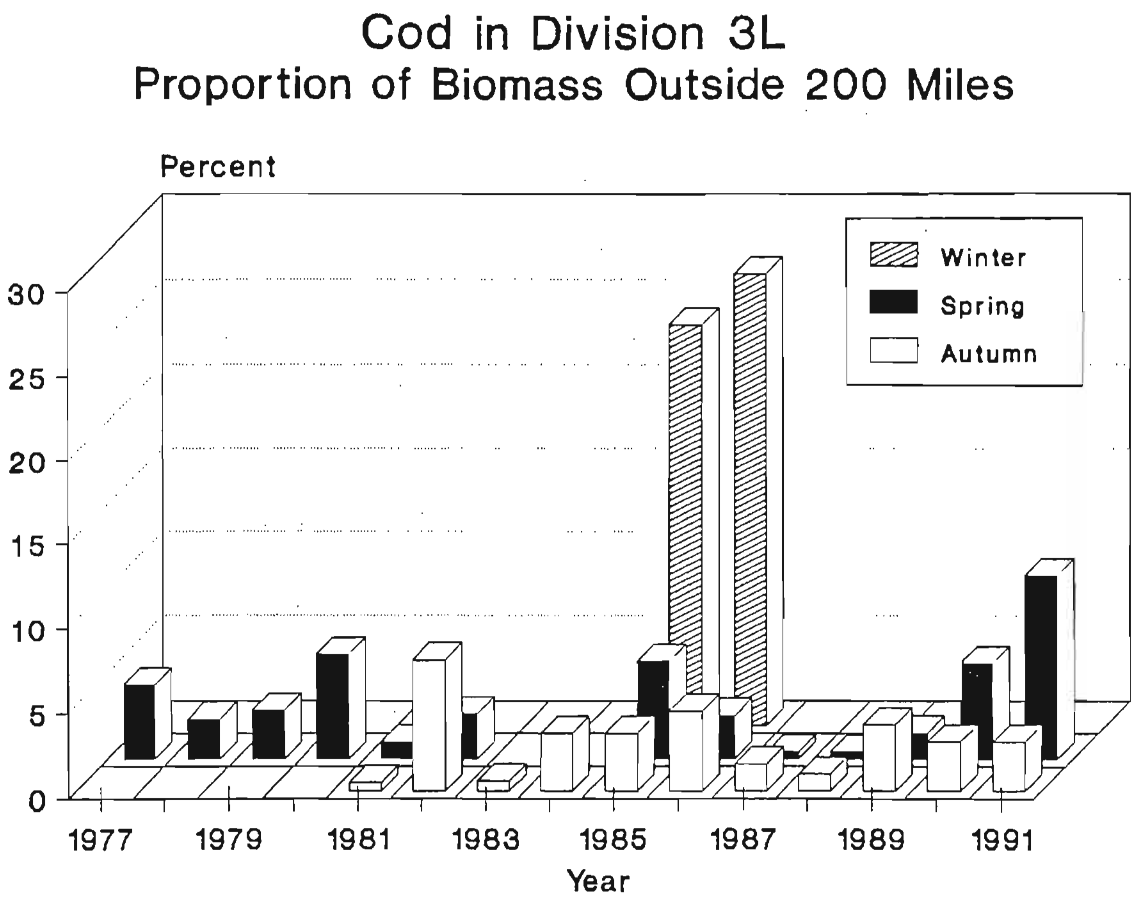

Figure 3. Proportion of Canadian research vessel biomass outside of 200 miles in Div.3L.

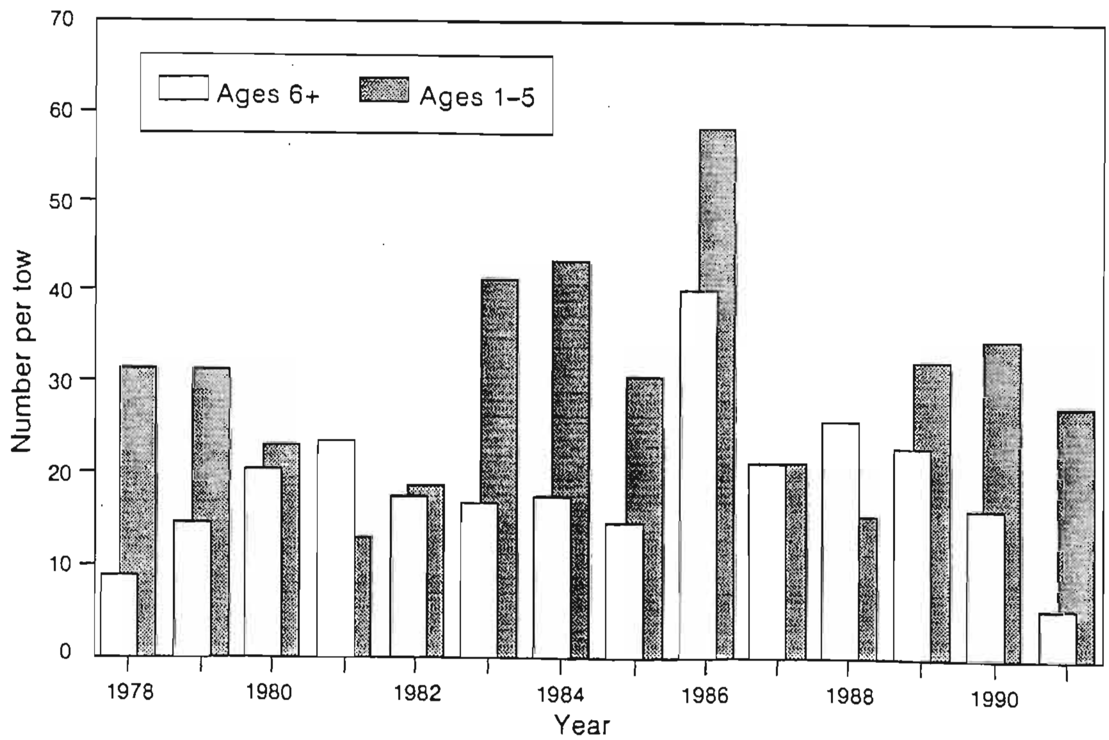

Figure 4. Survey abundances at ages 1-5 and 6+ in Div.2J3KL over the period 1978-91.

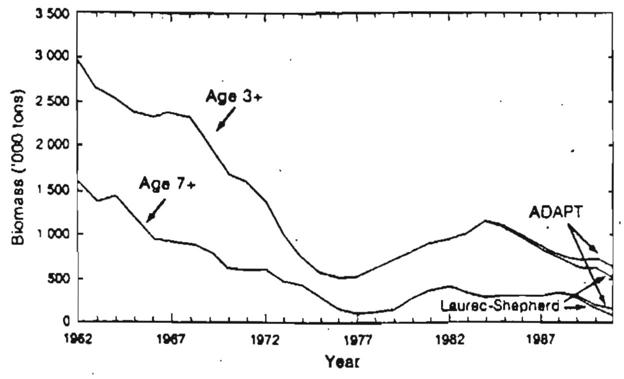

Figure 5. The Jan.1 population biomasses for Div.2J3KL cod (ages 3+ and 7+) from ADAPT and L/S from 1962-91.

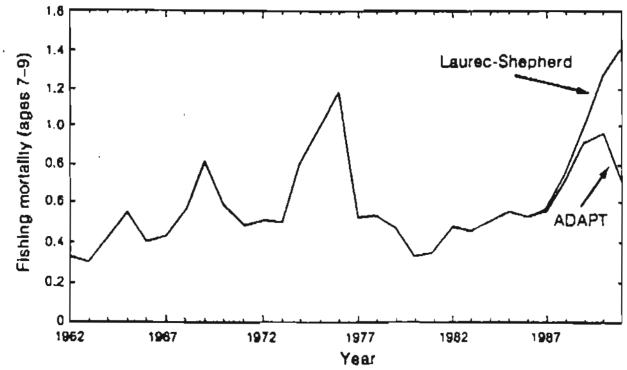

Figure 6. Mean fishing mortality (ages 7-9) for Div. 2J3KL cod from ADAPT and L/S from 1962-91.

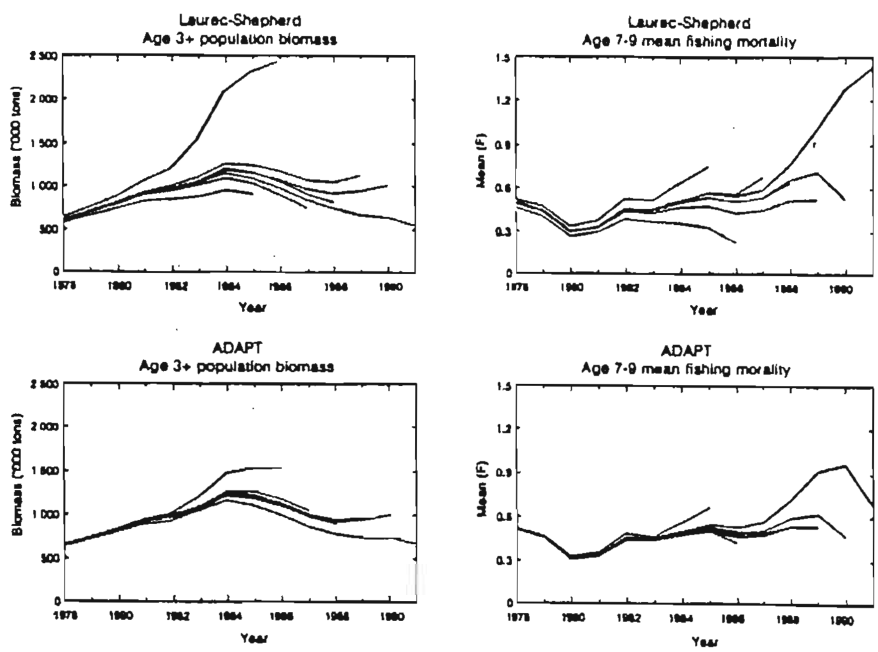

Figure 7. Retrospective analysis for 2J3KL cod showing age 3+ population biomass and age 7-9 mean F estimated by ADAPT and L/S.

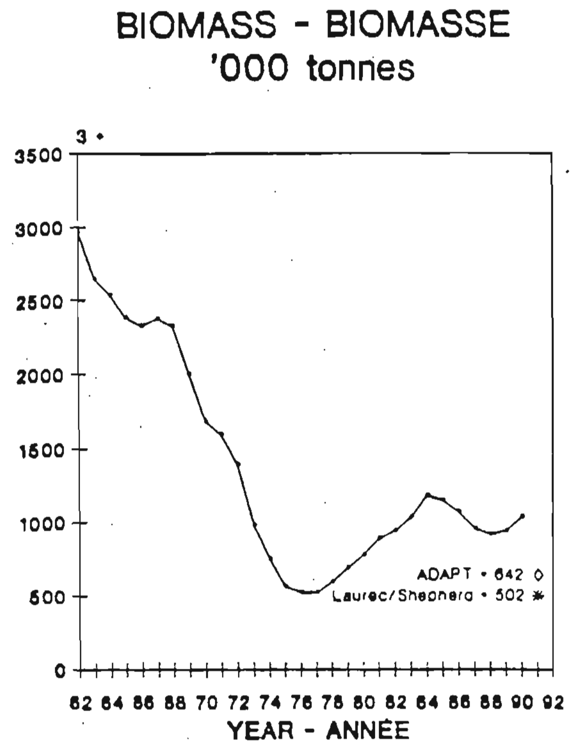

Figure 8. Figure from Advisory Doc. 92/7 comparing annual age 3+ biomass from the 1991 assessment with the 1991 estimate using ADAPT and L/S from the 1992 assessment.

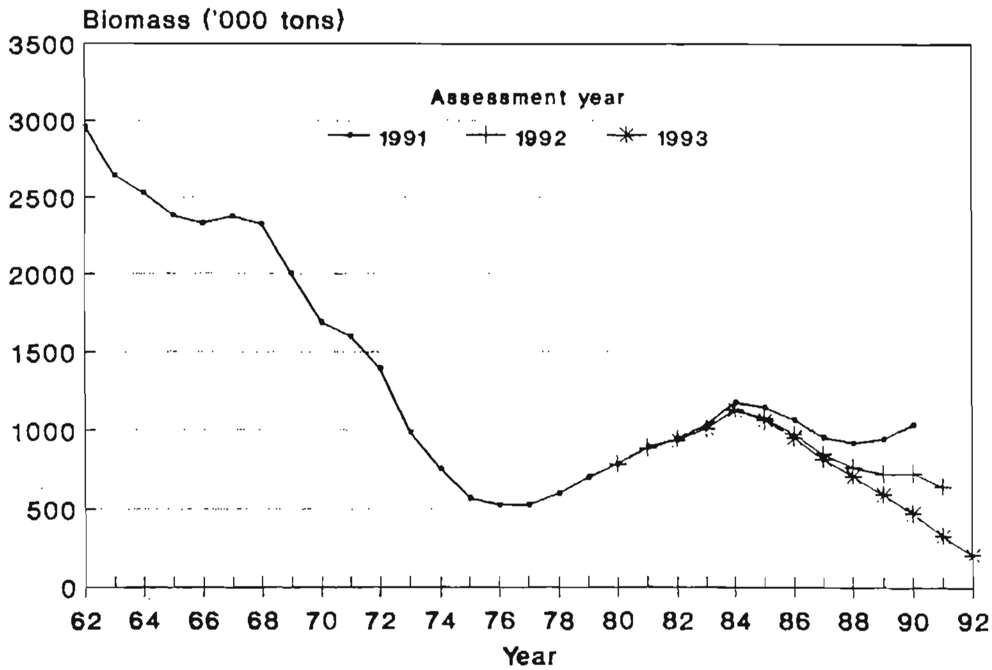

Figure 9. Population biomass (3+) for northern cod from ADAPT based assessments in 1991, 1992 and 1993.