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Foreword

These Proceedings are a record of the discussions at the Zonal Cod Assessment Review Meeting of March 1999. They were prepared by volunteer rapporteurs, and reviewed very briefly at the meeting. Their purposes are solely to archive the activities and discussion of the meeting, including research recommendations, and to provide a place to formally archive official minority opinions on stock status reports. They are not a complete verbatim record of all discussions, but do attempt to capture all major concerns raised and issues discussed. As such, intepretations and opinions presented and some questions posed in the Proceedings may be factually incorrect or mis-leading, but are included to record as faithfully as possible what transpired at the meeting. As consequence, no statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, often additional information and further review may cause the meeting to change its decision on a point where tentative agreement had been reached. **Therefore, only the Stock Status Reports, which contain the consensus decisions of the meeting, should be used as sources of information on the status of resources assessed.**

Abstract

Representatives from the fishing industry, provincial and federal government, FRCC, universities as well as invited experts participated in a zonal assessment of the Northwest Atlantic cod stocks on March 1-12, 1999, in Rimouski, Québec. The purpose of the meeting was the peer review of the analyses and information that serve as a basis for the evaluation of these stocks.

Résumé

Des représentants de l'industrie de la pêche, des gouvernements fédéral et provinciaux, du CCRH, des universités ainsi que des experts invités ont participé à une évaluation zonale des stocks de morue de l'Atlantique nord-ouest du 1 au 12 mars 1999 à Rimouski, Québec. L'objectif de cette réunion était une revue par les pairs des analyses et de l'information servant de base à l'évaluation de ces stocks.

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1. Introduction

A zonal assessment of the cod stocks in the Gulf of St. Lawrence (3Pn4RS and 4TVn), of cod off southern Labrador, eastern Newfoundland and on northern Grand Banks (2J3KL) and cod off southern Newfoundland (3Ps) was carried out on March 1-12, 1999, in Rimouski, Québec. The impact of consumption of cod by seals on the assessment of the cod stock on Eastern Scotian Shelf (4VsW) was also reviewed. The meeting also provided an opportunity to develop an overview of the current situation for the cod stocks in the Northwest Atlantic.

In his opening statement, the chairman indicated that many of the cod stocks in the northwest Atlantic are entering their 6th or 7th year of moratorium. Commercial fishing has been allowed recently for cod off southern Newfoundland (3Ps) and there was a limited commercial fishery in the northern Gulf cod. For the other stocks under consideration at this meeting, sentinel fisheries have been implemented starting in the mid-1990s and, in 1998 an index fishery program was introduced for the southern Gulf of St. Lawrence cod stock and for northern cod.

The chairman noted that for cod in 3Ps, the influx of cod from the northern Gulf of St. Lawrence into the area of Burgeo Bank had attracted considerable attention recently, together with mixing at the eastern limit of the stock boundary. Similarly, he noted that recent studies documented an increase of non-fishing mortality levels in years following the introduction of the moratorium for fishing. Finally, he noted that the predation of cod by seals had been raised as an issue in the context of the recovery of the cod stocks. The chairman indicated that the challenge is to take these changes into consideration in the assessment of the cod stocks under consideration at this meeting. The challenge is also to integrate in our assessment framework the information coming from various sources, such as the sentinel fisheries, the index fisheries, industry surveys and research surveys, so as to assess the trends in stock abundance, in recruitment and in various biological parameters.

The chairman indicated that the purpose of this meeting is peer review of the analyses and information that serve as a basis for the evaluation of the stocks and to integrate that information into a clear explanation of the status of the stocks, and uncertainty about stock status. He invited the participants to avoid statements related to allocation issues, operational (management) issues or partisan interpretation of information. This meeting is the first step in the development of advice on conservation requirements for the cod stocks in 1999. This step will be followed by the public release of the Stock Status Reports (SSRs) at the beginning of April in the respective regions. That release will be followed by public consultations by the Fisheries Resource Conservation Council (FRCC), planned for April 6-9, and by a meeting of the Council scheduled for April 14-16 in Québec City. The report of the Council is expected on May 6, 1999.

The chairman indicated that while the daily participation would likely vary over the course of the meeting, an overall participation of about 75 was expected from advanced registration. Advanced registration suggested a participation of about 25 from industry, of about 40 from various governmental agencies (provincial and federal), and of about 10 from the FRCC, universities and external experts. In particular, the chairman welcomed R. Conser, from the National Marine Fisheries Service (Oregon, USA), J.C. Mahé, from IFREMER-France and C. Field, from Dalhousie University, Nova Scotia. The chairman invited Dr. J. Boulva, Science Director, Laurentian region, and Dr. B. Davis, Acting Science Director, Newfoundland Region, to make opening statements.

The chairman reminded the participants that the analyses serving as a basis for the evaluation of the cod stocks under consideration at this meeting would have to be documented in the Research Document Series of the Canadian Stock Assessment Secretariat within two months following the release of the Stock Status Reports. After a review of technical aspects related to the

organization of the meeting (simultaneous interpretation, audio-visual systems, photocopying facilities, secretariat services, etc.), the chairman indicated that a media briefing was planned for the last day of the meeting. He indicated that the principal contact or resource persons had been identified as follows: G. Chouinard for 4TVn, P. Fanning for 4VsW; A. Fréchet for 3Pn4RS; B. Atkinson for 2J3KL and 3Ps; J. Rice for the Atlantic Cod Overview and himself (D. Rivard) for general questions related to the meeting.

The chairman indicated that interpretation services (French, English) would be available for the duration of the meeting.

The format of the minutes was discussed. It was agreed that it would include a summary of each major document, followed by a discussion section to be drafted by the rapporteurs. It was agreed that the summaries would be taken as provided by the authors of the documents.

The chairman requested that the draft minutes be available and be distributed to the participants on the day following the discussion and that major issues be discussed as soon as possible with the rapporteurs.

The draft agenda for the meeting is provided in Annex 1. The remits (objectives), which were prepared in advance of the meeting by a core group of scientists in consultation with regional managers and the chairman of the FRCC, are provided in Annex 2. The list of participants is provided in Annex 3. Rapporteurs were identified for each of the agenda and are identified accordingly in the proceedings.

2. Environmental Overview

(Rapporteur K. Drinkwater)

During this session, 5 working papers were presented. Ken Drinkwater started with an overview of meteorological and sea-ice conditions in eastern Canada during 1998. This was followed by reviews of the oceanographic conditions in 1998 off Newfoundland (2 papers by Eugene Colbourne and presented by K. Drinkwater; one on southern Labrador, northern Newfoundland and Grand Banks [2J3KLMNO] and the other on southern Newfoundland shelf [3Pn, 3Ps]). The final two presentations were on the Gulf of St. Lawrence (by Denis Gilbert) and on the Scotian Shelf/Gulf of Maine area (by Ken Drinkwater). These papers will be reviewed at the Fisheries Oceanography Committee meeting to be held at IML in mid-March. The following are summaries of the papers organized by region together with the questions raised during the discussions.

2.1 Newfoundland and Labrador

Along the Labrador coast and over Newfoundland, air temperatures were warmer-than-usual throughout most of 1998 resulting in positive annual anomalies of from 0.4° to over 1°C. Air temperatures also warmed relative to 1997. The North Atlantic Oscillation index (NAO), which is a measure of the strength of the large-scale atmospheric circulation pattern, was near normal. This was similar to 1997, up from the minimum value of 1996 and down from the high values of early 1990s. The warm air masses of 1998, coupled with a reduction in the northwest winds during winter, caused sea ice on the southern Labrador and Newfoundland shelves generally to appear late, leave early and be of shorter duration than usual. The areal extent in 1998 was less than in 1997 and about half that observed in the early 1990s. The number of icebergs reaching the Grand Banks increased over 1997 by over 36% but still remained below the large number of icebergs reported in the early 1990s. For the third consecutive year, water temperatures from southern Labrador to the Grand Banks generally showed near or above normal values. At Station 27, the hydrographic

monitoring site off St. John's, Newfoundland, the annual depth-averaged temperature for 1998 was near normal. This resulted from above normal temperatures during the first half of the year but below normal through most of the second half. Evidence of the warm conditions was seen by the lower amount of cold intermediate layer (CIL), defined by waters <0°, off Bonavista and Hamilton Bank. This continues a trend established in 1995 of less CIL waters than normal. The volume of the CIL waters over the entire southern Labrador to northern Grand Bank also was below normal and has been since 1995. This was in spite of near normal amounts of CIL along the Flemish Cap transect across the Grand Bank. The warm conditions were also evident from the above normal near bottom temperatures on the Grand Bank during the spring and on the northern Newfoundland shelf during the fall of 1998. As a result, the areal extent of bottom waters with temperatures below 0°C over most of these areas declined in recent years with a corresponding increase in waters of temperatures >1°C. Off southern Newfoundland waters temperatures over much of St. Pierre Bank increased significantly in 1998 to near normal values. This resulted in a dramatic decrease in the amount of bottom covered by temperatures <0°C.

2.2 Gulf of St. Lawrence

Air temperatures over the Gulf were warmer-than-normal throughout 1998, particularly in the winter and spring. The highest annual anomaly (1.5°C) within 8 stations around the NW Atlantic was in the Gulf on the Magdalen Islands. Ice coverage was less extensive than usual in 1998, and of shorter duration. Despite these milder than normal winter conditions, CIL minimum temperatures surprisingly cooled in 1998 by 0.3°C relative to 1997. No satisfactory explanation has yet been found for this unexpected cooling. Not only did the minimum temperatures with the CIL decline, but also the CIL thickness and volume both increased in 1998 relative to 1997. A direct consequence of this is that the area of bottom in the southern Gulf of St. Lawrence in contact with waters < 0°C and <1°C both increased in 1998. In the 100-200 m layer throughout the Gulf, 1998 temperatures remained stable relative to 1997, and were close to the long-term mean. In the 200-300 m layer, a slight warming of 0.2 to 0.3 C was observed in the northwest Gulf and Estuary. At the same time, a pulse of colder water has begun to propagate along the Laurentian Channel, reaching Cabot Strait with temperatures dropping by 0.7°C. Dissolved oxygen concentrations were normal at Cabot Strait in 1998, but were 2% of O2 saturation level below normal at Honguedo Strait. A stratification index of the upper layer (0-30 m as well as 0-50m) shows similar overall values in the 1997 and 1998 groundfish surveys. There were regional differences however; the 1998 waters being more stratified than in 1997 in the Estuary and northwest Gulf as well as in Cabot Strait. On the other hand, surface waters were less stratified in 1998 than in 1997 over the Magdalen Shallows and in the northeast Gulf.

2.3 Scotian Shelf

As in other regions, air temperatures were well above normal with the 1998 annual anomalies being over 1°C. Normally, sea ice extends onto the northeastern Scotian Shelf during February and March, however, in 1998 the warm air temperatures and reduced ice coverage in the Gulf of St. Lawrence meant that little to no ice appeared on the Scotian Shelf proper. The only significant amount of ice observed seaward of the Gulf was on Sydney Bight, but it arrived late, left early and was of shorter duration than normal. While surface layers over most of the Scotian Shelf were generally warmer than normal, subsurface waters in the northeastern Shelf remained below normal continuing a pattern that was established in the mid-1980s with minimum temperatures in the early 1990s. In recent years, including 1998, there has been a slow but steady increase in temperature in this region. In contrast to the northeastern area, cold, low salinity waters flooded into Emerald Basin and most of the bottom layers of the southwestern Scotian Shelf and into the Gulf of Maine early in 1998 and has remained throughout the year. Temperature and salinity in the deep regions of this area fell by order 2°-3°C and over 0.5 practical salinity units (psu) compared to 1997 values and are the lowest since the 1960s. This was due to the presence of the cold waters at the edge of the

Scotian Shelf that was subsequently transported on shore through channels and gullies. The cold conditions off the slope were due to an increase in the southward transport of Labrador Current water. These cold slope waters were located on the outer edge along the entire length of the Scotian Shelf by January of 1998 and extended along Georges Bank during February and March. These cold slope waters have also influenced the Gulf of Maine, including Georges Bank. Stratification over most of the Scotian Shelf, as measured by the density differences between 0 m and 50 m, has increased significantly over almost the entire Scotian Shelf in recent years. Indeed, this index of stratification during the past few years has been the highest in the almost 50 years of record. The cause of this increased stratification has not been examined in detail but is believed to be due to increased warming and perhaps lower salinities of recent years.

2.4 Discussions

There was a long-term upward trend in the NAO index from the 1960s to the mid-1990s, followed by the strong decline in 1996. Examining sea ice data from the Scotian Shelf, there does not appear to be a clear relationship with the NAO index or is there a lag between the NAO and the ice? There is a strong relationship between the NAO index and various meteorological and oceanographic variables from the Labrador Sea region including air temperatures, winds, areal extent of the sea ice, ocean temperatures and CIL area. Typically, 50% of these variables is accounted for by the NAO. The connection between NAO and variables in the Gulf of St. Lawrence and the Scotian Shelf tends to be much weaker and hence the NAO index does not account for much of the variability in sea ice distribution on the Scotian Shelf, with or without any lags.

What were the ice conditions in early 1999? Sea ice was late in forming. In the Gulf of St. Lawrence, this was largely related to the above normal air temperatures in December 1998 and January 1999. Recent reports suggest that the ice on the Magdalen Shallows in the Gulf of St. Lawrence may now be near normal.

What was the reason for choosing temperature bins ($T < 0°C$ and $1° < T < 7°C$) in the areal analysis for Newfoundland bottom waters and why was the 0-1°C bin not included? The <0°C temperature range is based on the accepted definition of the CIL waters in the Newfoundland region. All of the waters are less than 7°C hence it defines the upper limit. It is not clear why E. Colbourne choose the 1°-7°C temperature range for his analysis.

Could an areal index using temperature bins of preferred temperatures for cod be developed if information on the preferred temperatures was available? This is being done using the published temperature preferences on cod-temperature associations on the Scotian Shelf. An index of the area of bottom covered by temperatures of 2°-6°C within NAFO subdivisions (4Vn, 4Vn, 4W and 4X) using the summer groundfish survey data was generated. As well an FOC working group on cod distribution is presently examining the issue of cod-temperature associations, the results of which will be reported in future meetings. In the Gulf of St. Lawrence, for example, cod occupy approximately 2°C water in summer and go into deeper 5°C water in winter. There are also other data available to establish temperature preference ranges for cod in various stocks. These could be used to develop stock specific areal indices of preferred near-bottom temperatures.

Why was the temperature analysis for the Gulf of St. Lawrence not extended into subdivision 3Pn since the surveys on which the analysis was based included the area off southern Newfoundland? The analysis could be extended into 3Pn. The reason it has not is that the analysis has been based upon areas in the Petrie et al. (1996) atlas for the Gulf of St. Lawrence which did not include areas in 3Pn. Other atlases are available, however, and could be used in conjunction with the Petrie et al. atlas.

Could increased transport of cold Labrador Shelf waters through Belle Isle Strait have caused the lower CIL temperatures in the Gulf of St. Lawrence in 1998? While this is a possibility, the necessary data are not presently available to determine if there was a change in flow through the Strait. Differences in sea level height across the Strait could provide such information and although such data have been collected, they have not yet been quality controlled.

In connection with the colder than expected CIL temperatures in 1998, did the temperatures in the surface layer warm sufficiently in 1997 for that signal to influence the CIL the following year (1998)? For example, increased stratification may insulate the cold intermediate layers more than usual, keeping the waters colder for a longer period of time. This might account for the drop in temperature in 1998. Density stratification in the upper layers, which involves both temperature and salinity, was investigated throughout the Gulf. It was found to increase in 1998 relative to 1997 in both the Estuary and Cabot Strait but decreased on the Magdalen Shallows and in the northeastern Gulf. Thus, increased stratification through warmer temperatures does not appear to explain the drop in CIL temperatures in 1998 throughout the Gulf.

Scientists have to be careful about using the term "normal". For example, the mean temperatures in the 100-200 m layer of the Gulf of St. Lawrence shows that there were more points below normal than above normal in the time series. While this is true, the normal has defined as the average over the 1961-90 period. Most of the 100-200 m temperature values in the 1990s and in the pre-1960s were below the 1961-90 average. Care must also be used since "normality" tends to convey certain expectations. Also, biological normality may be different than physical normality.

2.5 Recommendations

- **To develop time series of stock-specific indices of preferred temperature habitat for cod.**

- **To continue to incorporate all of the available environmental information from the sentinel surveys in the overview papers.**

3. Report on Cod Mixing Project

(Rapporteur: P. Fanning)

3.1 Summary

The goal of the High Priority Project, *The Identification of Mixed Cod Stocks in the Gulf of St. Lawrence and its Approaches*, was to identify the cod stocks of the Gulf of St. Lawrence and its approaches, and through use of elemental, genetic and meristic markers, determine the stock composition and geographic extent of the winter mixing zones, as well as the validity of the current cod management units. Spawning stock identifiers based on otolith elemental fingerprints, microsatellite DNA and vertebral counts have all been developed, and all were capable of distinguishing among at least some of the cod stocks in the area. All three methods provided broadly consistent results, although some methods were more sensitive than others. Synoptic research vessel surveys carried out each January between 1994-1997 documented dense aggregations of cod along both flanks of the Laurentian Channel, with estimated biomasses exceeding 100,000 mt each year. In general, large-scale stock mixing was not evident; cod from the southern Gulf of St. Lawrence dominated the population composition along the southwestern flank of the Channel, while cod from the northern Gulf dominated the northern flank. There was little evidence of cross-channel mixing, and the contribution of 4VsW, 4Vn and 3Ps (particularly Fortune Bay and Placentia Bay) cod stocks to the survey region was minimal. There were significant extensions of both the 4T and 3Pn4RS stocks into the neighbouring

management units to the southeast, specifically into 4Vs and 3Ps respectively, indicating that current assessment and management boundaries do not accurately reflect winter stock-specific distributions. A review of recent and historical tagging, RV and catch information provided similar interpretations.

The most substantive winter mixing zone was in the Burgeo Bank/Hermitage Channel area of western 3Ps, where 3Pn4RS and 3Ps cod were present in a 3:1 ratio (based on the mean of the 1996 and 1997 estimates). An assumption of this analysis was that resident Burgeo Bank spawners made only a small contribution to the winter biomass in the area. To test the validity of this assumption, the elemental fingerprints of Burgeo Bank spawners were compared with those of other other spawning groups to determine if there was evidence of a distinct Burgeo Bank group. The fingerprints of Burgeo spawners were significantly different than those of 3Pn, 4R and other sites in 3Ps, but still very similar to those of 3Pn and 4R. All spawning groups except those on Burgeo Bank showed unimodal fingerprints; the bimodality of Burgeo spawners suggested the presence of two spawning groups, possibly resident spawners and smaller numbers of 3Pn spawners in transit, consistent with recent microsatellite DNA results. When the stock composition analysis of the Jan 1997 samples was repeated treating Burgeo Bank as one of the nine reference spawning groups, 56% of the cod were identified as being from 3Pn4RS, 30% from Burgeo and 14% from other spawning groups in 3Ps. The similarity of the 3Pn4RS and Burgeo fingerprints made it difficult to accurately estimate the relative contribution of the two components (± 20%). However, if the bimodal pattern in the fingerprints of the Burgeo Bank spawners corresponds to the presence of 3Pn cod, the contribution of the Burgeo cod to the winter mixture has been overestimated.

Several consensus-derived recommendations were proposed at the Nov 1998 workshop for dealing with the stock mixing. A workplan for the remainder of the project was also tabled.

3.2 Discussion

The project's most significant conclusion for this meeting regards the large fraction of the fish found on Burgeo Bank in the winter which are identified as Northern Gulf fish. Discussions fell into three major issues, techniques, sampling and spawning groups, which lead to a discussion of the implications of the conclusions for specific stock assessments.

The variability in the sensitivity of each technique (genetics, otolith fingerprints and vertebral counts) between stocks raised concerns about how to determine the relative weight to be given to each of the three techniques. The techniques are complementary in the sense that where one is insensitive, one or both of the others appear to detect differences. Development of the best way to utilize this, in an integrated analysis, is planned for later in the year. Problems with the use of mixed samples for the bootstrap/maximum likelihood estimation used in the genetic analysis was discussed and further work on that analysis is required. In response to a question, it was stated that the initial analysis of the otolith fingerprints did not attempt to distinguish between fish which spawn and overwinter on Burgeo and feed in the Northern Gulf from those which spawn and feed in the Gulf and overwinter on Burgeo. The otolith fingerprint technique was used only as a tag to identify groups of fish with similar histories, and was not being interpreted as to the actual movements of individual fish. However, subsequent analyses identified Burgeo Bank spawners as a discrete group, and were used to estimate the relative contribution of Burgeo spawners to the winter stock mixtures around Burgeo.

The issue of the adequacy of sampling is related to the number and distribution of spawning groups in the study area. Where available, smaller scale sampling was used to look for within group differences (e.g. east and west Southern Gulf) and, if none were found the groups were combined. The sampling did not allow all possible subgroups to be examined. The sampling did

not cover much of 3Ps and thus Burgeo Bank spawners which remained in 3Ps would be given little weight in the analysis. In response, it was noted that 3Ps fish in general are easily identified and the question centres on the relative size of the Burgeo Bank spawning group.

The cod mixing project found evidence of a spawning group on Burgeo Bank but concluded that it was not large. Based on the limited samples available, none of the techniques initially identified a unique marker for Burgeo Bank cod. The fishery data did not show any concentration on Burgeo during the spawning season although the data examined were incomplete, as part of the Newfoundland effort and the French effort were not available. The importance of spawning aggregations with respect to other spawning by the same fish was discussed. Aggregations seem to have a relatively short duration, days or weeks, while individual cod are capable of spawning over a month or more.

Subsequent presentations of French maturity ogives suggested that stock mixing in the Burgeo Bank area became most pronounced in the mid 1980's. It was acknowledged that the extent of mixing probably varied from year to year, and that long-term trends may also have been present. The reanalysis of the otolith elemental fingerprint data which treated Burgeo spawners as a distinct group was discussed, concluding that Burgeo Bank and other 3Ps cod did not account for the majority of the cod in the winter mixture in the Burgeo area. In addition, it appeared that at least some of the cod on Burgeo Bank in April were not of Burgeo Bank origin.

The longstanding question of the association of the fish on Burgeo Bank dates back to discussions about the definition of the original ICNAF boundaries and Templeman commented on the extent of cod stock mixing in the Burgeo Bank area in 1962. The chairman asked whether it was premature to apply these conclusions. It was reported that the cod mixing project had made these recommendations after extensive discussion and after consensus was reached, and it was not premature to apply them. There is room for additional research to address some of the outstanding issues but, in terms of the conclusion regarding Burgeo Bank, the outcome is unlikely to change.

Implications for individual assessments were reported by the lead scientists.

For 3Ps cod, it is not proposed to change the management unit because of the problem of underestimating the 3Ps component of Burgeo Bank. The ratio of 3:1 for 3Pn4RS:3Ps was considered too high. Therefore no changes to either the management or assessment unit were considered.

In 3Pn4RS, the impact of moving 75% of the Burgeo Bank catch into the Gulf catch at age will be presented in a model run. The timing of the Gulf survey removes any problem because of mixing in the survey data.

In 4T, cross-channel mixing is not considered an issue and the mixing between 4T and 4Vs and 4Vn has resulted in changes in the timing of the management unit. All winter catches in 4Vn are considered part of 4T and it is estimated it is about 6:1 over the 4Vn resident stock. Analyses were conducted to estimate the relative amount of 4T and 4Vs fish in the 4Vsb area in the winter. Adjustments were made, from 2000-8000 t, for the years from 1986 to the closure of 4Vsb and then the fishery. This problem may return when fisheries are reopened. The mixing will have no effect on the 4T surveys.

4. Report on Cod Mortality Project

(Rapporteur J. Rice)

Partitioning the Total Mortality of Atlantic Cod Stocks : a Progress Report

4.1 Summary

The multidisciplinary interregional project entitled "Partitioning the Total Mortality of Atlantic Cod Stocks" was initiated by DFO in 1995. The aim set for this project was to ascertain the degree of variability in the total mortality of Atlantic cod stocks which can be attributed to environmental and ecosystem factors and how these may affect or compound the impacts of human activities.

Previous attempts to summarize the causes of the cod collapse have been polarized. The project on "Partitioning the Total Mortality of Atlantic Cod Stocks" and other recent studies on Atlantic cod, have shed new evidence to conclude that, while exploitation is a dominant factor in the collapse of the cod stocks, other factors, such as increased natural mortality and decreased productivity, have contributed to the collapses. The relative contributions of exploitation, increased natural mortality and lowered productivity is not yet quantified.

More insights into the causes of the collapse are still possible to be gained. First, a reconstruction of the numbers of fish that went missing, as available for 2J3KL, should be done on a stock by stock basis. A comparison of these numbers with the capacity of the fleet, and in relation to known fishing practices, could help infer whether excessive fishing could realistically account for all missing fish. Secondly, an analysis of the effect of changes in production (condition, growth, fecundity and recruitment), as carried out on 3Pn4RS, on the resilience of a stock, should be extended to every stock. Finally, a quantitative analysis of changes in consumption of fish by predators, illustrated by the work on 4Vs, could help explain portions of the fish gone missing.

4.2 Discussion

There was an initial discussion of plans to draw a fuller synthesis together. It was noted that this is the last year of funding for the project. The presentation was a far as it has been possible to go with the information available at present.

A question was raised regarding the consideration given to the effect of the loss of older fish in recent years, making the stock more sensitive to environmental stresses, and more vulnerable to recruitment collapse. The aspect was discussed but no papers have been prepared addressing it. Several participants thought this material should be prepared, because it would be a particularly clear illustration of the precarious situation of the stocks at present.

In response to a question about the treatment of natural mortality in the 1998 assessments, it was confirmed that, aside from 3Ps, M was increased from 0.2 to 0.4 for all cod stocks north of Halifax.

Another question addressed the frequent stories that during the period of the collapse the cod had aggregated to an exceptional degree, and this had resulted in a substantial increase in effective fishing effort. Maps which document aspects of that question have been included in past assessments of several stocks. Although patterns consistent with that stories are present for the stocks examined, the material has not been brought together fully. Some of this work is included in a paper for a recent NAFO session.

Another question asked about studies of unreported catch. It was noted that although such work was originally included in the project, papers have not been prepared on the results for any of the stocks.

It was noted that the summary graph for 4VsW presented to the group could have multiple interpretations, and that the phrase "perfect management" could easily be over-interpreted. The figure appears to suggest that even if exploitation had been controlled perfectly, the stock would have nearly collapsed. It is possible that only during a period of changing natural mortality or unreported fishing mortality that the problem in the figure occurs. This again suggests that the stock has become less resiliant, and perhaps the proper frame of reference for a "resiliant" age composition would have to be before the heavy exploitation in the 1960s, and not just before the collapse in the early 1990s.

With regard to the figure on partitioning gross and net productivity, it was argued that the figure is more informative when presented on a per capita basis. Presented this way, it becomes clear that for the Northern Gulf stocks there have been two phases to M, the recruitment per capita has no time trend, and there is a clear 2-3 fold drop in growth. These plots can be repared easily if given the data on numbers at age and growth.

It was agreed that these production plots will be done back to the 1960s for each stock, once the population reconstructions are accepted. Gascon will do the plots, given vectors of biomass, F, catch and numbers at age. They will also be done for 4X and 5Zj,m.

There may be a problem for Northern cod, because of the huge residuals in the early 1990s, which mean that the stock trajectory in the 1989-1992 period is unknown.

5. Report on Seal Consumption Workshop

(Rapporteur: M. Castonguay)

5.1 Summary

The process of evaluating seal consumption in the context of fish assessments is divided in three parts: 1) a workshop to focus on the details of the seal consumption models and the methods of estimating the numbers-at-age of cod consumed; 2) based upon the approaches developed at the workshop, seal consumption estimates must be incorporated into the current round of cod assessments, where appropriate, and 3) an overall synthesis of the information on seal consumption and its impacts on prey population dynamics should be attempted for all areas of the Northwest Atlantic, at least for selected species of groundfish. The results of the work should be communicated to our clients in the context of a broader synthesis of sources of groundfish mortality.

The workshop was held on December 1 to 4, 1998, in Halifax N.S. Eighteen stock assessment and marine mammal biologists from DFO teamed up with four international experts in predator-prey relationships to tackle the following objectives:

1. document data requirements (i.e. diets, population size and trends, population distribution, energy requirements of seals and seasonality of these components), data availability, methods used to obtain these data, assumption and biases associated with these methods, and models used to estimate consumption of groundfish by seals;
2. develop consistent approaches, dependent upon the amount and type of data available for each stock, for estimating the quantity and age structure of fish consumed by seals that can be incorporated into groundfish assessments;

3. examine ways in which consumption estimates should be incorporated into the next round of groundfish assessments;
4. develop short- and medium-term workplans (identifying approaches, data requirements, and recommending timing) for following up on the results of this workshop that would lead to an overall synthesis of seal consumption information.

Recommendations by the working group most relevant to the current round of cod assessments are as follows.

On seal consumption:
- consumption should be re-estimated to reduce biases, particularly those resulting in the under representation of certain prey items;
- annual diet data should be used to estimate consumption. If this is not possible, data should be blocked over years.

On the age structure of the cod consumed:
- annual, if possible, or blocked length frequencies should be used to estimate the age structure of cod consumed by seals;
- appropriate age length/weight keys should be applied to the length frequencies for different time periods.

On the incorporation of the seal consumption data into the Virtual Population Analyses (VPA)
- incorporate seal consumption as a separate fleet in the 2J3KL, 4VsW and 3Pn/4RS stock assessments.
- investigate influence of assuming that non-fishing mortality varies with age of cod, and possibly also over time.
- incorporate cannibalism by large cod in the VPA model assuming:
- constant consumption rate;
- consumption is proportional to the abundance of young cod.
- incorporate any change in natural mortality as a parameter to be estimated in the fitting of the VPA.
- investigate formulations of VPA which allow for errors in catch at age, in particularly to make allowances for the uncertainties in estimates of seal consumption.

5.2 Discussions

Regarding the 4th recommendation about M, no specific recommendations were made as to the timing and magnitude of changes in M. It would be possible to block years by ecological time periods when specific annual estimates are not possible. Methods to estimate M, within the cod assessments will need to be developed. It has not proved possible, in the past, to estimate M and numbers in a VPA simultaneously.

Catch-at-age for seal predation on 3Pn4RS cod is calculated for time periods equivalent to the VPA. Aggregates for all years are currently used. Then, they are added to the catch-at-age like a new fleet.

Biases in consumption estimates exist because seals do not necessarily eat entire prey, or they may eat soft-bodied prey, causing difficulties in detecting the prey in the diet samples. Fatty acid signatures of blubber, integrating months of diet, may be the answer, however, what is missing is a library of prey fatty acid signatures.

Recent video and photographs confirm the longstanding report from fishermen that seals can and do eat cod stomachs and livers. Images have shown the bottom littered with cod 60-80 cm long,

posssibly covering a large area. Hence for northern cod, the calculation of this "seal fleet" may be biased as many more large cod can be preyed upon by seals than what is shown by the available data. This problem may impact on our entire perception of the energetic balance of both cod and seals. Because of how the cod consumption balances energy, not biomass, consumed, it is not possible to know without careful calculations if a difference in age composition would lead to more or less total consumption of cod by seals.

6. Report on the National Hydroacoustic Project

(Rapporteur: J. Rice)

6.1 Summary

A presentation was made of preliminary results from the High Priority National Hydroacoustic Project integrated survey conducted in southern 4R in May 1998. This survey was designed as an operationally useful mixed acoustic/trawl groundfish survey which would produce absolute abundance estimates of groundfish (mainly cod and redfish) for a given area and to study factors affecting the geographic and vertical distribution of the target species aimed at improving the precision and accuracy of these estimates. The survey protocol involved conducting an initial acoustic survey with systematic transects between the 150 and 300 m depth contours to locate a significant cod concentration. An experimental area was then defined for the mixed acoustic/trawl experiment which would encompass the cod concentration and which could be completed within a 24 hr period. The area backscatter from the initial survey was stratified into low, medium and high densities for the allocation of the trawl stations. The systematic acoustic transects were resurveyed alternately with the 10 selected trawl stations.

Trawl data showed that the vast majority of the fish in the area were cod, with an increase in the percentage of redfish with depth. There was also a pattern of larger cod (45-48 cm) in the southern and the northern ends of the area, with smaller cod (40 cm) in the central zone. Trawl catch rates showed that the majority of these cod were in the south and in the north, with low catches in the central area. The stratified mean density of cod gave a biomass estimate of 4200 t for the area.

The acoustic data showed two centers of biomass, one in the southern zone and the second at the northern extremity of the area, similar to the pattern from the trawl catches. There were visible differences in the vertical distribution between transects conducted in day versus at night, cod being distributed up to 50 m off the bottom at night, and within a few meters of bottom in the day.

Although cod off bottom are available to the acoustic technique, fish close to bottom in the so-called "dead zone" are undetectable, therefore the acoustic estimate must be biased downward. However, the sample volume of the dead zone can be estimated and is a function of depth. A correction was applied to the acoustic biomass estimates in which the unsampled fish density in the dead zone was extrapolated by a linear inference to the fish density immediately above this zone (Ona and Mitson, 1996). This resulted in a average correction to the transect biomass estimates of 21 and 9% for day and night transects, respectively.

The cod biomass was estimated by two methods using the acoustic data. The first method involved first classifying the backscatter into 3 major groups using information from the trawl catches and visual patterns on the echograms: cod (cod >80%), cod and redfish (30%<cod<80%) and redfish and cod (cod<30%), attributing the backscatter within each class to the two species from the proportions in the corresponding trawl sets, and estimating the mean cod and redfish densities within the area from the weighted transect backscatter means. This

resulted in a total cod biomass estimate for the experimental area of 4600 t. The dead zone correction increased this estimate to 5300 t, or by 15%. The second method involved kriging of the acoustic data within various layers off bottom, and using the relationship between the proportion of cod and redfish in the trawl catches and depth to proportion the backscatter to species. This technique resulted in a total dead-zone-corrected biomass estimate of 4300 t and showed that, on average, 50% of the biomass was above the headrope height of the trawl (approx. 4 m) during the acoustic data collection. The trawl biomass estimates would therefore be negatively biased due to this diel vertical migration, although it was noted that most of the trawl sets that were conducted in high cod-density stations were in daytime (06:00 and 20:00) and therefore may not be severely biased. The trawl estimates were very similar to the dead-zone-corrected kriged estimate, although they were 1100 t less than the dead-zone-corrected mean transect estimate.

Although these analyses are preliminary, it is clear that the major potential source of error in trawl survey estimates would be due to their diel vertical migration where on average 50% of the cod were above the headrope height over a 24 hr period and were therefore unavailable to the gear. For the acoustic estimates, the combined day/night dead zone correction was in the order of 15%, and can be estimated assuming a linear relationship between the cod density in the dead zone and the density in the zone immediately above it.

6.2 Discussions

The difference in the method of extrapolation from the lowest meter(s) sampled by the hydroacoustic system through the "dead zone" was discussed. **It was agreed** that the linear extrapolation used by in this project would give a different value than the power function applied recently to the 1997 inshore Newfoundland hydroacoustic survey for cod. The distribution of individual fish in this study was given as the justification for a linear extrapolation in this case, but comparable information was not available to the meeting to evaluate the justification for a power function in the other study.

It was also observed that the size dependence of vertical migration reported here will have major implictions for all trawl survey results as well, if this result is found to be general.

Atkinson presented the results of analyzing the July bottom trawl survey of 3Pn4RS using the ACON implementaiton of the Delaney triangles method. The analysis indicated that the decline in abundance ended in 1994, and the stock has increased somewhat since then.

Discussion focused on the patterns present in the area and volume calculations, and whether one was to be considered more informative than the other. Both should be considered, particularly when they are changing at different rates. In that case the density of fish is altering, and this can have a substantial impact on success of fisheries.

There was substantial concern about the difference in estimated between STRAP and the Delaney triangle biomass estimates. Some area in the northern Gulf is not surveyed due to rough bottom, but **it was agreed** that the unsurveyed areas should affect both methods of analysis in the same way. It was also noted that the sentinel program finds cod to be increasing in abundance in the excluded strata.

There were suggestions that density calculations should be made and compared for both STRAP and Delaney triangles, and these should be contrasted away from the meeting. If the results shed light on the differences they would be presented later in the week, For now the STRAP estimate will be used in the SPA runs.

7. Treatment of Sentinel Fisheries Information

(Rapporteur: B. O'Boyle)

During the discussions on each stock, it became evident that the analysis of the sentinel survey information would benefit from a more consistent treatment than had been presented. It was agreed to convene a separate meeting, chaired by R. O'Boyle, consisting of the key scientists and industry participants of each survey, as well as both the external reviewers and other interested individuals to discuss the following:

- Briefly review sentinel survey protocols to develop a common understanding of the strengths and constraints of each program.
- Consider the main treatments and interaction terms and how best to identify these.
- Develop consensus on the most appropriate approach to summarize information within cells.
- Discuss adjustments for soak time.
- Review a draft Terms of Reference for a workshop on the Atlantic Coast's sentinel surveys.

7.1 Sentinel Group Discussion

7.1.1 Sentinel Survey Protocols

The protocols of each survey were briefly described. As the details are provided in the stock Research Documents, only the highlights will be presented here.

The Newfoundland sentinel survey design is characterized by a mixture of gillnets, linetrawls, and traps fishing at selected sites along the coast. Each site is about a 2.5 km radius area within a fisherman is free to choose a fishing location. Gear and set protocols have been established but differ according to local conditions.

The Northern Gulf survey again uses a variety of gears fished at locations under specified protocols. However, sets are made at specific locations.

The Southern Gulf survey also uses a variety of gears, under defined protocols. Contrary to the other surveys, strata are specified within which fishermen set their gear at defined locations. As with the Newfoundland surveys, there is flexibility within a small area of choosing the fishing locations.

The Eastern Scotian Shelf survey is a stratified random design, based on the DFO summer trawl survey. Only linetrawl gear is fished. The survey is composed of two parts – a stratified random part in which stations are fished at predefined locations under specified protocols and a commercial part in which fishermen choose the fishing locations.

7.1.2 Main Treatments and Interaction Terms

It was agreed that the discussions of the group should not be prescriptive but rather provide guidelines for analyses to be conducted at the meeting.

The general approach in defining main treatments should be to start at a high level of disaggregation and then, by identifying those that are not significant, combine treatments until the most parsimonious model is achieved.

It was generally agreed that main treatments should include, at a minimum, year, season (quarter, month, week) and area. Where needed, combination of time and area blocks could alleviate problems caused by missing cells. It was recognized that, due to selectivity differences, separate multiplicative models would be required for each gear. There was considerable discussion on the need to include fisherman as a treatment. It was pointed out that in many of the surveys, fishermen consistently fish at a specified location. In this case, fisherman and site would be equivalent and only one effect, site, would be needed.

Regarding interaction terms, as much as possible, those involving year should be avoided. However, when these are encountered, it is important to investigate the underlying causes of this. Otherwise, interaction terms that improve model fits should be explored.

As a priority at this meeting, it was considered important to investigate the amount of variation that can be attributed to the site/fisherman treatment.

7.1.3 Within Cell Considerations

The issue is whether or not to aggregate catch and effort before application of the multiplicative model. It was noted that analytically the sum of catch divided by the sum of effort was equivalent to the weighted (by the effort) average of the set by set catch rates. The former approach has most often been used in the analysis of commercial fishery information, in which the catch and effort information already is aggregated at a trip or higher level. In these situations, the sum catch/sum effort is an appropriate approach. In the case of sentinel surveys, in which reliable set by set information is available, the individual set information should be used. Specifically, a mean of the individual sets within a cell should be calculated. If there are large differences in the set time or effort, a weighted average should be calculated.

Under either the aggregated or individual set approach, it is important to examine the model diagnostics to ensure that its assumptions are not being violated. If, under the individual set approach, it is observed that the model assumptions are seriously violated, consideration needs to be given to the use of alternate distributions.

As a priority, it was considered that data visualizations need to be conducted as part of the modeling process.

7.1.4 Soak Time

Industry participants at the meeting felt strongly that adjustment for soak time was not appropriate. Soak times are to a great extent defined by the local fishing conditions (bottom type, current, etc.) and are thus associated with the set locations. Therefore, inclusion of site and/or fisherman should take differing soak times into account. It was considered important to ensure that set protocols are followed and that sets with large deviations from site specific soak times are not used in the multiplicative analysis.

There was discussion on what could be done in the longer term to correct for large differences in soak time. While inclusion of soak time in the analysis as a covariate could be investigated, it was felt that investigation of functional forms, while not discouraged, might not be productive. Notwithstanding this, the potential relationship between soak time and abundance remains an unresolved issue that requires further investigation.

7.1.5 Workshop on Atlantic Coast Groundfish Industry Surveys

A draft terms of reference for a workshop on industry surveys was distributed for comments. Due to the issues presented above, discussion was limited. However, it was agreed that the workshop should be focused on groundfish and should include all industry surveys and not just those funded by DFO (sentinel surveys). This was discussed further in the plenary session (section 7.2.1. below).

7.2 Discussion

R. O'Boyle presented the results of the sentinel group meeting. In the ensuing discussion, it was pointed out that when fisheries reopen, the current format of the sentinel surveys will likely have to be modified as vessels currently in the program will return to the fishery. This raised the broader issue of interaction between the sentinel and commercial fishery. There may be local area effects that need to be considered both in the design of the survey and the subsequent analysis. It would be useful to consider what changes would be required in the sentinel survey workshop.

It was noted that the sentinel group discussion did not cover and indeed avoided the issue of the relationship between catch rate and biomass. This was considered an issue for the plenary session.

The comment was made that the group report was vague of the conclusion that individual sets should be used in the analysis. This was an editorial problem that would be rectified. The question was raised as to what to do if the assumptions of the model were violated using the individual sets. For instance, sets with zero catches will be a problem. Some felt that data visualization is an important aspect of the analysis. However, this was considered to be a critical part of the data exploration leading up to this phase of the analysis. At this meeting, it was more generally felt that there is a strong seasonal signal in the data that has to be removed to see the annual effect. Treatment of the data should follow standard statistical practice to describe the temporal and seasonal trends.

The issue of gear saturation was discussed. If inshore sentinel sets are made in good fishing areas, and the resource contracts, then the catch rate would not be a good indicator of population trends. Saturation of the gear could occur. Also, the inshore area consists is a bead of populations along the coast, that get swamped by the offshore stock when it moves into the inshore, which can further confound the sentinel survey index.

The chair suggested that, to facilitate progress on the analysis of the catch rate data, the principal scientists and analysts of each assessment get together to discuss the approaches and assist each other in analyzing the sentinel survey information.

7.2.1 Workshop on Atlantic Coast Industry Surveys

A number of collaborative DFO/Industry surveys have evolved in different regions during the 1990's. These include inshore and offshore 'sentinel surveys', as well as various other collaborative surveys. These surveys have in most cases developed separately in the different regions, but the time series have grown to the extent that the information they contain is contributing more and more to the evaluations of stock status.

It is important that detailed discussions of these surveys, as well as the analysis of the data, take place so as to ensure that the most information possible can be obtained from them into the future.

Therefore, **it was recommended** that a Workshop be convened during 1999 with key industry and departmental participants as well as other invited experts to review the surveys to date.

Specific Terms of Reference for the Workshop are:

1. To review the stated goals of the various joint DFO/Industry surveys that are being conducted, and ensure this is clearly documented for all programs.
2. To review the current protocols and practices of these surveys in relation to the stated goals, and to document the likelihood of achieving the goals if current protocols and practices are maintained.
3. For those surveys for which it is determined that the goals are achievable, review and evaluate current and possible analytical approaches which will best suit the data with the objective of utilizing the data in analytical assessments. Similarities and differences between these programs should also be identified and evaluated in terms of opportunities to increase consistency among programs. Specific recommendations are to be made regarding analysis approaches and opportunities for increasing consistency.
4. For those surveys for which it is determined that the goals cannot be met, determine what practical revisions could be made to current protocols and practices such that the originally stated goals can be achieved. Advice should also be provided as to whether the required revisions would be practical to implement. Specific recommendations are to be made regarding necessary and practical changes.

A report of the meeting will be published in the CSAS Proceedings Series.

8. Cod in 4VsW (Update)

(Rapporteur S. Campana)

Mohn, R.K., W.D. Bowen and L.P. Fanning. 1999. New analyses of seal diet data and their implications to 4VsW cod stock status. CSAS WP 99/02.

8.1 Summary

The most recent assessment of 4VsW cod (Mohn et al. 1998) included three models of seal predation on cod all based on the same data. A number of approximations used in the past have been improved. To this point, the improved precision in the seal diet estimation has not suggested any significant change in the perception of fish stock status. The selection of seal-cod interaction model and the assumptions about the seasonal distribution of seals both have much larger impacts on the estimated fish stock status.

New and Revised Data

The data used last year have been augmented with additional sampling up to however the average percent weight in the diet has remained almost unchaged (12.7 from 12.5%). The most significant change was the use of a new otolith length to fish length regression derived from fish length samples collected specifically in the vicinity of Sable Island, the source of almost all the diet samples. The new regression indicates that the sizes of fish in the seal diet are shorter, and hence lighter, than did the previous relationship. As a result, the weight of cod in the diet is a smaller fraction of the total than previously. Since most of the other prey species have higher energy densities than do cod, the overall energy density of the diet increased, the total biomass required was lower, and the amount of it that was cod was smaller, both proportionately and

absolutely, i..e. the reworked data produced a much higher energy content with less cod. When these numbers are corrected for a 20% unseen diet, the total consumption is 76% and the biomass of cod consumed is 62% of that given in the last assessment (1998). The consumption is now estimated at 119 kt vs. 157 kt and the cod consumption is 13.6 kt vs. 22.1 kt in 1997 using a constant proportion model. Because the fish are smaller, the number of fish consumed is estimated at over 80% of those in the previous assessment.

It has not been possible to identify either seasonal or annual trends in the percentage of cod in the seal diet, nor in the size composition of the cod in the diet.

Three sources of variation in the seal consumption of cod at age were considered. First, the mean length composition from all the diet data was converted to numbers at age using annual or aggregated age-length keys from July groundfish surveys of 4VsW instead of the approximation used before. Secondly, the length composition was converted to biomass using survey mean weights at age or annual length-weight regression coefficients, also estimated from the survey. The third consideration was to vary the age composition of cod in the seal diet by estimating the 'catchability' by age of cod to seals and applying these to the population estimates. The third option introduced some degree of yearclass strength into the estimates of cod consumed.

Each of the options considered introduced differences from the model reported previously. In particular, the introduction of yearclass strengths into the diet composition through the 'catchabilities', produced a different trend in the historical estimates of numbers of cod consumed, particularly in 1980-85.

In spite of differences in the diets, the population model (biomass, age 1 and age 3 numbers), including all the revised data, was virtually indistinguishable from the last assessment model. The mortality rate estimates in the more recent years (since 1989) are generally lower, consistent with a smaller number of cod consumed by seals. The drop in predation mortality seen in the last assessment is no longer apparent and in fact both models estimate the most recent predation mortality at 0.18.

The seal diet reconstruction now includes more data and better estimation procedures for size and age composition however the impact on the modelled population estimates for cod are negligible and do not alter the previous perceptions of stock status. It is apparent that the choice of functional response model has a much greater impact than the refined diet data. While not examined in the current work, the spatial effects due to seal distribution including annual migration, is another factor in the assessment, more significant than improved precision in the application of diet size composition data.

8.2 Discussion

The question of which model best fit the diet data was raised. The data were sufficiently variable that none of the models could be rejected. However, the constant proportion model implies that recent recruitment has been high, despite the fact that very few young fish have been seen in recent RV surveys. The alternative models suggest that the recruitment to the 4VsW population in recent years has been very low, just large enough to meet the requirements of the seal consumption model. None of the models considered to date appear to account for all observations.

The predation mortality by seals was quantified, but the age groups upon which the mortality estimates were based were not stated. This is significant, since seal predation targets younger fish than does the fishery. Subsequently, the age groups were confirmed to be 5-7 for both.

The spatial distribution of the seal's diet is a significant factor in the consumption estimates, treated in a very coarse way as yet. It was suggested that consideration of the cod available to seals in the immediate vicinity of Sable Island based on the survey distribution of the cod population through time could be quantified., This can be used to scale the estimate of catchability of cod by seals, and used to prepare a more realistic model. The response was that there was not likely to be a significant change in the perception of stock status. It would also be another model for which there was insufficient data to test rigourously.

The question was raised whether 4VsW cod might be on the verge of extinction. The stock may already be commercially extinct; as to whether the population may yet recover is still unknown. If it does not, ecosystem compensation of some kind may be a factor.

8.3 Recommendation

- **Analyses and modelling should be undertaken to explore the effect on population parameters of 4VsW cod if catchability to the grey seal predator "fleet" changed over time.**

The rationale is that as the range of cod contracted over time, an increasing proportion of the cod stock may have become vulnerable to the seal herd centered on Sable Island. The spatial distribution of research vessel survey catches of cod over time are a potential source of data to constrain the pattern of change in q, but other data sources may be considered.

9. Cod in southern Newfoundland (3Ps)

(Rapporteurs: R. O'Boyle and P. Shelton)

9.1 *Brattey, J , N.G. Cadigan, G.R. Lilley, E.F. Murphy, P.A. Shelton, and D.E. Stansbury. 1999. An Assessment of the Cod Stock in NAFO Subdivision 3Ps (Working Paper 99/18)*

9.1.1 Summary

The results from the 1998 research vessel survey and catch data from the 20,000 t quota commercial fishery were given. A synthesis of information from several other sources including the sentinel survey, acoustic surveys, a fall industry survey, DFO Strategic projects on genetics and tagging, as well university research programs was also provided, based on working papers presented at the RAP in St. John's.

A brief history of recent assessments was given. Detailed information on the history of landings by country, gear sector, unit area and month was provided. The temporal and spatial distribution of offshore fishing effort by otter trawlers and fixed gear vessels was described, based on data from observers and port sampling along with information on catch rates. Catch-at-age based on extensive sampling of all sectors of the fishery was shown. Catch rates of commercial fixed gear vessels for both 1997 and 1998 based on analysis of data from science logbooks was presented. Detailed analyses of catch rates in the inshore fixed gear (linetrawl and gillnet) Sentinel fishery was given, based on data collected during 1995-98; three types of analyses were presented: daily catch rates for individual sites, monthly catch rates by gear sector and unit area, and a statistical comparison of annual catch rates for the whole of 3Ps at the level of individual fishermen. Catch rates during commercial and sentinel fisheries in 1997 and 1998 were compared. Results from acoustic surveys of limited portions of the stock area were given.

Information on stock structure and migration patterns was given based on tagging experiments conducted in 1998. Estimates of tag reporting rates and tag-shedding rates were presented. Estimates of exploitation rates and migration rates of 3Psc cod into 3L were given based on tag returns. Findings from a new study of genetic variation at micro-satellite loci, based on samples collected at inshore and offshore sites in 3Ps during 1998, were presented. The results of a second industry offshore trawl survey, conducted in the late fall, were presented and compared with results from the preceding year.

A detailed description of results from the spring research vessel survey were presented and compared with recent research surveys; this included information on abundance and biomass trends, spatial distribution of catches, and survey numbers at age. Trends in size, weight and condition-at-age of fish caught during research vessel surveys were described, along with trends in age at maturity of females. Changes in the maturity stages of cod sampled in three sub-areas of 3Ps during research surveys were presented. Information on the duration of spawning was summarized along with information on cod egg and larval distributions in Placentia Bay. Trends in year class strength, based on information from research surveys and recent commercial catches, were described.

SPA analyses were carried out on Canadian spring, Canadian winter and French surveys using the total catch at age of 3Ps cod. The results from three SPA approaches (ADAPT, QLSPA, and ICA) using identical inputs and as close as possible model conditions, were compared using as close as possible inputs. The methods all gave broad agreement. Results from a preferred run using QLSPA and ADAPT were also presented.

9.1.2 Discussion

The Fishery

In relation to the **landings** statistics in Table 1, it was asked if there was any evidence of unreporting in the recent years? It was replied that there was good observer coverage and dockside monitoring in 1998 and thus no indication of under-reporting.

The large recent increase in the inshore fishery was noted. As well, in recent years, the fishery has started quite late - in July and August, with most of the fishery now in the fall. For instance, in 1997, the fishery started in May. A lot of fishermen with IQ s in Placentia Bay waited until late in the season when the catch rates were high and the fish were in good condition.

It was queried whether or not a time series of landings from Burgeo Bank was available. The data were available in Table 3 of the working paper for Canadian landings, and indicated about 1000t of Burgeo Bank (3Psd) cod caught in 1998. While it is possible to produce an historical Canadian time series, this is more difficult for the French fleet. For this fleet, maps catch rates for 1981-87 is available and could be used to separate out the Burgeo Bank catch. After that, the French fleet was constrained in the areas in which it fished.

- **An historical time series of Burgeo Bank landings by gear is to be produced at this meeting.**

A new piece of information in this year's assessment is that the 3Psc cod are linked to catches in southern 3L, as indicated by tagging. Catches in southern 3L may be mostly 3Ps cod. This may be similar to what is happening on the western side of 3Ps. It was replied that while it has been suggested that the high catch rates in Placentia Bay were northern cod, genetic studies examining cod from Placentia Bay found that they were genetically different to offshore northern

cod. It was felt that the cod may be migrating out of the bay and into 3L in the summer after spawning and returning to the bay in the fall.

Clarification of the unit area boundaries of Burgeo Bank was requested, to which it was replied that the mixing area is mostly 3Psd and 3Psa.

It was noted that there appeared to be adequate sampling, three strong year classes (1989, 1990, and 1992), and a wide range of ages and sizes in the fishery, consistent with information from several components of the fishery and the 1998 assessment. However, cod older than age 10 are still rare.

It was asked if there are any differences in the **size composition** of the fish on the Burgeo Bank compared with other areas. This is difficult to determine as the catch comes from the latter part of the year, not from the time when the purported mixing occurs. It was pointed out that very little recent catch is from Burgeo Bank. Further questions of clarification were asked on sampling levels, and use of sentinel survey information.

There was considerable discussion on the treatment of the Burgeo Bank cod landings in the assessment. It had been agreed in the remit of the meeting that analyses would be conducted to examine the sensitivity of the assessment to the removal of some fraction of the January – March Burgeo Bank landings, under the assumption that the area contains a mixture of 3Pn4RS and 3Ps cod at this time of year. Comments from industry participants at the meeting indicated that they had observed the movement of gulf cod into 3Ps during the late fall for many years, and indeed had observed a change in the migration pattern in the late 1980s. They considered the winter closure as a positive step. However, it was countered that tagging studies indicate that cod spawn on Burgeo and that it is equally possible that some 3Ps cod migrate into the Gulf. While this was recognized, many participants considered that the majority of the migration was from the Gulf into 3Pn and the western area of 3Ps. Others thought that the problem could not be clarified without more information on the movement of the Burgeo Bank spawners. Examination of historical catch/effort data in relation to the timing of the migration was recommended. While consensus was not possible, **it was agreed** that it was important at this meeting to bracket the uncertainty surrounding the exchange of 3Pn4RS and 3Ps cod at the mouth of the Gulf of St. Lawrence.

It was pointed out that, while this discussion was interesting, the main issue is the appropriate matching of the population analysis calibration with the right catch matrix. In reply, it was noted that spawning affinity has been used to allocate catches among areas. This led to a discussion on the spawning stock definitions. It was shown that some cod on Burgeo in April were pre-spawners. It was also noted that genetic studies from April suggested the presence of two groups on Burgeo Bank.

Resource Status

Regarding **catch rates**, it was asked why sentinel linetrawl CPUE was so high. This is because CPUE is expressed on a per day basis. Sets of one or two hours duration were adjusted to a 24-hour period. This treatment could be a problem if gear saturation occurred but is probably not a major problem because of sentinel protocols on soak time. It was noted that sentinel CPUE was either stable or decreasing since 1996. However, due to the presence of a commercial fishery in 1998, which disrupted the sentinel program in 3Ps, interpretation of sentinel CPUE is difficult. As well, the signal in the sentinel survey is relatively weak. A multiplicative analysis of the sentinel survey information was attempted which included only main effects and no interaction terms. The treatment 'Trip' was a fisherman nested within unit area and division. This analysis indicated that line trawl CPUE had declined by almost 50% in recent years while the SPA indicated a substantial

population increase. It was pointed out that the analysis was conducted for illustrative purposes and was not intended for use as a calibration index, for the reasons stated above. Industry participants noted the interaction between the commercial and the sentinel survey and acknowledged the decline in the CPUE of the latter. However, they also considered that, while declining, they were still higher than historical levels. This raised the issue of the need to consider the interaction between the sentinel survey and the commercial fishery in the proposed sentinel survey workshop.

Regarding the **acoustic survey**, while it was noted that the age composition of the fish in Placentia Bay were consistent with other information, few other comments were made.

The **tagging** data may guide the choice among the SPA models presented. What is required is estimates of biomass and exploitation from this information that can be compared to the results of the SPA. This led to a discussion on the potential bias in the exploitation rates which are to be produced. They could be biased low (tagged fish migrating out of the area from the offshore to the inshore) or high (tagged fish are aggregated). The methods used for estimating exploitation rates for the 'coarse model' are provided in WP99/26 and 99/33. The techniques are complicated and comment from experts at the meeting was solicited.

- **Estimates of biomass and exploitation are to be produced from the tagging data to allow comparison with the SPA results. Comments on the potential bias in these data are to be provided.**

- **The tagging methods WP will be circulated for comment as the techniques formed a major component of the basis for the 2J3KL stock assessment.**

Regarding the surveys, it was asked if biomass and abundance estimates were available for the two **GEAC surveys**. Both are in the text of the working paper.

It was asked if the **genetics** samples were taken at spawning time (yes), but the samples from the two spawning components on Burgeo Bank are likely not large enough to differentiate between them.

It was asked if the changes in the 50% **maturity** could be a result of the change in the survey timing from February to April. The change in the maturity has a big impact on the estimation of the spawning biomass. It was noted that the decline in the 50% maturity was well on its way by 1993, before the change in the survey timing. It is interesting that similar patterns were reported from 3Pn4RS.

The sharp decline in **GEAC survey catch rates** was noted, but in response it was noted that the survey strata had been adjusted and that one would have to consider the same strata for a valid comparison. This prompted questions about why the change in strata. At the onset of the survey, **it was agreed** that the survey would be reviewed after one year, which occurred. In 1997, the survey consisted of both a stratified and grid design component. After review with industry, **it was agreed** to drop the grid design, and add more strata, with fewer stations sampled per strata. Regarding survey timing, which resulted in Burgeo not being sampled, this was constrained by vessel availability. It was queried if an analysis of similar strata could be conducted. This is possible but the survey is for ancillary information purposes but is not used in the SPA calibration.

It was asked if the widespread and protracted **spawning** seen in 3Ps is unique. It was noted that this occurs in both 2J3KL and 4VsW. It was asked if the spawning times by area should be put in the overview. However, if this is done, there should be a statement on why this is

important. It is interesting that generally spawning areas have been identified which are characterized by distinct retention areas. In 3Ps, it appears that no such retention area has been identified, at least in the offshore. It may be that the stock has adapted to the local oceanographic conditions by widespread spawning. This has implications for the definition of spawning biomass.

It was asked what happens to the 3Pn data of the 3Ps survey. This is provided to the 3Pn4RS assessment scientists.

- **STRAP2 is to be run on the 3Pn portion of the 3Ps survey and provided to A. Fréchet.**

The **ADAPT** model results were reviewed. It was pointed out that the ADAPT projections for 1998, in contrast to those of the QLSPA, were very different from those calculated at this meeting, which indicates problems with the formulation. Discussion focused on the potential exclusion of the two historical indices, the effects of which would have to be examined. This raised the issue of a combined versus offshore only assessment. After review of the 1998 assessment model formulations, **it was agreed** to proceed with the combined model at this meeting. It was further noted that the winter (February) survey catchabilities are twice as high as those in the spring (April) survey. Is this reasonable? Various potential explanations were provided, including inshore/offshore movement, migration to and from the Gulf, and vertical distribution. However, the problem becomes somewhat academic with exclusion of the winter survey from the analysis. There was also discussion on the observation that the survey catchability increases with age. This may be a consequence of using a flat-topped partial recruitment, as this does not occur with a dome-shaped PR. This was investigated at the Newfoundland RAP meeting.

Discussion then shifted to the **QLSPA** model, the assumptions of which were briefly described. It was asked to what extent does the February survey influence the fit, to which it was replied that it produces large residuals. It was further asked if the QLSPA model could be run with each index separately to judge the sensitivity of the last year's F to the survey indices. There was further dialogue on the factor of two – four difference in the Qs in the spring and winter surveys. The change to the Campelen trawl may explain this, and if so, would apply only to the spring survey, which changed gear in 1996. It was asked if it would be useful to consider the non-Campelen data to see if the change in Q is a consequence of mixing on Burgeo Bank, to which it was replied that it would be cleaner to remove the Burgeo Bank data from an analysis to examine its impact. At the end of this discussion, **it was generally agreed** that the ADAPT and QLSPA models are closely related in as much that both assume full recruitment at the oldest ages whereas the ICA assumes a dome-shaped PR.

There then followed a more **general discussion on the models and their assumptions**. It was pointed out that the QLSPA provides a more general framework than ADAPT to examine error assumptions, and that in the formulations considered, ADAPT assumed a constant CV with the survey index, in contrast with the QLSPA, which assumed linearity. The latter was considered a superior assumption when stock biomass and thus the survey indices were low. ADAPT works well when the stocks are at a high level but not when the stocks are low. In this case, the ADAPT tries to fit the very low survey values. **It was generally agreed** that the use of QLSPA is superior at low stock sizes. However, there was concern when it was noted that when the QLSPA formulation is made similar to that of the ADAPT, that the results of the two models were significantly different. Further investigation of the differences is given in the following working paper.

If the difference can be satisfactorily explained, the use of the QLSPA model would have implications for the other stocks being assessed at the meeting. Regarding the ICA model, it has the undesirable property of wanting to treat the catch as a random variable, when in fact it may be biased because of unreported removals. The **ICA** is well suited to multi-index data sets such as used in ICES and may not be suitable for the current situation.

Notwithstanding the problems and differences with the models, it was noted that the age 3+ biomass estimates from a range of models were reasonably tight, although there may be differences among the formulations in the risk curves. How should this be handled? It was suggested that this could be incorporated into the discussion on the uncertainty of stock status. The broader issue of model selection still remained. This could be facilitated by the production of key diagnostics. As well, in testing a model for instance, it is typically fit to part of a data set and then used to predict the remaining dataset. This could be attempted here.

It was considered essential to standardize as much as possible the **data inputs** to the models. A number of decisions on the data inputs were made and a number of runs requested. These are further described in the following sections.

There was considerable discussion on the appropriate analytical investigation of the 3Pn4RS/3Ps cod mixing on **Burgeo Bank**. In the remit of the meeting, it was requested that the impact on the 3Ps assessment of removal of 75% of the cod catches on Burgeo Bank (3Psa and 3Psd) during January – March since the 1970s be investigated. The basis of the 75% figure was questioned, to which it was responded that it came from the High Priority Project on Cod Mixing. It was pointed out that the 75% figure was presented to allow examination of the sensitivity of the 3Ps to the mixture assumption and that it was not universally accepted as a firm estimate. Notwithstanding this, it was considered that if it transpires that a particular scenario regarding stock mixing is adopted, then there should be a document in which the derivation of the 75% estimate is provided. As the removal of the Burgeo Bank catch is to examine model sensitivity, only one run was required. As there will be a number of runs, summary tables of the results will be required. Given that the number of requested runs is not great, the details of each run should also be provided.

- **S. Campana is to prepare a working paper documenting the derivation of the proportion of the Burgeo Bank catch that must be removed form the 3Ps assessment.**

- **Examine the removal of the Burgeo Bank catch in the age 3 – 9 index run.**

On a final note, it was considered important to solicit **industry's comments** and traditional knowledge on the 3Pn4RS/3Ps cod mixing issue.

Total mortality estimates based on the spring and winter survey data were presented. The results were highly variable and the plots were not easy to interpret. There appeared to be a large year effect. Last year, the April survey did not detect the large biomass that was there. This year, the GEAC survey had problems finding the fish. This indicates the difficulties in surveying this resource.

Stock Status Report : Below are some of the main points made:

  - In the Fishery section, the text should be modified to recognize the foreign (French) readership.

- The Ecological Factors section is to be taken out of the Resource Status section. The latter is to have subsections on at least Surveys and Population Analysis.

- Regarding the survey biomass plot, **it was agreed** that, as the February and April series are not comparable, they should be either put on separate plots or coloured/hatched differently. As well, the Burgeo Bank information should not be included in the index.

- It should be pointed out that the industry survey didn't cover Burgeo Bank.

- The efficiency of the Campelen to catch all size groups needs to be especially flagged.

- The positive features of the GEAC survey should be covered.

- The fixed gear sentinel survey section is to be reworked. It should particularly include the views of the meeting on the utility of these data, mention the CPUE declines along with the caviets.

- Comments on the uncertainty in the DFO surveys are to be added to the Sources of Uncertainty section.

- The results of the elemental analysis, as well as J.C. Mahé's comments are to be included in the Biological Information section. Specific participants were assigned to work on the wording.

- Information on the Placentia Bay Mark/Recapture study is to be included in the population analysis section. This stimulated discussion on the estimated biomass from this study (70kt) as compared to last year's estimate (50kt).

- The condition information needs to be added.

- The section on the acoustic survey in Placentia Bay needs reworking.

Outlook: To be determined by the group after review of the re-runs.

9.1.3 Recommendations

- **The historical catch/effort data in the 3Pn and adjacent areas should be examined to determine the timing of the migration and whether or not it has been consistent over time.**

- **Investigation of the nature of the differences between the ADAPT and QLSPA models should be continued.**

- **Examine the impact of commercial fisheries on sentinel surveys at the proposed sentinel survey workshop.**

9.2 *Cadigan, N. 1999. Comparisons of ADAPT and QLSPA for two SPA Formulations based on 3Ps Cod. WP 99/32*

9.2.1 Summary

An analysis of a comparison of the results of QLSPA and ADAPT were provided. It showed that when the models have the same formulations, the biased point estimators are very similar. The difference between the two models mentioned in WP 99/18 was due to the bias correction used in the ADAPT run. As well, there was some uncertainty whether or not a bias correction was appropriate.

9.2.2 Discussion

Bias correction was considered by the group as an important issue. This was discussed at the April 1998 Transboundary Resources Assessment Committee (TRAC) meeting, a number of issues identified and a remit sent to the ICES ComFie Working Group for consideration at its January 1999 meeting. It was reported by one of the participants (A. Sinclair) that while no definitive conclusions were made by ComFie, it stated that bias correction could be in the wrong direction. Notwithstanding this, Comfie did suggest bias correcting the point estimates.

It was asked if the degree of skewness in the model results was the reason for the differences observed. Is the median a better metric to use. Yes, it is the skew that is driving this, but it was uncertain whether or not we should model the median. This requires further investigation.

It was asked if we should adjust for bias. Can we use the ComFie guidance? It was then asked if bias could be calculated for the QLSPA model, to which the answer was yes and indeed was presented. However, it was then noted that the bias correction for ADAPT and QLSPA appeared to be quite different under similar model formulations. This difference was unresolved. However, the issue of bias correction and the differences in this for ADAPT and QLSPA are generic issues for a number of stocks assessed at this meeting. Re 3Ps cod however, for most stocks, we don't see bias values this large, at least in the ADAPT run. This draws attention to the level of uncertainty in the SPA.

The desired runs to be seen for the 3Ps assessment were then discussed. First, **it was agreed** that the February and April surveys would be used with ages 3 – 12 in the calibration matrix. Re the catch at age (ages 3 – 14), two options would be investigated, with and without the Burgeo removals. If possible, QLSPA and ADAPT will be used and the bias calculations conducted. As ADAPT is not set up to do bias unadjusted risk analysis, the Status Report will have to explain the differences in the numbers of the two methods. There was concern of the weighting of the various indices. This will be need investigation.

There was discussion on why we were including Burgeo fish of the April survey in the analyses. Why were we seemingly ignoring the information of Campana. In response, it was noted that the tagging data suggested that April is a transition month and that in particular, late April is not a problem re mixing of 3Pn4RS and 3Ps cod.

During the next discussion on the 3Ps analyses, QLSPA runs with the February and April surveys using constant CV for ages 3 – 8 and Poisson error for ages 9 – 12 were presented. The indices were self weighted (using the inverse of the variance). Three runs were considered which investigated the partial recruitment in the fishery. In run #1, the numbers at age 14 are estimated. The run #1 estimated numbers at age 14 for 1985-98 but flat-topped before that. F 14 was set to equal to the ave F11-13. Run#2, after looking at #1 decided that a domed PR was most consistent with the F's in the diagnostic run. Run #3 was senstiivity, similar to last year's F

on age 14 is the average F on ages 7-10. In run 2 and 3, age 14 for years 1993 to 1998 was estimated because there was not enough data to apply F constraints. The preferred run (2) assumed a dome-shaped PR in 1998. Also, to lower the CV around the 1998 age 3 estimate, the age 2 April Campelen survey index was added as a calibration index. This is important for the risk analyses which were also presented.

There was considerable variability in the fit to the survey data, particularly the 1997 point but there is no reason to exclude this point.

It was commented that the winter survey would appear to be getting more weight in the analysis than the spring survey, which would mean that the recent survey of year classes is being downweighted. However, this depends on the variance function and it was not apparent that this is the situation. The residuals appear reasonable.

It was asked how the Burgeo Bank strata were removed. They were, and this was relatively easy as they had their own age/length keys.

A comparison of the tagging results with the SPA was requested. This would need to be done by age group. A similar comparison with the Rose acoustic study would be useful. On the surface, the estimates in the SPA (100+mill) appeared too high compared to the acoustics (30-40mil).

- **Conduct a comparison of stock size estimates from acoustics, tagging and QLSPA**

The survey catchabilities appeared dome-shaped. Given the large error bars, this was questioned and indeed the real pattern might be flat-topped. However, it was felt that the combination of the Engels and Campelen gear in the April survey could produce the dome. It was acknowledged that a test of the trend would likely show insignificance. It was noted that this was the first year that age 14 was estimated and thus allowed the possibility of a dome, which indeed occurred. This led to a more extensive discussion of the three model runs which investigated the sensitivity of the QLSPA to the PR assumptions.

It was asked if the QLSPA could be bias corrected as per ADAPT, to which it was replied that as the model makes no assumptions on the 3rd and 4th statistical moments, no bias correction was needed.

Questions were raised on the sizes of the 1989 & 1990 year classes in the QLSPA. The previously considered strong 1989 year class now appeared average. However, it should be remembered that with the four year moratorium , even average year classes might appear good due to the overall improvement in stock conditions. Concerns were raised about the very high numbers of young fish in recent years. However, these were observed in the survey and the residual plots appear reasonable. Could the change to the Campelen trawl be the reason for this? Maybe**. It was agreed** to consider the SSB/recruit plot to see if recent year classes are reasonable.

- **Conduct a SSB/Recruitment plot to determine if recent year class estimates are reasonable.**

On a positive note, the removal of the Burgeo bank strata appeared to produce more comparable winter and spring survey catchabilities.

The meeting returned to the PR issue. Given the high percentage of the catch projected to come from gillnets, it was felt that the 1999 PR would also be dome-shaped. However, it was pointed out that a domed selection at length does not necessarily translate to a domed selection at age. Can this be checked empirally. This is in fact run 1, which produced a domed PR in 1998.

The risk calculations were then discussed. The two probabilities considered were SSB>100000t in 2000 and F age 7 > 0.2 for a range of TACs in 1999. This raised the issue of an F0.1 assuming a domed PR, the value of which is 0.43. While yield calculations for both F reference levels would be useful, it was considered important to calculate the Surplus production/Biomass ratio, as there is no reason to believe that F0.1 is sustainable.

- **Calculate SP/B ratios both historically and through the projection period.**

It was asked if there was a retrospective pattern, to which it was replied that examination of this is hindered by the fact that the Campelen survey information at age 2 is only in the QLSPA for three years. It was suggested to drop this series and run a retrospective analysis.

- **Conduct a retrospective analysis with the Campelen age 2 index removed.**

The retrospective bias was very pronounced, with 3+ abundance ranging between 40,000-300,000 thousand fish over recent years. The high 1995 RV value probably amplified the extent of the bias, suggesting that the 1995 value may have been anomalously high. Nevertheless the pattern was stronger than in many of other stocks and must be considered when the reliability of the current year is evaluated.

It was asked about the general sense of the stock status. Sentinel survey and GEAC survey CPUEs are declining while the QLSPA indicates near to historical high biomass. Industry reported that the resource is doing very well. The offshore fishery was directed at three large aggregations. Gillnetters had to cut back the number of nets that they used and mobile gear reported good CPUE. In the east (Placentia Bay), catch rates were exceptional, but this was not so in the west. It was asked why the TAC wasn't met in 1997 and 1998. This was due to unallocated IQ. And although sentinel CPUE had declined, the rates were still high compared to history.

Finally, the poor status of 3NO cod was noted. 3Ps cod is seemingly surrounded by a number of poor stocks. It was noted that this is due the fortuitous event of some strong year classes being protected by a four-year moratorium.

9.2.3 Recommendations

No specific recommendations.

9.3 *Winters, G.H. 1999 Integrated Catch Analyses (ICA) of 3Ps Cod. Working Paper 99/19.*

9.3.1 Summary

Integrated Catch Analyses (ICA) is an analytical stock assessment tool for analyzing catch at age and research vessel survey information. In this mode,l catches at age are assumed to be measured with error that has an independent log-normal distribution.ICA differs from most SPA models in that it provides options for weighting of survey indices and is therefore particularly suited for stocks which have multiple stock abundance indices. ICA was used to calibrate an SPA for 3PS cod based on 3 indices; (1) Canadian Research Vessel April surveys (1983-84, 1993-98) ages 3-10) (2) Canadian Feb-March surveys (1985-92) ages 3-10 (3) French RV survey (1983-91) ages 3-10. The ICA model was run for a variety of input constraints but the best fits were achieved when a dome shaped selection curve was used for the post-moratoria period (1994-98) and when the model was run with the same separable constraint but using the April survey only. In both cases, age 3+ biomass estimates for 1998 were in the 310,000-315,000 range.

9.3.2 Discussion

It was pointed out that the results of ICA run three should be similar to that conducted by Brattey et. al. but differed by about 100kt of 3+ plus biomass in 1998. The cause(s) of this difference need to be resolved before the ICA models could be accepted. Possible causes mentioned were the lack of use of one of the 1993 surveys and application of a dome-shaped partial recruitment (the oldest age selectivity was assumed as 0.5). Re the latter, it was noted that this was most likely the cause for the relatively (to the other presented population models) large increase in age 7 – 9 population numbers. In support of this assumption and thus these high numbers, it was replied that the lack of a fishery in recent years had allowed the growth of these older age classes.

- **It is necessary to test the sensitivity of the ICA model to the assumption of a dome-shaped partial recruitment.**

It was asked if the model considered all the abundance indices as equivalent. They are weighted by the inverse of their variance in some of the models. However, if one index is used in the population model after 1992, this is not an issue.

9.4 *Mahé, J.-C. and D. Briand. 1999. The French Cod Fishery in Subdivision 3Ps. Working Paper 99/20.*

9.4.1 Summary

A total of about 3120 t of cod (equivalent to the 1998 quota) was caught by France in 1998. The fishing activity was spread in three gear categories, a hand line fishery (15 boats of less than 10 meters) fishing mostly on the South coast of Newfoundland (Dantzig and Fairbanks), a gillnet fishery (7 boats of 10 - 11 m) fishing in a area 40-50 miles in the Southwest of Saint-Pierre island and a Bottom trawl fishery (2 Canadian boats) fishing mostly in the South of Halibut channel.

The handline fishery did not perform as well as in 1997, a total of about 77t was caught (171 t in 1997). The average cpue was 201 kg/day (276 kg in 1997), and was maximum in June to drop to a low level in August as it stayed close to its maximum level throughout the summer in 1997. The size and age composition of the catches showed that smaller individuals were caught in 1998 compared to 1997. The 1994 year-class is dominating in the catches.

Higher catch rates were observed in the 1998 gillnet fishery (average cpue of 1144 Kg/day in 1998, 737 in 1997). Two modes were distinguished in the length distribution and the 1990 year-class was dominant. The 1991 and 1992 year-classes were also well represented. The total catch was about 532 t which together with the other coastal component represented 19.5 % of the total 1998 French cod catch.

The other 81.5% was caught by two Canadian otter trawlers and landed in Saint-Pierre. The size and age composition of the catch showed bigger individuals than in 1997, as the 1989 and 1990 year-classes still dominate in the catches.

9.4.2 Discussion

It was queried whether or not the data provided in the working paper had been incorporated into the population analysis, to which it was replied yes.

9.5 *Mahé, J.-C. 1999. An Assessment of Subdivision 3Ps Cod using Extended Survivor Analysis (XSA). Working Paper 99/21.*

9.5.1 Summary

Another SPA calibration technique was applied to the 3Ps Cod catch at age data The method focuses on relationship between CPUE of tuning indices and population abundance. The algorithm performs

- A cohort analysis
- An adjustment of fleets cpues to the begining of the year using alpha and beta parameters (timing of the recorded cpue data) followed by regressions to estimate fleets catchabilities
- Calculation of fleet based estimates of population abundance at age from the cpue values and catchability coefficients
- Calculation of a weighed mean of the terminal population for each cohort in the tuning range from the fleet based estimates of abundance at age which are used to initiate the next iteration.

Two runs were presented, the first one using the same input data as used in the standard assessment for catch at age, catch and stock weight, maturity ogive natural mortality and 3 tuning indices :

- Canadian RV index spring 83-98 age 1 to 13
- Canadian RV winter 85-93 age 1 to 13
- French RV 78-91 ages 3 to 12

A second run using the same data plus an extra tuning fleet, the St-Pierre OTB2-5 trawler fleet from 1978 to 1992 ages 3 to 13.

The results of the first run showed strong year effects in catchability for the spring survey (years 95 and 98) for ages 4 and up but the age 3 was well estimated, because the winter RV showed no unusual pattern and no strong residuals, the French survey showing trends in catchability especially for the younger ages. Due to the weighing, however, and the time span of the data, this fleet had little influence in the estimates of survivors. A retrospective analysis showed a good concordance between the 1998 and 1997 estimations but a strong revision downward between the 1997, 1996 and 1995 estimates. The biomass estimates showed a increasing trend from 51000t in 1993 (22900t SSB) to 212600t in 1998 (124400 t SSB). Fbar (7-11) was estimated at 0.143. Assuming recruitment in 1999 equal to GM96-98 the total biomass is estimated at 246100 t at 01/01/1999.

Adding the French trawler fleets improved slightly the residuals pattern of the spring Survey catchabilities but the trawler fleet's residuals showed trends in over the last three years of data especially in the younger ages. This resulted in higher estimates of numbers at older ages in the last year bringing up the biomass estimates although the historic trend is similar. The retrospective pattern showed a tendancy to overestimate biomass. The biomass estimates showed a increasing trend from 74021t in 1993 (37751t SSB) to 247650t in 1998 (156600 t SSB). Fbar (7-11) was estimated at 0.113. Assuming recruitment in 1999 equal to GM96-98 the total biomass was estimated at 281200 t at 01/01/1999.

A comparative run was made with standard settings together with ADAPT, ICA and QLSPA. The XSA results lied in between the other methods (246100t of Total biomass for a range of 201900-294900 t).

9.5.2 Discussion

Comments were raised regarding the year effect trend in the residuals of the fit to the commercial trawler catch rates. This suggested that the fishery catchability was higher now than historically. It was replied that this became a problem only when the 1992 data were used. In the last assessment that this was used there was not such a problem. Further discussion on this was delayed until more general consideration of the 3Ps population analyses.

9.6 *Mahé, J.C. 1994. Median length at 50% maturity of Atlantic Cod in Subdivision 3Ps: Year to year variations and comparison of samples from Burgeo Bank, St. Pierre Bank, and South Slope. NAFO SCR. Doc. 94/11.*

9.6.1 Summary

The determination of size and age at sexual maturity is of major importance in conducting stock assessments, being the link between individual growth and the reproductive potential of a population. The median length at 50% maturity (L50) of a particular stock is dependent upon environmental conditions and the rate of exploitation. The evolution of this parameter over the years can be of interest in evaluating the level of exploitation of a population by fisheries but also, in areas of probable intermingling of two different populations, a fine analysis of the parameter could help in determining the extent of the mixing - individual stocks show significantly different values of median length at maturity. Data collected on cod maturity during the French research surveys conducted annually from 1978 to 1992 in Subdivision 3Ps were analysed first to identify a trend over the period and second to compare the values of the parameter in two areas of possible intermixing: Burgeo Bank (mixing with the cod stock from the Gulf of St. Lawrence – Division 4RS) and the South Slope of the Halibut Channel (possible mixing with the cod stock from the Grand Bank – Division 3O).

9.6.2 Discussion

It was asked when the changes in maturity occur. This occurred after 1986 in the western area of Burgeo. It was pointed out that figure 3 shows mixing since 1982. However, it is the divergence in the L50 that is important and this occurred since 1986. As has been reported many times, there has always been mixing but this has been at lower levels prior to 1986.

It was asked why the 1992 male L50 was so low, to which it was responded that this could be variation in the survey data.

9.7 *Bertrand, J., D. Briand, and J.C. Mahé. 1988. Atlas de l'Activite des Chalutiers de Sainte-Pierre et Miquelon de 1981 a 1987. IFREMER WP.*

9.7.1 Summary

An atlas of catch, effort and catch rates from the St. Pierre and Metro fleet (SPM) fleet during 1981 – 87 was presented. The data were provided by quarter and 10 minute square and could be used to assist in partitioning the catches of the SPM fleet in testing the sensitivity of the population to mixing from 3Pn4RS.

9.7.2 Discussion

It was pointed out that, based on Canadian observer reports, the catches by the SPM French fleet in the mid 1980s, in 3Psa and d were 68% of the total. These are somewhat larger catches than

reported here. However, the catches reported in the WP didn't include 3Psd. In the 3Ps WP, it was reported that most of these catches come from the St. Pierre fleet.

9.8 *Campana, S. 1999. Stock Composition Analysis of Cod in the Burgeo Bank Area in Winter. Addendum to WP 99/07.*

9.8.1 Summary

Clarification had been requested on the source of the statement that 75 percent of the cod in the Burgeo Bank area during January 1996 and 1997 were of 3Pn4RS origin. This was based on the DFO research surveys, of which an analysis was presented and the proportion shown to be closer to 80 percent.

It had been asked if resident Burgeo Bank cod could be differentiated from migrating 3Pn4RS cod on the basis of otolith elemental fingerprints. The overall response was yes, but less precisely than for the other stocks. Burgeo spawners are similar to, but significantly different from those of 3Pn and 4R. It is interesting that all spawning groups, except those on Burgeo Bank, showed unimodal discriminant scores. The bimodality characteristic of the Burgeo spawners suggests the presence of two spawning groups, possibly resident spawners and 3Pn spawners passing through the area in April. A new stock mixture analysis of the RV catches in the Burgeo area in Jan 1997 indicated that about 30% of the fish were resident Burgeo fish, with most of the remainder being from 3Pn4RS.

9.8.2 Discussion

This was felt to be an important contribution to the 3Pn4RS – 3Ps issue. It was asked if it was assumed in the analysis if there was a resident Burgeo Bank spawning component. This was assumed due to the presence of spawners. As well, the DFO survey was timed as close to the spawning time as possible. It was noted that the Burgeo spawners had been excluded from previous analyses due to uncertainty of the stock affinity.

It was asked if the DFO survey was always in April. It was late April in 1997. In 1996 – 98, few cod were seen in 4R at that time of year. They were probably in 3Ps or 3Pn. Thus the numbers presented were likely underestimating the contribution of 4R fish.

Clarification of otolith analysis was requested. Genetic analysis did not discriminate the Burgeo Bank group due to small sample sizes. On the other hand, for stocks which we know don't mix, genetics showed no difference. This underlined the importance to bring a variety of techniques to bear on the stock differentiation problem.

The two key observations of the presented analysis were summarized:

1. 3Pn or 4R fish are on Burgeo in late April, and
2. There is a Burgeo Bank spawning component

The group was asked if these observations had implications for the analyses on the 3Pn4RS – 3Ps issue already requested at the meeting. In response, it was mentioned that the runs on the catches separated out had been conducted. Catches are not a problem. However, the abundance indices may be. If the February surveys are used in the calibration, then we have an issue. However, if the April survey is used, there are not enough Burgeo Bank cod to worry about. To remove the western 3Ps strata would throw out more of the information than necessary**. It was agreed** that the April survey would be used without adjustment. On the other hand, if the February survey is used , the Burgeo Bank strata would have to be excluded.

It was asked if after seeing the information of J.-C. Mahe, is the 75% figure still appropriate. **It was agreed** to still use the 75% figure to estimate sensitivity of the model to the 3Pn4RS – 3Ps issue. Re adjustment of the February survey, this is more problematical.

9.9 Stock Stus Report

Additions were made to the section on stock structure to indicate that stock mixing in the Burgeo Bank area has long been present.

Sentences on the retrospective problem need to be added to the section on Major Sources of Uncertainty.

There was discussion about the preferred F for projections: the dome-shaped PR produces a $F_{0.1}$ = 0.42, which is very high. As a more conservative measure, it may be best to use the average F over ages 7-14 = 0.2 in both the Armstrong plot and risk curve.

The Outlook needs to include more statements concerning the negative indicators in the assessment, including the declining sentinel catch rates, the low 1998 GEAC estimate, and the continuing low age at maturity as an indicator of stress.

The Outlook needs to include some statements on stock mixing in Burgeo, and the benefits of continued closure during the winter.

10. Cod in northern Gulf of St. Lawrence (3Pn4RS)

(Rapporteurs: J.C. Brêthes, D. Gascon, J. Rice)

10.1 *Fréchet, A., M. Bérubé, P. Schwab, M. Hammill, G. Moreau, L. Pageau, G. Rowe and F. Collier. 1999. Morue 3Pn4RS Cod. (Working Paper 99/03).*

The work done since the last recommendations was presented. Errors in the catch at age in 3Pn and in the seals' diet were corrected. Interactions were considered in the standardization of the fixed gear catch rates.
Two VPA runs were presented :

- the first includes a long series of fixed gear data, linking " repères" fishery and " sentinel " fishery ;
- the second considers two different series in fixed gears (one for the " repères", one for the " sentinel ").

In both cases, seals consumption was considered.

The validity of the reconstruction of catch at age for fixed gears was questionned as inconsistencies seem to appear between calculated Catch rates and observed catch rates. Trends appear to be different between the oldest and the newest periods. This issue was not solved

Very few geographical overlaps are observed between the two series. The link between the two appears very tenuous.

The discrepancies between the two data series (catch rates trends, residual patterns) and the non convincing link between them discredited the first VPA run using the " long series ".

It was agreed that the first run was not defensible and should be abandoned.

The explicit inclusion of seal consumption as a " fleet " in the VPA was debated. Doubts were raised about the assumption of constant predation instead of proportional (variable) predation. **It was agreed** that using a variable consumption rate was not feasible during the current meeting, even if it should be explored in the future. However, uncertainty remains about the validity of the figures provided on the catch at age, considering the numerous sources of variations (actual consumption, resident time, geographical variations, etc.).

Two different views were expressed :

- seals predation should be explicitly expressed to show the order of magnitude of the predation, knowing the uncertainties (almost the period when uncertainties existed in the reported catches) ;
- seals predation should be removed as an explicit factor, as we do not know what the figures provided actually mean.

The **final consensus** was to keep the current assessment with seals explicitly presented just for comparison purposes during the current exercise.

- **The final run should use the same indices as in the present run 2, removing the explicit seal predation and using instead a constant M=0.4 for the period 1986-1998.**

A suggestion was made to set M=0.2 during the period 1993-1998, but was not retained.

10.2 Tagging-recapture experiment

A new figure showing the size at release was provided.

The issue of differential selectivity between tagged and captured animals was raised again. One view is that if the smallest tagged cods are less vulnerable to recapture than the larger ones, this may lead to an overestimation of the biomass. Even if that view seemed to reflect the majority of the opinions, no firm conclusion was made. A suggestion was made to adjust the catch of small fishes using a partial recruitment curve that could be derived from the size structure of catches.

Another concern was the effect of the recruitment on the assessment. The theory indicates that recruitment would induce an overestimation of the biomass over time. The results presented, however, do not show such trends (biomass declining from the 1997 assessment to the 1998 assessment in most cases).

No strong opinion was expressed that this work should be dismissed. Calculated values do not seem to be unrealistic considering the current values obtained with the VPA.

The consensus was that the estimated biomass is useful to give a range of values that can be compared with the output of the VPA.

The accepted values range from 147000 to 192000 t, excluding the value derived from 3Pn tagging areas.

The work will be referred to in the SSR.

It was also agreed not to mention the standard deviation as it does not reflect the various sources of variations involved in the technique.

10.3 3Pn4RS Cod Addendum #3

Concerns from the first week regarding application of sampling data to various fleets and numbers in the seal consumption tables both have been resolved.

There was a long discussion about the linking of the repère and sentinel fisheries programs. Only one individual fisher/site was carried over from one program to the other, and there was substantial concern that the two series were not well calibrated.

It was agreed that there would be an attempt to conduct a site by site standardization of the sentinel catch rates, and this information would aid in interpreting the linkage, if any, between the repère and sentinel programs.

There was also discussion about the degree of linkage between the sentinel and trawl surveys, and the degree to which the sentinel program catch rates gave information about the status of the entire stock. There was noteworthy overlap between the depth ranges covered by the two series, particualrly when the distirbutions of catches by depth are considered. **It was agreed** that the surveys were not completely comparable, but should pick up some patterns in common.

There was discussion about the survey Z calculations. There was concern that older fish may have a lower q in the trawl survey. It was noted that there would be more information presented on that subject later in the meeting.

There was also discussion about the relative degree to which the sentinel and trawl surveys contained information on stock status by NAFO area. For 3Pn and 4R some participants felt the sentinel program was the more relevant, whereas for 4S the trawl survey was more appropriate. There was no full resolution to this discussion, but more information was to be viewed later. For the interim the sentinel catch rates were kept in consideration as a tuning index.

When Addendum 3 was tabled there was more discussion of the linkage of the repère and sentinel catch rates. Soak times in the sentinel program were almost all in compliance with sentinel protocols, and showed little variance. Soak times for the repère were much more variable, with a different mean than the sentinel gears. This was considered to be a strong argument against linking the two series, because the functional relationship between catch and soak time is unknown but likely to be complex. There was also serious concern about site by time interactions which some thought should be examined prior to standardizing even the sentinel survey series.

There was also long discussion on whether or not to aggregate catches and effort within cells in the standardization of the sentinel catch rates. The controversy centered on the value of replication within cells for statistical analyses, contrasted with the distributional violations of glm assumptions and possibility of occasional artificially high values with fully disaggregated observations

It was suggested that sets with zero catches be addressed outside the standardizartion, but there were doubts that such analyses would be possible in the time available to the meeting.

An analysis of survey Z's was tabled and discussed.

Discussion of this work centered on the ways in which age class and year effects were handled in the Z=analysis. **It was agreed** that the treatment in the analysis was acceptable.

It was also noted that there seems to be some evidence that mortlaity in the most recent years may be somewhat lower than the very elevated levels earlier in the 1990s. This will be discussed when the desired SPA formulations are considered.

The concluding discussion on approaches to standardization of sentinel catch rates focused on four points:

- Should sets with zero catches be removed and analyzed separately?
- What level of disaggregation should be the basis for analysis?
- How should soak times be handled?
- How should seasonality be handled?

The discussion of soak times noted that the early points have very high leverage, so their interpretaiton is important. Also **it was agreed** that it would be impossible to produce a functional relationship between soak time and catches, especially for the historic series, so the decision would have to be on whether the soak times of the repère and sentinel programs could be considered functionally equivalent. Many felt that the differences in distributions of soak times were sufficiently different that the differences are particularly large for longlines. It was also noted that the industry perception is that catch rates have increased in the way displayed by the joined repère and sentinel program.

It was noted that the standardization of the two programs shows the same trend when month and major area are included, but very different when individual fishers are used to link the series. This was a serious concern because there were very few individuals linking the two series.

After extensive discussion, **it was agreed** that linking the two series by individuals was not appropriate, but linking by major area should be explored further. The effect of including the month area interaction term should also be included the standardizations. There was further discussion of how this exploration should be done, ending with the proposal to link them in the ADAPT run. Some thought this would be of little help, because a short series stuck several years back in the time series would have little influence on current population estimates. However**, it was agreed** that contrast in two ADAPT runs between one with the the series linked by a common standardization, and one where the two series were entered separately in ADAPT would shed some light on the comparability of the two series.

It was agreed that there are sufficiently few zeros that their treatment is not a major concern.

The discussion of degree of aggregation recovered the tradeoff between desirability of replication and problems with characteristics of individual values. **It was agreed** that aggregation at the individual cell level was a more tractable approach for this meeting. Further analysis of patterns in the sentinel catch data should be pursued in the coming year, however, so these questions can be revisited next year for all stocks. It was established, however, that linking the series had been by vessel and not site. It is likely that at the level of local community/site there would be much more continuity between the two series. **It was agreed** that a standardization should be attempted on a site by site basis, as a compromise between individual vessel disaggregation and aggregation at the level of a large area.

A discusison about the large difference in catch rates in 1991 between the original working paper and the new series led to the conclusion that the high value with the new analysis was due to applying the rule of dropping cases with very low catch or very low effort on a finer scale of disaggregation in the newer runs. This would drop a lot of effort with catch, compared to the working paper series, leading to a higher estimate of catch rate.

In a discussion of additional calculations to clarify the relationship between the Delaney triangle and STRAP analyses, it was suggested that the calculations contained an error, and did not support the inference initially drawn from the analyses. Further examination of the information however, clearly indicated that errors were not present. As a result the differences in the STRAP estimates and those using the Delaney triangle method remained unresolved. **It was agreed** that it is important to keep the area surveyed consistent over time in an index and that we would like to keep information on both change in the area occupied and biomass from the survey, when we are evaluating the status of the resource.

A proposal was made to make a new series of biomass estimates form the trawl survey, but taking the annual means of the stratum means. This was rejected on statistical grounds.
The proposed SPA runs for this stock were to be calibrated to:

- RV - Gadus 78-94 (full series) Needler 91-98 (90 was dropped because it lacks converage of 3Pn and inshore). Ages 3-9 for both surveys.
- July sentinel mobile fleet 94-98 and October 94-98 - only ages 3-9
- Not include catch transferred from 3Ps
- Fixed gear sentinel site by site standardized for short **and** long series - ages 5-9

The formulation will have M increased to 0.4 from 86-93 block ONLY, and seal predation will be included.

There was a discussion on the proposal for having M return to 0.2 in recent years. Several biological reasons were given when m may be returning to lower values, and with acknowledged high levels of misreporting and discarding in the late 1980s and early 1990s. The lower recent me was also consistent with some of the analyses tabled earlier in thw meeting. However, it was noted that there have been no analyses tabled which directly demonstrate that m has begun to decrease, and this should be kept clearly in mind.

10.4 3Pn4RS Cod Addendum #7

It was noted that the 'no seals' run actually incorporated seals indirectly, through use of M = 0.4. The 'with seals' run calculated an age-specific M due to seals, which was then used in risk analyses and projections, along with a revised $F_{0.1}$ = 0.5.

In the most recent years, the comparison of the seals-in and seals-out models indicates that mortality due to seals produced an overall M greater than 0.4. Therefore it was asked why a constant M of 0.4 was used, rather than an age-dependent seal M in addition to M=0.2. The response was that it could actually be adjusted to make the two M trajectories identical.

The largest discrepancy between the various runs is in terms of mature biomass, although the risk curves are similar. It was noted that even in the case of recruitment, the two models produce very similar trajectories, differing only in scale. The question of the impact of seals on recruitment cannot currently be answered, since the value of M independent of seal predation cannot yet be addressed.

In principle, the seal-in model should better account for the age-dependent consumption of seals. Based on the model output, there was no obvious reason to prefer one model over the other. However, given the similarity of the risk curves, it was proposed that only one be presented, and that the results of the other be noted in the document. The tagging estimate of 4+ abundance lay exactly midway between the estimates of the seal-in and seal-out models. Given the potential biases of the tagging study, it was suspected that the tagging estimate would have a

tendency to be high rather than low. If so, a slightly lower tagging estimate would appear to be more consistent with the seal-in model.

The risk curves for mature biomass are relatively similar between the two models. The yield curves differ more, due in part to a more difficult interpretation of exploitation rate when seals are in.

It was agreed that the preferred run was the seals-in model, and will form the basis for the risk curves, etc. Only the biomass risk plot will be presented, due to the problems of interpreting the exploitation rate risk discussed earlier. The SSR should note also that $F_{0.1}$ will no longer be 0.2, that it will be different, so that the current reference F is uncertain. The section on Sources of Uncertainty will discuss the seals-out model, particularly the influence on biomass and recruitment.

11. Cod in southern Gulf of St. Lawrence (4TVn)

(Rapporteurs: L. Currie and W. Brodie)

11.1 *Results of the sentinel surveys for cod conducted in the southern Gulf of St. Lawrence in 1994-1998. Chouinard, G.A., B. Parent and D. Daigle. WP 99/24*

11.1.1 Summary

Sentinel surveys are limited removals from fish stocks where fisheries are closed. The information collected from these surveys is designed to provide an index of abundance for the stock as well as well as other biological and oceanographic information. In the southern Gulf of St. Lawrence, the program started in the fall of 1994 and expanded during the following years. In 1998, 36 (27 fixed gear and 9 mobile gear) fishermen were involved in the program.

For both mobile and fixed gears, projects are conducted in five main areas: southern Gaspé coast, northeast New Brunswick, P.E.I., western Cape Breton and the Magdalen Islands. The surveys are conducted in traditional fishing areas identified by fishers.

For mobile gears, fishers identified large areas from the southern coast of the Gaspé Peninsula to western Cape Breton. These were subsequently divided in 3nm by 3nm squares. In each year, at the beginning of the project, stations are selected at random from the list of possible stations for each of the fishing trip. Twelve fishing trips (maximum of one per week) are conducted with either trawlers or seiners. The mesh size used is 145 mm square and liners are used on four trips for the purpose of collecting information on recruiting year-classes. A regular fishing set is conducted by seiners while trawlers conduct tows of one hour in duration.

For fixed gears, fishers have identified fishing sites that remain constant from year to year. A number of new sites have been added over the years. Two gears are used: longlines and gillnets. During the course of the season, fishers set their gear a maximum of 24 times (maximum of twice per week). Longliners use a maximum of 2500 hooks (12 circle) divided equally between two sites. Gillnetters use 10 gillnets (140mm, 25 meshes deep, 50 fathoms long) also divided equally between two sites.

With the expansion of the program, catches have increased from 46 t in 1994 to 366 t in 1996. Catches in 1998 amounted to 630 t. Mean (un-standardized) monthly catch rates by province gear and month show some variability from year to year. For seines and otter trawls using liners catch rates were generally higher in 1998. For both gillnets and longlines, catch rates increased from 1995 to 1997 but declined in 1998. Generally, catch rates for fixed gears have been low in

the western southern Gulf (Gaspé, New Brunswick) and have been highest near P.E.I. in both 1997 and 1998.

For lined mobile gears, year-classes can be tracked in the length frequencies which suggests that the information can be used in estimating abundance trends for the stock. The catch at age for the sentinel surveys is calculated separately for each of the six gear types (longlines, gillnets, seines and otter trawls (lined and unlined). In the program, observers are present on all of the vessels and thus sampling information is complete for all trips. In 1998, over 180,000 fish were measured..

Standardized catch rate series were estimated for longlines, otter trawls and seines (lined and unlined) using General Linear Models. Catch and effort data was first aggregated by cells of year, month and site (province for mobile gears). The data was examined for missing cells and categories which had large number of missing cells were eliminated. For longlines, only sites which had been fished for three out of the four years were retained. The general model used in the analyses was the following:

$$\ln A_{ijk} = B_0 + B_1 I + B_2 J + B_3 K + \varepsilon$$

where A_{ijk} = the catch rate for year i during month j and site (province) k
I = a matrix of 0 and I indicating year
J = a matrix of 0 and I indicating month
K = a matrix of 0 and I indicating site (province)

The resulting standardized catch rates series were relatively similar for the seines (lined and unlined) and the lined otter trawl all showing a decline in catch rates in 1997 and a subsequent increase in 1998. Catch rates increased for longlines from 1995 to 1997 but declined in 1998. A standardized effort for the various time series was calculated by dividing the sentinel catches for each gear type and year by the standardized catch rate. For each of the gears, a CPUE at age was calculated by dividing the gear-specific catch-at-age by the standardized effort. The 1988 year-class is apparent in the age composition of the various gears and can be tracked over most of the time period of the sentinel surveys. The lower abundance of the 1994 year-class in the catch at age suggests that this year-class may not be as abundant as adjoining year-classes

11.1.2 Discussion

Concerns discussed by the fishing industry included concerns that limited mechanisms are in place to measure cod recruitment; they suggested the annual research vessel cannot access inshore or hard-bottom areas where small fish concentrate. The sentinel survey should be used to examine this. Another suggestion for estimating recruitment would be to allow lined trawls on a fraction of tows in every trip, not just on every fourth trip as per the present protocols. Various problems were described from N.S. sites in 1998: grey seals destroyed nets and the fishery experienced 100% turnover in captains and vessels, resulting in a learning curve. Concerns were expressed that these factors, along with severe weather in 1998, contributed to the decline in catch rate in this area. It was noted that although these factors may be more influential for gillnets than for longlines, there were also declines in catches in other areas.

In the analysis of seine data, month was not significant, but it was kept in the analysis because of significant interaction terms with month and other affects, such as area. It was also valid to use the index if interactions do exist, unless the interaction is with year. Only a few zero values were removed from the analyses. There was no adjustment for soak time for fixed gears; protocols were in place for each gear.

The sentinel fishery is only a short time series at this point and it may be difficult to detect yearly trends in the data. The stock appears to be relatively stable from these catch rates, agreeing with other information (research survey) thus there may not be much contrast in the data from one year to the next; thus the year effects are not significant, and others only marginally so.

11.1.3 Recommendations

- **The data for longlines and unlined trawls indicated a drop in 1998, but there appears to be one influential point in each series. The analyses had included these points, and it was suggested to examine the analyses with these points removed.**

- **The sentinel data were pooled and not examined set-by-set which initially showed a lot of variability. However, it can still be used in a SPA because there are useful data on tracking year classes in these indices. A suggestion was made to examine the data site-by-site.**

- **Although the age-disaggregated index is the one used in SPA calibration, the effort used to derived the age-disaggregated indices are derived from the age-aggregated models. It was agreed that the age-disaggregated index should be examined.**

These questions may be dealt with by the Working Group set up to examine the analyses of sentinel data in general.

11.2 *A review of information relevant to the issue of consumption of Atlantic cod (Gadus morhua) by seal species in the southern Gulf of St. Lawrence. Hammill, M., J.F. Gosselin, F. Proust and D. Chabot. WP 99/06*

11.2.1 Summary

Four species of seals: grey seals (*Halichœrus grypus*), harbour seals (*Phoca vitulina*), harp seals (*Phoca groenlandica*) and hooded seals (*Cystophora cristata*) occur in the southern Gulf of St. Lawrence. Harp seals and grey seals are the most important seal predators owing to their abundance (harp seals), or time of residency in this area and possibly high incidence of cod in the diet (grey seals). Harbour seals and hooded seals are less important predators in this region owing to their small numbers. Pinniped consumption of cod in 4T may be in the order of 7,000-11,000 t, but these estimates should only be considered as being very tentative. The absence of comprehensive diet information for pinnipeds in the southern Gulf is one of the major factors limiting attempts to quantify groundfish consumption in this area. However, the impact of predation on 4T cod stocks cannot be evaluated until predation is considered within the context of total natural mortality.

Résumé

On retrouve quatre espèces de phoques dans le sud du Golfe du Saint-Laurent : le phoque gris (*Halichœrus grypus*), le phoque commun (*Phoca vitulina*), le phoque du Groenland (*Phoca groenlandica*) et le phoque à capuchon (*Cystophora cristata*). Les phoques du Groenland et phoques gris sont les prédateurs les plus importants du fait de leur abondance (phoques du Groenland), ou de leur temps de résidence dans cette zone et du taux peut-être élevé de morues dans leur régime alimentaire (phoques gris). Les phoques communs et phoques à capuchon sont des prédateurs moins importants dans cette région du fait de leur faible nombre. La consommation de morues par les Pinnipèdes dans la zone 4T pourrait être de l'ordre de 7 000 à 11 000 tonnes, mais ces estimations ne doivent être considérées que comme tout à fait provisoires. L'absence d'information complète sur le régime alimentaire des Pinnipèdes dans le sud du Golfe est l'un des principaux facteurs limitants pour quantifier la consommation de poissons de fond dans cette zone. Toutefois, l'impact de la prédation sur les stocks de morues de la zone 4T ne pourra être évalué que si la prédation est considérée dans un contexte de mortalité naturelle totale.

Species	Factor	Estimate	Certainty	Impact on cod
Harp seal	Abundance	5000000, two components (Front & Gulf)	Good	
	Age structure		Well known	
	Residency in Gulf	~40% of population, Dec. – May	Good; variable between years	
	Residency in 4T	Most seals from the Gulf for pupping (late Feb. through mid-March), variable but unknown outside of this window	Poor	~2000 tons mostly on 0-20 cm cod
	Diet in 4T	Unknown. In other areas cod represents small part of diet. Also cod (except juveniles) leave 4T during the time most harp seals are found there. No data on year-to-year variations.	Poor	(Very tentative)
Hooded seal	Abundance	500000	Good	Negligible - small number of seals
	Age structure		Well known	in the area
	Residency in Gulf	~16000	Good	
	Residency in 4T	Most of the herd during March (reproduction), but variable outside of this window	Poor	
	Diet in 4T	Unknown, used data for inshore Eastern Newfoundland	Poor	
Grey seal	Abundance	190000, two components (Sable & Gulf)	Good	5000-9000 tons or 8000-13000 tons depending on rate of increase used for Gulf component. Cod 0-40, with most being 20-40 (Very tentative)
	Age structure		Fair to Good	
	Residency in Gulf	Year-round for some animals, and migrations between feeding and reproduction areas for others.	Good	
	Residency in 4T	Same, animals of both components can spend time in 4T. Cod (except juveniles) leave the area at times when grey seals are abundant there.	Good	
	Diet in 4T	Few samples suggesting 6-19% cod in % of occurrence, used data for eastern Scotian shelf in model (15% by mass).	Poor	
Harbour seal	Abundance	Maybe 30000	Poor	Negligible - small number of seals
	Age structure		Poorly known	in the area
	Residency in Gulf	Unknown fraction of the above, but animals do not migrate	Poor	
	Residency in 4T	Same	Poor	
	Diet in 4T	No data for 4T, some data for Scotian shelf and Bay of Fundy, where cod represented a small part of the diet	Poor	

11.2.2 Discussion

Concerns were raised that seal consumption could have affected cod recruitment in years (e.g. the early 1990s) when ice persisted later than usual, allowing seals to remain in the area longer, coinciding with the migration of cod to the Gulf.

The satellite telemetry figures on seal distribution indicated some overlap between adult seals and cod, however, the large majority of occurrences of tagged seals were in areas where cod are not found. This should be taken into account in the consumption estimates.

11.2.3 Recommendations

- **It was agreed that more data on diet (including distinguishing juvenile and adult cod) and movement of seals in 4T are needed before conclusions can be drawn on the impact of seals on the cod stock.**

- **It is not appropriate to use consumption estimates from other areas and apply them to this cod stock.**

11.3 *Size selective mortality of cod in the southern Gulf of St. Lawrence. Sinclair, A.F., J.M. Hanson, D.P. Swain and L. Currie. WP 99/04*

Disentangling the effects of size selective mortality, temperature and density on the growth of cod in the southern Gulf of St. Lawrence. Sinclair, A.F., D.P. Swain and J.M Hanson. WP 99/05

11.3.1 Summary

Lengths at age of southern Gulf of St. Lawrence cod have declined in the last 20 years from historical (since 1950) high values in the late 1970s to the lowest values observed in the mid-1980s. These changes have had a considerable effect on stock production but the causes have not been well described. Results of an analysis of size selective mortality, and its possible contribution to these changes in length at age were presented to this meeting.

Year-class specific regressions of backcalculated length at age 3 vs. age of capture were used to test for size selective mortality. In the absence of size selective mortality one would expect no change in the backcalculated length at age 3 as the year-class gets older. Otoliths collected from annual research vessel surveys (1971-97) were used. The first series of regressions were restricted to otoliths collected before the fishery was closed in 1993. Two periods of size selective mortality were identified (Fig. 10.3.1). Selection (in an evolutionary sense) was for larger fish in the 1968-71 year-classes, as indicated by positive slopes. The situation reversed for the 1974-87 year-classes where these slopes were negative. In an analysis restricted to data collected after the fishery closed, there was no evidence for size selective mortality (Fig. 10.3.2) This suggests that fishing may have been the main contributor.

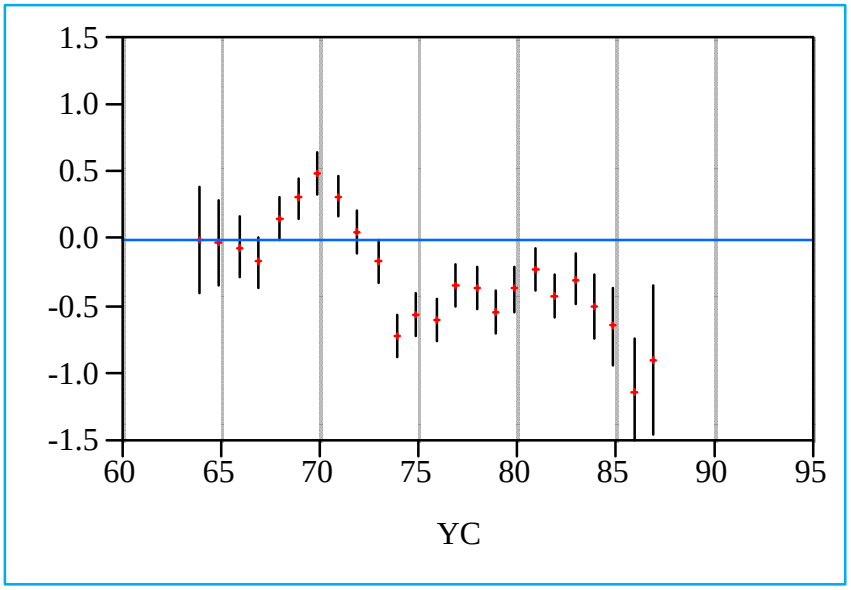


Figure 10.3.1: Slopes of regressions of backcalculated length at age 3 vs age of capture for the 1964-1987 year-classes of southern Gulf of St. Lawrence cod. The data were taken for the period 1971-93, when the commercial cod fishery was active.

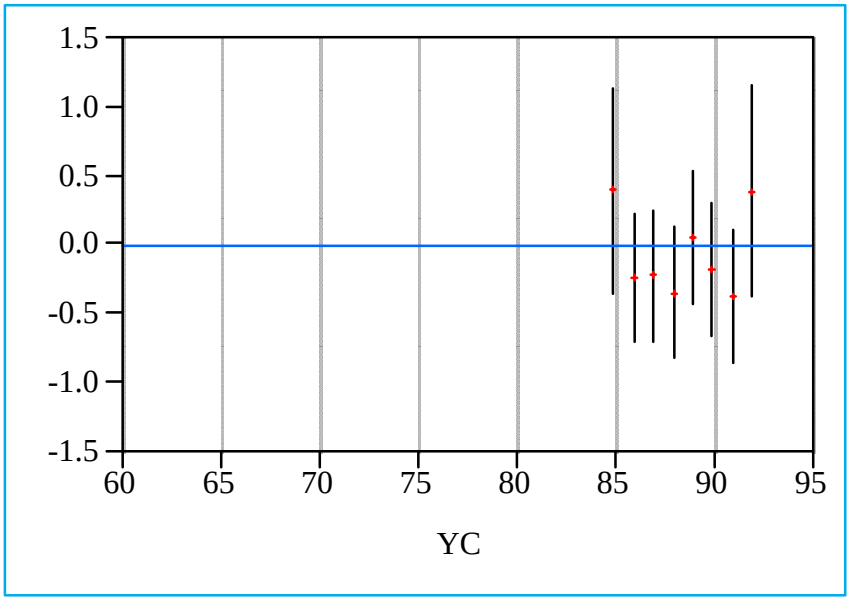


Figure 10.3.2: Slopes of regressions of backcalculated length at age 3 vs age of capture for the 1985-1992 year-classes of southern Gulf of St. Lawrence cod. The data were taken for the period 1994 - 97, after the commercial cod fishery was closed.

A simulation was used to investigate the effects of size selective mortality on population mean length at age. A subsample of fish from the backcalculation database was used as a test population. There was considerable variation in the spread of size at age. Two fishery selectivity curves were used. One was knife edged, selecting only fish between 40-60 cm, corresponding to the terminal lengths (L_∞) of slower growing fish. The other, which represented the average selectivity from the fishery in the 1982-93 period, was at about 65 cm and declined at longer lengths. The slower growing fish in the test population never fully recruited to the length range of maximum fishing mortality. The simulated fishery with the knife-edged selectivity curve

resulted in lengths at age greater than the test population means (Fig. 10). Switching to the observed selectivity curve produced lengths at age below the test population mean. This suggests that increases in fishery selectivity, brought about by regulations such as increases in minimum mesh size, may in fact depress population mean lengths at age. The magnitude of the effect will depend on the intensity of fishing. Although not tested specifically here, it is expected that moderate levels of F (~0.2) would have little effect on mean length at age.

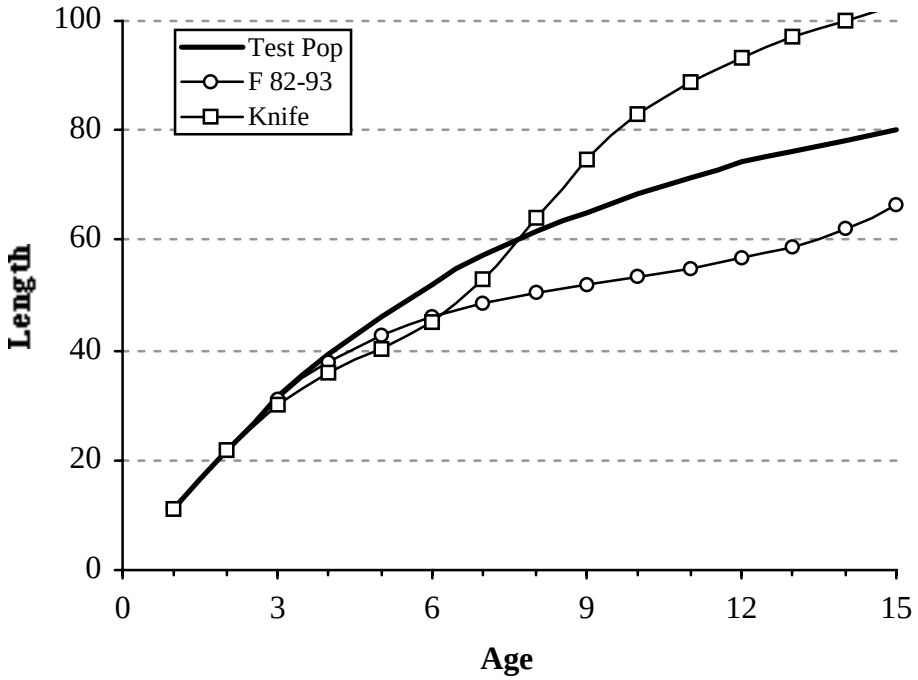


Figure 10: Population mean length at age for the unfished population and populations exposed to fisheries with either knife edged (40-60 cm) or observed (1982-93) selectivity. The selectivity curves were scaled to a maximum F of 1.0.

This simulation was also used to investigate the effects of size selective mortality on yield per recruit. In the presence of size selective mortality, mean length (and weight) at age and PR would be affected by the level of fishing. Using the observed fishery selectivity between 1982-93, length at age would decrease as F increases. Traditionally, yield per recruit vs. F is calculated with a constant weight at age and PR vector calculated from observed values. In the presence of size selective mortality, these mean weights at age would reflect, in part, the recent level of fishing. A size selection yield per recruit curve is compared to other yield per recruit curves calculated using inputs corresponding to a range of F levels (Fig. 11). It can bee seen that the true $F_{0.1}$ and F_{max} values are overestimated in all cases.

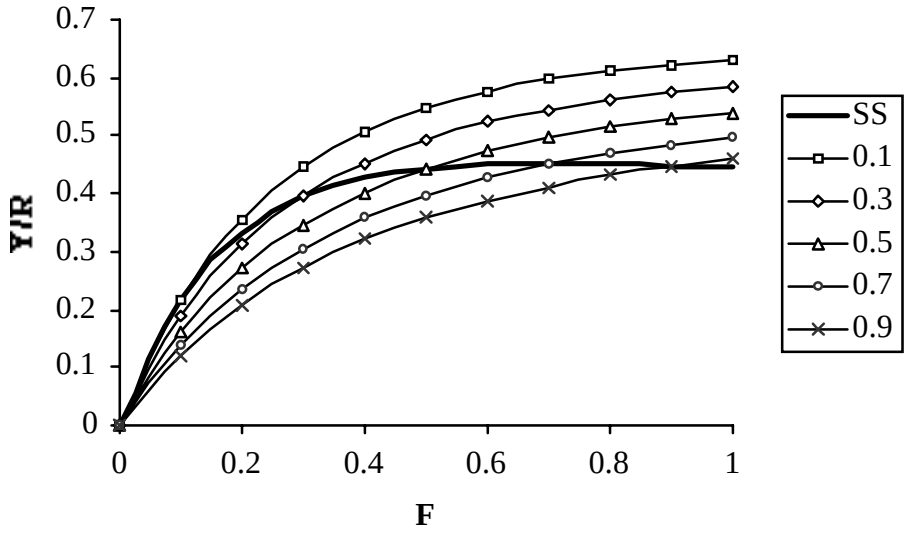


Figure 11: Comparison of yield per recruit curves for a length based selectivity pattern corresponding to the 1982-93 southern Gulf cod fishery. The solid, unmarked curve was calculated accounting for size selective mortality. The other curves were calculated from fixed weight and selectivity at age inputs corresponding with the level of fishing mortality indicated on the legend.

Two indices of size selective mortality were calculated for inclusion in subsequent analyses of factors influencing size at age. An annual size selection index was calculated as the difference in mean size at age estimated in the year of capture and the backcalculated size at the same age and year-class from fish caught in the following year. For a fish of year-class j caught at age i+1 in year i+j+1, we can backcalculate the length at its last annulus (age i+1) and its second last annulus (age i). Positive values indicate that the mean length of fish surviving to year i+j+1 was larger than the mean length of the same year-class in year i+j. A cumulative size selection index was also defined as the year-class specific difference in mean backcalculated length at age 3 (L_3) between the year of capture and when the fish were age 3. For a fish of year-class j caught at age i+1 in year i+j+1, we can backcalculate the length at its third annulus ($L_{3,j+i+1,j}$), and compare this length to the backcalculated length at age 3 when the year-class was 3 years old. A negative value indicates that smaller, and thus slower growing, age 3 fish had a higher survival rate than larger fish and one would expect lower growth rates than if the index were positive.

Two analyses of the influence of size selective mortality, population density (N) and temperature (T) on growth of southern Gulf cod were conducted. One was a linear model of growth increments of individual fish as a function of initial length and environmental factors (E) was used. Only the cumulative size selective index was used in this analysis. The results indicated that size selective mortality was the most important factor, followed by population density. The temperature effect was of marginal significance. The second analysis used a non-linear analysis described by Millar and Myers (1990) in which annual mean lengths at age were used. In this case, both the cumulative and annual indices of size selection were used. Interestingly, the cumulative index was not significant in any analysis. However, the order of significant terms was annual size selection, temperature and population density. The difference in results between the two analysis in the relative importance of factors affecting growth will be investigated further.

Conclusions
There is evidence of size selective mortality for this stock and that it shifted from selecting (in the evolutionary sense) for fast growing fish in the late 1970s, to selecting for slower growing fish in the 1980s and 1990s. It is likely that fishing was the main source of the recent size selection as the effect has disappeared since the closure of the fishery.

Size selective mortality appears to have been a major contributor to the changes in length (and weight) at age of southern Gulf cod, both inflating length at age in the 1970s and deflating it subsequently.

Failure to account for size selective mortality may leas to incorrect conclusions about the relative importance of other factors affecting growth rates (such as temperature and density) and the efficacy of management measures (such as yield per recruit and changes in mesh size).

11.3.2 Discussion

It was noted that size selective mortality may be diagnosed by differences between the size at age of fish in commercial catches and those in RV surveys, as noted by Hanson and Chouinard (1992).

A concern was raised that changes in survey vessels in 1985 and 1992 may contribute to the shifts seen here; but comparisons have shown that there was no change in survey effect to explain the size selective mortality.

In the 1980s, the selection for slow growers was found mainly at older ages and in the 90s the whole range of ages was affected. The higher fishing mortality in the late 80s and early 90s produced more size selective mortality.

It was clarified that 'selectivity' does not refer to the selectivity of the gear, but to selectivity in the evolutionary sense (i.e. selection for faster growing fish can be interpreted as faster growing fish survive better).

11.3.3 Recommendations and Future Directions

- **The correlation between size selective mortality and temperature was given as r=+0.3, and it was agreed that an overlay of the trend in cod-weighted temperature to the trend in size selective mortality would be useful to see.**
- **Time series plots of size selectivity as a function of year-class should also be examined. The discontinuity in the 1970s is a function of year-class. If there was a change in mesh selection over the year it should have been spread across all ages rather than indicating a sharp decline in one year-class.**
- **The study used a cod weighted mean temperature from the research survey, and it would be interesting to examine other temperature indices, for example the cold intermediate layer.**
- **Concerning the recent shift observed, the authors believe there is a temperature/density correlation. Large cod densities are forced to expand their range, while small densities will seek the preferred temperatures. Other interactions will be considered in future, such as density and temperature, which**

may indicate possible size selective mortality before age 3 (i.e. there may already be some effect on a cohort before the first age used in the analysis).

- **Given the similarities in changes in size at age among cod stocks, it may be worthwhile investigating possible size selective mortality in these stocks.**

11.4 *Assessment of cod in the southern Gulf of St. Lawrence, March 1999. Chouinard, G.A., A. Sinclair, L. Currie, G. Poirier and D. Swain. WP 99/23.*

11.4.1 Summary

Catches in 1998 totaled 2558 t, an increase of about 900 t over 1997. The directed fishery continued to be closed but an allocation of 3,000 t was established for sentinel surveys (650 t), by-catch and an index fishery (2350 t) . Most of the fishing activities took place between July and October. Management measures were similar to previous years. There were closures in flatfish fisheries when the by-catch of cod exceeded the prescribed limits. The recreational fishery was open from July to September but the limit was reduced to 5 fish per person.

An index fishery program to obtain another index of abundance for cod was started. Mobile gear started in July and extended until December. Most of these fishing activities were concentrated in the same areas where sentinel surveys were conducted. The seine catch rate was about double the catch rates experienced prior to the closure of the fishery. Large catches were experienced in late November and December near the overwintering areas in eastern 4T. Most of the fixed gear activities in this program took place in August of September.

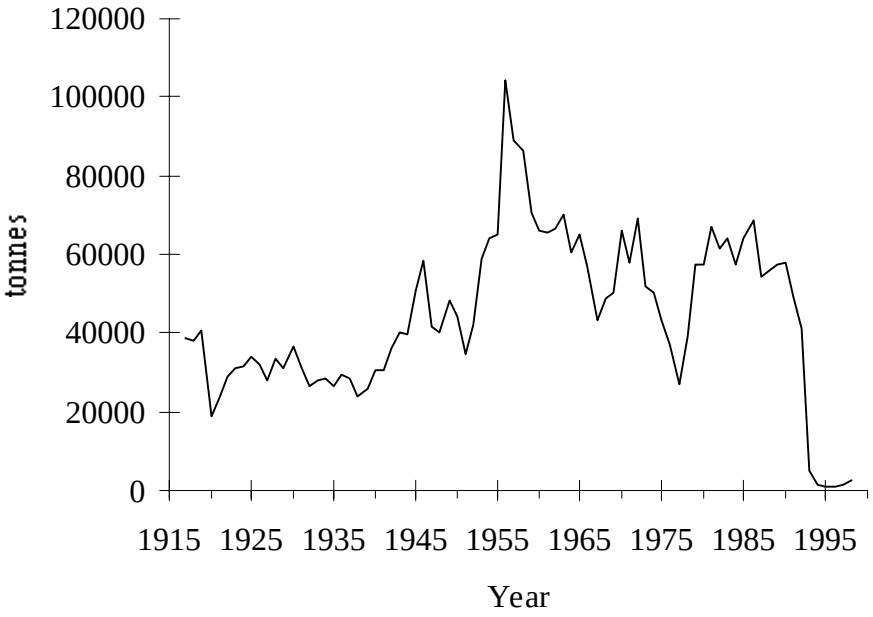


Figure 1: Landings (t) of southern Gulf cod, 1917 - 1998.

A telephone survey of active groundfish fishers has been conducted since 1995. Sixty-two of the 192 fishermen contacted indicated that cod was their first priority in 1998. Most indicated that cod were larger than in previous years. There was some difference in opinion regarding the abundance of cod compared to previous years. Sentinel fishers thought that abundance was lower while other fishers thought that abundance was higher or much higher than previous years. Differences could not be attributed to the geographic location of the fishermen.

The landings at age were calculated by gear type and quarter. The 1992 and 1993 year-classes were dominant in the landings at age. Weights at age appear to be increasing but continue to be low compared to the 1970's. Condition was examined using the seasonal index from monthly samples as well as an annual index calculated from the research vessel survey. Both indices suggest that condition in 1998 was slightly lower than during the previous few years.

Numbers per tow from the 1998 groundfish survey in the southern Gulf of St. Lawrence were unchanged from previous years at about 52 fish/tow. The survey length frequencies indicate that recruitment continues to be below average. The proportion of the survey biomass found in the eastern southern Gulf has attained the highest level in the time series with about 45% of the biomass found in the area. There appear to be a continuing trend for a higher proportion of the biomass to be found in the eastern southern Gulf.

The distribution of survey catches indicate that cod were most abundant south of Miscou Bank and in waters off the northern coast of Prince Edward Island and between the Magdalen islands and Cape Breton. A spatial analysis of the research vessel data indicated that both the extent of the distribution (area occupied by 95% of the population) and the depth distribution were consistent with distribution observed during periods of low abundance.

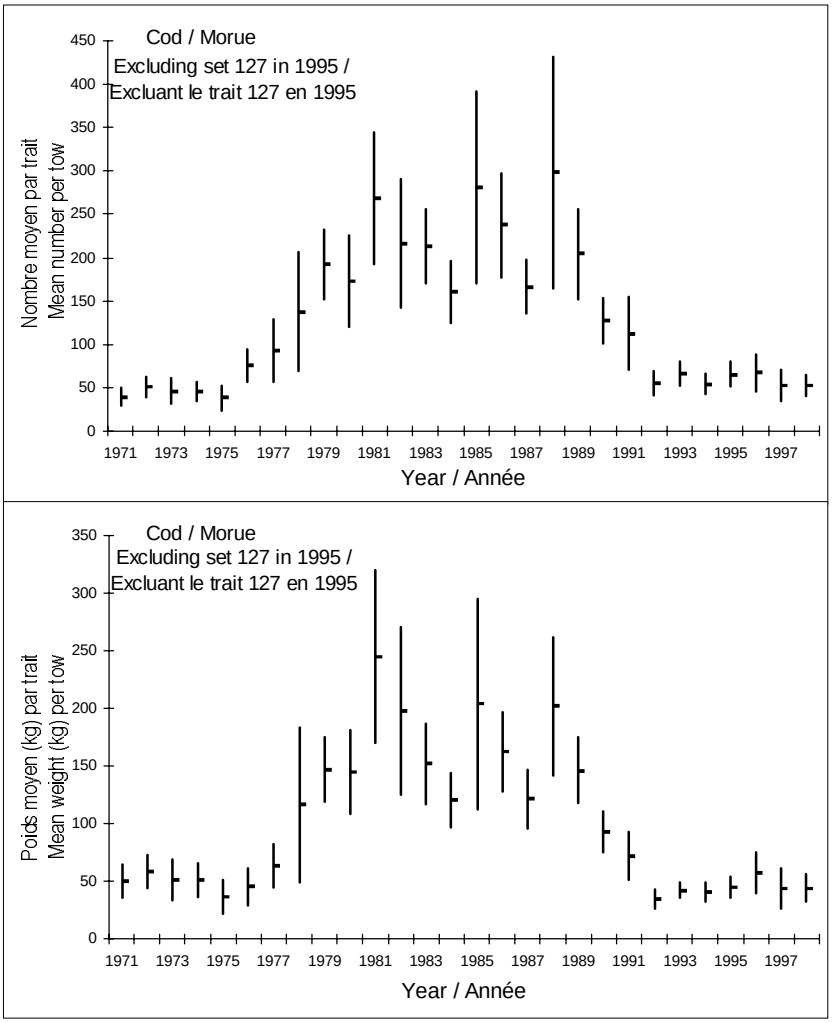


Figure 2:Mean number per tow (top) and mean weight per tow in kg (bottom) for ages 0+ cod in the southern Gulf of St. Lawrence September groundfish surveys. Error bars indicate approximate 95% confidence intervals.

Both the research vessel index and the various sentinel survey indices were analyzed using multiplicative analyses to obtain estimates of year-class size and of trends in total mortality. The analyses revealed that the year-classes produced at the end of the seventies and early eighties were large. The abundance of year-classes produced after 1987 progressively declined. The 1993-1994 year-classes appear to be the lowest on record. The 1995 and 1996 year-classes appear to be somewhat larger than the other year-classes produced during the 1990's. Trends in total mortality indicate that the 1985-1987 year classes experienced very high mortality. The 1992-1994 year classes have the lowest estimate of Z.

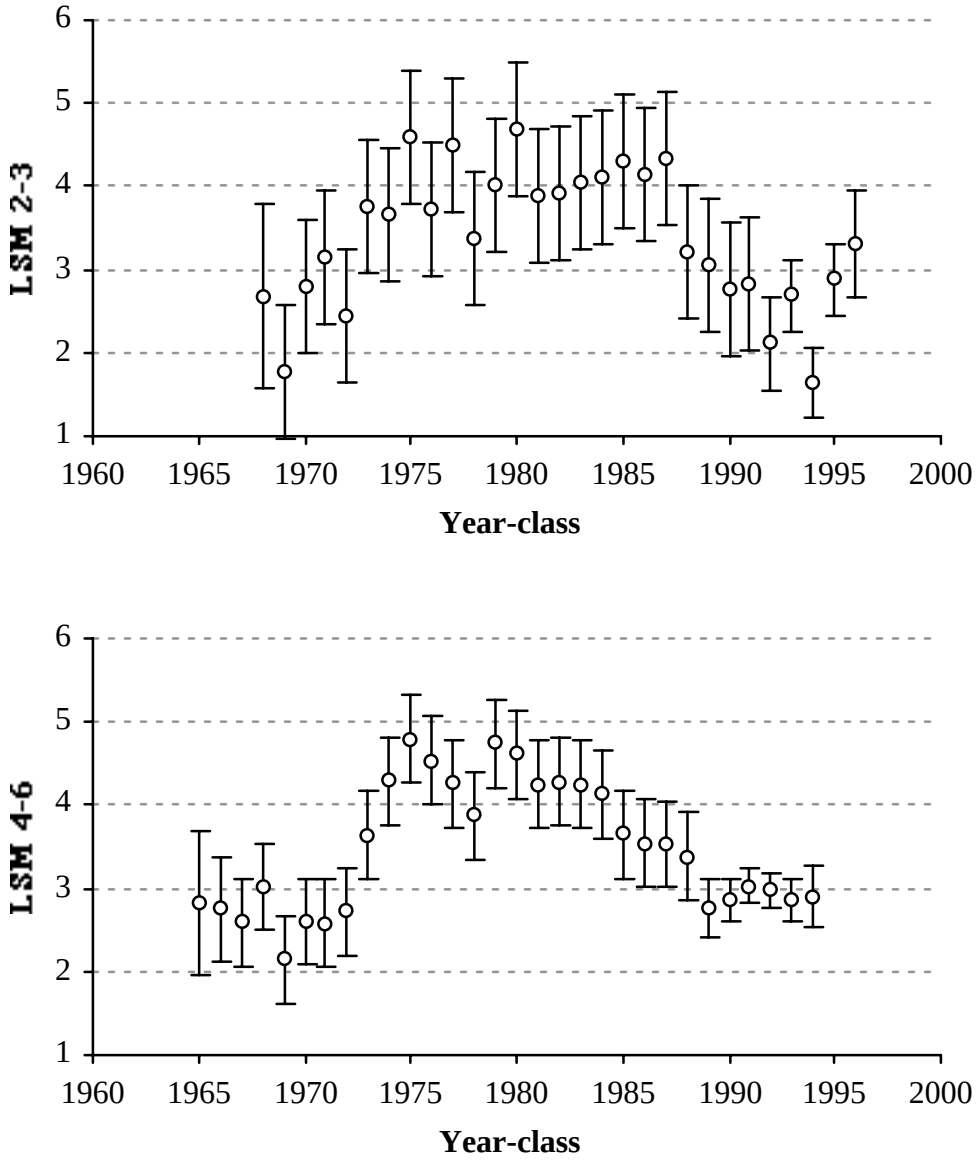


Figure 3: Relative year-class abundance estimated from research vessel and sentinel survey results for southern Gulf cod. The upper panel is for ages 2-3 and the lower is for ages 4-6. Error bars give 2 standard errors. The estimates are in the ln scale.

Direct estimates of relative F were calculated as the ratio of catch at age divided by the research vessel population estimates at age. The estimates of relative Z peaked in 1992 and declined after the closure. Estimates of relative F in recent years are very low.

Estimates of total mortality were calculated using a modified catch curve analysis. The model was an analysis of co-variance using 4-year windows of research vessel mean number per tow for ages 7 to 11. During the period of the moratorium, these estimates would constitute an estimate of the natural mortality (M). The model was:

$$\ln A_{ij} = \beta_0 + \beta_1 \mathbf{Y} + \beta_2 I + \varepsilon$$

where Aij = the stratified mean catch per tow of age i in year j
Y = a matrix of 0 and 1 indicating year-class Y
I = the covariate age

The RV gave estimates of Z in the range of 0.25 in the mid-seventies. Total mortality increased subsequently to 0.6-0.8 throughout the mid-1980's. . There was then a rapid increase in total mortality as the fishery intensified in the late 1980s and early 1990s. Total mortality then declined sharply when the fishery was closed, however, not to as low a level as in the mid-1970s.

The same analysis of covariance was used for the results of the five sentinel surveys and the results were compared to those from the RV survey for the same years (1995-98). Point estimates of Z varied from 0.33 (otter trawl unlined) and 0.59 (seine lined). Despite these variable estimates, there was considerable overlap in the 95% confidence intervals of the estimates. The overall mean of the five sentinel surveys and the RV survey was 0.46. Allowing for the fact that there have been limited catches of cod since the closure, this indicates that natural mortality has been close to 0.4 during the post-moratorium years. That recent values of total mortality have been higher than those in the mid-1970s indicates that natural mortality may have increased at some point in the 1980s.

Trends in spawning biomass and recruitment were obtained directly from the research vessel survey by multiplying the RV survey estimates by the mean weight at age. The scatter of spawning stock and recruits showed a weak relationship however two time series were apparent in the data from an examination of residuals from a Ricker stock recruitment relationship. Two curves were subsequently fit to the two time periods. The analysis suggested a change in conditions that affected survival of juveniles. The analysis of the research vessel data suggests that biomass abundance and recruitment are currently at a low level.

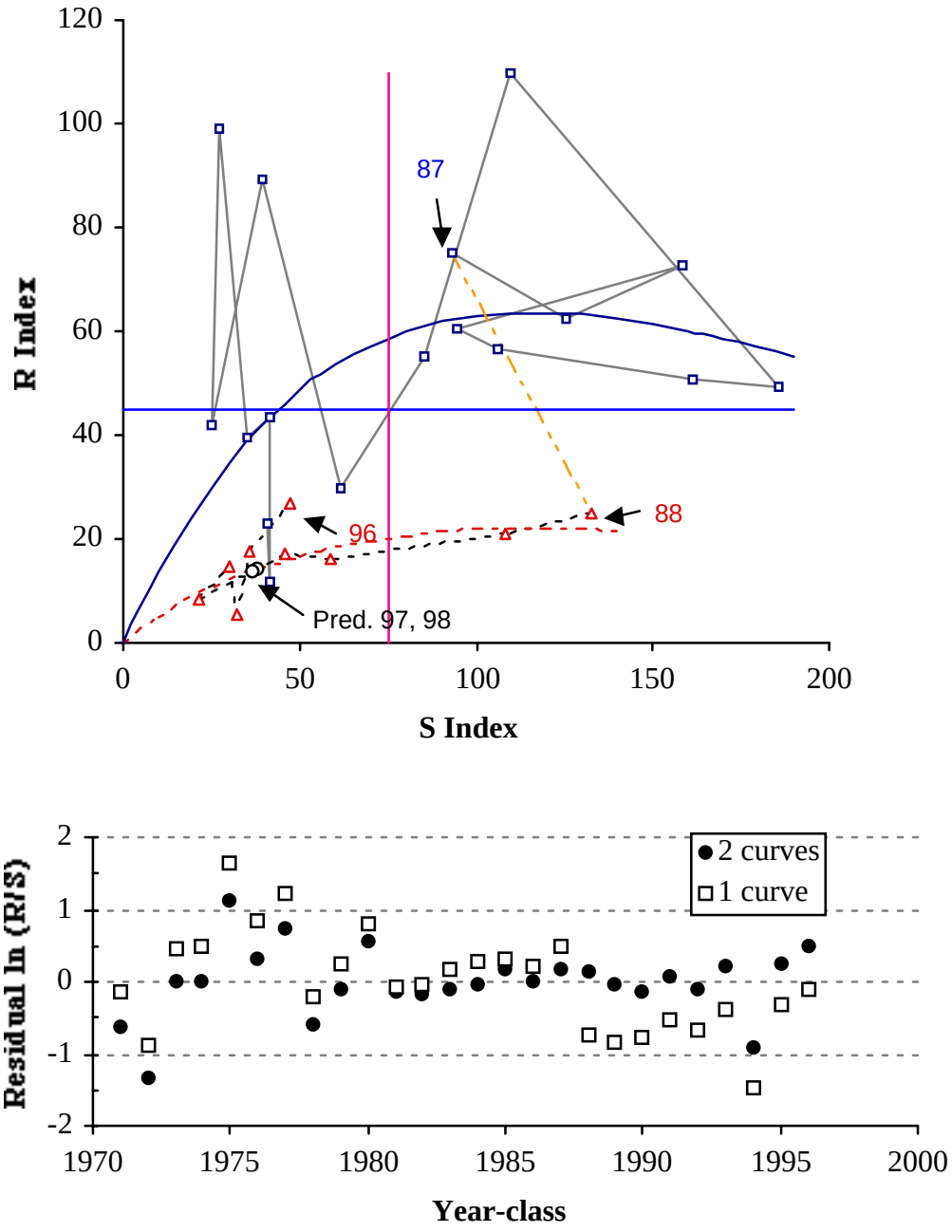


Figure 3: Stock and recruitment estimates for southern Gulf cod obtained from RV and sentinel survey results. The upper panel plots spawning stock biomass and recruitment. The points are connected in temporal sequence and key year-classes are labelled. It includes lines separating the plot in quadrants of high and low recruitment (and index of 45 and biomass (75 kg per tow). It also includes two fitted Ricker stock recruitment relationships. The lower panel shows residuals from fitting one curve (open square) and two curves (closed circle.

Sequential analyses were conducted using ADAPT. The analyses of the indices on their own suggested that M had increased. Prior to conducting calibrations, ADAPT was also used to estimate natural mortality. The analysis included the RV index, the 5 sentinel survey indices, a recruitment index as well as the CPUE index from the commercial fishery used in previous assessment of this stock. In the analysis, M was set to 0.2 from 1971-1981. Five values of M were estimated: 1982-1987 (all ages); 1988-1993 (ages3-6); 1988-1993 (ages 7-15); 1994-1998 (ages 3-6) and 1994-1998 (ages 7-15).

The ADAPT formulation was:

Parameters

Terminal N estimates:

$N_{i,1999}$, i=3 to 12

Calibration coefficients:

RV i=3 to 10
CPUE i=5 to 12 (2 parameters per age)
Rec Index 1=3
L i=3 to 11
S1 i=3 to 10
S0 i=5 to 11
O1 i=3 to 10
O0 i=5 to 10

Natural Mortality

M1 1982-87 all ages
M2 1988-93 ages 3 to 6
M3 1988-93 ages 7 to 15
M4 1994-98 ages 3 to 6
M5 1994-98 ages 7 to 15

Structure Imposed:

Error in catch at age assumed negligible
PR on ages 12 - 15 in 1998 = 1.0
F on oldest age equal to average (unweighted) at ages 9-10
M = 0.2 1971-81 for all ages

Input:

C_{ik} i=3 to 15, k=1971-1998
RV i=3 to 10, k=1971-1998
CPUE i=5 to 12, k=1982-93
Rec Index i=3, k=1971-99
L i=3 to 11, k=1995-98
S1 i=3 to 10, k=1995-98
S0 i=5 to 11, k=1996-98
O1 i=3 to 10, k=1995-98
O0 i=5 to 10, k=1995-98

Objective function:

Minimize sum of squared ln residuals

Summary:

Number of observations:

494

Number of Parameters

78

The resulting of M were as follows:

block	Age Specific k	Constant k
82-87	.32	.29
88-93/3-6	.59	.55
88-93/7-15	.36	.35
94-98/3-6	.15	.13
94-98/7-15	.57	.55

These estimates provide additional evidence for an increase in M in the 1980's. The pattern seen in the 88-93 and 94-98 blocks were somewhat surprising. It was concluded that further analyses would be required.

The analyses of the indices on their own and the estimation of M with ADAPT both indicated that M had been higher in the recent time series. However, the estimates of M in the recent time series could not be refined further. Consequently, the analyses assumed an M of 0.2 from 1971-1985 and M=0.4 from 1986 to the present as was done in the last assessment.

Four calibrations were conducted. First, a similar calibrations to the one conducted in the 1998 assessment of this stock but with the updated catch-at-age and research vessel index (including 1998) with M was set at 0.2 from 1971 to 1985 and 0.4 from 1986 to 1998 was done. In the 3 subsequent analyses the other types of indices were included progressively, first adding the 5 sentinel survey series, then the recruitment series (see Fig. 6.1 (top) and finally the CPUE index (OTB, 1982-1993) . The formulation for the full analysis was as follows:
The formulation of the model for the calibrations using all the indices was as follows:

Parameters

Terminal N estimates:

$N_{i,1999}$, i=3 to 12

Calibration coefficients:

RV i=3 to 10
CPUE i=5 to 12 (2 parameters per age)
Rec Index 1=3
L i=3 to 11
S1 i=3 to 10
S0 i=5 to 11
O1 i=3 to 10
O0 i=5 to 10

Structure Imposed:

Error in catch at age assumed negligible
PR on ages 12 - 15 in 1998 = 1.0
F on oldest age equal to average (unweighted) at ages 9-10
Natural Mortality

Run 1: M=0.2 1971-1998
Run 2: M=0.2 (1971-1985); M=0.4 (1986-1998)

Input:

C_{ik} i=3 to 15, k=1971-1998
RV i=3 to 10, k=1971-1998
CPUE i=5 to 12, k=1982-93
Rec Index i=3, k=1971-99
L i=3 to 11, k=1995-98
S1 i=3 to 10, k=1995-98
S0 i=5 to 11, k=1996-98
O1 i=3 to 10, k=1995-98
O0 i=5 to 10, k=1995-98

Objective function:

Minimize sum of squared ln residuals

Summary:

Number of observations:

494

Number of Parameters

78

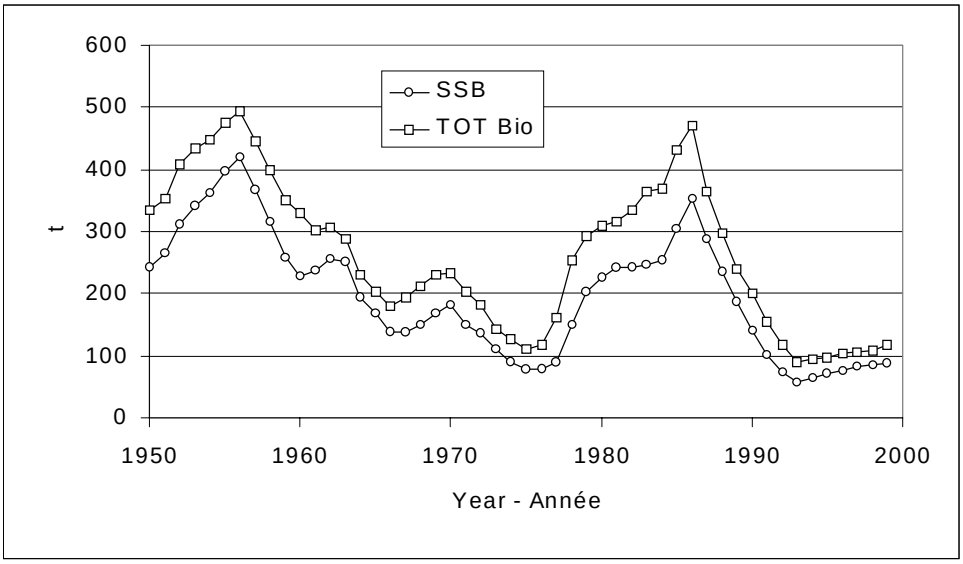
Analyses using all indices produced more precise estimates for RV index than using it on its own. An examination of the residuals suggested that the RV residuals showed a similar pattern in calibrations with and without the other indices. The addition of the Recruitment index provided an estimate at age 3 in 1999. The RV catchability estimates were very similar between all four analyses . However, the RV index alone tended to give lower estimates for recruiting age groups in 1999 than when combined with the other indices . It should be noted that the RV covers the entire area of the southern Gulf where the sentinel surveys are predominantly conducted closer to shore where younger fish are found. The analysis using all the information was retained.

The results show that the spawning stock biomass has increased slightly since the moratorium but that it has remained about stable in the last 3 years. The biomass of the entire population increased in 1999 due to the increase in the size of the last two year-classes. Spawning stock and population biomass remain near the low values seen in the mid-1970's.

The trends in recruitment show that it declined almost steadily since the mid-1980's but that the two most recent year-classes (particularly the 1996 year-class) is higher than the ones from the mid-1990's. Despite this increase, this year-class is below long–term average values. This year-class will start contributing significantly to the spawning stock biomass in 2001.

The spawning biomass trends from this analysis are quite similar to the ones with the M changes except for the period in the mid 1980's.

With the increase in reported catches in 1998, the estimated fishing mortality has increased somewhat but remains near the low values of the recent years.



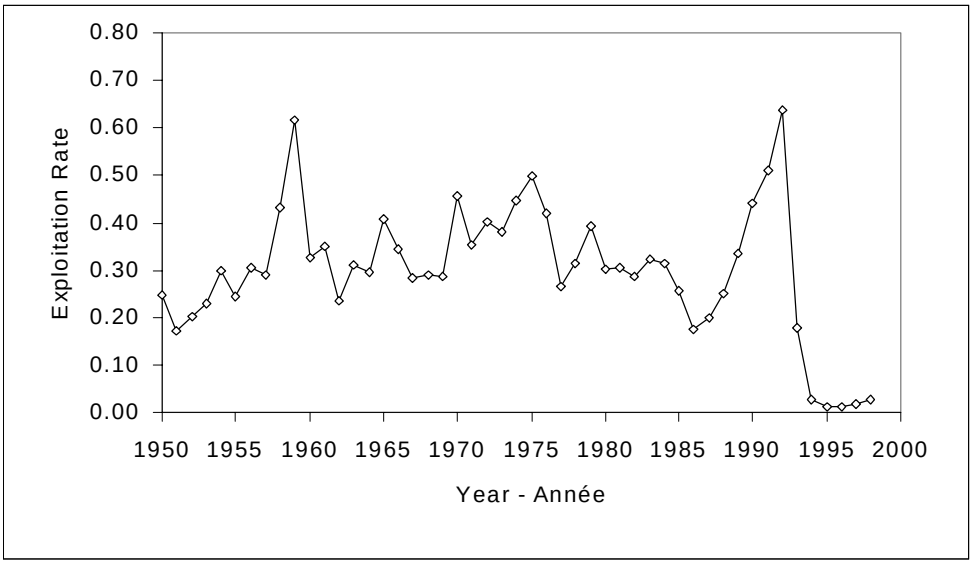


Figure 4: Recruitment, population and spawning biomass and exploitation rate trends for southern Gulf of St. Lawrence cod.

11.4.2 Discussion

A question was posed as to whether, based on the RV data, the late 1970s - 1980s period was normal or abnormal compared to the early 1970s and the present in abundance.

In response, reference was made to the historic time series. The SPA goes back to 1950 and indicates high biomass in earlier years. The total landings (to 1917) ranged from 20 - 40 thousand tonnes from 1917 to 1945, then increased in the 1950s. Historical surveys in the 1960s also indicate high biomass. Thus, the low abundance in the early 1970s and 1990s appear to be abnormal for the stock.

Various concerns were raised by the fishing **industry**:

- One participant queried the idea that high discarding in the 1988-93 period contributed to a higher natural mortality. It was stated that discarding during the years from 1988 to present was limited. The ITQ started in 1989 and there was no need to high-grade. Observers have been present, along with test fisheries and gear testing; fishers did not observe dumping or discarding. It was argued the M increased in those years because the ice was present in the Gulf later, allowing the seals to remain longer in the Gulf.
- In response, it was noted that fishers participating in previous RAP meetings reported discarding and dumping during those same years, also reported by observers. Although the high Ms are thought to be attributed to discarding and dumping, the high Ms could also be due to unknown causes.
- A concern was raised that the research survey is conducted in September, however, in mid-October 1998 the sentinel fishery encountered an area of small fish (2-3 years old) in the western Gulf stretching 30 miles long. The Needler survey would have missed them, and without the sentinel these observations are not included in the assessment.
- It was noted that the sentinel indices are used in tuning, and also in a recruitment index used in SPA tuning. Attention was drawn to the numbers of small ages (age-classes of 1995 and 1996) seen in the research survey in higher numbers than before, and large catches of small fish by the sentinel seiners. In terms of the annual survey, it is important to keep the timing the same from year to year.
- There was discussion on the differences in trawls used in the RV surveys, noting that the Western IIA trawl has been used in the RV surveys for this stock for many years, and that industry felt that the trawl itself may not fish properly in all circumstances.
- Where vessel and/or gear had changed, the results of comparative fishing experiments were used to derive conversions, and these results have been documented previously.
- General concerns were raised that the distribution of fish had changed; recruitment was not being estimated properly; questions as to whether the cod were leaving the Gulf earlier; and concerns about seals and their affect on cod recruitment.

An abrupt change in indices prompted concerns about the confidence of the comparative surveys which were used to provide conversion factors between the different vessels and gears used in the surveys. Although there were some changes in design in 1985 and 1992 the correlations are tight. The breakpoints in the data were in 1988 and 1991 where other factors affected the change in distribution.

There was considerable discussion on the SPA run showing an increase in M from 1988-1993, followed by a drop in M for young fish from 1994-98. It is felt this also indicates recruitment is down and fish distribution may have changed. Concerns were expressed over the reliability of estimating M in the SPA model, and the influence of some of the recent short time series on the tuning process. It was noted that the estimate of M becomes highly correlated with other parameters, for example survivor estimates.

It was agreed to take a closer look at the correlation matrices from ADAPT as a useful diagnostic and to look at trends in the survey catchability. Resolving the issues with survivor is important to management issues.

There were discussions on the technical aspects of the SPA runs, such as patterns in residuals, increased precision in parameter estimates by adding more indices to the tuning. The catch of

sentinel gears used in the calibration totaled about 650 tons compared to about 2000 tons from other gears.

It was concluded that this was not a reason to exclude these indices from VPA tuning.

One calibration used a trend parameter for CPUE. It was acknowledged that the recruitment index contained data also used in another tuning index, and that this could be explored further.

The baseline run presented was done with the same formulation used in the 1998 assessment. Ages 1 and 2 were not used in this calibration, although a run with a new recruitment index does contain information on age 2. There was reluctance to include age 1. Other runs were proposed, using ICA, where all indices would not get equal weighting in the calibration, to determine the effect of adding the new sentinel series, which are relatively short.

Another suggestion was that runs could be made to estimate the sensitivity of population estimates to the F constraints imposed on the oldest ages in the terminal year. Other opinions were that this may not be necessary, as Fs at the oldest ages were unlikely to change much. This type of sensitivity analysis had not been requested for other stocks at this meeting. An opposite opinion is that these runs were necessary to indicate any effect on the changes estimated in M.

It was noted that there were some zeroes in the catch matrix, and that replacing these with some small value may create some problems.

No estimates of seal consumption were available for inclusion in any SPA runs.

To do:

1) a calibration leaving out age 3 and 4 from the RV and two sentinel indices with liners
2) calibrations to look at natural mortality estimation using the RV index only
3) a run with the high 1995 survey point left in.

11.4.3 Recommendations

- Some exploration of plus groups, and the double counting of age 2 in two indices should also be examined. A run without age 2's in two indices should be made.

- A "best run" should be proposed from the reruns, followed by risk analysis based on this run.

There were comments and suggestions on the assessment meeting and process in general:

- It is important to come up with population numbers which contain our best estimates of variability.
- It was proposed that a template of analytical methods used in stock assessments be set up to help in running the various models such as ADAPT, ICA, QLSPA, XSA, etc. A couple of concerns are the variability in indices may not be captured in the models, and the retrospective analyses are important.
- There should also be improved access to software and skills in the Regions; through training these techniques could be better used.
- All expertise at the meeting should work in a coordinated fashion where possible.
- Another suggestion would be to examine one or 2 stocks outside of the ZAP schedule, which would include external reviewers.

This led to a general discussion of risk analysis - what was needed and how to accomplish it. Options which may be useful include using exploitation rate instead of catch on the x-axis in some of the risk plots, and showing full probability distributions of SSB for various TAC levels.

It would be useful to know how the FRCC will be applying the risk values across various stocks. A general discussion of risk management followed, including how it will be applied, and whether it would be used in a qualitative or quantitative sense. There was no apparent consensus on the type of risk calculations that should be used or presented. However it was clear that risk need to be considered.

11.5 *Addendum #1 - Southern Gulf of St. Lawrence (Monday 8 March, 1999 - 19:30)*

11.5.1 Summary

Re-analyses that had been requested were related to two main topics: the level of aggregation in the standardization of sentinel catch rates and the SPA calibrations using ADAPT. The sentinel longline catch and effort which had been aggregated by month, site and year for the original analysis were re-done with no aggregation (set by set). Out of the 14440 observations, there were 191 instances where a null catch was recorded. These observations were replaced with an un-transformed catch rate value of 0.1. The diagnostics from the General Linear Model indicated that this model explained about 72% of the variation but the residual distribution was not optimal and showed the typical pattern when zeros are present. A second analysis was conducted using 15-day periods. In this case, percentage of zero values was reduced slightly to about 10% but hte residual pattern was still abnormal. Finally, another analysis was conducted using the monthly aggregation but removing one outlier. The three analyses were compared with the original analysis. This indicated that the various treatments of the data had little impact on the overall trend. An analysis was also attempted with the dis-aggregated otter trawl but did not explain much of the variability and was not pursued further.

It was proposed that the analysis using the monthly aggregation be used in the final analysis but that further exploration of the data be conducted in the coming year.

In the original presentation, the ADAPT calibration included a recruitment index. This recruitment index was derived using catch rate at ages 2 and 3 from the survey and sentinel surveys. The catch rate at age 3 was then used again with the original indices. This could create some problems as some of the same data was used in more than one index. As a result, a revised analysis was conducted using the catch rate at age 2 for the RV and the two lined sentinel indices. Age 2 catch at age were assumed to be negligible. The analysis resulted in similar estimates as the original analysis including all indices (RV, CPUE, 5 Sentinel) but the estimate of age 3 in 1999 was about 25% higher.

The second analysis examined the impact of set 127 in 1995. This was a large set which was considered anomalous and has never been included in the RV index of abundance. The population estimates for ages 3, 4 and 5 were about 5% higher than the analysis excluding it. It was indicated that the anomalous set had been examined in detail and that other information did not suggest that there was a very high concentration of fish in that area (sentinel surveys and subsequent research surveys).

It was proposed that the final analysis should not include the anomalous set.

Another analysis was used to estimate M but only with the RV index. The results were very similar to the analysis that had included all of the indices in the working paper. It showed an increase in M to 0.3 from 82-87, then high M's in the period of 88-93 and finally low M (about 0.24) on young ages (3-6) and high M on older fish.

The last analysis examined the impact of the sentinel indices at ages 2,3 and 4 on the estimates by removing these age groups for those indices in the calibrations. The results of the analysis resulted in population estimates at age 3 in 1999 of about 58 millions or about 60% of the estimate including the full indices.

The authors concluded that the first analysis above was appropriate and should be used for projections.

11.5.2 Discussion

Sentinel Surveys Catch Rate Standardization

Disaggregated analyses by vessel and partially aggregated at 2 week intervals, were run after replacing 0 catches with C/E=.1 and including interactions but, in all cases, the resulting trends are similar to results of the initial model. Removal of one identified outlier also had no impact on the result.

Given very minimal difference between runs, **it was agreed** to use the original standardization series for ADAPT.

A standardization of OTB catch rates on set by set basis had very poor explanatory power, about 10% of variance explained, and was not used any further.

Raw data plots for selected sites were provided to show variability and seasonal patterns.

There was virtually no discussion of these items.

ADAPT Runs

Time varying M estimate for younger ages in recent years has high CV and is negatively correlated with population numbers, consistent with poor estimation in upper corner of SPA. Because of these estimation problems, the time varying M estimates are not used in the current ADAPT but are useful area of future research.

The question was raised that, since the 1995 survey point (set 127) has little effect on estimates, why not leave it in? Although not reported in detail, there has been extensive examination of the available data to corroborate the set and it remains anomalous and so has been excluded. In particular, the set contained large numbers of ages 2-3 in a known nursery area. Neither of these yearclasses appeared again in any significant numbers supporting the existing conclusion that it is not indicative of abundance.

Inclusion of sentinel data gives more precise estimates, i.e. smaller mean square residual that without the sentinel indices.

Several quasi-likelihood estimations were used to examine the effect of some of the constraints used in ADAPT. Estimation was based on ages 3-15, including all indices except CPUE. The indices were self-weighted. In one run the oldest age F's (age 15 in 1985-98) as well as ages 12-14 in 1998 were estimated directly. These were compared to results from imposing constraints of either, the mean for ages 11-13 on age15 or mean for ages 9-10 on age 15. The constraint of ages 9-10 on 15 provides results consistent with the direct estimates. Self weighting of the surveys downweighted OTB lined index 3-4 times with respect to the others. The SNU unlined received the most weight, but generally the weights were similar (0.1-0.2) except for the OTB lined (0.4).

The ADAPT estimates tend to be a bit larger at older ages than the QL estimates which will affect biomass. This model uncertainty will need to be considered in the risk analysis.

Survey Z's (A. Sinclair)

Further information was presented on estimating total mortality from surveys data collected in the post-moritorium period. The analysis investigated the evidence for differences in total mortality among separate year-classes as well as model diagnostics. For the research vessel survey and seine lined sentinel survey, it appeared that younger year-classes (1988 – 1991) had a lower total mortality than older year-classes (1984-1987). It was noted that this trend may also reflect a reduction in catchability of older fish to the surveys or a general increase in mortality with age. If this was the case, one would expect a dome-shaped pattern of model residuals vs. year. Investigation of the residuals revealed relatively strong survey year effects, that could mask this trend. If the trends in mortality with year-class are indeed real, it suggests that natural mortality may be decreasing on this stock.

This analysis suggests that M has declined on younger fish since closure. The hypothesis was offered that fish which had survived to end of the fishery in 1993 had been size-selected for low Linf and had intrinsically higher M. The decline in M on the younger ages since that time may be indicative of these fish growing older and the current younger age classes experiencing little fishing, i.e. size-selective, mortality. This is offered for consideration in future work. The pattern of M on the younger ages is consistent with the M estimates on the younger ages in the time-varying M ADAPT model.

There was a discussion of the medium term risk analysis. Short term does not require any catch assumptions except 1999 for which the planned TAC is known. Middle term needs some basis for catch assumption, for intervening years. Guidance from FRCC or elsewhere would be nice. Maintaining last years reference points would be least confusing for the clients, in the absence of other direction. Desire for 3 year projections is real in both FRCC and managers. Minimize impact of recruitment assumptions by using older ages e.g. 6+ as a proxy for SSB, as long as the past relationship is stable i.e. the maturity at age is constant.

Current practice does not include enough sources of variation, nor does it fully propagate the errors it does include more than one year. An option is to provide a mean projection and discuss the implications of various uncertainties on the medium term projection. Develop optimistic and pessimistic scenarios to provide the basis of the implications.

Addendum #2 - Southern Gulf of St. Lawrence (Thursday, March 11, 1999)

There was a short discussion on Addendum #2 presenting a risk analysis over 3 years.

11.6 Review of the Minutes

The minutes resulting from the presentation of southern Gulf of St. Lawrence cod were reviewed. Changes included a re-wording of a couple of the discussions, for clarity.

A concern was raised that the Proceedings should capture only the true concensus of the meeting and not the general discussion; the concern being that the Proceedings may be interpreted that all particpants agreed on everything reported in the minutes.

Other opinions indicated the Proceedings should reflect an account of what was discussed surrounding the assessment. It was noted that past CAFSAC minutes were terse, and did not

truly reflect the discussions presented. It was proposed that a foreword be included with the Proceedings of the ZAP to identify the Proceedings as a record of the discussions that took place, including major concerns raised and issues discussed. The foreword will indicate that although all statements and opinions recorded may be interpreted differently by the reader or may contradict other parts of the record of discussions, the Proceedings are merely a record of the discussions. The foreword will also state that only the Stock Status Reports should be used as sources of information on the status of the resources assessed.

11.7 Review of Stock Status Report

It was noted that the word 'commercial' does not represent the fisheries which presently exploit the cod stocks since the moratorium. Cod landings may presently be composed of catches from the by-catch, sentinel, index, recreational fisheries.

The suggestion was made to clarify the wording for each document.

It was felt the attention paid to seals is not significant enough in the stock status report (SSR), but estimates are given for all other cod stocks and the 4TVn (N-A) presentation included a document on seal consumption. **It was agreed** that a degree of uncertainty exists on the consumption by seals on cod in the southern Gulf, and felt by some that a numerical estimate should be included in the SSR, whether that be a range of estimates, or a number representing the mid-point of the estimates. The range of consumption estimates agreed upon (given in the summary of the document on seal consumption) is 7,000 to 15,000 tonnes, which can be broken down as the low (5,000 t) and the high (13,000 t) of the two ranges given for grey seals, plus the 2,000 t estimate for harp seals in the southern Gulf. This wide range will also underline the uncertainty surrounding the consumption estimates. The wording of the SSR should outline the absence of diet data for the southern Gulf of St. Lawrence and emphasize these are very tentative estimates of seal consumption on cod.

The maturity ogives being used to estimate the spawning stock biomass are based on ogives obtained from July surveys in the southern Gulf from 1990 to 1995. The stock has shown a decline in age at maturity in the late seventies. However, it was noted that the age at maturity from Beacham for the late 1970s are comparable to the present; therefore the maturity ogives from 1990 to 1995 were used to calculate the historic spawning stock biomass. It was proposed that the stock status report include an account of how the spawning stock biomass was calculated by using the maturity ogives from the summer surveys of 1990 to 1995 and that spawning stock biomass may be over-estimated in the early period.

The indications of a decline in mortality for younger ages in recent years was noted in the SSR but this caused confusion as it was stated that at the same time, M was high. It was suggested that the indication of M declining should be removed as it is still very preliminary. However, in the end, **it was agreed** that there was no strong reason to reject the analysis and it should at least be noted. Participants were asked to re-word the section on M to clarify this point.

It was agreed that sources of uncertainty in the SSR should be more fully described. Finally, when describing changes in spawning biomass or catch, **it was agreed** that numbers should be used instead of adjectives.

The stock status report for the southern Gulf of St. Lawrence cod was accepted with the suggested revisions.

12. Northern Cod (2J3KL)

(Rapporteurs: B. Atkinson and A. Sinclair)

12.1 *Lilly, G.R., P.A. Shelton, J. Brattey, N.G. Cadigan, E.F. Murphy, and D.E. Stansbury. 1999. An assessment of the cod stock in NAFO Divisions 2J+3KL. (Working Paper 99/28)*

12.1.1 Summary

The history of the northern (2J+3KL) cod stock was reviewed, with emphasis on the period of apparently rapid decline in the late 1980s and early 1990s and the absence of significant recovery since imposition of a moratorium on directed fishing in July 1992. The inability to reconcile catches with the research vessel indices has resulted in the lack of an accepted sequential population analysis for several years. The 1998 assessment concluded that there was no indication that the 2J+3KL cod stock had begun to recover in the offshore. There were clearly some aggregations in the inshore, but the size of these aggregations was very uncertain.

The present paper updated the status of the stock based on presentations during a Regional Assessment Meeting (St. John's, February 15-19). The information included an additional year of data from commercial by-catch, the research bottom trawl surveys in 2J, 3K, 3L in autumn and 3L in spring, acoustic surveys in specific areas, sentinel surveys and a brief food fishery. A new source of information was the index fishery conducted in the inshore and the offshore. Also new were descriptions of cod distribution and migrations based on returns from recent tagging studies and an estimate of population size based on those returns. Estimates of the consumption of cod by seals were revised and updated.

Because there have been requests that a fishery be permitted in the inshore, information regarding the presence and stock relationships of cod in the inshore was reviewed. The results of genetic and tagging studies in the 1990s provide evidence that the cod currently inshore tend to stay inshore and are largely genetically distinct from cod in the offshore. Tagging studies also indicate that cod north of a line down the axis of Trinity Bay tend to remain north of that line and that a high proportion of the cod caught south of that line are summer migrants from 3Ps.

Patterns in the historic landings were reviewed. Landings in 1998 came from by-catch (363 t), sentinel surveys (388 t), the food fishery (696 t) and a new inshore index fishery (3139 t). The 1998 catch at age was presented by gear type. Combined landings from all gears came mainly from ages 4-8, with age 6 dominant.

Information from the autumn and spring bottom-trawl surveys was reviewed. The autumn biomass index in 1997 and 1998 was 1.4% of the average in the period 1983-1988 (excluding 1986). All yearclasses born in the 1990s have been very small, and each cohort has experienced high mortality. The time-series of size-at-age and age at maturity were updated. Distribution was illustrated.

A survey of pelagic 0-group cod revealed that abundance was lower than in 1994-1995 but higher than in 1996-1997. There were very few cod found offshore in 2J3K, but good catches were taken inshore. Most of the fish caught offshore came from southern 3L and were contiguous with larger catches immediately to the south in Divisions 3NO.

The results of acoustic studies in 2J and in a small inlet on the east coast were reviewed. Variability in sentinel survey catch rates over the three years of the surveys (1995-1998) was explored in three ways. Individual catch rates for each site and gear (gillnet, linetrawl, and handline) were plotted against time, percentiles of catches aggregated by unit area, month and

gear were plotted against time, and statistical tests were conducted to determine how many sites experienced significant increases or decreases from one year to the next. Catch rates have been low in Division 2J and north of White Bay in Division 3K since the start of the surveys. Catch rates from White Bay south continue to be described by participants as high. Seasonality was apparent for some sites, and there appeared to be a significant increase from 1995 to 1996 with little overall trend thereafter. Age compositions from sentinel surveys reveal that the 1990 yearclass was relatively strong in Divisions 3K and 3L and that the 1989 yearclass was stronger in Division 3L than in Division 3K.

There was very little effort north of White Bay during the inshore index fishery. Catch rates elsewhere varied among unit areas. Highest catch rates occurred in Bonavista Bay for linetrawls and in St. Mary's Bay for gillnets.

No cod concentrations were located during the offshore index fishery in Division 3L. Catch rates were extremely low.

Exploitation rates calculated from the tag returns were 6% for 3K and northern 3L and 12% for southern 3L. These rates are substantial, given that only 4000 t of cod were landed.

Previous estimates of the quantity of cod consumed by seals declined following several changes to the method of calculation. Numbers of cod at age consumed by seals were to be calculated based on the revised consumption estimates. Additional uncertainty in the number and size/age distribution of cod consumed by seals is caused by observations of seals feeding on the bellies of cod without consuming the rest of the animal. Such cod are not included in reconstructed seal diets.

12.1.2 Discussion (Day 1)

The working paper was structured by section and discussion proceeded on a section by section basis as follows:

Stock Structure: The information presented suggested that currently the fish in the inshore are possibly different from those offshore as indicated by genetics as well as age structure. The fish that 'disappeared' offshore including the strong 1986 and 1987 yearclasses which also disappeared inshore, and the stronger yearclasses present inshore now are more recent ones suggesting that there was not a simple redistribution of fish from the offshore to the inshore. While one genetics study found differences between the offshore and inshore, another study did not. The two studies used different loci in their analyses and it is hoped to bring both datasets together for a fuller analysis and review.

Questions for clarification were posed concerning details of the genetics and tagging work with respect to sampling locations and times, and answers were provided.

The question was asked whether we are ready to draw any conclusions regarding separation of the inshore and offshore. The assessment group responded that while we are not ready to draw conclusions yet, the evidence is mounting.

There was also discussion of movement in the inshore and the relationships of fish in 3L and 3Ps.

Catch and Catch-at-age: It was questioned whether there were differences in growth rates inshore and offshore. The response was that there may be differences but it might just reflect the different age groups in the 2 areas now. Back in the 1960's, it was reported that there were no differences but the sampling may have been of offshore fish in the inshore as well as offshore.

Current trap catches in the sentinel consist of many larger older fish unlike in the 1980's. An interpretation of this could be that it reflects an accumulation of older fish in the area or a different catch-at-age of an inshore component. It was reported many years ago that larger fish were taken in traps but the sizes declined in the 1960's. It was suggested that the declines in the 1960's were due to the development of the offshore fishery and the introduction of gillnets in the inshore.

Questions were put forward regarding possible disaggregation of the weight-at-age data from the inshore to look at the changes over time in more detail. It was considered that this could be done.

Research Surveys: Questions focussed on clarification of the survey coverage over time as well as the 'offshore' nature of the surveys in relation to what is referred to as 'inshore'. The surveys have covered off similar depths including the deep areas since their start. Also, the 'inshore' shallower area varies in distance from the coast due to different topography along the coast. In some areas the depth drops very rapidly. When the survey coverage was extended closer to shore in the bays, catches were found to be greater nearer shore but the sentinel fishery and index fishery in 1998 took place even closer to shore than the expanded RV survey. The traditional inshore fishery took place generally in depths less than 50 m. This is much shallower than depths covered by the RV surveys.

The disappearance of older fish from the offshore was discussed. There is no current explanation for this although one could speculate that they are dying, moving to the inshore or simply moving elsewhere outside the survey area. It was also pointed out that overall the catches are very small during the survey such that 1 or 2 fish can result in large suggested changes in biomass and age structure. Environmental conditions seem to be warming during recent years.

The maturity at age declines were questioned with regard to possible causes. There are a number of different possibilities including selective reduction of the faster growing fish through fishing. There has not been an increase in age-at-maturity in 3Ps. There is only limited data historically from the inshore, but what is available showed similar trends as the offshore.

Recruitment Surveys and Observations: Some clarifications of the pelagic survey design and analysis were requested and provided.

Discussion of the interpretation of the 1998 results from the 3LNO area focussed on the high numbers found in the area overlapping the 3 divisions and the implications of this with regard to stock affinity. There is limited data from tagging but what is available suggests that this is a feeding area and an area of stock mixing. It was suggested that studies of stock structure in the area be pursued.

Acoustic Surveys: Although the revised estimate from the 1997 acoustic survey of the inshore from St. Mary's Bay to White Bay represented a doubling of the original estimate, if a power curve rather than an exponential curve was fit to the data, the estimate would have been about 10 times higher. Overall, more information from the acoustic 'dead zone' is required for this type of work. Neither of the extrapolations was accepted as a final estimate by the meeting.

At the same time as there are large amounts of fish in Smith Sound, there are also fish in other inshore areas. The problem is we don't have measurements of the biomass in other areas. It is not being claimed that the Smith Sound fish are the only ones around. If resources were available, work would expand to other areas.

Sentinel Fisheries: The observations of fishers are that catch rates are higher now than historically. A problem exists in that the historical data are only for vessels >35' and these represented only a small proportion of the fleet and catches. There was a clear increase in sentinel catch rates from 1995 to 1996 and this occurred in 3Ps as well. At present there is no explanation for this. Historically one would see variability between years but usually on a smaller scale than here. It was pointed out that fishermen believe cold water played a role in 1995.The point was made that in the 3KL area catch rates are better than in 3Ps. Since there isn't a problem with stock abundance in 3Ps perhaps the same is the case here.

Although there are trap data available, they have not been examined in detail yet because the catches are only estimated rather than actually measured.

It was questioned whether it would be fair to expect that if catch rates are similar in 3Ps and 3KL then the biomass could be a similar order of magnitude? There needs to be ways developed to examine this.

Index Fishery: There was little initial discussion on this topic. The offshore index fishery in 3L found very few fish and an industry survey for American plaice in 3L in 1998 also found few cod in the area.

Food fishery: The highest catch rates were in Bonavista Bay. Overall, catch rates seemed lower than in 1996. No other discussion took place.

12.2 *Cadigan, N and J. Brattey. 1999. Estimation of 3Psc and 3KL course exploitation and migration rates in 1997 and 1998 from tagging experiments in these regions. WP 99/26.*

There was considerable technical discussion regarding the tagging studies. **It was agreed** that the results should be examined for correlations and this would be done. Questions were also raised regarding model sensitivities to such things as movement timings in relation to tagging. The sensitivity of the model to model structure and recycling of fish should also be explored. These will be done and presented. Also, the size distribution of the tagged fish versus returns will be examined.

The model assumed M=0.2. If this was set at 0.4 the estimated exploitation rates would go up.Further explanation of how the model works was requested.

It was agreed that a simple example would be developed and presented. It was questioned what the model might do with the 3Pn4RS tagging data.

The apparent high exploitation estimated for southern 3L was questioned. The confidence interval is very wide and includes 100%. The results are such that it might only indicate that exploitation was above 5%. Even this estimate was worrisome to some but if exploitation is lower it is difficult to understand why so many tags were returned from such a small fishery.

Since catch rates in southern 3L and 3Ps are the same based on sentinel, the apparent large difference in biomass estimates doesn't make sense. This resulted in a discussion of sentinel sites and how they are chosen. It was also pointed out that while biomass appears to have increased in Placentia Bay over the past few years, the sentinel catch rates in that area have not tracked this increase so there are still problems interpreting what these catch rates mean. It could be that while these track changes when overall abundance is low, there is a 'ceiling' above which catch rates cease to reflect further abundance increases. The question is how high can catch

rates actually go. Data suggest they can get as high as 400-500 lb. per gillnet which is 'incredible.'

Seals: This topic resulted in lively discussion. It was suggested that with the lowered estimates of consumption, the credibility of science would diminish. Further explanation of the reasons for the revised estimates was requested as well as information regarding the model sensitivity to these adjustments. It was noted that this information could be obtained.

Concerns were expressed regarding the application of the satellite tagging information to the estimation of proportions of time spent inshore and offshore. It was suggested that the juveniles are the ones that are closer to shore and the tagging, if done on adults, would give biased results. At the same time it was pointed out that the tagging results showing larger numbers offshore was consistent with the differential loss of older fish offshore if seals are causing mortality of the larger fish. Also, seals were in Bonavista Bay in 1999 as late as July.

Details of the process by which the revised calculations came to be were provided. The population estimates were revised during a meeting of the National Marine Mammals Committee. Also, recommendations on how to revise the consumption estimates came from a special workshop held in November 1998.

There are still huge gaps in the sampling data that raise further questions. It was pointed out however, that it would be worse to do nothing. There is much more information coming out regarding the issue of seals not eating all of the cod but only tearing out the bellies. This has been known for many years but with the lack of ice in the bays in recent years there are many more examples of this occurring. The overall extent of this is unknown. In the past cod have been seen on the ice well offshore with their bellies gone. This type of kill is not taken into account in the consumption estimates because they are based on the hard parts remaining in stomachs (e.g., otoliths). Thus the consumption estimates may be biased.

It was suggested that there may be similar problems with the 'bellies' issue elsewhere and this may be important since the consumption estimates are being included in SPA's.

Concern was expressed about the consumption data since once a number is produced it seems to have considerable credibility without consideration of the confidence intervals around it. As indicated above, the change in the estimate will impact credibility and we should not expect that the revised estimate will not change again as more information becomes available.

There is a 'sense' amongst scientists that seals are probably having an impact on the recovery but it is difficult at present to express this in scientifically defensible terms.

Outlook and General Discussion: Concerns were expressed regarding the casting of the section in the working paper in that it may raise expectations regarding increased catches beyond current levels. The wording will be addressed later once all information is reviewed.

It was pointed out that development of catches through the year in the sentinel survey were picking up the traditional patterns. However, traditionally the inshore catches were largely driven by the offshore fish migrating inshore so it is unclear why the pattern would now be the same.

There are temperature data from the inshore and **the meeting recommended** that these should be examined.

There are stories of black market cod in Newfoundland and the question was asked whether it is true. It is suspected and the FRCC commented in a previous report of estimates in the range of

5000-10,000 t but this could not be substantiated. At present, fish management is studying the historic discarding issue but there is no current study looking at possible illegal fishing during the moratorium.

It was asked whether substantial misreporting would result in overestimates of the exploitation based on tagging. The response was no.

A fisher indicated that, in his opinion, there is more cod in the 3KL area than science thinks.

Discussion of the utility of carrying out an SPA took place. The problem of severe residual problems in the late 1980's still persists and cannot yet be resolved. Also, SPA was originally carried out when fish were plentiful in the offshore and were considered to represent the overall resource. Currently, there are only a few fish in the offshore compared to the inshore areas and the age structure is different. Therefore, it is felt that an SPA would no longer be representative of the resource. It is not possible to split out the historical catches with regard to 'true' inshore fish so an SPA of the inshore alone is not possible.

There was discussion as to whether the results of an earlier SPA should be put in the Overview document**. It was agreed** that this would not be appropriate due to all of the problems of interpretation in the late 1980's and that the research vessel series would be adequate.

Since it was agreed that an SPA is not appropriate, it was also concluded that attempting to model seal consumption in an SPA was not appropriate either. However, since the work on estimating seal removals-at-age was almost complete, it would be useful to look at it. It was also noted that loss of yield calculations could be carried out using these data.

End of First Day of Discussion: It was agreed that the essence of the discussions would be captured in summary form and presented to the meeting for further discussion.

Discussion (Day 2)

A summary of the first day's discussions was prepared as follows:

WE AGREE AND CONCLUDE THAT AT PRESENT IN THE 2J3KL AREA THE COD ARE LOCATED PRIMARILY IN THE INSHORE AND FROM NOTRE DAME BAY SOUTH. THE DISTRIBUTION OF COD IN 2J3KL REMAINS VERY RESTRICTED IN RELATION TO THE SITUATION HISTORICALLY. IN ADDITION, THERE MAY BE DIFFERENT EVENTS OCCURRING INSHORE AND OFFSHORE.

This is based on:

- research surveys continue to indicate very few fish in the offshore (current estimates are only about 1.4% of those of the 1980's). This is supported by industry based on index and research work they conducted in offshore 3L during 1998 (is current activity in 2J3K and information could be obtained from this)
- based on sentinel survey information, very few cod are present in the inshore areas north of about White Bay
- it appears that the older fish are disappearing in the offshore but not at the same rate in the inshore
- since it was the 1986 and 1987 year-classes which disappeared from the offshore in the 1990's while the 1989 and 1990 year-classes are the strong ones inshore, there is no evidence that the fish that disappeared in the offshore are the same as those which are now in the inshore

WE AGREE AND CONCLUDE THAT, AT PRESENT, CARRYING OUT OF AN SPA IS INAPPROPRIATE.

This is based on:

- all of the above arguments in that the 'traditional' SPA is based on calibration with the offshore survey index. This index which no longer represents the resource appropriately given the presence of fish inshore but with only low numbers offshore. There is also the issue of different age structures in the 2 areas.
- it is not possible to split out catches between inshore and offshore in historic time series so inshore SPA not possible
- it then follows that modeling mortality due to seal consumption in an SPA is not worthwhile

WE AGREE AND CONCLUDE THAT THERE ARE TWO GROUPS OF FISH INSHORE IN THE 3KL AREA, ONE OCCUPYING NORTHERN 3L AND 3K, AND THE OTHER OCCUPYING SOUTHERN 3L. THE NORTHERN BODY IS 'PURELY' 3KL FISH WHILE THE SOUTHERN GROUP IS A MIXTURE OF 3L AND 3PS FISH.

This is based on:

- tagging data which indicates there is fish movement between 3K and northern 3L but not with southern 3L and the 'boundary' of this movement seems to be in the area of Trinity Bay
- tagging data indicates that there is movement of fish between Placentia Bay and southern 3L. Because tags placed on fish in Placentia Bay during spawning were recovered during summer in 3L, it is believed the origin of these fish is Placentia Bay and not 3L
- inshore tagging data doesn't include information from offshore since there is no fishery there so it is not possible to speculate on current exchange between the inshore and offshore

WE AGREE AND CONCLUDE THAT SEALS ARE CONSUMING CONSIDERABLE AMOUNTS OF COD IN THE AREA BASED ON THE CONSUMPTION ESTIMATES. HOWEVER NUMEROUS QUESTIONS AND UNCERTAINTIES REMAIN REGARDING THE CALCULATIONS AND THE RECENT REVISIONS.

This is based on:

- revised consumption estimates place the amount of cod consumed in 1998 at about 65,000 t, down from the previous estimate of about 108,000 t
- the new estimates result from revisions to a) the population size of seals, b) the relationship between otolith size and fish length, c) additional stomach sampling and d) updated information of seal distributions inshore and offshore based on tagging
- the sensitivities of the seal consumption model are currently not available so it is difficult to evaluate the changes (this is being pursued).
- there are reports that it is the younger seals that are prevalent inshore and if the tagging was of adults the proportions inshore/offshore may be biased
- the increasing reports of seals eating cod bellies can not be quantified based on current methodologies and the impact of this activity cannot be evaluated with current methods resulting in further uncertainties regarding the consumption estimates as well as the estimated sizes of fish killed.

WITH REGARD TO SEALS, WE ALSO AGREE THAT THEY ARE IMPACTING RECOVERY IN A NEGATIVE MANNER. THE DIFFICULTY WITH MAKING STATEMENTS ON THIS FACTOR IS FROM A SCIENTIFIC PERSPECTIVE: AS SCIENTISTS WE ARE REQUIRED TO CAST SUCH CONCLUSIONS IN A FORM THAT IS DEFENSIBLE AMONGST SCIENTIFIC PEERS. THIS IS A 'CONSTRAINT' OF SCIENCE THAT WE MUST ABIDE BY.

WE AGREE AND CONCLUDE THAT CATCH RATES IN BOTH THE SENTINEL FISHERY AND 1998 INDEX FISHERY IN 3K AND 3L ARE HIGH AND ABOVE WHAT WOULD HAVE BEEN CONSIDERED GOOD CATCH RATES DURING THE FISHERY IN THE 1980'S.

This is based on:

- information from fishers themselves that catch rates are higher than seen in very many years and are considered 'excellent'
- sentinel and index log book information which supports the high catch rate observations which increased from 1995 to 1996 but have generally remained the same since although demonstrating variability between sites

THE AMOUNT OF FISH IN THE INSHORE IS STILL AN UNRESOLVED ISSUE WITH DIFFERENT PERSPECTIVES ON THE TABLE.

This is based on:

- the revised acoustic estimate for entire area from St. Mary's Bay to White Bay (1997) increased from 18,000 t to 38,000 t based on assumption of pattern of distribution in acoustic 'dead zone' near bottom (exponential).
- acoustic surveys of Smith sound alone have yielded biomass estimates from only 300 t to about 15,000 t in 1998 and 1999
- was suggested by fisher that there is just as much fish in Bonavista Bay
- tagging information suggests exploitation inshore in southern 3L above 5% with a 1998 reported catch of only about 800 t. This does not suggest a large biomass is present (about 15,000 t). Actual exploitation estimated to be about 12% but with unacceptably high confidence interval
- sentinel catch rates in southern 3L are on a par with those in Placentia Bay where the biomass, from a number of different studies, is about 70,000 t. It is argued that with similar catch rates there cannot be such a difference in biomass between the 2 areas (order of magnitude)
- at the same time, although it has been estimated that the 3+ biomass in Placentia Bay has doubled during the moratorium, this increase is not reflected in the catch rates so the relationship between sentinel catch rates and biomass is still unclear
- if it is asserted that the biomass in Placentia Bay is about 70,000 t, and 7% of these move into 3L then about 4900 t of 3Ps fish are in 3L. With an exploitation rate of 12.3%, the catch would be about 600 t which is about 3/4 of the reported catch of 851 t. Is it reasonable to assume/expect that the southern 3L sentinel and index fisheries in 1998 took predominantly 3Ps fish?
- the tagging data suggest an inshore biomass of about 50,000 t in northern 3L and 3K based on an estimated exploitation rate of 6.2% and catch of 3200 t
- what are estimates of Z from the sentinel data (this is being pursued)?

OTHER ISSUES REMAINING TO BE RESOLVED:

- what exploitation rate might be reasonable for the inshore?
- what would risk be of exploitation on inshore of recovery in offshore? Comment was made that we are not yet in a position to separate inshore from offshore but the evidence in mounting.
- what are risks associated with exploitation of 3Ps fish in 3L and/or vice versa?

The points presented were discussed issue by issue and **it was then agreed** that a revised summary would be prepared.

There were also discussions on some of the points that resulted in further work being carried out. This included standardization of sentinel catch rate data, as well as extrapolation of Placentia Bay sentinel catch rates/biomass to the 3KL area in the same manner as was done in 1998.

The revised summary is as follows:

WE AGREE AND CONCLUDE THAT AT PRESENT IN THE 2J3KL AREA THE COD ARE LOCATED IN THE INSHORE AND FROM NOTRE DAME BAY SOUTH. THE DISTRIBUTION OF COD IN 2J3KL REMAINS VERY RESTRICTED IN RELATION TO THE SITUATION HISTORICALLY IN THE CONTEXT OF THE ENTIRE 2J3KL AREA. IN ADDITION, THERE MAY BE DIFFERENT EVENTS OCCURING INSHORE AND OFFSHORE.

This is based on:

- research surveys continue to indicate very few fish in the offshore (current estimates are only about 1.4% of those of the 1980's). This is supported by industry based on index and research work they conducted in offshore 3L during 1998 (is current activity in 2J3K and information could be obtained from this)
- based on sentinel survey information, very few cod are present in the inshore areas north of about White Bay
- it appears that the older fish are disappearing in the offshore but not at the same rate in the inshore
- since it was the 1986 and 1987 year-classes which disappeared from the offshore in the 1990's while the 1989 and 1990 year-classes are the strong ones inshore, there is no evidence that the fish that disappeared in the offshore are the same as those which are now in the inshore

WE AGREE AND CONCLUDE THAT AT PRESENT CARRYING OUT OF AN SPA IS INAPPROPRIATE.

This is based on:

- all of the above in that the 'traditional' SPA is based on calibration with the offshore survey index which no longer represents the resource appropriately. There are fish present inshore of the area covered by the research surveys but there are only low numbers offshore within the survey area. There is also the issue of different age structures in the 2 areas with higher proportions of older fish inshore based on sentinel catches.
- it is not possible to split out the possible inshore and offshore components in historic time series of catch data so inshore SPA not possible
- it then follows that modeling seal consumption in an SPA is not worthwhile
- because of uncertainties in interpretation of SPA in the late 1980's and early 1990's due to the residual patterns, the research survey series should be used in the Overview to reflect the stock trend in the offshore

WE AGREE AND CONCLUDE THAT FOR BOTH THE SHORT AND INTERMEDIATE TERM THE PROSPECTS FOR THE COD RESOURCE IN THE OFFSHORE IS POOR.

This is based on:

- all of the above

WE AGREE THAT THE AVAILABLE DATA (TAGGING INFORMATION) SUGGESTS TWO GROUPS OF FISH INSHORE IN THE 3KL AREA, ONE OCCUPYING NORTHERN 3L AND 3K, AND THE OTHER OCCUPYING SOUTHERN 3L. THE LINE OF DIVISION APPEARS TO BE IN THE TRINITY BAY AREA. THE NORTHERN BODY IS 'PURELY' 3KL FISH WHILE THE SOUTHERN GROUP IS A MIXTURE OF 3L AND 3PS FISH.

This is based on:

- tagging data which indicates there is fish movement between 3K and northern 3L but not with southern 3L and the 'boundary' of this movement seems to be in the area of Trinity Bay
- tagging data indicates that there is movement of fish between Placentia Bay and southern 3L. Because tags placed on fish in Placentia Bay during spawning were recovered during summer in 3L, it is believed the origin of these fish is Placentia Bay and not 3L **(George Winters to provide words)**
- inshore tagging data doesn't include information from offshore since there is no fishery there so it is not possible to speculate on current exchange between the inshore and offshore

WE AGREE AND CONCLUDE THAT SEALS ARE CONSUMING CONSIDERABLE AMOUNTS OF COD IN THE AREA BASED ON THE CONSUMPTION ESTIMATES AS WELL AS OBSERVATIONS HOWEVER, NUMEROUS QUESTIONS AND UNCERTAINTIES REMAIN REGARDING THE CALCULATIONS AND THE RECENT REVISIONS.

This is based on:

- revised consumption estimates place the amount of cod consumed in 1998 at about 65,000 t, down from the previous estimate of about 108,000 t
- the new estimates result from revisions to a) the population size, b) the relationship between otolith size and fish length, c) additional stomach sampling and d) updated information of seal distributions inshore and offshore based on tagging
- the sensitivities of the seal consumption model are currently not available so it is difficult to evaluate the changes **(this is being pursued)**.
- there are reports that it is the younger seals that are prevalent inshore and if the tagging was of adults the proportions inshore/offshore may be biased
- the increasing reports of seals eating cod bellies can not be quantified based on current methodologies and the impact of this activity cannot be evaluated with current methods resulting in further uncertainties regarding the consumption estimates as well as the estimated sizes of fish killed.

WITH REGARD TO SEALS, WE ALSO AGREE THAT THEY ARE IMPACTING RECOVERY IN A NEGATIVE MANNER. THE CHALLENGE IS FROM A SCIENTIFIC PERSPECTIVE IN THAT, AS SCIENTISTS, WE ARE REQUIRED TO CAST THIS IN A FORM THAT IS DEFENSIBLE AMONGST SCIENTIFIC PEERS.

WE AGREE AND CONCLUDE THAT CATCH RATES IN BOTH THE SENTINEL FISHERY AND 1998 INDEX FISHERY IN 3K AND 3L ARE HIGH AND ABOVE WHAT WOULD HAVE BEEN CONSIDERED GOOD CATCH RATES DURING THE FISHERY IN THE 1980'S.

This is based on:

- information from fishers themselves that catch rates are higher than seen in very many years and are considered 'excellent'
- sentinel and index log book information which supports the high catch rate observations which increased from 1995 to 1996 but have generally remained the same since although demonstrating variability between sites

THERE IS NO SPECIFIC CONCLUSION FROM THIS BUT IT SERVES AS A LEAD-IN TO THE FOLLOWING SECTION.

THE AMOUNT OF FISH IN THE INSHORE IS STILL AN UNRESOLVED ISSUE WITH DIFFERENT PERSPECTIVES ON THE TABLE.

This is based on:

- the 1997 acoustic estimate for entire area from St. Mary's Bay to White Bay was originally determined to be 18,000 t. Based on assumption of an exponential pattern of distribution in acoustic 'dead zone' near bottom this estimate doubles, and assuming a power curve relationship increases about 10 fold. The possible range due to uncertainty is such that these data are not considered useful in determining the inshore biomass
- acoustic surveys of Smith sound alone have yielded biomass estimates from only 300 t in 1997 to about 15,000 t in 1998 and 1999 and it was suggested by fisher that there is just as much fish in Bonavista Bay. Perhaps the inshore fish winter in deep holes around the coast and there is a series of these locations from Conception Bay to about White Bay
- tagging information suggests exploitation inshore in southern 3L above 5% with a 1998 reported catch of only about 800 t. This does not suggest a large biomass is present (about 15,000 t). Actual exploitation estimated to be about 12% but with unacceptably high confidence interval **(Further analyses coming from G. Winters)**
- sentinel and index fishery catch rates in southern 3L are on a par with those in Placentia Bay where the biomass, from a number of different studies, is about 70,000 t. It is argued that with similar catch rates there cannot be such a difference in biomass between the 2 areas (order of magnitude) **(Further work to be done)**
- at the same time, although it has been estimated that the 3+ biomass in 3Ps has doubled during the moratorium, this increase is not reflected in the catch rates so the relationship between sentinel catch rates and biomass is still unclear
- if it is asserted that the biomass in Placentia Bay is about 70,000 t, and 7% of these move into 3L then about 4900 t of 3Ps fish are in 3L. With an exploitation rate of 12.3%, the catch would be about 600 t which is about 3/4 of the reported catch of 851 t. Is it reasonable to assume/expect that the southern 3L sentinel and index fisheries in 1998 took predominantly 3Ps fish? **(To be discussed further in conjunction with 4 above)**
- the tagging data suggest an inshore biomass of about 50,000 t in northern 3L and 3K based on an estimated exploitation rate of 6.2% and catch of 3200 t **(To be discussed further with above)**
- what are estimates of Z from the sentinel data (this is being pursued)?

OTHER ISSUES REMAINING TO BE RESOLVED:

- what exploitation rate might be reasonable for the inshore?
- what would risk be of exploitation on inshore of recovery in offshore? Comment was made that we are not yet in a position to separate inshore from offshore but the evidence in mounting.
- what are risks associated with exploitation of 3Ps fish in 3L and/or vice versa?

Discussion (Day 3)

During the third day of discussions, 5 additional pieces of information were tabled as follows:

12.3 *"Extrapolation of 3Ps tagging experiments to 3KL using sentinel catch rates"*

Discussion of the estimate focussed on the considerable difference in the estimates between 1997 and 1998. The difference was for 2 main reasons; the increase in biomass in Placentia Bay

between years, and the decline in Placentia Bay catch rates in the time window used (weeks 24-40) in 1998 compared to 1997. **It was agreed** that these differences need to be captured in the final report. Also the differences observed in Placentia Bay catch rates need to be better understood since overall, the 1998 catch rates were similar to those of 1997.

It was clear that the method is very sensitive to input and this must be kept in mind when doing this type of analysis.

Because of the number of concerns about the derived estimate of biomass, it was decided not to include any number in the SSR but to only reflect the work that was done along with an explanation as to why there is a big difference. It was emphasized that the Newfoundland Region staff have considerable concerns about this type of extrapolation and cannot support its use, even in principal.

12.4 *Cadigan, N. and J. Brattey. 1999. Addendum 1, for Estimation of 3Psc and 3KL coarse exploitation and migration rates in 1997 and 1998 from tagging experiments in these regions. WP 99/26 (addendum).*

Discussion began with a presentation of a simple example of how the model works as had been requested during the first day of discussions. The addendum included information as requested previously and suggests that the model is robust to the model formulation of numbers of cells and population structure. The same uncertainty exists with regard to the 3L exploitation but the minimum is still estimated to be at least 5%.

It was re-iterated that by changing the assumption of M from 0.2 to 0.4 that the exploitation rates will increase.

12.5 *"Spatial Patterns in the fall RV data relative to recolonization of the shelf"*

It was questioned as to whether, based on the information presented, that there has been no collapse of range and cod are distributed in the 3 divisions as in the past. While cod are still broadly distributed in low numbers in 2J and 3K, there are no cod present on the plateau area of 3L with the exception of a few large cod caught in the area of the Virgin Rocks. Also, although the distribution is wide, the numbers are very low. Previous calculations of the area occupied by 90% of the biomass indicated a shrinkage to about 1992 but as the remaining concentrations disappeared, the area appeared to spread out again. This is an artifact of disappearance of fish concentrations rather than increases in the overall amounts present.

It was suggested that the switch from the Engel trawl to the Campelen trawl in 1995 may be confounding the issue. As such, it was proposed that restricting the analysis to fish over a certain size (e.g., 30 cm) might help to clarify the picture.

12.6 *Stansbury, D., P. Shelton and G. Lilly. 1999. 2J3KL Cod – Addendum. 2. Consumption by harp seals. WP 99/28. Addendum*

Based on the information presented it was difficult to get a sense of the relative impacts of the different changes in the model. The change in the population estimate alone made the consumption estimate go up. The most important contributor to the decline in the estimate was the change in the otolith length-fish length and cod length-weight equations. The remaining changes, including the change in assumption regarding inshore and offshore distributions had relatively minor effects. There is still a necessity to clarify whether adults alone were tagged or not and this will be investigated further for this meeting.

It was reiterated that the current estimates do not include the consumption of only soft parts of larger cod as opposed to consumption of the entire fish (bellies issue). The question was posed as to whether it might be possible to carry out a sensitivity analysis to investigate the impact of assuming a different age distribution of cod killed by seals. **It was agreed** that this might be possible but it would require work by the seal experts who are not at this meeting. There would be a need to examine differences in energy derived from e.g., small whole cod versus larger cod livers and stomachs.

A number of different potential biases with the current sampling were discussed. These included the possibility of collectors taking samples from areas where the cod-seal interactions are taking place. If the interactions are with smaller cod then the estimates may be biased up but if the interactions are with larger cod then the estimates may be biased down.

It was recommended that consideration should be given to setting up and intensive sampling program for 2000 to get better estimates of the ' bellies' consumption as well as the numbers of seals that may be involved in this activity in the inshore. It would also be helpful to try to obtain estimates of the amounts of cod over-wintering in the inshore 'pockets' as well as the numbers possibly killed.

One problem identified with the revised consumption estimates is that they were calculated based on recommendations of the December 1998 Marine Mammal meeting and have not been peer reviewed at the NAFO/ICES Marine Mammal Working Group. Others felt this meeting was to be the peer review and that point was clear at the seal consumption workshop in December 1998.

It was reiterated that the downward revision of consumption at a time when the 'bellies' issue was receiving greater attention would lower credibility of science.

There was considerable discussion regarding possible analyses that might be carried out although there was no consensus on what might be reasonable. One view was that it may be possible to look at daily energy requirements (or some other time period) and using information on the energy contained in cod livers/stomachs to estimate how many seals it may take to have an impact on the 'pockets' of cod in the inshore. The opposing view was that these types of calculations may result in poorer reflections of reality. It was suggested that the bioenergetic models would not help in assessing possible impacts. It was suggested that when videos, etc. exist they could perhaps be used to try to obtain some estimate of the numbers killed.

A current problem is that the marine mammal scientists and fisheries/assessment scientists are not necessarily discussing the same problems and issues. It was therefore **recommended** that a Joint Working Group be pulled together including both groups so that a more multi-species approach can be taken to the problems identified. A number of multispecies problems were suggested for this group.

12.7 *Winters, G.H. 1999. Analysis of mark/recapture data for northern cod. WP 99/33.*

There was considerable technical discussion regarding the results in this paper compared to those in the Cadigan/Brattey paper (WP 99/26). While both gave a similar 'panmictic' estimate of exploitation, the derived biomass estimates are quite different. The 2 methods make very different assumptions regarding the distribution of tagged fish and their mixing with the population overall.

No resolution of the issues was forthcoming during these discussions. **It was agreed** that the explicit and implicit assumptions of the 2 models be documented through consultation between the authors and presented to the meeting. It would then be possible to examine each of these in relation to available ancillary information in order to better determine which might be most appropriate.

It was also requested that the variance around the estimates in WP99/33 be provided so as to enable evaluation of the uncertainties around the estimates.

12.8 *"Standardization of sentinel catch rates in NAFO divisions 3KL" WP 35*

There are so few data from Division 2J that they were not included in the analyses. The raw data were examined regarding soak time and the window used to select data for the analyses was based on this.

Discussion focussed on testing for interactions. It was indicated that division*month was tested for with trip nested in the interaction. It was also clarified that 'trip' refers to 'site' or 'fisher.' It was suggested that both month*site and month*year interactions be investigated further. This will be done and presented later during the meeting. If there are interactions with year then comparisons of trends should be done including and excluding the year effects to see if the trends are the same.

Additional discussion during this period focussed on a first draft of the SSR. Attention was paid to messages to be delivered as well as the most appropriate wording.

Discussion (Day 4)

On March 11, one participant (G. Winters) was required to leave due to illness in his family. Since much of the discussion surrounding the mark-recapture experiments hinged on differences between analyses in WP's 99/26 and 99/23, the Chair proposed that further discussion of this issue would be curtailed, and suggested that the different views now on the table be described in the SSR with the assumptions associated with each carefully described and evaluated. It was indicated that some additional analyses and views were available and should be discussed by remaining participants. It was also expressed that it would be difficult to go forward with 2 options regarding status and it would be better to try and determine which is most appropriate as well as the associated risks. It was also suggested that this (presenting 2 options) would move the debate as well as its resolution away from science. The Chair agreed with this perspective but suggested that reaching consensus amongst remaining participants might result in a false sense of accomplishment since there would still not be consensus amongst key players in the debate. The perspectives of the Chair (that the different views now on the table be described in the SSR with the assumptions associated with each carefully described and evaluated) was agreed to. It was done so with the acceptance of the idea that because of the unfortunate circumstances we may not be able to go as far as we might have liked, but we must live with the situation.

Further discussion took place regarding the mark-recapture experiments and the resultant estimates of exploitation and biomass. A presentation was given with the aim of clarifying the methods and assumptions involved in the area-by-area estimations, and whether they were appropriate. The examples presented indicated that although it had been claimed that 'clumping' of the tagged fish would result in overestimates of exploitation, the reality is that the estimates may be over- or under-estimated depending on the behaviour of the fish. It was argued that by selecting larger areas than those in the original analysis, the Petersen method seems to be satisfactory. Grouping of the data into 3K plus northern 3L gave estimates of biomass similar to the estimates from the alternate modeling exercise.

It was confirmed that it was correct to exclude tag returns from areas outside the selected study area although this was counter-intuitive.

It was suggested that the approach that had yielded the high biomass estimates had properly used standard techniques but had also misinterpreted what the results were indicating.

Lastly, it was emphasized that the estimates of biomass were for a narrow time window (Sept. 24 – Oct. 16) when the index fishery had occurred.

Questions were raised regarding information on dispersion of tagged fish. It had been argued earlier that there was little dispersion in the tagging data that would impact the exploitation estimates. Information was presented to address this concern. The information showed considerable dispersal after the first year for the 1996 tags. Only 1 year of information was available for the 1997 tagging work. Statistical analysis showed there were significant differences between 1996 and 1997 distances but not between 1997 and 1998 dispersals. This was considered a key result to address the mark-recapture assumptions in conjunction with the approach that generated the higher biomass estimate.

Discussion then focussed on whether the different estimates should be included in the SSR**. It was agreed** that they should be but there needed to be careful text included so as to ensure the difficulties and uncertainties were fully captured.

Discussion then moved to examine information on calculations of Z based on the research vessel data from inshore strata as well as from sentinel survey data as adjusted for gear selectivity. The results were variable and there were serious concerns about how well the age selectivities of the gears had been accounted for therefore, it was considered premature to attempt to use the information in evaluating the present status of the stock. Nonetheless, it was suggested that there may very well be useful information in the data and **it was recommended** that further analyses of the inshore database be carried out in an attempt to extract more information on Z for future years.

Information was also tabled indicating the 1998 index fishery effort and catches were widely distributed although this only applied to areas south of White Bay. The lack of catch north of this area was interpreted as reflecting the low amount of fish in this area.

Further discussion of 2J3KL cod focussed on the SSR.

13. Atlantic Overview: cod stocks

Due to the time required to complete reviews of Working Papers, Addenda, and draft SSRs, it was **agreed** that it would be impossible to review a draft of the Atlantic Groundfish Overview during the meeting. The CSAS Coordinator, who will oversee preparation of the Overview, summarized the proposed content of the Overview. It would begin with a brief history of the cod rebuilding and subsequent collapse, and a summary of the environmental overviews, following the general presentation in past overviews. It would summarize fairly completely the conclusions of the Cod Mortality High Priority Project, with the objective of putting the issue of what caused the high mortality to rest as much as realistically possible. With regard to post-collapse issues on which to focus, it would give prominence to the production plots reviewed earlier in the meeting, and presented for several stocks just prior to the discussion of the Overview. The meeting **agreed** that plots would be included for all cod stocks, not just the ones assessed at the ZAP,

and acknowledged that in the absence of a SPA it might not be possible to prepare such a plot for 2J3KL.

The Overview would also highlight the current views on the roles of seals in the dynamics of the cod stocks, and, in a larger context, the implications of the increased natural mortality observed since at least the mid 1980s. Other newer concerns warranting attention included the inshore-offshore differences in at least 2J3KL and 3Pn4RS and the apparently changing patterns of stock structure and migration. Stress would be given to the reasons for extreme caution with the inshore stock sub-components in light of the failures to observe noteworthy rebuilding offshore. In discussion, the meeting **agreed** to this general approach. Participants also noted that another general message was that prior to the collapse scientists were able to talk about some general patterns in Canadian Atlantic cod, whereas since the collapse different stocks appear to be performing in much more different ways.

The meeting also **agreed** to the following process for approving the Overview. After the meeting, the CSAS Coordinator would circulate a draft outline for the Overview, to Regional RAP coordinators, lead cod assessment scientists, and the meeting Chair for comment. When the comments have been assimilated, a draft Overview document will be prepared by the CSAS coordinator, working closely with the Atlantic Regional RAP coordinators. When the Draft is ready for review, individual regions can have the review done in the most suitable way for the Region, as long as those who comment actually participated in the ZAP, and the structure of the review does not result in giving every individual in each Region effective veto power over the Overview. Final approval of content will require agreement of the RAP coordinators of Laurentian, Maritimes, and Newfoundland regions, the meeting Chair, and the CSAS Coordinator.

14. Closing Remarks

The Chairman asked the participants to forward the formatted Stock Status Reports to the Canadian Stock Assessment Secretariat (CSAS) by Friday, March 19, 1999, for inclusion as Annexes to the Minutes. For the Stock Status Report on 3Pn-4RS cod**, it was agreed** that the next draft would be sent to the regional coordinators in the upcoming days for final reading, and that the formatted version would also be forwarded to the CSAS by March 19th.

The Chairman thanked the participants for their support throughout this meeting. The meeting adjourned around 17:45.

Annex 1. a) Agenda for the Zonal Assessment Process (ZAP) of March 1-12, 1999 - Rimouski, Québec.

March 1 Monday	March 2 Tuesday	March 3 Wednesday	March 4 Thursday	March 5 Friday	March 6 Saturday	March 7 Sunday
9:00 Welcome Environmental Overview Report on Cod Mixing Project	Cod in southern Newfoundland (3Ps)	Cod in northern Gulf of St. Lawrence (3Pn-4RS)	Cod in southern Gulf of St. Lawrence (4TVn)	Northern cod (2J-3KL)	Reruns	No meeting planned
Report on Cod Mortality Project Report on Seal Consumption Workshop Cod 4VsW Update						

March 8 Monday	March 9 Tuesday	March 10 Wednesday	March 11 Thursday	March 12 Friday
Reruns	Reruns	Atlantic Overview for cod stocks and discussion on conclusions of Cod Mortality Project	Review of draft SSRs and minutes	Review of draft SSRs and minutes
		Review of draft SSRs and Minutes		17:00 Meeting Adjourns

Annex 1. b) Horaire du processus d'évaluation zonale (PÉZ) du 1 au 12 mars, 1999 - Rimouski, Québec.

1 Mars Lundi	2 Mars Mardi	3 Mars Mercredi	4 Mars Jeudi	5 Mars Vendredi	6 Mars Samedi	7 Mars Dimanche
9:00 Mot de bienvenue Revue des conditions environmentales Rapport du projet sur le chevauchement des stocks de morue	Morue du sud de Terre-Neuve (3Ps)	Morue du nord du Golfe St. Laurent (3Pn-4RS)	Morue du sud du Golfe St. Laurent (4TVn)	Morue du nord (2J-3KL)	Perfection des analyses	Aucune réunion prévue
Rapport du projet sur la mortalité de la morue Rapport de l'atelier sur la prédation par les phoques Mise-à-jour pour la morue du 4VsW						

8 Mars Lundi	9 Mars Mardi	10 Mars Mercredi	11 Mars Jeudi	12 Mars Vendredi
Perfection des analyses	Perfection des analyses	Revue des stocks de morue de l'Atlantique et discussion des conclusions du projet sur la mortalité de la morue	Revue des ébauches pour les RES et les minutes	Revue des ébauches pour les RES et les minutes
		Revue des ébauches pour les RES et les minutes		17:00 Ajournement

Annex 2. a) Remits.

REMITS for the Zonal Assessment of March 1-12, 1999
Rimouski, Québec

1. General

1.1 Provide an overview of the November 1998 Workshop on the DFO High Priority Project on the Identification of Mixed Cod Stocks in the Gulf of St. Lawrence and its approaches. This overview should draw particular attention to the implications for the assessment of cod stocks in the northern Gulf of St. Lawrence (3Pn-4RS) and off southern Newfoundland (3Ps).

1.2 Provide an overview of the results obtained from the DFO High Priority Project on Cod Mortality and evaluate the implications of the findings for the assessment of cod stocks under consideration. Also, the review should evaluate the generality of the HPP on Cod Mortality conclusions in light of the current assessment results.

1.3 Review the recommendations of the December 1998 Workshop on Seal Consumption, evaluate the progress made towards their realization and evaluate the implications of any new findings for the assessment of cod stocks under consideration.

1.4 Prepare a Stock Status Report providing an overview on Cod Stocks in the Northwest Atlantic. This overview should provide:

- A description of changes in environmental conditions for the Labrador Shelf and the Newfoundland Grand Banks, the Gulf of St. Lawrence, the Scotian Shelf and Georges Bank.
- A unified framework for interpreting the similarities and differences of dynamics among the stocks, and for integrating the results of the most recent assessment of each Canadian Atlantic cod stock.
- A description of the changes in the productivity of Atlantic cod stocks since the 1970s, including a discussion on the reasons for such changes.
- A discussion on the reasons for continuing poor recruitment since the early 1990s.

2.2 2. Northern cod (2J3KL)

2.1 Assess the status of the 2J3KL cod management unit until 31 December 1998. As such, the assessment will:

a) Update all anthropogenic removals up to the end of 1998.

b) Compute age composition of catches for 1998 disaggregated by gear type, fishery type, quarter and subareas.

c) Update research vessel time series estimates of abundance and biomass by stratum and mean numbers per tow.

d) Update time series of length, weight, condition and maturity at age from research vessel data.

e) Evaluate Sentinel Survey data from 1995 to 1998 by gear type and subarea as potential indicators of relative stock size and year class strength in the inshore.

f) Evaluate index fishery data as potential indicators of relative stock size and year class strength.

g) Evaluate food fishery results for possible information regarding the relative abundance of fish in the inshore and year class strength.

h) Evaluate pre-recruit survey indices as potential indicators of relative year class strength.

i) Re-examine the 1997 inshore acoustic survey data for 2J3KL cod under different assumptions to explore the sensitivity of the 18,000 t estimate to these assumptions.

j) Evaluate tagging results for information on cod mixing, both between unit stock areas and between inshore and offshore areas within unit stocks.

k) Evaluate genetic results from the high priority project on inshore/offshore cod components.

l) Evaluate tagging data for information on exploitation rate and stock size.

m) Evaluate the results of ad hoc acoustic surveys directed at cod during 1998.

n) Reconsider population reconstructions in the light of a possible change in natural mortality at some time in the 1980s or early 1990s.

o) Evaluate population reconstructions for which some changing fraction of the unit stock occurs outside of the area surveyed.

p) Consider the sensitivity of SPA results to different levels of catch misreporting and discarding.

q) Attempt to reconcile commercial removals and harp seal consumption for cod in a single analytical model, under alternative assumptions of additive mortality and mortality compensation, taking into account different levels of non-seal mortality on the pre-recruit ages.

r) Evaluate spatial analysis methods for deriving indices from survey and catch data.

s) Evaluate the by-catch of juvenile cod in the shrimp fishery.

2.1 Evaluate the results of the High Priority Project on Cod Mortality in relation to the stock trajectory of 2J3KL cod. In that context, also consider the possibility that northern cod may have emigrated to 3Ps in the early 1990's and that cod from 3Ps may have moved to 3K and 3L in recent years.

2.2 Evaluate the potential contribution of the inshore Stock Spawning Biomass in rebuilding the offshore component of the 2J3KL stock complex.

2.3 For a limited number of population reconstruction scenarios, conduct short term (1 year) and median term (3 years) risk analyses to quantify the probability of a change in spawning stock biomass at different levels of annual catch.

2.4 Produce a Stock Status Report and supporting Research Document documenting the results of the assessment.

3. Cod off southern Newfoundland (3Ps)

3.1 Assess the status of the 3Ps cod management unit until 31 December 1998. As such, the assessment will:

a) Update all anthropogenic removals up to the end of 1998.

b) Compute age composition of catches for 1998 disaggregated by gear type, fishery type, quarter and subareas.

c) Update research vessel time series estimates of abundance and biomass by stratum and mean numbers per tow.

d) Update time series of length, weight, condition and maturity at age from research vessel data.

e) Evaluate Sentinel Survey data from 1995 to 1998 by gear type and subarea as potential indicators of relative stock size and year class strength in the inshore.

f) Evaluate GEAC survey data as a potential indicator of relative stock size and year class strength.

g) Evaluate food fishery results for possible information regarding the relative abundance of fish in the inshore and year class strength.

h) Evaluate tagging results for information on cod mixing, both between unit stock areas and between inshore and offshore areas within unit stocks.

i) Evaluate genetic results from the high priority project on inshore/offshore cod components.

j) Evaluate tagging data for information on exploitation rate and stock size.

k) Evaluate the results of ad hoc acoustic surveys directed at cod during 1998.

l) Reconsider population reconstructions in the light of a possible change in natural mortality at some time in the 1980s or early 1990s.

m) Evaluate population reconstructions for which some changing fraction of the unit stock occurs outside of the area surveyed.

n) Evaluate population reconstructions in which a significant portion of the catch and survey biomass for the Burgeo Bank region is considered to belong to the Northern Gulf unit stock.

o) Consider the sensitivity of SPA results to different levels of catch misreporting and discarding.

p) Evaluate spatial analysis methods for deriving indices from survey and catch data.

3.1 Evaluate the results of the High Priority Project on Cod Mortality in relation to the stock trajectory of 3Ps cod.

3.2 For a limited number of population reconstruction scenarios, conduct short term (1 year) and median term (3 years) risk analyses to quantify the probability of a change in spawning stock biomass at different levels of annual catch.

3.3 Produce a Stock Status Report and supporting Research Document documenting the results of the assessment.

4. Cod in the northern Gulf of St. Lawrence (3Pn-4RS)

4.1 Assess the status of the 3Pn, 4RS cod management unit until 31 December 1998. As such, the assessment will:

a) Update all anthropogenic removals up to the end of 1998.

b) Compute age composition of catches for 1998 disaggegated by gear type, fishery type, quarter and subareas.

c) Update research vessel time series estimates of abundance and biomass by stratum and mean numbers per tow.

d) Update time series of length, weight, condition and maturity at age from research vessel data.

e) Evaluate Sentinel Survey time series by gear type and subarea as potential indicators of relative stock size and year class strength in the inshore and evaluate biomass estimates and mean numbers per tow from mobile sentinel surveys by stratum.

f) Evaluate the results of the survey undertaken under the high priority hydroacoustics program.

g) Calibrate a sequential population analysis based on the recent trends from research surveys, sentinel fisheries (both fixed and mobile):
   - the analysis should take into account the consumption of cod by the seals in the area and,
   - consider the influx of the Northern Gulf cod into the western part of 3Ps (Burgeo Bank).

a) Detail the controls that were implemented in 1998 to avoid by-catch of juvenile cod in the shrimp and turbot fisheries and the means that were put in place to avoid concentration of the fishery on the 1993 year-class (FRCC.98.R.2 Recommendation #3.2.2.1. items 3 and 6).

4.1 Evaluate the results of the High Priority Project on Cod Mortality in relation to the stock trajectory of 3Pn-4RS cod.

4.2 Conduct short term (1 year) and median term (3 years) risk analyses to quantify the probability of a change in spawning stock biomass at different levels of annual catch.

4.3 Produce a Stock Status Report and supporting Research Document documenting the results of the assessment.

5. Cod in southern Gulf of St. Lawrence (4TVn)

5.1 Assess the status of the 4TVn cod management unit until 31 December 1998. As such, the assessment will include:

a) An update of all anthropogenic removals up to the end of 1998.

b) A computation of age composition of catches for 1998 disaggregated by gear type, fishery type, quarter and subareas.

c) An update of the research vessel time series estimates of abundance and biomass by stratum and mean numbers per tow.

d) An update of time series of length, weight and condition at age from research vessel data.

e) An analysis of the relative importance of size selective mortality, population density, and temperature on long term changes in length at age of the stock. An analysis of the management implications of the findings should be included.

f) An update of the sentinel survey data with the 1998 information. Where possible, this information should be compared and contrasted with the DFO September survey results.

g) A description of index fishery data and an evaluation of its potential use as an indicator of stock size and relative year class strength for 4TVn cod.

h) An analysis of the DFO September survey data for trends in natural mortality to support estimates used in the SPA. Alternate explanations for the trends such as a change in survey catchability should be considered.

i) A detailed summary of the available information on seal consumption of 4TVn cod, as per the recommendation of the December 1998 Seal Consumption workshop.

j) A Sequential Population Analysis using as long a historical time series as possible. Attempts should be made to incorporate the sentinel indices in addition to the research survey index into the calibration of the SPA. This analysis should produce estimates of uncertainty in the current population status.

5.1 Evaluate the results of the High Priority Project on Cod Mortality in relation to the stock trajectory of 4TVn cod.

5.2 Conduct short term (1 year) and median term (3 years) risk analyses to quantify the probability of a change in spawning stock biomass at different levels of annual catch.

5.3 Produce a Stock Status Report and supporting Research Document documenting the results of the assessment.

6. Cod on Eastern Scotian Shelf (4VsW)

6.1 Update the estimates of seal consumption of 4VsW cod as per the recommendation of the December 1998 Seal Consumption workshop.

6.2 Evaluate whether or not the updated seal consumption estimates significantly change the Outlook as stated in Stock Status Report A3 - 35 (1998).

6.3 If significant change in 4VsW cod stock status occurs with the update of the seal consumption information, conduct a new assessment of 4VsW cod and produce a new Stock Status Report and supporting Research Document.

6.4 If no significant change in 4VsW cod stock status occurs with the update of the seal consumption information, prepare a section for the Proceedings of the Zonal meeting documenting the new seal consumption estimates and their evaluation.

NOTE:
The results of these assessments will be documented in Stock Status Reports, in the Proceedings series and in Research Documents of the Canadian Stock Assessment Secretariat (CSAS).

Annex 2. b) Objectifs.

OBJECTIFS de l'évaluation zonale – 1er au 12 mars 1999
Rimouski, Québec

1. Généralités

1.1 Présenter un survol de l'atelier de novembre 1998 sur le projet hautement prioritaire du MPO sur l'identification des échanges entre les stocks de morue couvrant le golfe du Saint-Laurent et ses approches. Le survol devrait faire le point sur les répercussions des résultats pour l'évaluation des stocks de morue du nord du golfe du Saint-Laurent (3Pn-4RS) et du sud de Terre-Neuve (3Ps).

1.2 Présenter un survol des résultats du projet hautement prioritaire du MPO sur la mortalité de la morue et évaluer les répercussions des résultats sur l'évaluation des stocks de morue visés. Le survol devrait aussi inclure une évaluation du caractère général des conclusions tirées à la lumière des résultats d'évaluation actuels.

1.3 Passer en revue les recommandations de l'atelier de travail de décembre 1998 sur la consommation de morue par les phoques, évaluer les progrès réalisés au titre de la mise en œuvre des recommandations et évaluer les répercussions des nouveaux résultats sur l'évaluation des stocks de morue visés.

1.4 Préparer un rapport sommaire sur l'état des stocks de morue de l'Atlantique nord-ouest. Le rapport devrait inclure les éléments suivants :

- Une description des changements dans les conditions environnementales du plateau continental du Labrador, des Grands Bancs de Terre-Neuve, du golfe du Saint-Laurent, de la plate-forme Scotian et du banc de Georges;
- Un cadre unifié pour interpréter les ressemblances et les différences au niveau de la dynamique entre les stocks et pour inclure les résultats de la plus récente évaluation de chaque stock de l'Atlantique canadien;
- Une description des changements dans la productivité des stocks de morue de l'Atlantique depuis les années 70, y compris une discussion des raisons sous-tendant ces changements;
- Une discussion des raisons à la base du faible recrutement continu depuis le début des années 90.

2. Morue du Nord (2J3KL)

2.1 Évaluer la situation de l'unité de gestion de la morue 2J3KL au 31 décembre 1998. L'évaluation comprendra :

a) Une mise à jour de tous les prélèvements anthropiques jusqu'à la fin de 1998;

b) Le calcul de la composition des prises selon l'âge en 1998 ventilée selon les types d'engin, les pêches, le trimestre et les sous-zones;

c) Une mise à jour des séries temporelles d'estimés d'abondance et de biomasse selon la strate et le nombre moyen par trait obtenus dans le cadre des relevés de recherche;

d) Une mise à jour des séries temporelles de longueur, de poids, de la condition et de l'état de maturité selon l'âge en fonction des données des relevés de recherche;

e) Une évaluation des données des relevés par pêche sentinelle menés de 1995 à 1998 selon le type d'engin et la sous-zone comme indicateurs potentiels de la taille relative des stocks et de l'abondance des classes d'âge dans les eaux côtières;

f) Une évaluation des données des pêches indicatrices comme indicateurs potentiels de la taille relative des stocks et de l'abondance des classes d'âge;

g) Une évaluation des résultats de la pêche vivrière pour y relever tout renseignement sur l'abondance relative du poisson dans les eaux côtières et l'abondance des classes d'âge;

h) Une évaluation des indices de relevés de l'abondance des pré-recrues comme indicateurs potentiels de l'abondance relative des classes d'âge;

i) Un nouvel examen des données du relevé acoustique côtier de 1997 visant la morue de 2J3KL en fonction de nouvelles hypothèses afin d'établir la sensibilité de l'estimation de 18 000 t à ces hypothèses;

j) Une évaluation des résultats d'étiquetage pour y relever des renseignements sur le mélange de la morue, tant entre les zones unitaires de stock qu'entre les secteurs côtiers et hauturiers de chaque zone de stock;

k) Une évaluation des résultats génétiques du projet hautement prioritaire sur les composantes côtière et hauturière du stock de morue;

l) Une évaluation des données d'étiquetage pour y relever tout renseignement sur le taux d'exploitation et la taille du stock;

m) Une évaluation des résultats de relevés acoustiques spéciaux visant la morue en 1998;

n) Un nouvel examen des reconstitutions de populations à la lumière d'un changement possible dans la mortalité naturelle à un certain moment dans les années 1980 ou au début des années 1990;

o) Une évaluation des reconstitutions de populations pour lesquelles une certaine partie variable du stock unitaire vit à l'extérieur de la zone étudiée;

p) Un examen de la sensibilité des résultats de l'ASP à différents niveaux de déclarations erronées et de rejet des prises;

q) Un essai de conciliation des prélèvements commerciaux et des quantités de morue consommées par le phoque du Groenland dans un seul modèle analytique fondé sur des hypothèses alternatives de mortalité additive et de compensation de la mortalité tenant compte des différents niveaux de mortalité des pré-recrues non imputable aux phoques;

r) Une évaluation des méthodes d'analyse spatiale utilisées pour calculer les indices à partir des données sur les prises et des données de relevés;

s) Une évaluation des prises accessoires de morue juvénile récoltées dans le cadre de la pêche à la crevette.

2.1 Évaluer les résultats du projet hautement prioritaire sur la mortalité de la morue par rapport à la trajectoire du stock de morue 2J3KL. Dans ce contexte, examiner aussi la possibilité que

la morue du Nord puisse avoir émigré dans 3Ps au début des années 1990 et que la morue de 3Ps puisse avoir émigré dans 3K et 3L au cours des dernières années.

2.2 Évaluer la contribution potentielle de la biomasse de reproducteurs du stock côtier au rétablissement de la composante hauturière du complexe du stock 2J3KL.

2.3 Pour un nombre limité de scénarios de reconstitution de population, faire des analyses des risques à court (1 an) et à moyen terme (3 ans) pour quantifier la probabilité d'un changement dans la biomasse du stock reproducteur à différents niveaux de prises annuelles.

2.4 Préparer un rapport sur l'état du stock et un document de recherche à l'appui documentant les résultats de l'évaluation.

3. Morue du sud de Terre-Neuve (3Ps)

3.1 Évaluer la situation de l'unité de gestion de la morue 3Ps au 31 décembre 1998. L'évaluation comprendra :

a) Une mise à jour de tous les prélèvements anthropiques jusqu'à la fin de 1998;

b) Le calcul de la composition des prises selon l'âge en 1998 ventilée selon les types d'engin, les pêches, le trimestre et les sous-zones;

c) Une mise à jour des séries temporelles d'estimés d'abondance et de biomasse selon la strate et le nombre moyen par trait obtenus dans le cadre des relevés de recherche;

d) Une mise à jour des séries temporelles de longueur, de poids, de la condition et de l'état de maturité selon l'âge à l'aide des données des relevés de recherche;

e) Une évaluation des données des relevés par pêche sentinelle menés de 1995 à 1998 selon le type d'engin et la sous-zone comme indicateurs potentiels de la taille relative du stock et de l'abondance des classes d'âge dans les eaux côtières;

f) Une évaluation des données du relevé effectué par le Conseil des allocations aux entreprises de pêche du poisson de fond (GEAC) comme indicateurs potentiels de la taille relative du stock et de l'abondance des classes d'âge;

g) Une évaluation des résultats de la pêche vivrière pour y relever tout renseignement sur l'abondance relative du poisson dans les eaux côtières et l'abondance des classes d'âge;

h) Une évaluation des résultats d'étiquetage pour y relever des renseignements sur le mélange de la morue, tant entre les zones unitaires de stock qu'entre les eaux côtières et hauturières de chaque zone de stock;

i) Une évaluation des résultats génétiques du projet hautement prioritaire sur les composantes côtière et hauturière du stock de morue;

j) Une évaluation des données d'étiquetage pour y relever tout renseignement sur le taux d'exploitation et la taille du stock;

k) Une évaluation des résultats de relevés acoustiques spéciaux visant la morue en 1998;

l) Un nouvel examen des reconstitutions de populations à la lumière d'un changement possible dans la mortalité naturelle à un certain moment dans les années 1980 ou au début des années 1990;

m) Une évaluation des reconstitutions de populations pour lesquelles une certaine partie variable du stock unitaire vit à l'extérieur de la zone étudiée;

n) Une évaluation des reconstitutions de populations pour lesquelles une importante partie des prises et de la biomasse du relevé sur le banc Burgeo est considérée comme appartenant au stock unitaire du nord du golfe;

o) Un examen de la sensibilité des résultats de l'APS à différents niveaux de déclarations erronées et de rejet des prises;

p) Une évaluation des méthodes d'analyse spatiale utilisées pour calculer les indices à partir des données sur les prises et des données de relevés.

3.1 Évaluer les résultats du projet hautement prioritaire sur la mortalité de la morue par rapport à la trajectoire du stock de morue 3Ps.

3.2 Pour un nombre limité de scénarios de reconstitution de population, faire des analyses des risques à court (1 an) et à moyen terme (3 ans) pour quantifier la probabilité d'un changement dans la biomasse du stock reproducteur à différents niveaux de prises annuelles.

3.3 Préparer un rapport sur l'état du stock et un document de recherche à l'appui documentant les résultats de l'évaluation.

4. Morue du nord du golfe du Saint-Laurent (3Pn-4RS)

4.1 Évaluer la situation de l'unité de gestion de la morue 3Pn-4RS au 31 décembre 1998. L'évaluation comprendra :

a) Une mise à jour de tous les prélèvements anthropiques jusqu'à la fin de 1998;

b) Le calcul de la composition des prises selon l'âge en 1998 ventilée selon les types d'engin, les pêches, le trimestre et les sous-zones;

c) Une mise à jour des séries temporelles d'estimés d'abondance et de biomasse selon la strate et le nombre moyen par trait obtenus dans le cadre des relevés de recherche;

d) Une mise à jour des séries temporelles de longueur, de poids, de la condition et de l'état de maturité selon l'âge à l'aide des données des relevés de recherche;

e) Une évaluation des séries temporelles de données des pêches sentinelles selon le type d'engin et la sous-zone pour y relever des indicateurs de la taille relative du stock et de l'abondance des classes d'âge dans les eaux côtières et évaluer les estimations de la biomasse et les prises moyennes par strate obtenues dans le cadre des pêches indicatrices aux engins mobiles;

f) Une évaluation des résultats du relevé effectué dans le cadre du programme d'hydroacoustique hautement prioritaire;

g) L'étalonnage d'une analyse de population séquentielle basée sur les récentes tendances indiquées par les relevés de recherche et les pêches indicatrices (aux engins mobiles et aux engins fixes) :
    - l'analyse devrait tenir compte de la consommation de morue par les phoques dans la région;
    - l'analyse devrait considérer la possibilité d'un apport de morue du nord du golfe dans la partie ouest de 3Ps (banc Burgeo).

h) La description des contrôles mis en œuvre en 1998 pour éviter les prises accessoires de morue juvénile lors de la pêche à la crevette et au flétan noir et les moyens mis en place pour éviter que la pêche cible la classe de 1993 (CCRH.98.R.2, Recommandation 3.2.2.1., points 3 et 6).

4.1 Évaluer les résultats du projet hautement prioritaire sur la mortalité de la morue par rapport à la trajectoire du stock de morue 3Pn-4RS.

4.2 Faire des analyses des risques à court (1 an) et à moyen terme (3 ans) pour quantifier la probabilité d'un changement dans la biomasse du stock reproducteur à différents niveaux de prises annuelles.

4.3 Préparer un rapport sur l'état du stock et un document de recherche à l'appui documentant les résultats de l'évaluation.

5. Morue du sud du golfe du Saint-Laurent (4TVn)

5.1 Évaluer la situation de l'unité de gestion de la morue 4TVn au 31 décembre 1998. L'évaluation comprendra :

a) Une mise à jour de tous les prélèvements anthropiques jusqu'à la fin de 1998;

b) Le calcul de la composition des prises selon l'âge en 1998 ventilée selon les types d'engin, les pêches, le trimestre et les sous-zones;

c) Une mise à jour des séries temporelles d'estimés d'abondance et de biomasse selon la strate et le nombre moyen par trait obtenus dans le cadre des relevés de recherche;

d) Une mise à jour des séries temporelles de longueur, de poids, de la condition et de l'état de maturité selon l'âge à l'aide des données des relevés de recherche;

e) Une analyse de l'importance relative de la mortalité selon la taille, de la densité de la population et de la température par rapport aux changements à long terme de la longueur selon l'âge dans le stock. Analyser aussi les répercussions des résultats au plan de la gestion;

f) Une mise à jour des données de relevés par pêche sentinelle en fonction des données de 1998. Lorsque possible, comparer l'information aux résultats du relevé MPO de septembre;

g) Une description des données des pêches indicatrices et une évaluation de la possibilité d'utiliser celles-ci comme indicateurs de la taille du stock et de l'abondance relative des classes d'âge de la morue de 4TVn;

h) Une analyse des données du relevé MPO de septembre pour y relever des tendances dans la mortalité naturelle qui serviront à étayer les estimations utilisées dans l'APS. Considérer d'autres explications des tendances, comme un changement dans la capturabilité lors du relevé;

i) Un résumé détaillé de l'information disponible sur la consommation de morue de 4TVn par les phoques, selon la recommandation formulée lors de l'atelier de travail sur la consommation de morue par le phoque tenu en décembre 1998;

j) Une analyse de population séquentielle basée sur une série temporelle de données historiques aussi longue que possible. Essayer d'inclure les indices des pêches indicatrices et l'index du relevé de recherche dans l'étalonnage de l'APS. L'analyse devrait donner des estimations de l'incertitude entourant l'état actuel de la population.

5.1 Évaluer les résultats du projet hautement prioritaire sur la mortalité de la morue par rapport à la trajectoire du stock de morue 4TVn.

5.2 Faire des analyses des risques à court (1 an) et à moyen terme (3 ans) pour quantifier la probabilité d'un changement dans la biomasse du stock reproducteur à différents niveaux de prises annuelles.

5.3 Préparer un rapport sur l'état du stock et un document de recherche à l'appui documentant les résultats de l'évaluation.

6. Morue de l'est de la plate-forme Scotian (4VsW)

6.1 Mettre à jour les estimations de la consommation par les phoques de morue de 4VsW selon la recommandation formulée lors de l'atelier de travail sur le sujet tenu en décembre 1998.

6.2 Évaluer si les estimations mises à jour de la consommation modifient nettement ou non la perspective énoncée dans le Rapport sur l'état des stocks A3 - 35 (1998).

6.3 Si l'information sur la consommation donne lieu à un changement marqué dans l'état du stock de morue de 4VsW, effectuer une nouvelle évaluation de la morue 4VsW et préparer un nouveau rapport sur l'état du stock et un document de recherche à l'appui.

6.4 Si l'information sur la consommation ne donne pas lieu à un changement marqué dans l'état du stock de morue de 4VsW, préparer une section à inclure dans le compte rendu de la réunion zonale documentant les nouvelles estimations de la consommation et les estimations.

REMARQUES :
Les résultats des évaluations seront documentés dans des rapports sur l'état des stocks, dans la série de comptes rendus et dans des documents de recherche du Secrétariat canadien pour l'évaluation des stocks (SCÉS).

Annex 3. List of participants.

PARTICIPANT	ORGANIZATION
ARCHAMBAULT, Diane	DFO, Laurentian
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GREGOIRE, Francois	DFO, Laurentian
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LANDRY, Jean	DFO, Laurentian
LANE, Dan	FRCC / Ottawa University
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LEMELIN, Dario	GOVERNMENT, Québec
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LILLY, George	DFO, Newfoundland
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MACKINNON, Clarrie	GOVERNMENT, Nova Scotia
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MAHÉ, Jean-Claude	IFREMER, France
MCQUINN, Ian	DFO, Laurentian
MEUNIER, Gilles	INDUSTRY, Québec
MOREAULT, Guy	INDUSTRY, Québec
MORIN, Bernard	DFO, Laurentian
MORNEAU, Renée	DFO, Laurentian
MURPHY, Eugene	DFO, Newfoundland
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RIVARD, Denis	DFO, Ottawa
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ROY, Marcel	INDUSTRY, Québec
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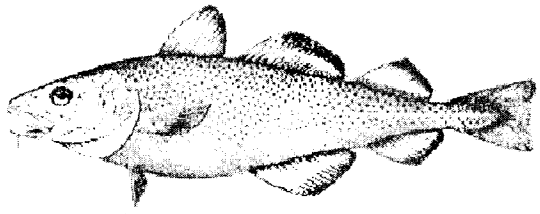
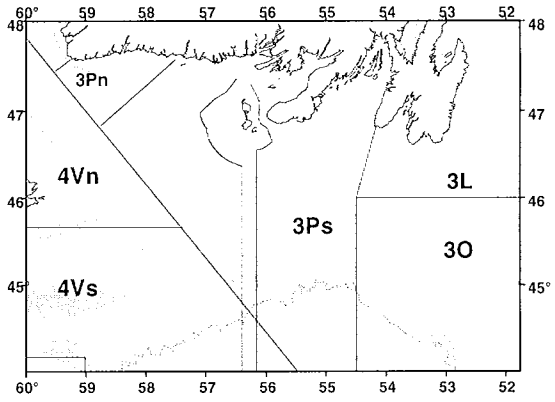
WOODMAN, Fred	FRCC
YEADON, Maureen	FRCC

Fisheries and Oceans / Pêches et Océans
Newfoundland Region

DFO Science
Stock Status Report A2-02(1999)



Subdivision 3Ps Cod



Background

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The 'St. Pierre Bank' stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank.

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered to be a complex mixture of sub-components. These may include fish that move seasonally into the area from adjacent stocks as well as fish that migrate seasonally between inshore and offshore. Fish are caught offshore by mobile gear and inshore by fixed gear. The extent to which the different components contribute to the fisheries is not fully understood.

Cod from this stock generally grow faster than those in more northerly areas. At least 50% of the females have been found to be mature by age 5 (53cm) in recent years, compared to age 6 (58cm) in the 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and have been of vital importance to the area. The stock was heavily exploited by Spain and other non-Canadian fleets in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August, 1993 ended in 1997 with a quota set at 10,000 t. The TAC was subsequently increased to 20,000 t for 1998.

History of the Fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 84,000 metric tons in 1961.

After the extension of jurisdiction in 1977, catches averaged around 30,000 metric tons until the mid-1980s when fishing effort by France increased and total landings reached about 59,000 metric tons in 1987. Catches then declined gradually to 36,000 metric tons in 1992.

A moratorium was imposed in August 1993 after only 15,000 metric tons had been landed. Although offshore landings have fluctuated, the inshore fixed gear fishery reported landings around 20,000 metric tons each year up until the moratorium. The fishery reopened in May 1997 with a TAC of 10,000 t and this was subsequently increased to 20,000 t in 1998.

In 1998 the 3Ps cod fishery, including a French allocation of 3,120 t, together with catches from sentinel surveys, a recreational fishery and by-catch resulted in reported

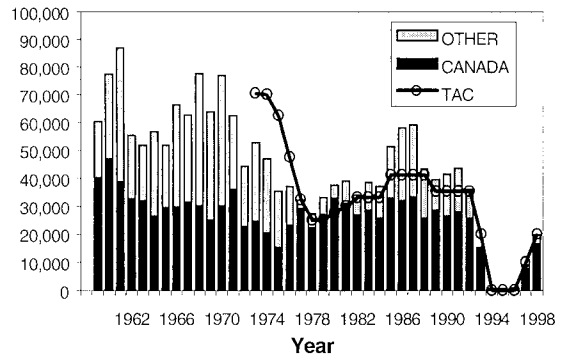
catches from sentinel surveys, a recreational fishery and by-catch resulted in reported landings of 19,681 t. Approximately 5,900 t was caught by otter trawlers and the remainder by fixed gear, particularly gillnets. Total landings by gillnets exceeded 10,000 t for the first time in history and accounted for more than half of the total landings. The Burgeo Bank area (3Psd) was closed to directed cod fishing during the winter of 1998-1999; this is an area of stock mixing and the purpose of the closure was to minimize the possibility of detrimental effects on the recovery of the neighbouring 3Pn4RS (northern Gulf) stock.

Landings (thousand metric tons)

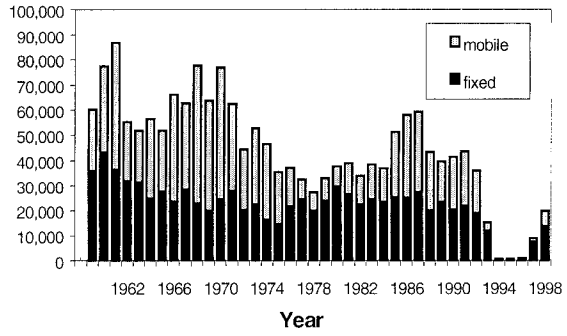
Year	59-76 Avg.	77-92 Avg.	1993	1994	1995	1996[1]	1997[1]	1998[1]
TAC	-	-	20	0	0	0	10	20
Can.	30	29	15	1	1	1	7	16.5
Others	29	12	+	-	-	-	2	3.1
Totals	59	41	15	1	1	1	9	19.6

[1] Provisional
[+] Catch less than 500 metric tons

Reported catch (t)



Reported landings (t) by gear sector



Resource Status

Sources of information

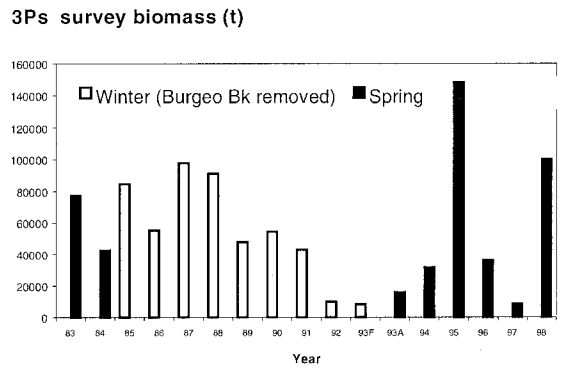
Stock status was estimated from **commercial landings** in conjunction with **abundance and biomass indices** from Canadian (1978-1998) and French (1980-1991) research vessel trawl surveys. Additional sources of information for 1998 included a second **industry trawl survey** on St. Pierre Bank, **sentinel surveys** (1995-1998), **acoustic surveys** in Placentia Bay and adjacent areas, tagging experiments, and genetic studies. As in 1997, a **science logbook** for vessels less than 35 ft. was used in 1998 to provide detailed information on catch and effort for the inshore fixed gear fishery.

A reliable interpretation of stock status is hampered by complex stock structure, seasonal migrations, variability in trawl survey estimates and poor quality historical data on catch and effort. Nevertheless, a variety of new analyses were carried out in an attempt to extract as much information as possible on stock status from the available data.Information from surveys

The 1998 spring **bottom trawl survey** was carried out on this stock with the Campelen 1800 shrimp trawl. The surveyed area

included inshore strata in trawlable areas of Fortune Bay and Placentia Bay. Before the results could be compared with pre-1996 surveys, which were conducted with Engels gear, the pre-1996 time series had to be converted to Campelen units. Conversions were based on the results of extensive comparative fishing experiments carried out with the old and new gear. The new trawl is much more effective at catching small cod than the old gear but similarly effective at catching larger cod up to 84 cm, thereafter the new trawl is less effective than the old gear. Duration of tows was 30 min for the old gear and is 15 min for the new gear.

The converted **biomass index** from 1983 to 1998 shows considerable variability, particularly during the past 4 years. The 1995 estimate is influenced by a single enormous catch contributing 87% of the biomass index. The 1997 Canadian trawl survey index was the lowest observed in the time series, which goes back to 1983, being less than half of the 1996 index. In contrast, the 1998 survey biomass index was much higher. The minimum trawlable biomass in 1998, including new inshore strata added in 1994, and extended further shoreward in 1997, was 104,000 t (95% confidence interval = 43,200 t – 164,800 t), more than ten times the 1997 survey estimate. The corresponding estimate for index strata only was 100,100 t.



The age compositions of fish in the 1998 research vessel survey were comparable to those seen in the 1996 research vessel survey, the fall 1997 industry trawl survey, and the commercial and sentinel catches in both 1997 and 1998. Ages 8 and 9 were strongly represented together with considerable numbers of ages 3-6.

The second in a developing time-series of **industry bottom-trawl surveys** was carried out on the St. Pierre Bank portion of the offshore in the fall of 1998. This survey used the same basic stratified random design adopted in the spring research vessel surveys but does not cover the entire offshore; the Burgeo area as well as Hermitage Bay, Fortune Bay and Placentia Bay are not surveyed. The results will be useful in determining stock status in future assessments when an adequate time series is available. The surveyed area in 1998 was expanded compared to the preceding year. Aggregations of cod were found in the Halibut Channel area, and on the southern end of St. Pierre Bank. The preliminary estimate of trawlable biomass was 47,875 t (95% confidence intervals = 38,933 – 56,818 t), i. e. approximately 50% of the 1997 estimate of 99,330 t. Fish aged 4-6, and 8-9 dominated the catches and there were few fish older than age 13. Age compositions were broadly similar to those seen in the 1997 industry survey.

An **acoustic survey** of inner Placentia Bay in early May revealed only 316 t of cod. Results of a subsequent survey of the inner bay in June revealed 3,000 t, suggesting that cod were moving into Placentia Bay. A broader-scale acoustic survey conducted in June 1998 and extending across Halibut Channel shoreward into Placentia Bay located a large dense school of spawning cod on Oderin Bank, comprising an estimated 72,000 t. Samples taken mainly by hand-line indicated that fish aged 6 and 8 predominated, with 4 and 5 year olds also well represented. These results were consistent with tagging studies, which showed that some offshore cod had moved into the inshore by the time the fishery opened at the end of June.

A fixed gear **sentinel survey** has been conducted at several sites along the south coast of Newfoundland from St. Brides to Burgeo. The survey began in late February of 1995 and continued in 1998.

Gillnet catch rates, mostly from sites in Placentia Bay, were low in 1998 relative to previous years but show no clear trend during 1995-1997; they also show strong seasonality and are consistently highest during fall in the eastern side of Placentia Bay.

Line-trawl catch rates, mostly from sites west of the Burin Peninsula, have declined since 1995 and exhibit strong seasonality within each year. Sentinel catch rates were reported by fishers to be generally good during all four years of the survey, and were substantially higher than commercial catch rates in concurrent years.

Biological information

Stock structure and **migration** patterns of 3Ps cod are not fully understood. Migration of offshore components of the stock to inshore areas during spring and summer, as well as the possible existence of inshore components that remain outside the survey areas throughout the year, also complicate the assessment of stock status.

Estimation of stock size is complicated by a seasonal movement of cod into 3Ps from adjacent management units, notably the northern Gulf of St. Lawrence (3Pn4RS) during winter. The main area of mixing appears to be the Burgeo Bank-Hermitage Channel area of western 3Ps. Recent analysis of elemental, genetic, and meristic markers from cod sampled in the mixing area during January in both 1996 and 1997 suggests that the proportion of 3Pn4RS cod present in the Burgeo-Hermitage Channel area during the winter can be substantial (>50%), declining in extent towards April as 3Pn4RS cod resume their return migration.

Information from recent and historical tagging studies, research vessel surveys, and commercial catches suggests that winter mixing in this area has occurred for many years. However, analyses of changes in length-at-maturity across the mixing area during winter suggests that the extent of mixing is variable.

Tagging studies initiated in 1997 in Placentia Bay were expanded in 1998 to include Fortune Bay and two offshore areas (Burgeo/Hermitage and Halibut Channel). Tag returns indicated that offshore stock components contributed to inshore fixed gear catches on the south coast throughout the summer and fall, with some cod tagged in the Burgeo area in April moving into 3Pn-

4RS and others migrating eastward along the inshore of 3Ps.

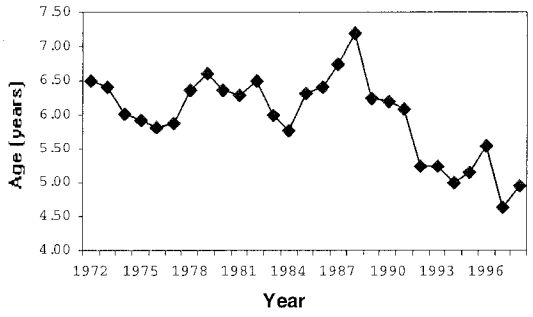
Recaptures also indicated a spring-summer movement of cod from the inner reaches of Placentia Bay toward the mouth of the bay. Several of these cod were recaptured in southern 3L during the fall index survey. The pattern of recaptures suggests a spring-summer movement of some 3Ps cod across the stock management boundary into 3L, with a return migration during late fall. Tagging of offshore cod in southern 3Ps in the mid-1980's also revealed some movement of cod between this area and the southern Grand Banks (3NO).

A new study of **genetic variation** revealed differentiation between inshore spawning cod in Fortune Bay and Placentia Bay, but little differentiation between inshore cod and those sampled offshore in 3Ps. Placentia Bay cod were also distinct from offshore northern cod, but not from inshore cod in 3KL.

Age at maturity in trawl survey samples has typically averaged 6 years but declined rapidly during the late 1980's and early 1990's, from a high of 7.2 years during 1988 to a low of 5 during 1994. An apparent reversal of the declining trend during 1995 and 1996 has not been continued. Recent estimates have been low but variable and the current (1998) estimate of age at 50% maturity is close to the lowest in the time series at 5.0 yrs.

Males generally mature about one year younger than females but show a similar trend over time. Maturities at age in the 1997 sentinel survey were similar to those found in the trawl survey.

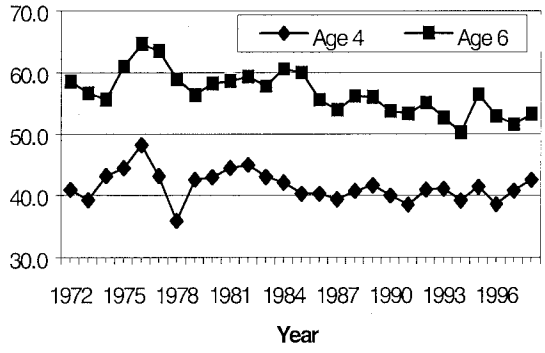
Age at 50% maturity (females)



Spawning is spatially widespread in 3Ps, occurring throughout the inshore as well as offshore on Burgeo Bank, St. Pierre Bank, and in Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. Spawning activity does not have well defined peaks although fish in spawning condition appeared to be common in the inshore during May-July during 1997 and 1998.

Growth, calculated from length-at-age in trawl survey samples, declined among the older ages (age 6) during the past decade but remained constant among younger ages (age 4). Current length-at-age remains low at 53.2 cm for age 6 cod, about 5 cm smaller than the values seen in the early 1980's.

Mean lengths (cm) at age



The **age composition** in commercial and sentinel fixed gear catches comprised a range of ages from 3 to 13, but was dominated by 5 and 6 year olds, with 8 and 9 year olds well represented in gill-net and line-trawl catches. Otter trawl catches in the offshore commercial fishery, fall industry survey, and spring research vessel survey consisted mainly of 8 and 9 year olds, with ages 5 and 6 also well represented. The spring research vessel survey also found substantial numbers of 3 and 4 year olds.

The **condition** of cod is typically determined by measuring temporal changes in the weight of the body muscle (gutted weight) or of the liver. Condition varies seasonally and tends to decline during winter and early spring; consequently, timing of sampling is an important consideration when investigating long-term changes in condition.
Cod collected during April 1998 surveys were generally in better condition than those sampled at the same time of year during 1993-95; comparison of post-1992 condition with condition during 1985-1992 is difficult because survey timing has changed. Nonetheless, condition of cod in the 1998 survey appeared to be normal. Fishers reported that cod caught during the commercial fishery were in good condition, particularly during fall.

Oceanography

Time series of **temperature anomalies** at depths less than 75m show cold periods in the mid-1970s and since the mid-1980s, similar to conditions on the shelf along the East coast of Newfoundland. The most recent cold period, which started around 1984, continued in the early 1990s with temperatures as much as 1°C below average, and as much as 2°C below the warmer temperatures of the late 1970s and early 1980s in the surface layers. Temperatures in deeper water off the banks show no significant changes.

Since 1991, temperatures have moderated somewhat in some areas and deep-water bottom temperatures are above normal, but large areas continued to have anomalously cold temperatures up to 1996, particularly on the eastern portion of St. Pierre Bank. In 1997, conditions were variable across the stock area with deep-water bottom temperatures above normal and a continuing cold trend on St. Pierre Bank. In contrast, conditions during 1998 were markedly improved, with warmer waters covering approximately 50% of the total area of the banks in 3Ps, the first significant amount since 1984.

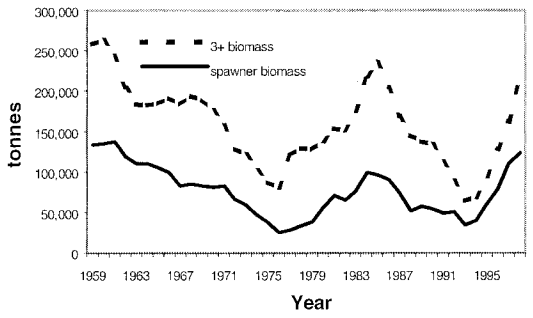
Population Analysis

Sequential population analysis was used to reconstruct the population using inshore fixed gear and offshore fixed and mobile gear commercial catches together with research vessel survey data. The research vessel information was divided into two time periods (February-March and April). To account for mixing in the Burgeo Bank/Hermitage Channel area these strata were removed from the February-March series. Separate analyses of inshore and offshore populations were considered to be no longer warranted, based on the relative abundance of cod in the offshore during 1998 from industry and research vessel trawl surveys. Evidence from tagging studies that also indicated that a significant portion of cod caught in the inshore originated from the offshore.

The current **population biomass** is estimated to be the 250,000 t and has

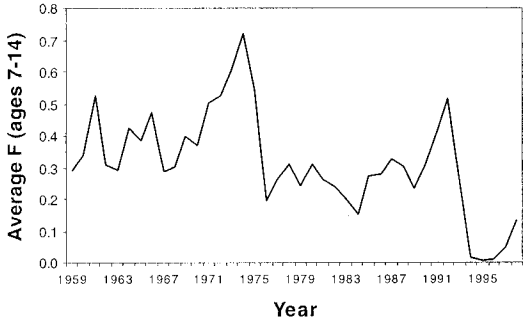
increased since the moratorium. **Spawner biomass** has also increased substantially and is currently estimated to be 145,000 t. This is largely a result of the high survival and maturation of the strong 1989, 1990 year classes combined with a reduction in the age at maturity. With the exception of the 1991 year class, subsequent **recruitment** appears to be strong but is estimated with considerable uncertainty.

Spawner Biomass and 3+ biomass



Average **fishing mortality** (ages 7-14) was very low during the moratorium and was 0.05 in 1997 with a 10,000 t fishery, and has increased to 0.13 during 1998 with a 20,000 t fishery.

Average Fishing Mortality (Ages 7-14)



Independent estimates of **exploitation rates** in Placentia Bay were obtained for 1997 and 1998 from tagging studies. The analyses indicated similar exploitation rates of approximately 10% in each year, in spite of a substantial increase in Placentia Bay landings in 1998. These estimates are consistent with the results from the sequential population analysis.

Sources of Uncertainty

The origins of fish that make up the 3Ps cod fishery are diverse and as yet not fully understood. This complicates the interpretation of trawl survey, sentinel survey, and commercial catch data and reduces confidence in the results of sequential population analysis.

Strong year effects in the spring research vessel survey index, particularly during the most recent years, introduces considerable uncertainty in the estimates of current population size from sequential population analyses.

The timing of the trawl survey has varied considerably over the years. This complicates the interpretation of abundance estimates because of seasonal migration patterns and changes in distribution.

Introduction of the new trawl survey gear during 1996 may have resulted in more reliable estimates of year-class strength at younger ages. Although the time series of survey indices has been standardized through comparative fishing, there is uncertainty as to whether the abundance of young fish in the early portion of the time series is adequately represented.

There is concern regarding the continuing low age-at-maturity among 3Ps cod. This may be an indicator of stress to the stock and has been observed in adjacent cod stocks that have undergone population declines.

Outlook

The current population biomass on January 1, 1999 is estimated to be 250,000 t and the spawner biomass is estimated to be 145,000 t . The increase in spawning stock in recent years is due to the growth, maturation and good survival of the 1989 and 1990 year classes over the moratorium period, as well as the reduction in the age at maturity.

An intensive tagging study in Placentia Bay gave an estimated exploitation rate of about 10% from a 20,000 t commercial fishery in 1998. This exploitation rate is compatible with the 1998 assessment.

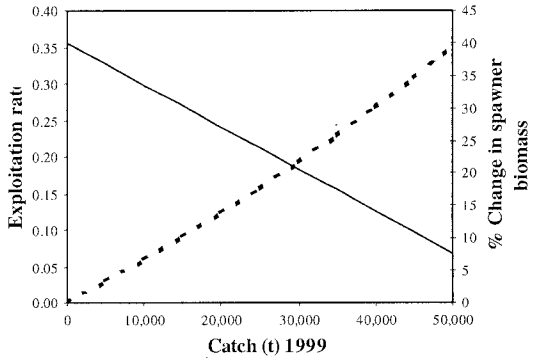
Standardized catch rates from the sentinel survey show a substantial decline for line-trawls in 1997 and 1998 and somewhat lower catch rates for gillnets in 1998. Fishermen suggested that this was attributable to competition for fishing sites and the disruption of high density fish aggregations and thus should not necessarily be interpreted as a decrease in stock biomass.

The fall industry survey gave a biomass estimate of only 50% of the 1997 estimate. This is only the second year of this new time-series and, as in the research vessel surveys for this stock, large year affects are anticipated.

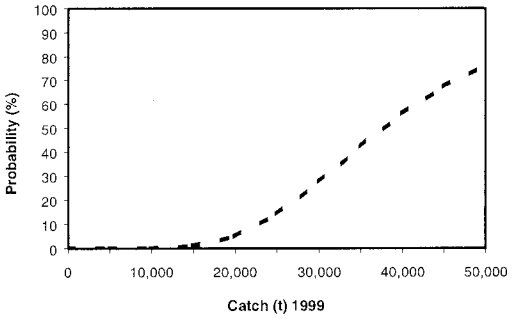
Mixing of northern Gulf (3Pn4RS) cod with 3Ps cod in the Burgeo Bank-Hermitage Channel area of 3Ps during winter continues to present problems. This area was closed to directed cod fishing in the winter of 1998-1999; significant landings from this area during winter could have detrimental effects on the recovery of the neighbouring 3Pn4RS cod stock.

A **risk analysis** propagating the uncertainty in the estimated population size to January 1, 2000 was carried out for a range of catch options. The risk of the spawner biomass falling below 100,000 t was estimated to be 9% with a catch of 20,000 t in 1999. The probability of exceeding an average fishing mortality of 0.25 over ages 7-14 in 1999 at this catch level is estimated to be 5%.

Exploitation rate and percent change in spawner biomass at different catch levels during 1999



Probability of average fishing mortality (ages 7-14) exceeding 0.25 at different catch levels in 1999.



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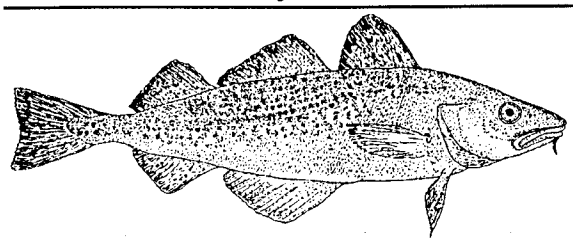

Cod in the Northern Gulf of St. Lawrence

Background

Cod in the northern Gulf of St. Lawrence (Divisions 3Pn, 4RS) undertake distant annual migrations. In winter, the fish gather southwest of Newfoundland at depths of over 400 m (200 fathoms). During April and May, they move towards the Port au Port Peninsula on the west coast of Newfoundland (Division 4R), where spawning begins. In summer, the cod disperse toward inshore areas, along the west coast of Newfoundland (Division 4R) and the Middle and Lower North Shore of Quebec (Division 4S). This inshore migration is influenced by warmer waters and the presence of capelin, a primary prey species for cod.

Based on the results of numerous tagging experiments, this stock is fairly isolated from other neighbouring stocks (those in 4TVn, 2J, 3KL and 3Ps). Mixing may occasionally occur in the northwestern Gulf (with the 4T,Vn stock), the Strait of Belle Isle (with the 2J, 3KL stock) and on Burgeo Bank (with the 3Ps stock). Recent studies have quantified the magnitude of the mixing around Burgeo Bank during the 1990s.

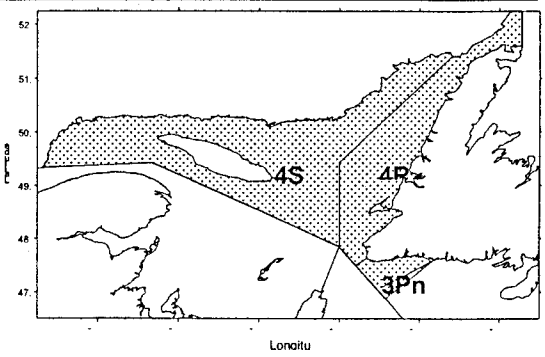

Figure 1. Range of the cod stock in the northern Gulf of St. Lawrence.

Landings (thousands of tonnes)

Year	1993	1994	1995	1996 [1]	1997[1]	1998[1]
TAC	18	0	0	0	6	3
Landings	18	0.4	0.3	0.7	4.4	3

[1] *Preliminary data*

Summary

- This assessment is based on eight indices; four bottom trawl research surveys (Gadus, Needler, July mobile sentinel and October mobile sentinel) and four fixed gear time series (Repère and sentinel using hook and line and gill nets).
- The lowest adult biomass was observed in 1994 at 17 Kt, it has slowly increased to reach 55 Kt in 1998. Although there is an improvement, this adult biomass is still much lower than the maximum of 348 Kt observed in 1983.
- The 1993 and 1995 year classes are estimated at 129 million individuals at age 3. This value is close to the historical average. These two year classes are the strongest observed in the 8 last years. The majority of the 1993 year class will spawn for the first time in 1999 and the 1995 year class appears as strong but only a small proportion of them will be mature in 1999 at age 4.
- The directed fishery in 1998 produced landings of 3,000 t with a fishing mortality of 0.11. A harvest of more than 10,000 t in 1999 would be likely to reduce mature biomass.
- Mortality caused by factors other than recorded landings was high in the late 1980s and played a

role in the stock's collapse. It is very likely that, during the 1990s, this mortality remained at least twice as high as assumed in assessments before 1998.

Description of the fishery

The stock was under moratorium from 1994 to 1996. In 1997, a limited fishery was authorized, with a TAC of 6,000 t. Landings totaled 4,400 t. This was brought back to 3,000 t in 1998 and 3,029 t were landed. The directed fishery was restricted to longlines, with fishing effort not exceeding 2,000 hooks per trip. No fishing by foreign vessels was allowed, and the small catches made by trawlers occurred within the context of scientific projects. In Division 4S, 442 t were landed on an initial allocation of 300 t, mainly by gillnets.

The Burgeo Bank area (3Psd) was closed to directed cod fishing during the winter of 1998-1999; this is an area of stock mixing and the purpose of the closure was to minimize the possibility of detrimental effects on the recovery of the neighbouring 3Pn, 4RS (northern Gulf) stock.

Assessment of this stock is complicated by seasonal movement of cod from 3Pn, 4RS into the Burgeo Bank- Hermitage Channel area of 3Ps during winter. Recent analyses of elemental, genetic and meristic markers from cod sampled in the mixing area during January in 1996 and 1997 suggest that the proportion of 3Pn, 4RS cod present in the Burgeo-Hermitage Channel area during the winter can be substantial (more than 50%) declining until April as cod resume their return migration to the Gulf. Information from recent and historical tagging studies, research vessel surveys and commercial catches suggest mixing has occurred in this area for many years. Analyses of changes in length at maturity across the mixing area during winter suggests that the extent of mixing is variable.

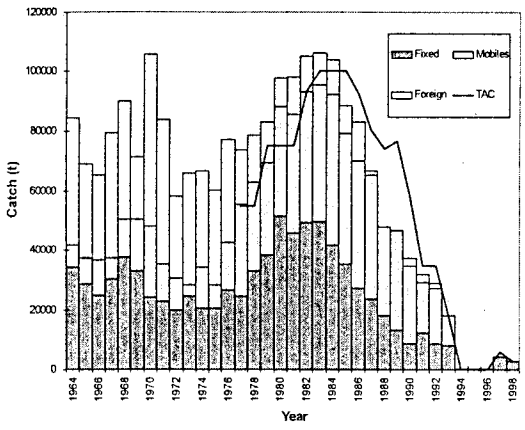

Figure 2. Landings and Total Allowable Catches (TAC).

Results of a telephone survey of fixed gear cod fishers provided a description of their experience and vessel type, fish size, fish condition, timing of migration, fishing depths, occurrence of spawning activity and catch rates for the 1998 cod fishery. Respondents noted improvements in fish size, fish condition and catch rates in 1998 relative to 1992, 1993 and 1997. These improvements were thought to be significant compared to the 1992-93 period (just prior to the northern Gulf cod moratorium) than when comparing 1998 to 1997. The timing of the fish migration into and out of traditional fishing grounds as well as the depth of water in which fish were caught has remained relatively constant since 1992-1993. The majority of fishers did not observe any cod spawning activity during 1998. Similar trends were observed for NAFO divisions 4R, 4S and 3Pn.

The sentinel catches are now included within the TAC. An allocation of 400 t is used to record these landings. Landings from sentinel in 1998 were 350 t.

Biological characteristics

The 1993 year class is moderately strong for the recent time period and the FRCC has recommended not to target this year class. This year class was the only one of importance over the last eight years as indicated in last year's report. The use of hook and line has a large range of selected

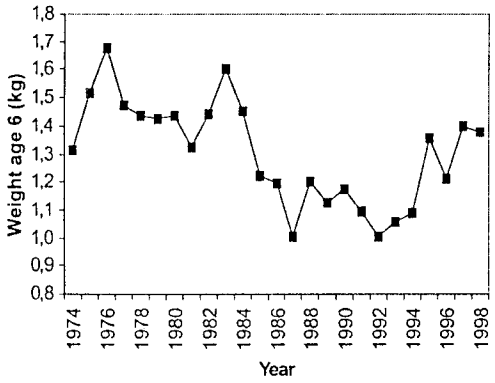

Figure 3. Mean weight of a six-year-old cod caught in the commercial fishery.

fish and only 20% of the 1998 catch at age is comprised by the 1993 year class. The most important age groups from the 1998 fishing season range from 5 to 9 years of age.

The mean weight at age rose in 1996 and 1997 and stabilised in 1998. The average size of the individuals taken by the sentinel fisheries using longlines rose each year during the moratorium. This has shifted to smaller fish somewhat since the commercial reopening in 1997. There are no changes in size composition of the gillnet catches from the "Repère" (1990-1993) and Sentinel programs (1995-1998).

The condition of individual cod reflects their state of health. The condition influences their potential for growth, reproductive success and survival after spawning. It is measured in a variety of ways, by looking at the length weight ratio, the relationship between the liver and the somatic weight (total weight less stomach weight and gonads weight) and finally, the water content of muscle and liver. Since 1995, the condition of the fish has remained good during the summer and fall.

In summer, cod caught by fixed gear near the east coast are in better condition than those caught in deeper waters by mobile gear. This finding may relate to different feeding patterns in the two environments. Inshore cod feed abundantly on prey with a higher energy content (fish), whereas the cod caught offshore eat less food and their diet is less rich (invertebrates). The depletion of oxygen in deep water may also affect digestion rates. These findings are based on the sentinel program and are currently being investigated further.

The condition of cod declined in the late 1980's, reaching a record low in 1991 and 1992, but has improved after that. Condition of cod in the early 90's were very low. Laboratory kept cod with comparable conditions were dying which leads us to believe they could have been mass mortalities in the wild.

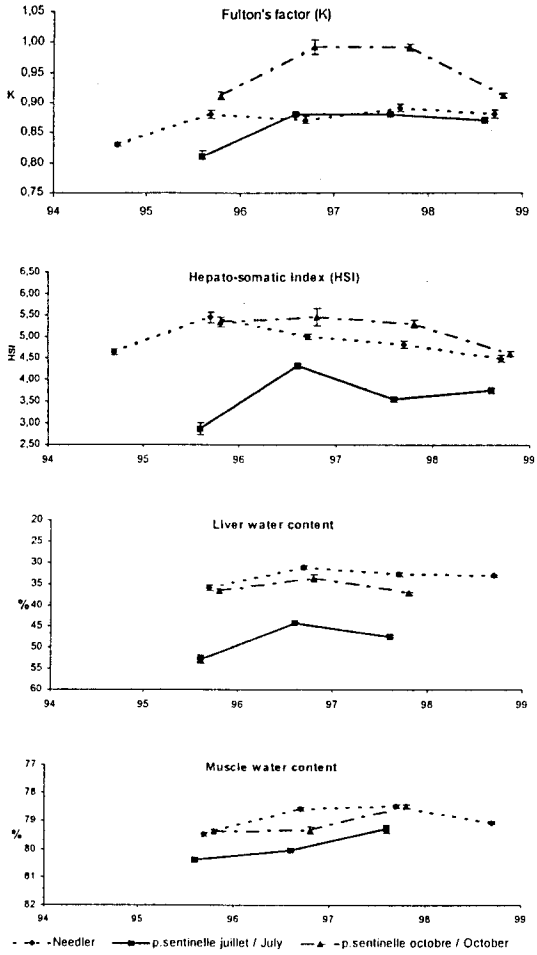

Figure 4. Cod condition from research survey (August) and sentinel survey.

Based on the data from DFO trawl surveys and the sentinel fisheries, **total mortality rate** during the moratorium may have reached 40%. Since no fishing was conducted during the period, that estimate represents natural mortality (M). This high value is incompatible with the value of 18% used in our analyses in the past.

Several factors may explain the increase in natural mortality. They include unfavourable environmental conditions, an increase in unreported catches (discards, misreporting, etc) and higher seal predation. Estimates of the total mortality for the 1995 to 1998 time period remain high (0.46 to 0.62).

The consumption of cod at age by grey and harp seals was calculated for the period 1974 to 1998 based on a constant diet model, and a seal population growth model. For both species, cod at age 1 to 3 make up the majority of ages consumed. Based on ages of otoliths from stomachs of grey and harp seals, they eat cod up to age 11 and up to age 7 respectively. It is estimated that 42 million individuals of age 3 and older were consumed by grey seals in 1998, and 38 million by harps.

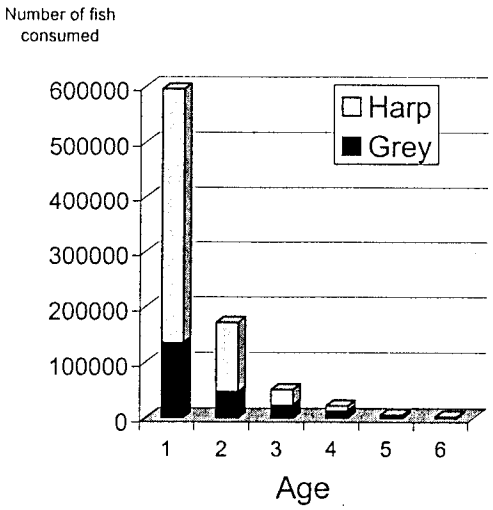

Figure 5. Consumption at age by seals in 1998.

When the seal consumption estimates were included in the sequential population analysis, the historic value of M=0.2 was used from 1993 onwards. Seals were assumed to account for the major part of the increased natural mortality during this period.

For comparison, an additional sequential population analysis not including seals was carried out. For this, the natural mortality is set at 0.4 from 1986 onwards.

During the fall of 1996, approximately 9000 tagged cod were released at sentinel sites in

3Pn, 4RS. A simple Petersen model, applied to returned statistics from 1997 and 1998 estimated biomass in the fall of 1996 to be about 147,000 t.

A comprehensive research program on stock mixing in and around the Gulf of St. Lawrence has demonstrated that in recent years more than 50% of the cod around Burgeo Bank (western part of division 3Ps) in winter are migrants from the northern Gulf of St. Lawrence. Although trawlable biomass in this area has averaged 30,000 t in recent years, management closed the area to fishing during the winter months of 1998. In the absence of a winter fishery on Burgeo Bank, the presence of 3Pn,4RS cod in winter is not expected to impact stock recovery efforts of northern Gulf cod.

Abundance indices

Fixed gears

The "Repère" (1990-1993) and sentinel (1995-1998) sampling protocol and deployment were examined in order to verify if they could be considered as a single index of abundance for the 1990 to 1998 time period. The lack of continuous fishing at individual sites between the the "Repère" (1990-1993) and sentinel (1995-1998) programs and differences in soak time precluded these being considered as one single time series.

The four fixed gear indices used showed similar inter-annual patterns for both gillnets and hook and line (Figure 6). The 1998 catch rates for these gears improved in almost all areas (Figure 7).

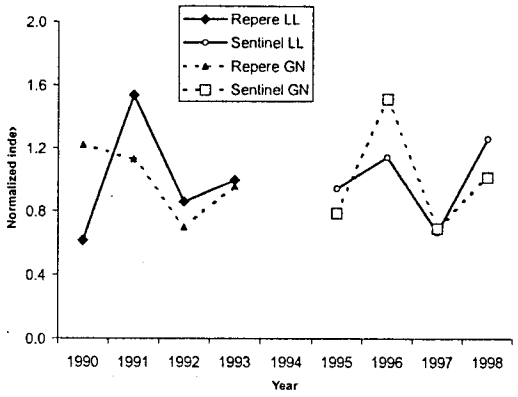

Figure 6. Abundance indices from fixed gears.

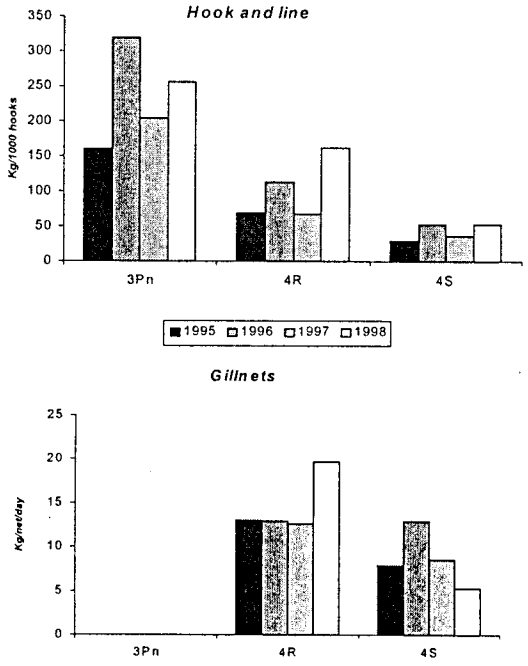

Figure 7. Catch rates of the fixed gear sentinel fisheries.

Bottom trawl surveys

The **sentinel fishery program using mobile gear** began in the northern Gulf in 1994, but it was not until 1995 that the entire offshore stock area was covered. These surveys are conducted twice a year (July and October) using nine trawlers. They carry out stratified random sampling like that done by DFO staff aboard the *Needler*. The gear employed by the nine trawlers was standardized in 1997 by introducing the use of a restrictor cable, which keeps the size of the trawl opening constant throughout fishing operations.

The July abundance index doubled between 1995 and 1997, but remains low in absolute terms. The population abundance estimate declined slightly between 1997 and 1998 for the July surveys. However, the 1995 year-class at age three is the most important in the time series. The October index rose between 1995 and 1996, but declined in 1997. The index of the 1998 October sentinel survey is the highest in the time series exceeding slightly the 1996 and 1997 surveys. The major part of the biomass is located in Division 4R. The distribution of cod does not vary significantly between July and October.

The 1993 year-class dominated catches during the last five surveys, from age two in 1995 to age four in 1997. However, the 1995 year class was the most abundant in both 1998 mobile gear sentinel surveys at age 3.

The *Alfred Needler* (DFO) survey was initiated in 1990 to assess the shrimp and redfish populations in the Gulf. In subsequent years, it was adjusted to enhance coverage of the geographic range of the northern Gulf cod by surveying fishing area 3Pn and waters shallower than 50 fathoms. The number of cod peaked in 1991, fell sharply after that and remained at a low level from 1993 to 1996. The population size rose slightly in 1997. The index from the 1998 survey follows the increasing trend observed since 1993.

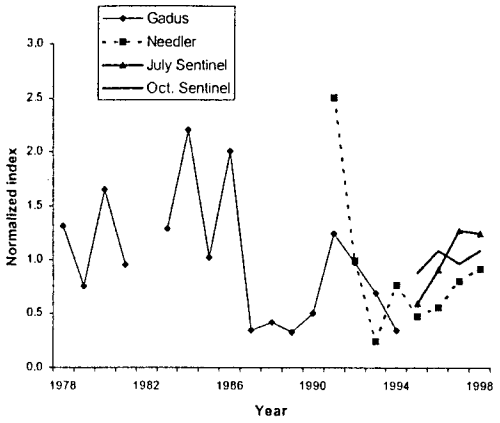

Figure 8. Abundance indices from research surveys.

As in the sentinel fisheries, the 1993 year-class dominated the catches from the 1996 and 1997 surveys. This result attests to the similarity of results from the sentinel operations and the research surveys conducted aboard the *Needler*.

Population analysis

This assessment is based on a calibration that uses eight different indices that encompasses both inshore and offshore gear sectors.

Sequential population analysis, based on combined inshore fixed gear and offshore mobile gear commercial catches together with research vessel survey date, was used in the population analysis. In the last assessment of this stock, the recent increase in natural mortality was reflected indirectly by changing the value used for natural mortality form 0.2 to 0.4 from 1986 onwards. This year, age by age estimates of the number of cod consumed by grey and harp seals were available and were incorporated directly into the population analysis in order to better reflect their contribution to the status of the cod stock.

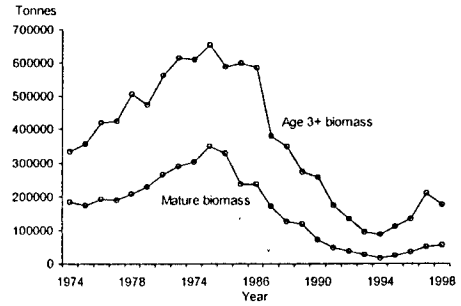

Figure 9. Total 3+ biomass and mature biomass estimated by sequential population analysis.

The abundance of fish three years old and over declined from 613 million in 1985 to 159 million in 1993 but subsequently increased to 232 million in 1998. The spawning biomass was 55 Kt in 1998 which corresponds to only 16% of the historic peak observed in 1983. The minimum mature biomass of 16 Kt was reached in 1994.

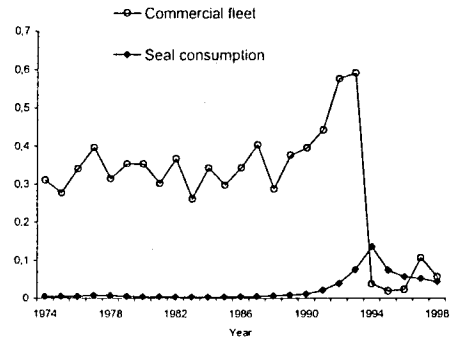

Figure 10. Yearly mortality estimates on fish age 5 to 9 from commercial fleet and seals.

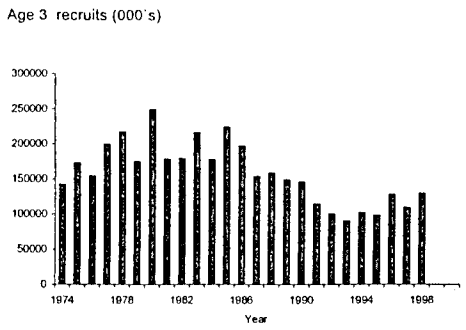

Figure 11. Estimate of recruitment at age three.

The 3 000 t of cod caught by the directed fishery in 1998 resulted in a fishing mortality rate of 0.11.

Sources of uncertainty

The potential impact of the incursions of 3Pn, 4RS cod on Burgeo Bank during the winter was examined by reallocating 75% of the landings taken in 3Psa and 3Psd between January to March and adjusting the catch at age for the Northern Gulf stock accordingly. Landings ranged between 1,200 t to a maximum of 4,144 t in the 1974 to 1993 time period. Yearly landings since 1994 were less than 42 t. These represented only a marginal increase to the northern Gulf cod catch at age.

A population analysis including the Burgeo Bank catch data had a negligible impact on the view of the northern Gulf cod. The 1998 beginning of year 3+ population numbers increased by only 7%. The current approach of limiting the winter fisheries on Burgeo Bank will help keep fishing mortality on the northern Gulf stock to a minimum.

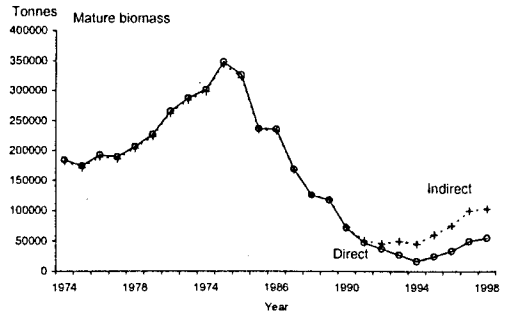

Figure 12. Impact of selecting the seal diet at age (direct) and the change in natural mortality (indirect).

The estimate of the quantity of cod consumed by seals, based on average occurrence of cod otoliths across all years and adjusted to the growth of both seal herds has a number of assumptions. The impact of this formulation is quite high with respect to

the estimate of the recent mature biomass (Figure 12). In addition, there is uncertainty about the number of cod consumed by belly-feeding.

An examination of distribution of catches from the *Needler* survey suggests a recent concentration of cod along the west coast of Newfoundland. The highest concentrations are found in the shallowest strata (30-50 fathoms). It is likely that a variable proportion of cod is found in unsampled inshore areas where the fixed gear fishery takes place.

Any difference in trends of the inshore to the offshore biomass should be picked up by the inshore and offshore indices and will result in large year residuals of the population reconstruction model.

The estimate of the 4+ biomass (147Kt) from the tagging experiment lies half way between the preferred analysis including seal predation estimate (112Kt) and the other analysis in which seal predation on cod was indirectly addressed by assuming a natural mortality of 0.4. The latter produced a biomass in 1997 of 186 Kt.

Under the circumstances of having a relatively high and age-dependent natural mortality, the interpretation of $F_{0.1}$ as a reference point in unclear. In a yield per recruit analysis, high natural mortality generally implies that a higher rate of fishing mortality is required. This is to avoid foregoing catch which would be lost to other sources of mortality. This is questionable in the case, as exists here, that the greater part of the natural mortality will be on age groups younger than those in the fishery i.e. the fishery is targeting age groups that have already survived most of the age-dependent natural mortality. For this reason, no risk analyses in terms of exploitation rate with respect to $F_{0.1}$ are provided.

Outlook

Risk analyses have been done to evaluate the effect of various catch levels in 1999 on the spawning biomass. The results indicate that the productivity of the stock should increase marginally in the short term due to faster individual growth and new recruitment. A ban on fishing in 1999 would allow the adult segment of the stock to grow by 7%, whereas a fishery with a TAC of 10,000 t would prevent any population growth. A catch in the order of 7,000 t would cause fishing mortality of 20% and would allow a marginal increase in the spawning stock.

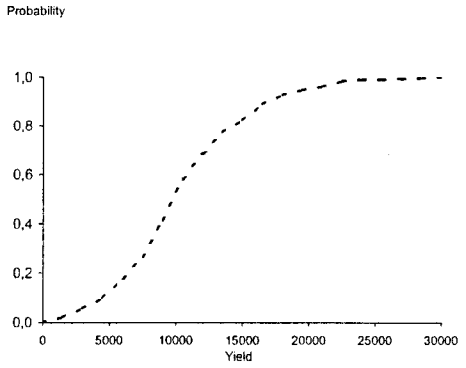

Figure 13. Probality of a decline in mature biomass in relation of various catch levels for 1999.

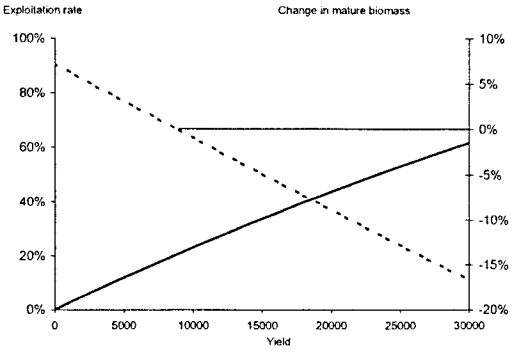

Figure 14. Projected exploitation rate and change in mature biomass relative to various catch levels in 1999.

For more information.

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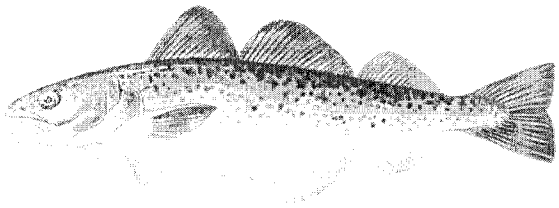
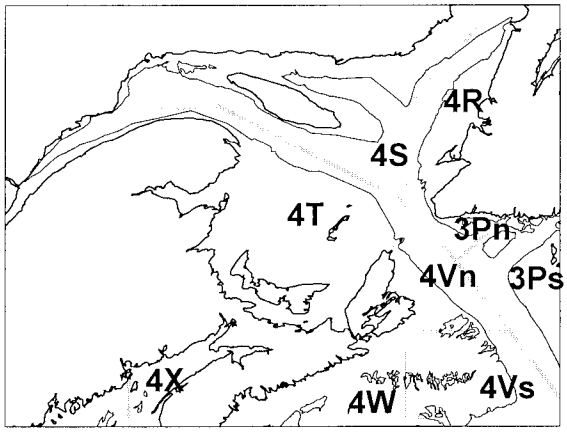


Cod in the Southern Gulf of St. Lawrence



Background

Southern Gulf of St. Lawrence cod are relatively long lived, and may reach ages of 20 or more when mortality is low. They begin to reach commercial size at age 4, and are fully available to the commercial fishery by age 7. They mature sexually at a size slightly below the commercial size of 41 cm (ages 4-5).

Southern Gulf cod are highly migratory. Spawning occurs in the Shediac Valley and around the Magdalen Islands from late April to early July. During the summer, the cod are widely distributed while they feed heavily on krill, shrimp, and small fish, primarily herring, Am. plaice, and capelin. The fall migration begins in late October and cod become concentrated off western Cape Breton in November as they move into 4Vn. The stock overwinters in 4Vn and northern 4Vs, along the edge of the Laurentian Channel. The return migration begins in mid-April, although in some years (1991-92) this was delayed by the late breakup of the winter ice. The management unit for this stock includes all of 4T and catches in 4Vn during November-April. In some years, catches in 4Vs in January-April ere attributed to this stock. In recent years, the winter fishery has been closed in 4Vsb to avoid catches of southern Gulf cod.

Southern Gulf cod have been exploited at least since the 16th century. Landings varied between 20,000 - 40,000 t annually between 1917-1940, and then began to increase to a peak of over 100,000 t in 1958. The fishery was primarily prosecuted with hook and line until the late 1940s, when a ban on otter trawling was lifted. Landings remained relatively high in the 1960s and early 1970s, in the range of 60,000 t. TACs were first imposed in 1974, and these became restrictive as the stock declined in the mid-1970's. The stock recovered somewhat, and landings returned to the 60,000 t range during the 1980s. During the 1980's, the fixed gear fishery declined drastically, and the fishery was mainly prosecuted by mobile gear until it was closed in September 1993, due to low abundance.

Summary

- The closure of the cod fishery in the southern Gulf of St. Lawrence in September 1993 stopped the rapid decline in abundance and biomass of the stock. Since the fishery closure in 1993, the stock has remained low.

- The recruitment produced in the early nineties has been well below the historical average. However, there are now indications that recruitment is improving; the 1996 year-class is about average.

- Estimates of total mortality from research and sentinel surveys indicate that the natural mortality rate of this stock remains higher than the historical estimate of 0.2. Natural mortality is estimated to be in the range of 0.4 to 0.5.

- Stock projections indicate a 5% expected improvement in spawning stock biomass in 1999 if there is no fishing.

- The spawning stock biomass could increase by 10% in 2001 provided that the 1996 year-class continues to be about

average and catches in 1999 and 2000 are near the 1998 level.

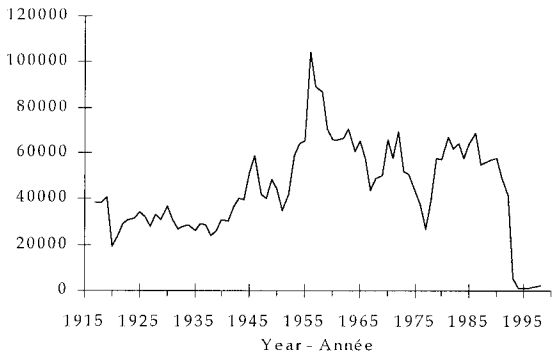
The Fishery

In 1998, the cod fishery in the southern Gulf continued to be closed but a 3,000 t allocation for by-catch, sentinel surveys, and index fishery was established. Cod were caught as by-catch in fisheries directed at other species, mainly flatfish. These fisheries were closed if the catch of cod exceeded 20% by weight in winter flounder and witch fisheries and 25% in the American plaice fishery. A recreational fishery using hook and line gear was allowed but the bag limit was reduced to 5 fish from 10 fish in 1997. The sentinel surveys, conducted under a scientific protocol designed to obtain additional indices of abundance of the stock, accounted for 629 t of the total catch. The catch of the index fishery amounted to 1221 t and about 738 t were caught in the by-catch and recreational fisheries.

Landings (thousands of tonnes)

Year	70-79 Avg.	80-89 Avg.	90-94 Avg.	95	96	97	98
Landings	50	61	26	1	1	2	3
TAC	48	59	31	0	0	0	0

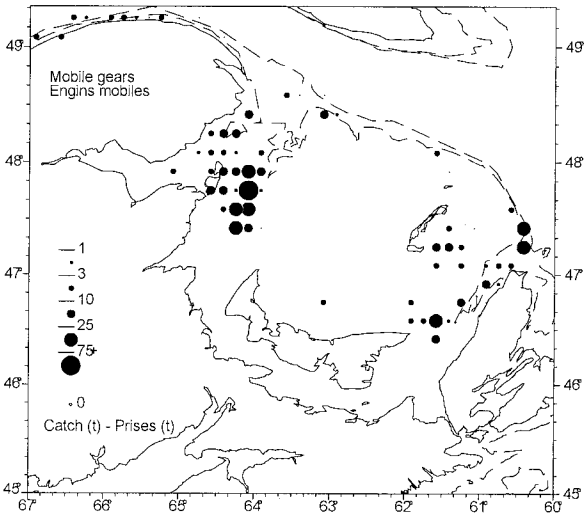
Landings (t)



The total reported **landings** were 2588 t in 1998. This was higher than landings in 1997 (1726 t). The lowest landings since 1917 were recorded in 1995.

It was the first year of the **index fishery** which are fishing activities to obtain further information on the status of the stock. This fishery was conducted by fixed gears in August-September and by mobile gears between late July and December

Distribution of mobile gear index fishery catches



The fixed gear index fishery was conducted near-shore in most areas and accounted for about 320 t .

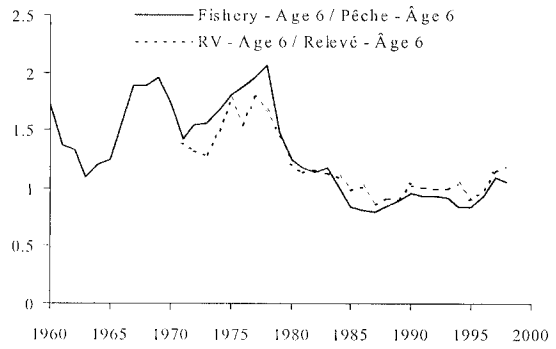
The **views of fishers** on the state of the resource were obtained through various

meetings and a telephone survey of active fishermen in 1998. During the meetings, fishers from the eastern southern Gulf and those active near Miscou Bank generally thought that the status of the stock was better.

Of the 18 sentinel fishers interviewed through the telephone survey, 11 thought that the status of the stock was lower than they have seen over the years that they have fished. However, in the same survey, 29 out of 42 fishermen who were active in index or by-catch fisheries felt that the status of the stock was the same or higher when compared to past experience. This difference in opinion was consistent throughout the southern Gulf.

Age 6 and 7 were the most important age-groups in the total 1998 landings but fish of 8 to 10 years of age were also well represented. The **weights at age** of cod in the research vessel survey have again increased slightly but remain low relative to the period before 1980. Weights at age in the fishery declined slightly because of the higher proportion of mobile gear catch in 1998.

Weight (kg)



It appears that the variation in growth rates for the stock is the result of a combination of factors including size-selective fishing mortality, density and temperature. Size-selectivity effects are not evident since the fishery closed.

Resource Status

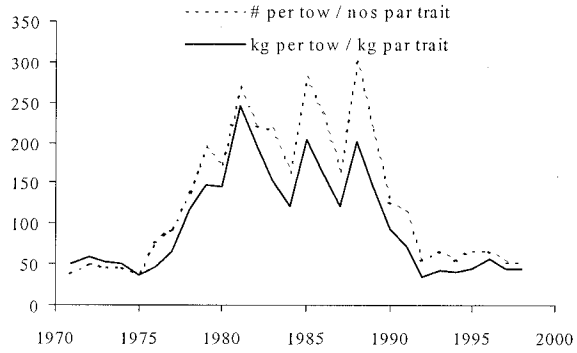
The information used in this assessment included the landings data from 1917-1998, the research vessel survey data from 1971-1998, sentinel survey data from 1994-1998, the otter trawl catch rate data from 1982-1993, and the commercial catch at age from 1971-1998.

The **annual groundfish survey** has been conducted in September since 1971. The results of the 1998 survey indicate that the stock continues to be at low abundance.

Although the total abundance (mean numbers per tow) of the population remains unchanged, the abundance of cod of ages 2 and 3 was about 30% higher than that seen in the previous 2 years of the survey.

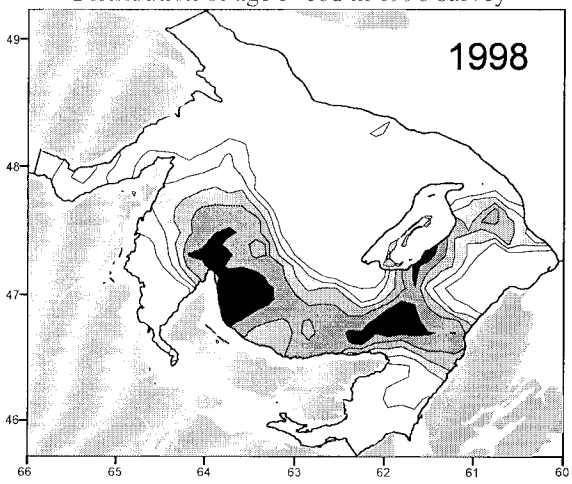
Stock biomass, measured by the survey mean weight per tow, indicate that it has remained stable over the last few years.

Survey Index (All ages)



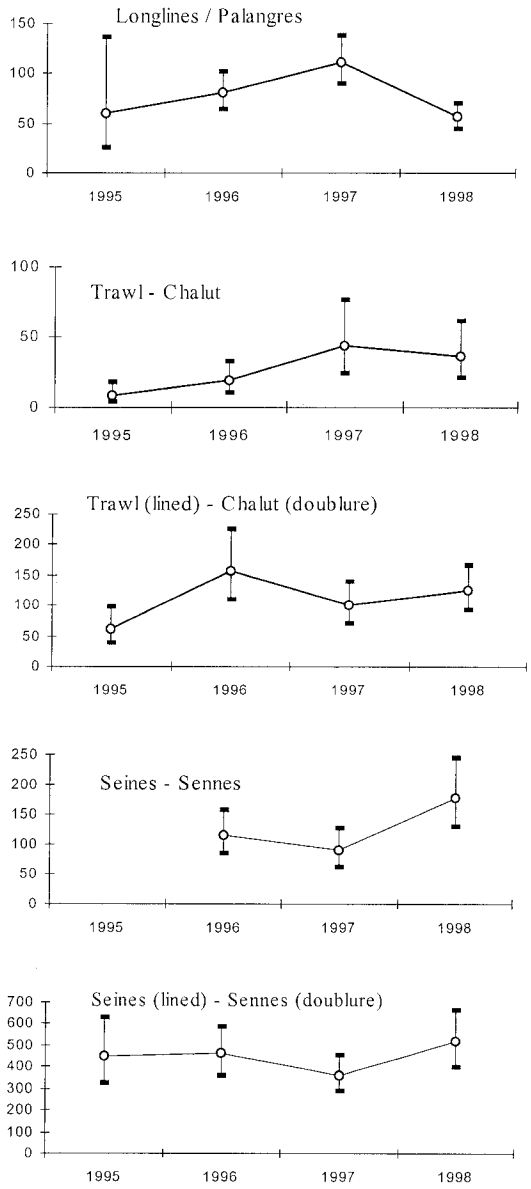
The spatial distribution of catches during the survey was typical of that observed in periods of low abundance; close to shore and in shallower waters. The proportion of the total biomass found in the eastern region of the southern Gulf increased again in 1998.

Distribution of age 5 cod in 1998 survey



The **sentinel survey** program was continued in 1998. Thirty-six vessels fishing with fixed and mobile gears in various areas of the southern Gulf were used to monitor cod abundance. Standardized catch rates for longlines declined between 1997 and 1998. However, the mobile gears sentinel surveys generally increased over those seen in 1997.

Standardized Catch rate



Sentinel catch rates were higher off north-eastern New Brunswick (Shediac Valley) and near P.E.I.

Cod condition has been monitored seasonally since September 1991. Indices in 1998 showed that condition was slightly lower than in 1997 but near the levels seen in previous years.

The previous assessment had indicated an increase in **natural mortality** rate (M) of this cod stock. Estimates of M calculated

previously were updated and the new estimates continue to indicate values in the range of 0.4 - 0.5, more than twice that traditionally assumed. Other analyses supported this conclusion: sentinel survey data indicate that M is high recently and a sequential population analysis where M was estimated also produced high estimates in the recent period. As a result, the assessment model included an increase in M from 0.2 to 0.4 starting in 1986 for all age groups.

Although M remains high, some preliminary analyses suggested that it may have started to decline at younger ages. Further investigations and the new data collected in 1999 would help determine whether this is the case.

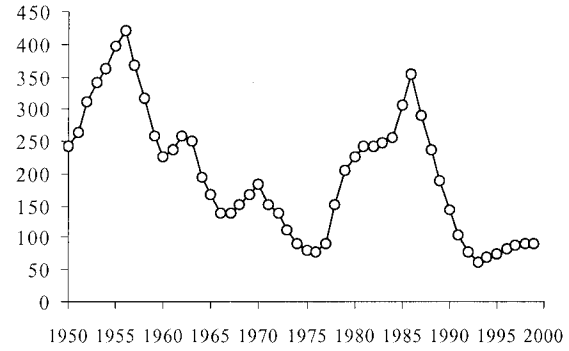
The exact causes of the high estimates of M recently are undetermined but would include all sources of unaccounted mortalities such as poor environmental conditions, seal predation, unreported catches and changes in life history characteristics.

The absence of comprehensive diet information for seals in the southern Gulf is limiting the ability to quantify their impacts on cod. Tentative estimates of the combined cod consumption by grey and harp seals range from 7,000 to 15,000 annually.

Spawning stock **biomass** was relatively high in the 1950's, but it declined throughout the 1960's and reached a minimum in the mid-1970's. There was a sharp increase in spawning biomass with the recruitment of strong year-classes born in 1974-75, and 1979-80.

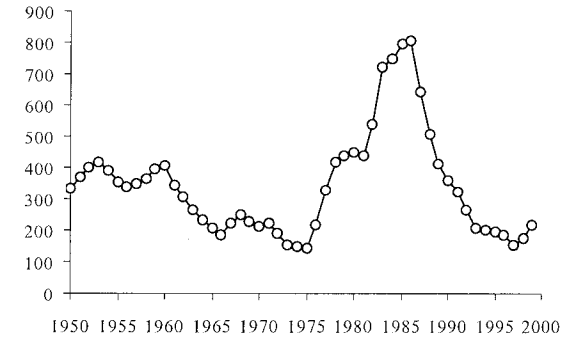
Spawning biomass was relatively high in the early- to mid-1980s, but then declined rapidly, reaching a minimum in 1993. With the closure of the fishery, the decline in biomass stopped and it has remained stable since.

Spawning Biomass ('000 t)



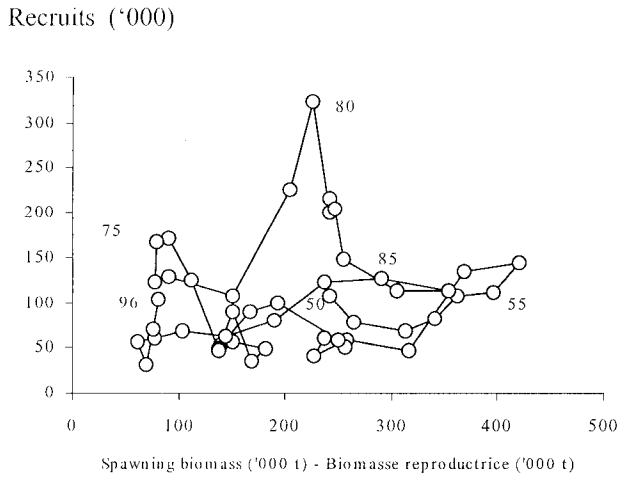
The trend in total **abundance** is similar to that of spawning biomass, except that the relative heights of the peaks in the 1950's and 1980's are reversed. Spawning biomass was lower in the 1980's than the 1950's due to lower weights at age. The increase in population abundance observed in 1999 is due largely to the 1996 year-class which does not yet contribute significantly to the spawning biomass.

Age 3+ abundance (millions)

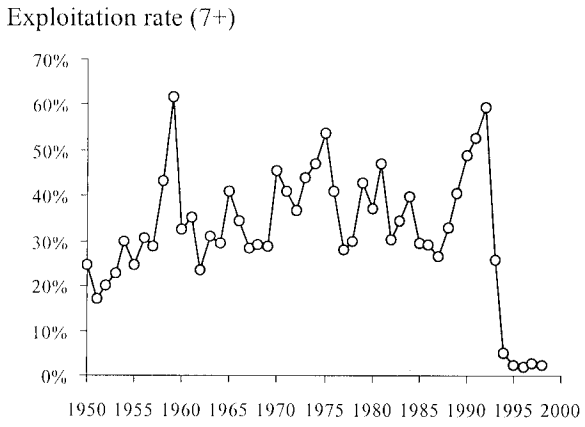


Recruitment of year-classes produced in the late 1980's and early 1990's appears to be well below average.

The 1994 year-class is estimated to be the lowest seen for this stock. However, there appears to be some improvement in recruitment. The 1995 year-class, although relatively low, is the highest of the preceding five year-classes and the 1996 year-class is estimated to be near average.



The **exploitation rate** increased from the early 1950's to the mid-1970's, with the exception of a high value in 1959. There was a decrease in 1977 and 1978 with the extension of fisheries jurisdiction. The exploitation rate increased again and averaged approximately 40% up to 1988. The exploitation rate then increased sharply and reached 60% in 1992. Fishing effort was reduced markedly in 1993 with the closure of the fishery. Exploitation rates in the last few years have ranged between 2 and 3%.



The main source of **uncertainty** in the assessment is the estimate of the 1996 year-class. Analyses excluding the sentinel indices of abundance at ages 2 to 4 gave a less precise but significantly lower abundance estimate for this year-class. However, it should be noted that the 1996 year-class will not contribute significantly to the fishery or the spawning biomass until 2001. There is continued uncertainty about the rate of natural mortality and its dynamics. Finally, the estimate of spawning biomass prior to the late seventies is based on recent maturity observations and may be over-estimated.

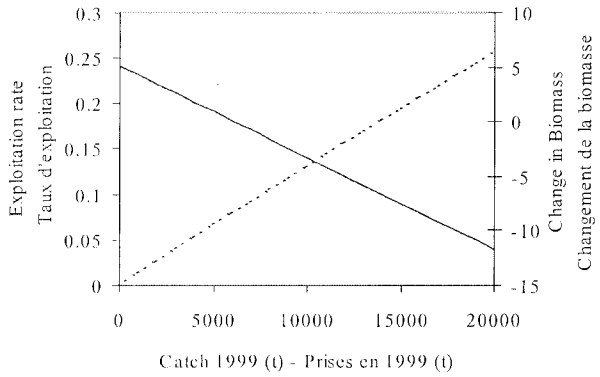
The distribution of cod, as observed in the research and sentinel surveys, causes the perception of the various groups of fishermen to differ depending upon their geographic location. Fishers from Cape Breton, P.E.I. and those who participated in fishing activities near Miscou Bank (northeast N.B.) tend to perceive that the status of the stock has improved. Fishermen from other areas tend to be more pessimistic. The results from the September RV survey and the sentinel surveys support the views of both groups. The surveys indicate that cod are distributed closer to shore in recent years, that cod are rarely found in the central part of the survey area, contrary to the early 1990's, and that the relative abundance of cod in the eastern part of 4T has increased.

Outlook

The productivity of the stock has been low recently because of low recruitment, poor growth and high natural mortality. The situation appears to be improving slowly in terms of growth and incoming year-classes seem to be larger.

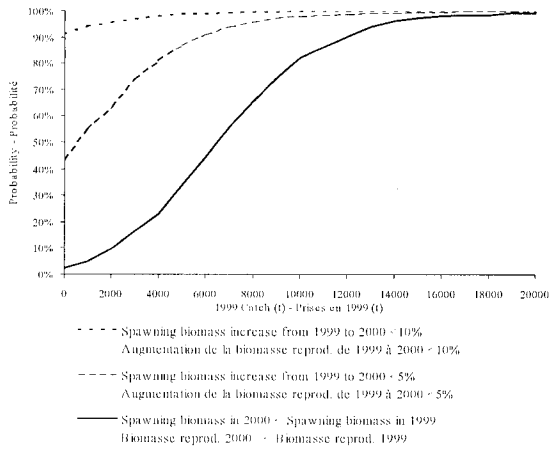
The results of **catch projections** at various levels of catch in 1999 are provided. For any catch in 1999, the associated exploitation rate is determined by reading up to the dotted black line, then across to the left side.

The percent change in spawning stock biomass can be determined by reading up to the solid line then across to the right side.



The spawning biomass is expected to increase by about 5% if there is no catch in 1999. A catch of 6,000 t in 1999 would result in no increase in spawning biomass. The estimates referred to above were made using the best available "point" estimates of stock size. It is also possible to estimate the uncertainties regarding stock size and then use these in **risk analysis**. The risk analyses considered were: a) the probability that the 2000 spawning biomass would be less than the 1999 biomass, and b) the probability that the 2000 spawning biomass would increase by less than 10%.

There is a 90% probability that spawning biomass would not increase by 10% in 1999 with no catch. The chance that the spawning biomass would decline if landings in 1999 would be the same as in 1998 (2588 t) is about 13%.



These risk analyses include uncertainties of the population estimates but not those associated with natural mortality, weight at age and partial recruitment. However, they do provide some guidelines for decision making.

The mid-term outlook (3 years) depends on the estimate of the 1996 year-class and the trends in natural mortality. If the 1996 year-class is not as large then there would be little increase in spawning stock biomass at the level of catches seen in recent years. Otherwise, a 10% increase in spawning biomass could be expected by 2001.

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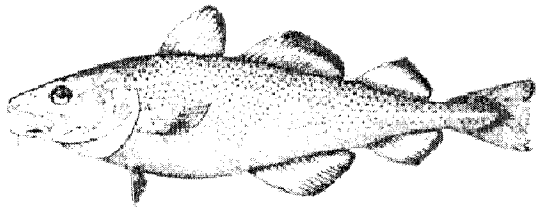


Northern (2J3KL) Cod

Background

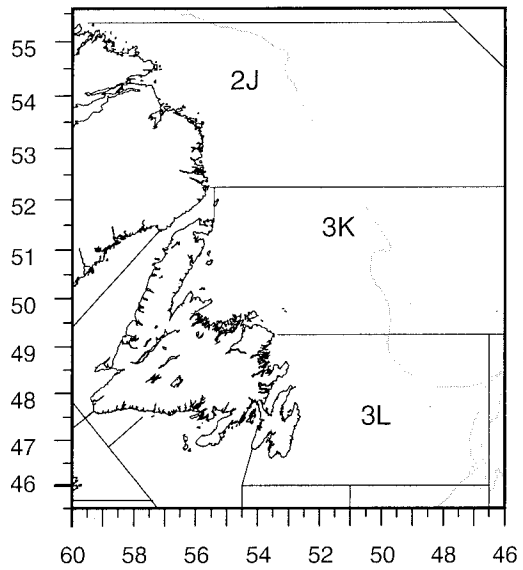
Cod has traditionally been called the "Newfoundland currency," and played a significant role in the settlement of the island. The northern (NAFO divisions 2J3KL) cod stock has been and remains potentially one of the largest in the world.

The stock covers about 117,000 square miles. Historically many cod migrated from overwintering areas offshore to feeding areas inshore. From the 1960s to the early 1990s the fishery was prosecuted with large otter trawlers offshore, mainly in the winter and spring, and a large fleet of smaller vessels that deployed traps, gillnets and hook and line inshore from late spring to autumn. Some fish overwintered inshore in the past. It appears that a substantial portion of the fish currently in the stock area remain inshore throughout the year.

Cod from this stock grow more slowly than in warmer areas. An age 5 cod would be about 50 cm.(about 20 inches) long. Throughout the area female cod have a variable age at maturity, presently about age 5.

Cod in divisions 2J3KL feed on a wide variety of food items but as adults take mainly capelin.

This stock has supported a commercial fishery since the 16th century. For the century prior to 1960 the catches were mainly between 200,000 metric tons and 300,000 metric tons. With high catches in the late 1960s, mainly by foreign fleets, the stock declined until the mid 1970s. After the extension of jurisdiction in 1977, the stock increased until the mid 1980s but has since declined to a very low level. A moratorium on commercial fishing was declared in July, 1992.



The Fishery

Catches by non-Canadian fleets increased rapidly in the 1960s, with the total catch peaking at 800,000 metric tons in 1968. Catches both offshore and inshore declined during the 1970s. The stock declined to a low biomass by 1977.

Landings (thousand metric tons)

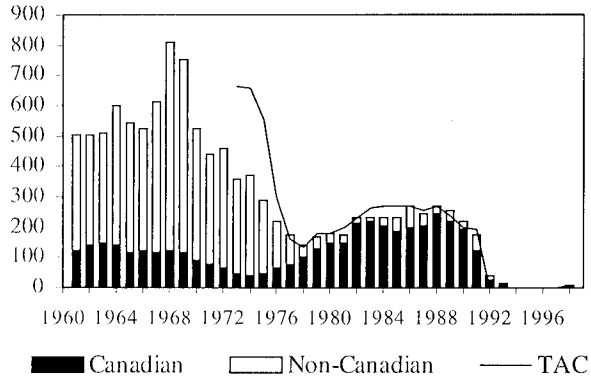
Year	62-76 Avg.	77-91 Avg.	1994[1]	1995[1]	1996[1]	1997[1]	1998[1]
TAC	N/A	N/A	0	0	0	0	0
Can. Fixed	88	90	1	+	2	1	5[2]
Can. Mobile	9	84	0	0	+	+	+
Others	405	38	+	0	0	0	0
Totals	502	212	1	+	2	1	5[2]

[1] Provisional

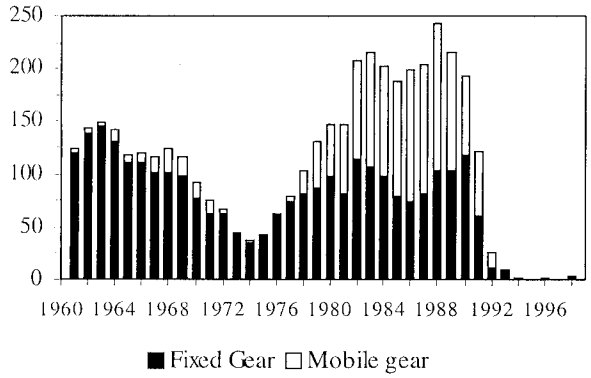
[2] Catch from bycatch, a food fishery and sentinel and index surveys.

[+] Catch less than 500 metric t

Reported catch ('000 t)



Reported Canadian catch ('000 t)



Following extension of jurisdiction the stock began to recover as a consequence of smaller catches, entry of the strong 1973-1975 yearclasses, and an increase in individual growth rate. However, recovery of the spawner biomass stopped after about 1982 as a result of higher fishing mortality, entry of the weak 1976-1977 yearclasses and a decline in individual growth rate. The 1978-1982 yearclasses were moderate to strong but experienced slow growth rates. Catches during the mid- to late 1980s were relatively stable but fishing mortality was higher than thought and the stock declined through the latter half of the 1980s. The 1986-1987 yearclasses appeared strong at an early age, but in concert with older yearclasses appeared to decline very rapidly in the early 1990s. Fishing mortality was very high during this period but reported landings including documented discards are insufficient to account for the decline observed in the research vessel indices. A moratorium on directed commercial fishing was imposed in July 1992.

Reported catches in 1993-1998 came from bycatch, food fisheries (1994, 1996, 1998) and sentinel surveys (1995-1998). The reported catch of about 4500 t in 1998 came mainly (68%) from a new inshore index fishery. There is evidence of removals in excess of sentinel surveys and legal fisheries, but the magnitude of these removals cannot be estimated.

Resource Status

Stock status at the end of 1998 was updated from 1997 based on an additional year of data from commercial bycatch, the research bottom trawl surveys, prerecruit surveys, acoustic surveys in specific areas, sentinel surveys and a brief food fishery. A new source of information was the index fishery conducted in the inshore and the offshore. Also new were descriptions of cod distribution and migrations based on returns from recent tagging studies, and estimates of population size in the inshore based on those returns. Estimates of the consumption of cod by seals were revised and updated.

Stock Structure

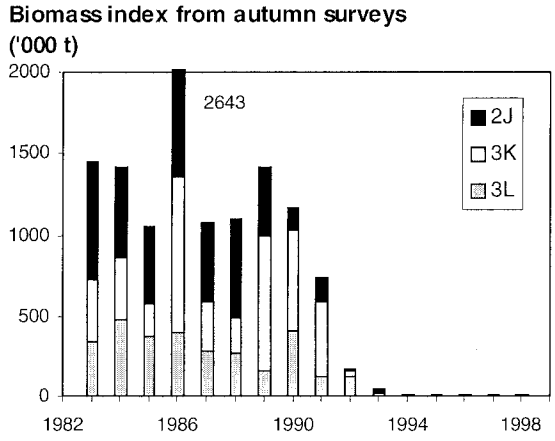
Since the mid-1990s a dichotomy has arisen between continued low cod density in the offshore and indications of higher fish densities in the inshore from White Bay in central Division 3K southward to the boundary with Subdivision 3Ps. A review of historical data indicates there have always been some cod that have overwintered

inshore, and there has always been spawning inshore. An examination of age compositions reveals that the cod inshore in 1995-1998 are of younger yearclasses than those that disappeared from the offshore in the early 1990s, indicating that the cod now inshore are not predominantly fish that formerly migrated between offshore and inshore and have remained inshore. The results of **genetic** and **tagging** studies in the 1990s provide evidence that the cod currently inshore tend to stay inshore and are genetically distinct from some but not all of the cod components in the offshore. Tagging studies also indicate that cod north of a line down the axis of Trinity Bay tend to remain north of that line. A portion of the cod caught south of that line are from pre-spawning and spawning aggregations tagged in Subdivision 3Ps in the spring, both within Placentia Bay and near the outer edge of the shelf, particularly in the vicinity of Halibut Channel.

Because of the dissimilarity between the offshore and the inshore, information from the two areas will be presented separately where available. It is emphasized, however, that it is not clear that inshore (coastal, bay) components are any more distinct from offshore components than the various offshore components are distinct from one another. Many studies, including tagging, meristics and genetics, have shown that fish sampled from different regions of the offshore in winter/spring appear distinct, with the degree of distinction increasing with distance. Even though samples of cod from different parts of the stock area can be shown to be distinct with respect to various features, the cod move over considerable distances on a seasonal basis. Different groups of cod occupy the same area at different times and often at the same time. Attempting to keep track of the removals from a specific component would appear to be impossible.

Surveys and index fisheries

The abundance index from the **autumn research bottom-trawl survey** in the offshore of divisions 2J3KL declined from 1995 to 1997 and increased a little in 1998. Very few fish older than age 5 were caught. The biomass index from this survey increased a little from 1995 to 1997 as a consequence of individual growth and remained unchanged in 1998. The biomass index in 1997 and 1998 was 1.4% of the average in the period 1983-1988 (excluding 1986).



The **spring research bottom-trawl survey** in the offshore of Division 3L continued to show low abundance and biomass indices in 1998. The average biomass index for 1996-1998 was 0.7% of the average in the period 1985-1988.

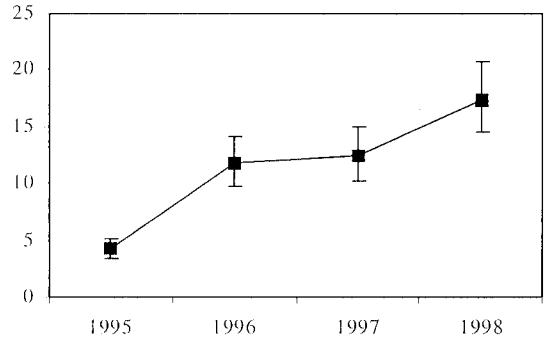
An **offshore index fishery** was conducted by one trawler in Division 3L in November 1998. No cod concentrations were located and catch rates were extremely low.

Offshore acoustic studies were conducted in Hawke Channel in Division 2J in June

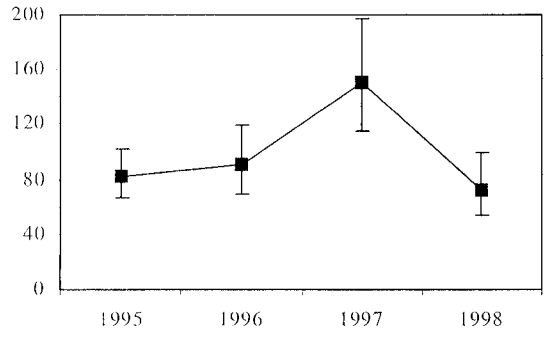
1994-1996 and 1998. There was no evidence of an increase in the number of fish in the study area over the five years of study.

The **sentinel surveys** in divisions 2J3KL, initiated in 1995 to provide catch rates of cod in inshore waters, have been conducted primarily with gillnets and linetrawls but also with handlines and cod traps. Catch rates have been low from White Bay north including southern Labrador since the start of the surveys. Catch rates from White Bay south are described by participants as being good and to have increased since initiation of the surveys. Seasonality was apparent for some sites. An analysis of standardized catch rates in divisions 3K and 3L combined revealed that gillnet catch rates increased from 1995 to 1996, remained steady in 1997, and increased in 1998, whereas linetrawl catch rates showed relatively little change from 1995 to 1996, increased in 1997 and declined again in 1998 to approximately the level seen in 1995.

Standardized gillnet catch rate from sentinel surveys in 3KL (number of fish per net)



Standardized linetrawl catch rate from sentinel surveys in 3KL (number of fish per 1000 hooks)



An **inshore index fishery** was conducted to provide information to supplement sentinel surveys. Almost 3000 enterprises using <65 foot vessels fished individual quotas of 2700 lb. (round weight) during September 24 – October 16, 1998. Fish harvesters in sentinel survey communities reported that north of White Bay many harvesters did not fish or attained very poor catch rates. Catch rates from the Baie Verte Peninsula to St. Mary's Bay were reported to have been good to excellent in all but a few communities. Catch and effort data are available from science logbooks that were a requirement of licence. Catch rates were highest in eastern Notre Dame Bay, in a continuous band from northern Bonavista Bay to western Trinity Bay, and in St. Mary's Bay.

Inshore acoustic studies have been conducted in Smith Sound in western Trinity Bay at various times since spring 1995. Why cod aggregate in this Sound and how frequently they move in and out is not known. A simple but incomplete description is that fish overwinter and perhaps spawn in the Sound in winter/spring, move into shallow water and along the coast from late spring to early autumn, and return to the Sound in late autumn. The quantity of cod detected in the Sound at any specific time will depend on where the cod are in their annual cycle. Studies in June 1998 and January 1999 gave biomass estimates of 14-15 thousand t. The size and age compositions differed considerably between the two surveys, indicating that the total cod population in Trinity Bay may be greater than 15 thousand t. Previous biomass estimates for Smith Sound have been as low

as 150 t in April 1996 but others were higher (13 thousand t in May 1995 and 21 thousand t in April 1997).

Pelagic juvenile fish surveys, designed to provide an index of the abundance of 0-group cod prior to settling, were conducted in offshore and inshore waters of 2J3KL in August-September 1994-1998. The abundance index for all of 2J3KL in 1998 was lower than in 1994-1995 but higher than in 1996-1997. In 1998 there were very few cod found offshore in 2J3K, but good catches occurred in the bays of 3K. Most of the fish caught offshore came from southern 3L. The catches in this area were contiguous with larger catches immediately to the south in divisions 3NO. It is thought that cod in the large catches in southern 3L may have come from spawning in 3NO.

A broadscale **beach seine survey** of demersal 0-group and 1-group cod had been conducted in divisions 3KL in 1992-1997. Results of surveys on a much smaller scale in Newman Sound in southwestern Bonavista Bay in 1995-1996 and 1998 were consistent with the broadscale survey. A combination of the two series indicated that the 1997 and 1998 yearclasses are stronger than the 1995 and 1996 yearclasses. The pelagic surveys and the demersal surveys are consistent in indicating that the 1996 yearclass is weak and there is improvement in 1997 and 1998.

Stock biology

The **distribution** of cod differs from the historical norm. There are few cod in the offshore. From catches during the autumn bottom-trawl survey the cod appear to be broadly distributed, with most of the larger/older cod on the plateau of Grand Bank in Division 3L. Acoustic studies in Hawke Channel (Division 2J) in winter and spring reveal small cod at low densities. Cod in the inshore appear to be in low abundance north of White Bay but to be broadly distributed from late spring to late autumn at traditional fishing depths (less than about 50-60 m) from White Bay south to St. Mary's Bay. The seasonal movements of these fish are not well understood. A simple but incomplete description, based largely on observations of the cod in Smith Sound, Trinity Bay, is that they overwinter in deep inshore waters, often within fjords, and move into shallower water and along the coast in spring, returning to the overwintering areas by late autumn. Tagging studies demonstrate that these fish move into adjacent bays, often moving northward. For example, the Smith Sound fish appear to migrate along the north shore of Trinity Bay, with some moving into Bonavista Bay and even into Notre Dame Bay. There is no evidence of movement to the offshore, but there has been no offshore fishery that might recover tags. Additional aggregations exist in other Sounds in Trinity Bay, in Bonavista Bay and in Notre Dame Bay, but the number and size of such aggregations are not known. There is no evidence of such aggregations south of Trinity Bay or north of White Bay, with the exception of the small population in semi-enclosed Gilberts Bay in southern Labrador.

Size and age compositions differ considerably between the offshore and the inshore. Although there are differences in selectivities between the Campelen bottom-trawl used in the offshore and the various fixed gears (mainly gillnet and linetrawl) deployed inshore, it is clear that the offshore has very few fish larger than about 50 cm whereas the inshore has high proportions of larger fish. Age compositions from sentinel surveys in 1995-1998 reveal that the 1990 yearclass was relatively strong in Divisions 3K and 3L and that the 1989 yearclass was stronger in Division 3L than in Division 3K.

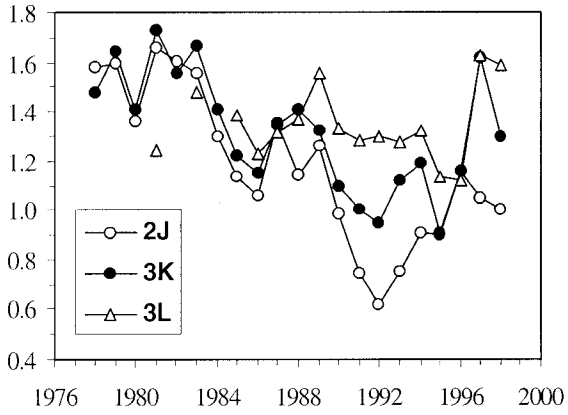
Neither of these yearclasses was prominent in the offshore.

Over the period 1994-1998, **recruitment in the offshore**, as measured at the pelagic 0-group stage, was greatest in 1994. Catches during the autumn bottom-trawl survey have shown that this yearclass was weak relative to many yearclasses born in the 1980s and appears to be suffering high mortality. It is expected to contribute very little to offshore spawner biomass. The 1998 yearclass was third strongest at the pelagic 0-group stage, but most of the fish were caught in southern 3L. It is not clear whether these fish were spawned in 3L and will contribute to the 2J3KL stock. The bottom-trawl survey did catch some of this yearclass in 3L in the autumn. **Recruitment in the inshore** may be better than in the offshore. The pelagic 0-group survey has consistently experienced higher catch rates in the bays than offshore. The beach seine surveys have experienced good catches for the 1997 and 1998 yearclasses. Fish harvesters in many sentinel survey communities, especially from the Baie Verte Peninsula south, reported that small cod were abundant in 1998.

Trends in size, maturity and condition are presented from sampling during the autumn bottom-trawl surveys. The time series from sentinel surveys is now four years long and will be presented during the next assessment.

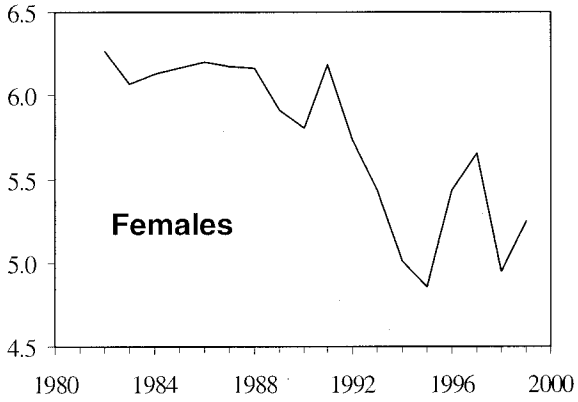
Size-at-age declined during 1983-1985 and again in the early 1990s, especially in Division 2J. Size-at-age has increased in recent years but is still low compared with peak values in the late 1970s. Much of the variability in growth is related to variability in water temperature.

Mean weight at age 5 (kg)



Age at 50% **maturity** declined in the early 1990s and has fluctuated considerably in recent years. In recent years female cod mature approximately one year earlier than they did in the 1980s.

Age When 50% Are Mature



Condition, as measured by both gutted body weight and liver weight relative to fish length, declined in Division 2J in the early 1990s. Gutted condition has since returned to approximately normal whereas the liver index has improved but not fully recovered. In Division 3K gutted condition declined and has since improved whereas liver index has changed little. In Division 3L gutted

condition has remained relatively unchanged over time whereas liver index increased considerably in the early 1990s and has since returned closer to normal. The historic trends in condition indices are complex and poorly understood. Condition in 1998 was near normal. Fish harvesters in sentinel survey communities reported that condition of cod caught during the inshore index fishery was good to excellent.

Population Analysis

An **analytical assessment** was not attempted. The inability to reconcile reported catches with the research vessel index in the late 1980s and early 1990s has not been resolved. In addition, the low abundance and high mortality of cod sampled by the research vessel catches is not reflective of the quantity, larger sizes and older ages of cod found in the inshore.

It was decided that an analytical assessment of the inshore alone was not possible because inshore catches prior to the moratorium could not be apportioned into those coming from inshore components and those coming from components that migrated into the inshore from the offshore. It is thought that most of the historic inshore catch came from the latter.

Information from recaptures of cod tagged in divisions 3KL during 1997 and 1998 were used to estimate **exploitation rates and stock size** for the 1998 index fishery. This essentially involved examining the fraction of tagged cod returned by the fishery, with adjustments made for tag loss, reporting rates and migration rates. Estimates were made for two areas; (1) 3K and northern 3L, including Bonavista and Trinity bays and (2) southern 3L from Conception Bay to St. Mary's Bay. The exploitation estimate for 3K and northern 3L was 6.2%. The estimate for southern 3L was quite variable, but a reasonable lower bound on exploitation in this region was 5%. Using the reported commercial landings in 1998 for these regions, the exploitation rate estimates suggest that 52,000 t of cod were available to the index fishery in 3K and northern 3L, with a 95% confidence interval of 36,000 – 135,000 t. The analysis suggests that no more than 15,000 t of cod were available to the index fishery in southern 3L. Some of these had migrated into southern 3L from Placentia Bay in Subdivision 3Ps. An analysis of distance moved by tagged cod showed that they were well dispersed from the tagging site and that the degree of dispersal did not increase between 1997 and 1998. Consequently, it was concluded that the tagged cod were well mixed within the population and that the estimate of biomass was not likely to be biased due to incomplete mixing. A second estimate of inshore biomass during 1996 and 1997 based on tag returns was also presented. This analysis suggested a much higher inshore biomass. However, it was demonstrated that this estimate did not account for migration of cod between bays and was therefore biased upward.

Mortality rates estimated from the research vessel surveys remain well above 0.2. Extremely few fish older than age 5 have been caught in recent years, especially in divisions 2J and 3K.

In 1998 the biomass of cod in the inshore of divisions 3KL was estimated by (i) calculating the ratio between sentinel gillnet catch rates in Placentia Bay (Subdivision 3Ps) and a mark-recapture estimate of biomass in that bay and then (ii) applying that ratio to sentinel gillnet catch rates in 3KL. The estimate is subject to many uncertainties, the most important of which

are the relationship between catch rate and fish abundance and whether the relationship derived for one area can be extrapolated to others. High catch rates can be maintained over a wide range of fish densities; ideally multiple measures of catch rate over a wide range of densities for different areas are required. It was found that the method was sensitive to the quantity of cod estimated to be in Placentia Bay, the time of the year during which the catch rates in Placentia Bay were calculated and year-to-year variation in the catch rates. The situation could arise, for example, where the catch rates within 3KL were constant from one year to another and yet the biomass estimated in one year could differ from the other because of changes in sentinel survey catch rates in Placentia Bay or the biomass estimate in Placentia Bay. It was decided that the method was unreliable.

Ecological Factors

Annual changes in **water temperatures** are hypothesized to have been associated with variability in several aspects of the biology of 2J3KL cod, including distribution, timing of migration, recruitment, mortality and individual growth rate. Water temperatures declined in the late 1980s to very low levels by 1991, started to moderate during 1994 and were above normal by 1996. During 1997 and 1998 temperatures continued above normal over many areas, particularly on Grand Bank during spring and over deep portions of the Northeast Newfoundland Shelf. The main exception to the above generalization occurred in the upper to middle ranges of the water column in coastal regions where temperatures were lower than normal during summer and early autumn. The warmer water temperatures in recent years may explain some of the improvement in cod size-at-age. However, recruitment of cod in the offshore and survival of the few cod that are there have not improved during this period of warmer water temperature.

The quantity of cod consumed by **harp seals** during the period 1972-1998 was calculated using estimates of the harp seal population numbers, energy requirements of individual seals, the average duration of occurrence within 2J3KL, the relative distribution inshore and offshore, and diets of seals sampled in the inshore and offshore in winter and summer. Several aspects of the calculations were modified based on new information or different assumptions. These changes resulted in a reduction by nearly 50% in the 1998 estimate of 108,000 t of cod consumed by seals. The magnitude of this change illustrates the uncertainty involved in these calculations. The major reason for the lower estimate of consumption is a revision in the weights of individual cod consumed by the seals as calculated from the sizes of cod otoliths found in seal stomachs. The second most important factor in the decline is a change in the proportion of the seal energy requirement estimated to be coming from the inshore. The previous estimate of 45% in both summer and winter was revised to 14% in winter and 11% in summer. This is a consequence of defining a more narrow inshore zone (the zone in which inshore stomach samples were collected) and revising the estimate of the proportion of the seal population occurring within the inshore zone. The previous estimate assumed random distribution, whereas the new estimate came from monitoring of seal movements using satellite telemetry tags. The reduction in the proportion of energy coming from the inshore caused a decline in the estimate of cod consumed because the proportion of cod in the harp seal diet is higher in the inshore than in the offshore.

The number of cod at various ages consumed by harp seals during the period

1986-1995 was calculated using the estimated quantity of cod consumed, the length frequencies of cod consumed by the seals as determined from the sizes of cod otoliths found in seal stomachs, and ages at length determined from sampling during the spring bottom-trawl survey in Division 3L and the autumn survey in divisions 2J3KL. From 1986 to 1991 most of the predation was on cod ages 0-2, with the bulk occuring on age 1. In 1992, 1993 and especially 1995 there was a greater proportion of older cod (ages 3-5) in the diet.

For many years there have been reports of seals preying on cod by taking bites from their bellies, thereby consuming the liver and most of the gut but leaving the rest of the body. Diets used in the present calculations are reconstructions of the prey composition based on hard parts found in the seal stomachs with some adjustment for predation on soft bodied animals. Belly-feeding is not included in these reconstructions. This implies that the quantity of cod consumed by harp seals may be biased, but the direction of the bias has not yet been determined. In addition, previous calculations of the size and age compositions of the cod consumed by seals have been biased toward smaller and younger cod, because cod killed by belly-feeding tend to be larger than those represented by the otoliths found in seal stomachs. The weight of cod killed by belly-feeding is much higher than the weight consumed.

Sources of Uncertainty

Reasons for the dichotomy between a low abundance of fish in the offshore and the presence of aggregations encompassing many large fish in the inshore are not well understood.

Catch rates in the sentinel surveys are considered by participants to be high relative to catch rates during commercial fisheries prior to the moratorium. As noted by participants in the sentinel surveys, this may be due in part to lack of competition for sites and fish. The sentinel survey covers only the traditional inshore fishing grounds (less than 50-60 m), and thus provides information on local fish density. The degree to which the survey reflects overall stock abundance is not yet clear. Interpretation of the catch rates is complicated by seasonal patterns at each site, the along-shore movements of fish and the migration of fish into southern Division 3L from Subdivision 3Ps.

Some of the concerns with interpretation of sentinel survey catch rates were addressed with the index fishery. Because the fishery was conducted over just 3 weeks, it demonstrated that good catch rates could be attained at about the same time over most of the area from White Bay to St. Mary's Bay. However, it also demonstrated that fish density, as reflected in catch rates, was highest in the relatively small area from northern Bonavista Bay to western Trinity Bay on the east coast and in St. Mary's Bay on the south coast. Many of the fish in the latter area were likely migrating back into 3Ps.

Exploitation rates from tagging can be overestimated if aggregations of untagged cod are exploited less than aggregations of tagged cod. It was felt that this was unlikely in the index fishery because the fishery occurred throughout the inshore and tagging included areas where cod were abundant.

The impact of seals on the 2J+3KL cod stock remains unclear. The estimate of the quantity of cod consumed, based on the reconstructed diets, has declined

considerably from the previous estimate, but is still high. There are numerous uncertainties in the calculation of the quantity of cod consumed. The diet data are sparse, especially in the offshore, and the proportion of cod in the inshore samples might be too high if a disproportionate number of the seal stomach samples have been obtained near the cod overwintering areas. In addition, there is uncertainty about the number of cod consumed by belly-feeding. Reports of this mode of predation have increased over the past two winters. Most reports have come from two relatively small areas. There is little information on what proportion of the seal herd is engaging in this manner of feeding, for how long it goes on, and how many cod a seal kills each day. There is a concern that perhaps the proportion of the seal herd occupying the inshore, as estimated from the satellite telemetry, has been underestimated if a high proportion of the seals inshore are young animals and the tags had been applied only to older animals. However, the tags had been applied to younger and older seals in the same proportions as the occurrence of these two groups in the population.

The consumption of cod by hooded seals needs to be calculated.

Outlook

The risk of fishing the 2J+3KL cod stock at various catch levels cannot be quantified because the current stock size is poorly measured. It is clear however that the size of the stock as a whole remains low relative to levels in the 1980s, and the level during the peak of partial recovery in the mid-1980s was itself characterized by low abundance, truncated age distribution and poor inshore catches compared with levels prior to the huge removals offshore in the 1960s and 1970s.

The prospects for recovery of cod in the offshore based on regeneration by those cod currently there appears to be dismal in both the short and medium term. The spawning biomass continued to decline after imposition of the moratorium and has for several years been extremely small, especially north of Division 3L. All yearclasses born in the 1990s have been small and have experienced high mortality.

The status of cod in the inshore remains uncertain. It is important to recognize that the inshore fishery historically was highly dependent on fish arriving from the offshore and will not return to its former prominence until such time as a substantial biomass of cod builds up in the offshore and resumes its summer feeding migration to the inshore. The risk associated with fishing those aggregations of cod in the inshore from White Bay in the north to St. Mary's Bay in the south cannot be quantified because the biomass currently inshore remains uncertain. Acoustic estimates for Smith Sound in Trinity Bay in 1995-1999 at times when cod aggregations were present have ranged from 13,000 to 20,000 t. Additional aggregations exist in Bonavista and Notre Dame bays, but the number and size of these aggregations are not known. The exploitation rates calculated from tag return data indicate a population in Division 3K and northern 3L in autumn 1998 of 36,000 – 135,000 t. An additional biomass of no more than 15,000 t of cod was available to the index fishery in southern 3L. Some of these fish had overwintered in Placentia Bay (Subdivision 3Ps) and had migrated into Division 3L during the spring-autumn period. Catch rates during the sentinel survey and the index fishery were good, but the biomass to be inferred from these catch rates is not clear.

Any consideration of exploitation of cod in the inshore of 2J3KL needs to take into account a number of additional issues. Any fishery in southern 3L will impact resident 3L fish and those components of the 3Ps stock that currently migrate into southern 3L to extents dependent on both the magnitude of the harvest and the migration rate of 3Ps fish. The migration rate cannot be predicted in advance, but if it were lower than assumed when the catch limit for 3L was set, then the fishery might cause high mortality on resident 3L fish.

Fishing those cod currently in the inshore might also create risk for recovery of cod in the offshore. This is because it will reduce the possibility that the cod currently inshore might move to the offshore as their abundance increases and thereby repopulate the offshore environment. In addition, an inshore fishery from late spring to autumn would capture some portion of any cod from the offshore that might resume the historic summer feeding migration to the inshore. Many of the fish historically caught in the inshore were immature, so the inshore fishery would capture some offshore fish before they had a chance to spawn.

It remains difficult to estimate the impact of harp seals on cod. However, the estimates of removals based on reconstructed diets are high and do not incorporate the mortality caused by seals feeding on cod bellies alone. It appears that predation by seals has been an important source of mortality of cod since the start of the moratorium. There is also the possibility that predation by seals is retarding the recovery of the cod stock, not simply because considerable numbers of cod are being consumed but also because some of those cod have already recruited to the spawning population.

For More Information:

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Reference

Lilly, G.R., P.A. Shelton, J. Brattey, N. Cadigan, E.F. Murphy, and D.E. Stansbury. 1999. An assessment of the cod stock in NAFO Divisions 2J+3KL. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Research Document 99/42.

This report is available from:

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Annex 8. Production charts
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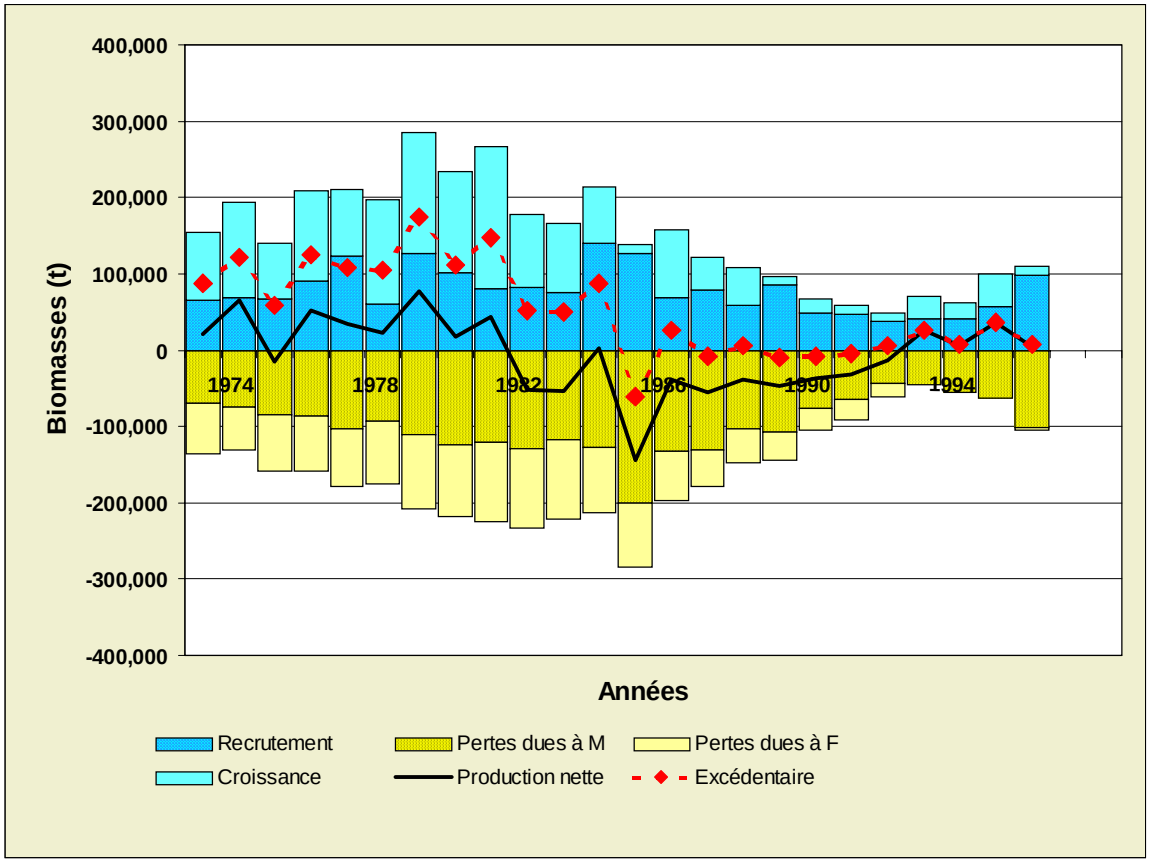
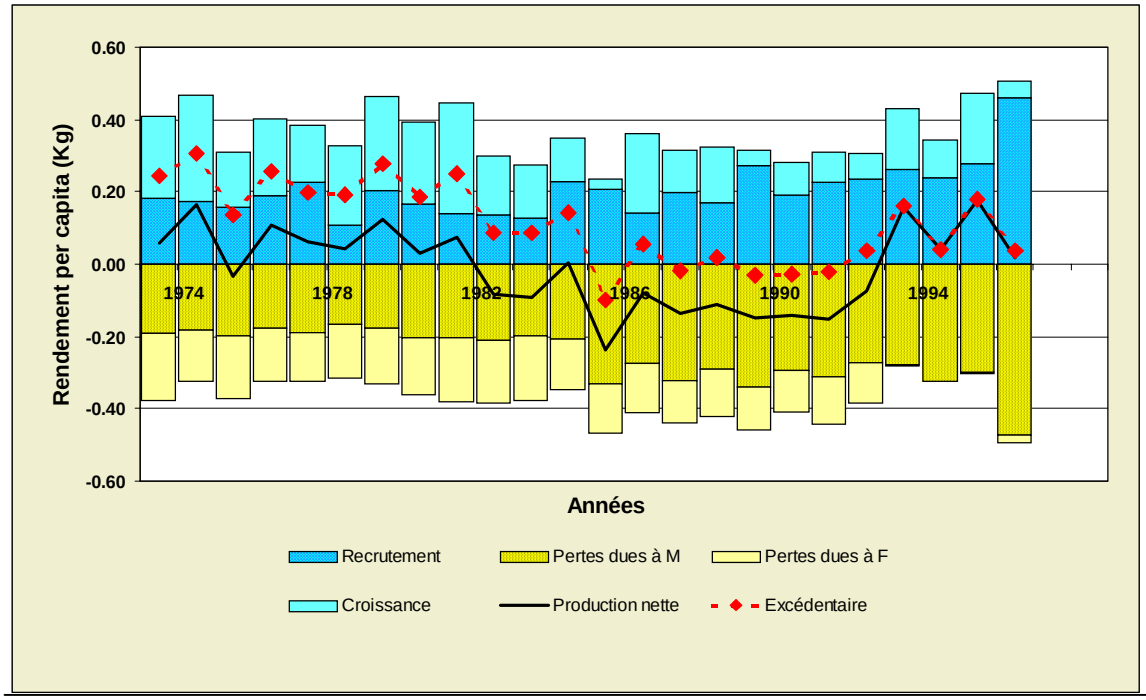
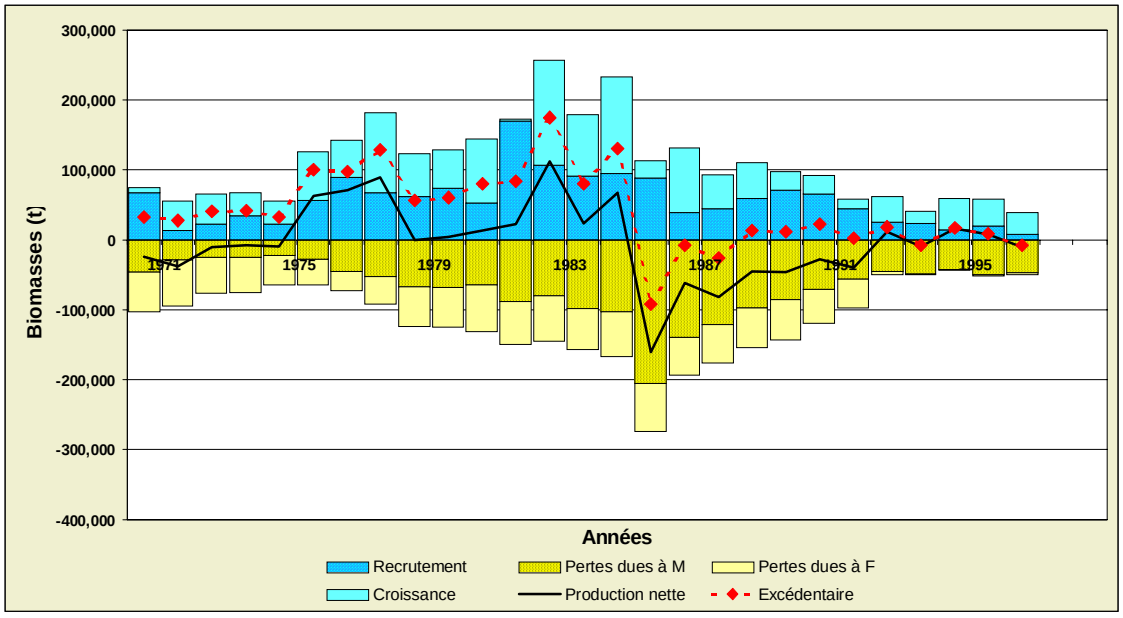
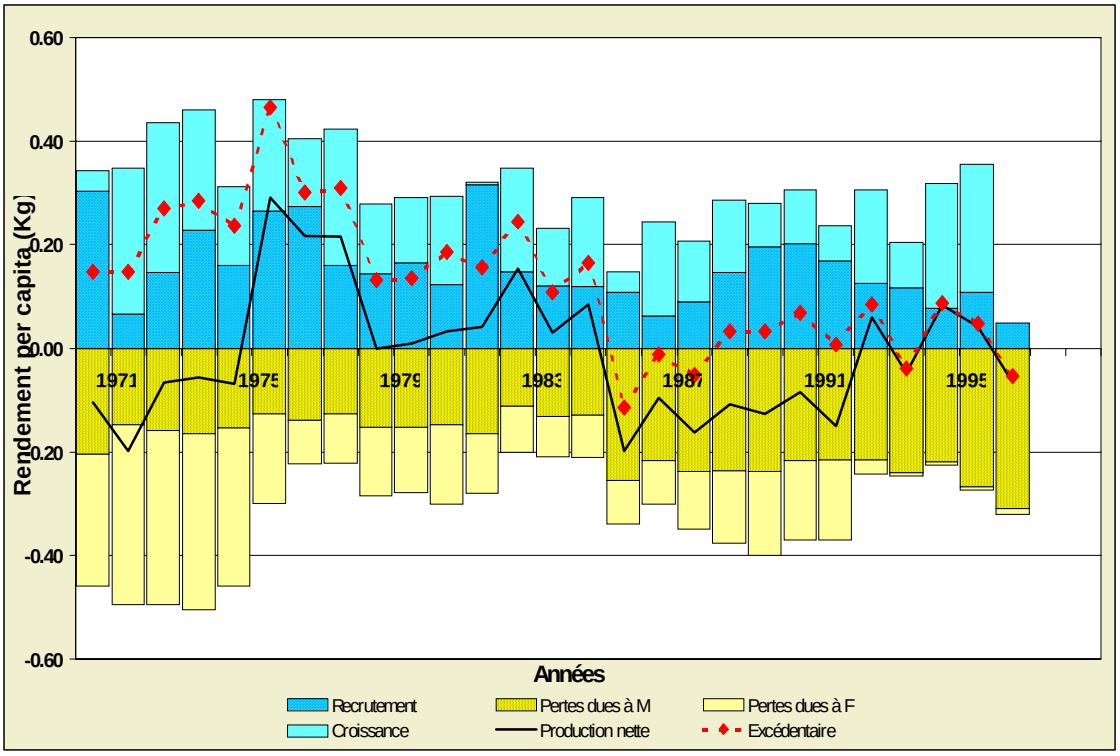




(b) 4TVn


300,000
200,000
100,000
0
-100,000
-200,000
-300,000
-400,000
Biomasses (t)
1971
1975
1979
1983
1987
1991
1995
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire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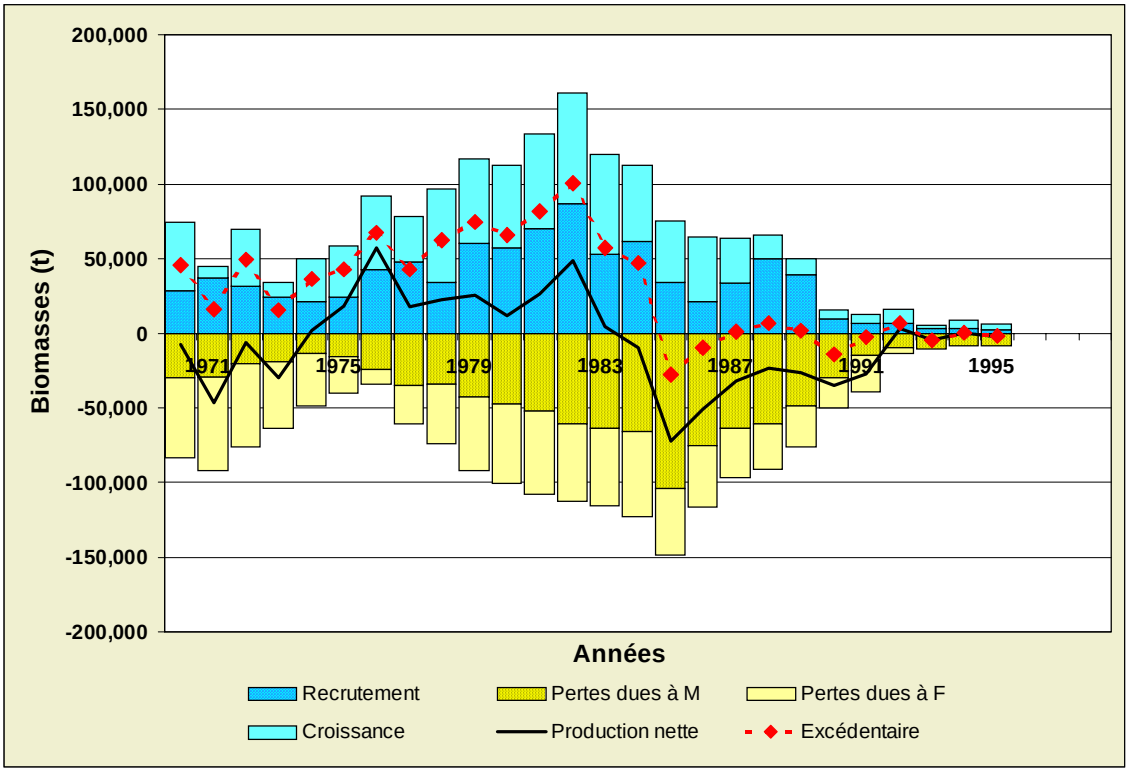
0.40
0.20
0.00
-0.20
-0.40
-0.60
Rendement per capita (Kg)
1971
1975
1979
1983
1987
1991
1995
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire

(c) 4VsW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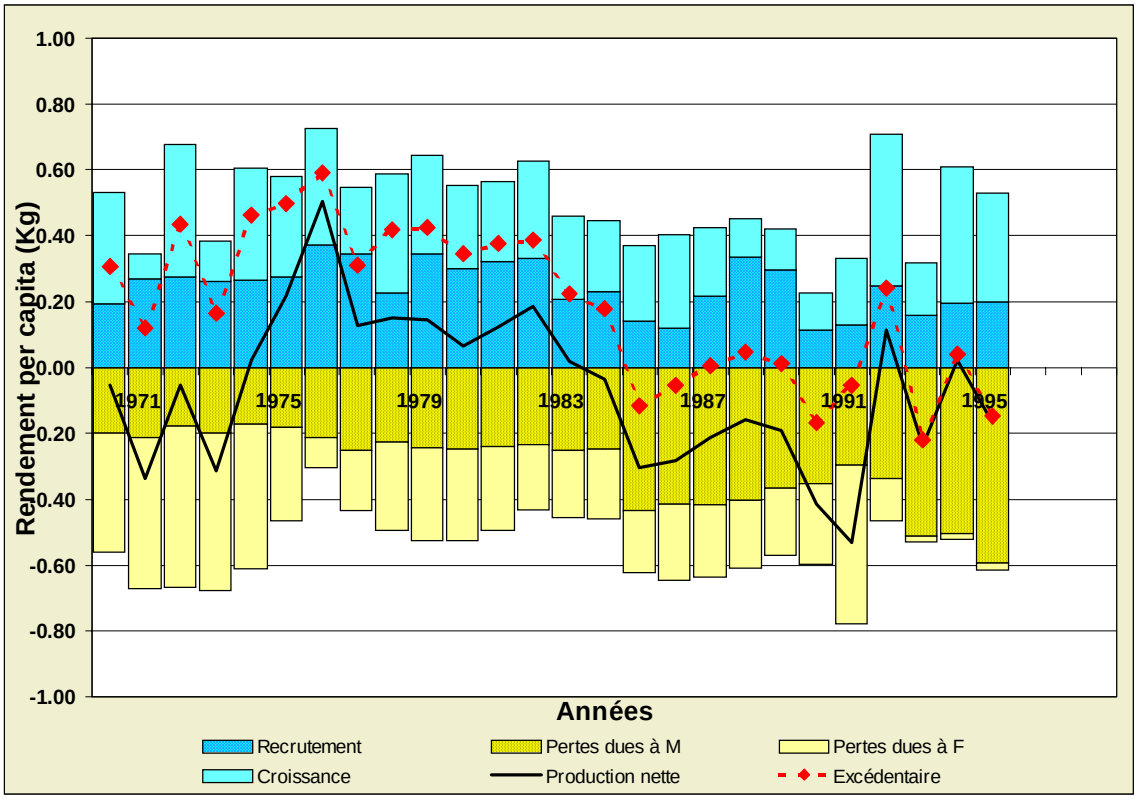
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
Biomasses (t)
1971
1975
1979
1983
1987
1991
1995
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire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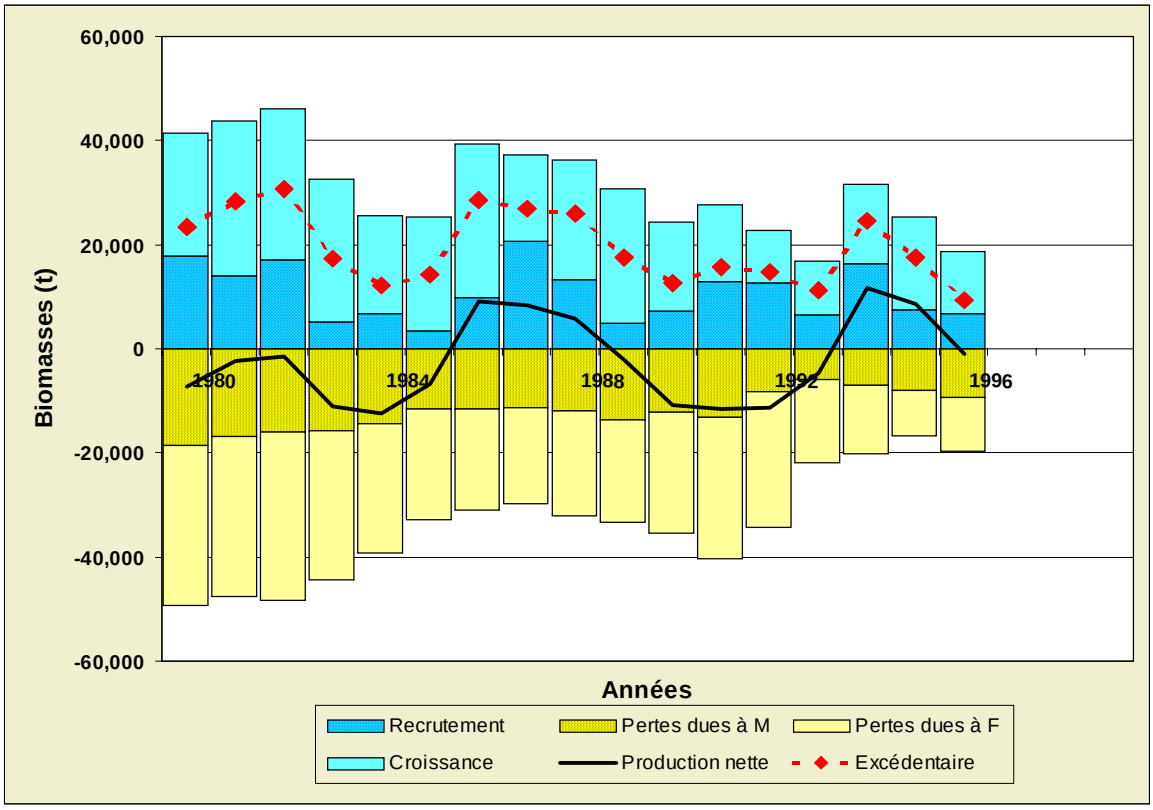
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
Rendement per capita (Kg)
1971
1975
1979
1983
1987
1991
1995
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire

(d) 4X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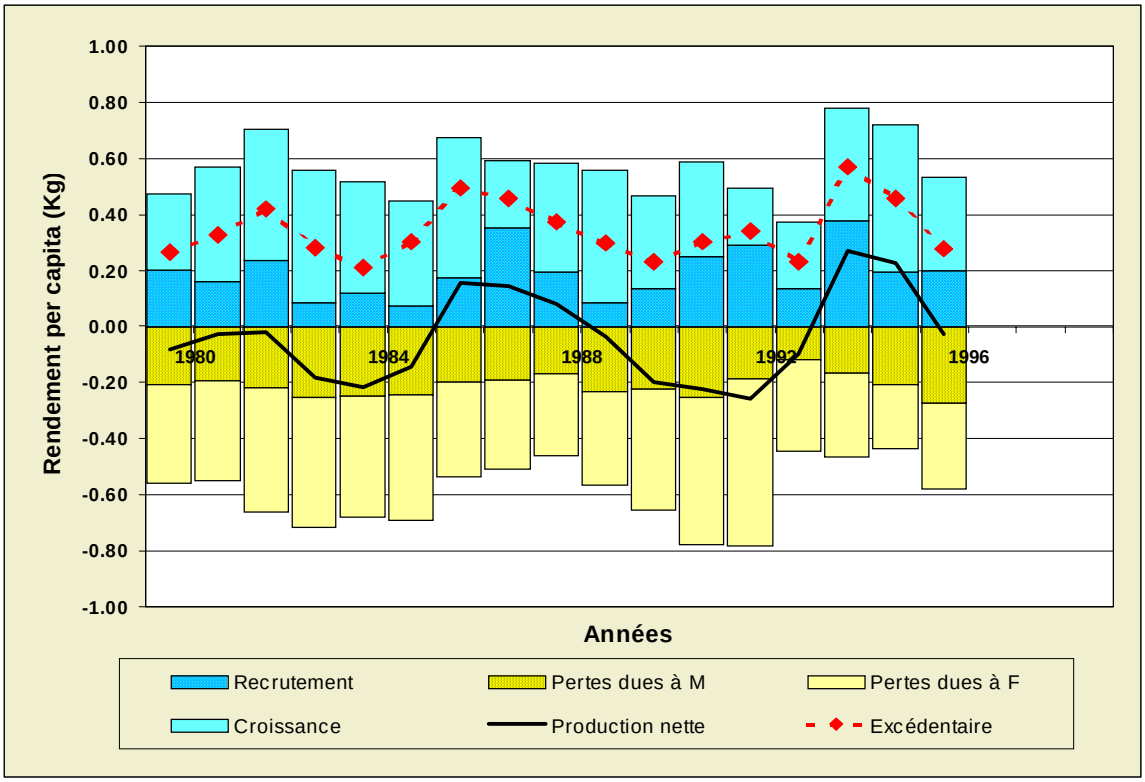
40,000
20,000
0
-20,000
-40,000
-60,000
Biomasses (t)
1980
1984
1988
1992
1996
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire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0.80
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0.00
-0.20
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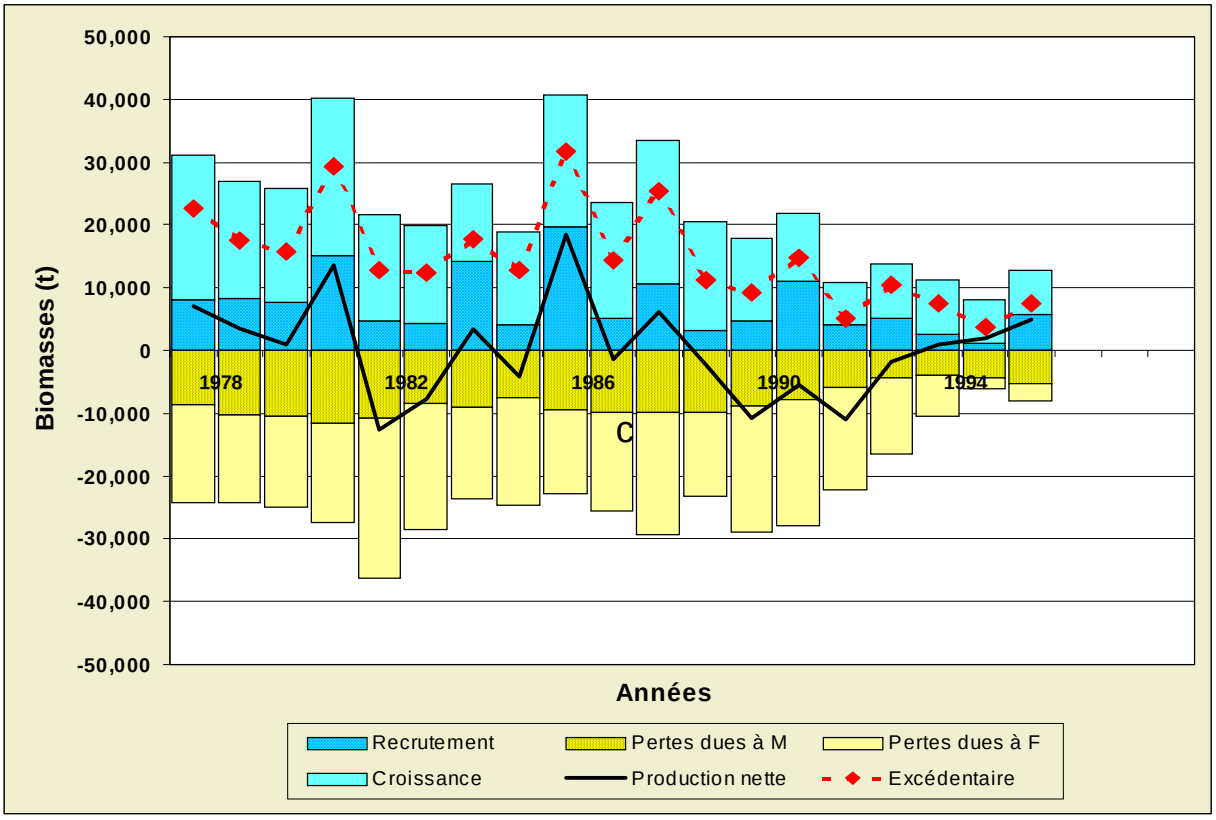
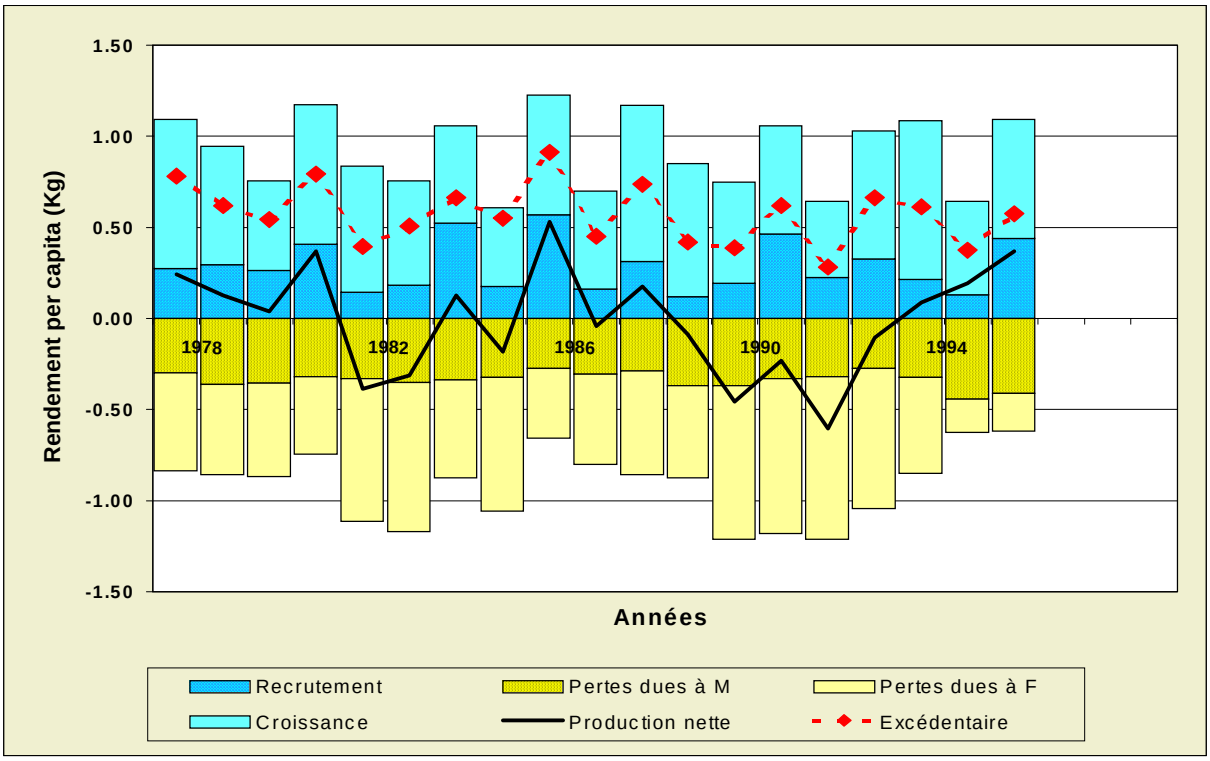
-0.60
-0.80
-1.00
Rendement per capita (Kg)
1980
1984
1988
1992
1996
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire

(e) 5Zj,m


50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
Biomasses (t)
1978
1982
1986
1990
1994
C
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire


1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
Rendement per capita (Kg)
1978
1982
1986
1990
1994
Années
Recrutement
Pertes dues à M
Pertes dues à F
Croissance
Production nette
Excédentaire

Annex 9. List of Working Papers

CSAS WP	TITLE	AUTHOR(S)
99/01	A review of predators of cod in the Northwest Atlantic.	A. Bundy
99/02	New analyses of seal diet data and their implications to 4VsW cod stock status.	R.K. Mohn W.D. Bowen L.P. Fanning
99/03	Morue 3Pn4RS Cod. Addendum #1 Addendum #2 [labelled #2 WP 98/03] Addendum #3 [labelled #3 WP 98/03] Addendum #4 [labelled # 3 WP 98/03 - ACON] Addendum #5 [labelled 0586] Addendum #6 Addendum #7	A. Fréchet M. Bérubé P. Schwab M. Hammill G. Moreau L. Pageau G. Rowe F. Collier A. Fréchet A. Fréchet A. Fréchet A. Fréchet A. Fréchet A. Fréchet A. Fréchet
99/04	Size Selective Mortality of Southern Gulf of St. Lawrence Cod.	A.F. Sinclair J.M. Hanson D.P. Swain L. Currie
99/05	Disentangling the effects of size selective mortality, temperature and density on growth of cod in the southern Gulf of St. Lawrence.	A.F. Sinclair D.P. Swain J.M. Hanson
99/06	A review of information relevant to the issue of consumption of Atlantic cod (*Gadus morhua*) by seal species in the southern Gulf of St. Lawrence.	M. Hammill J.F. Gosselin F. Proust D. Chabot
99/07	The identification of mixed cod stocks in the Gulf of St. Lawrence and its approaches, with implications for management. Addendum	S. Campana J. Brattey G. Chouinard K. Drinkwater K. Frank J. Gagné D. Ruzzante D. Swain C. Taggart P. Yeats S. Campana
99/08	Condition de la morue de 3Pn4RS.	M. Bérubé
99/09	Discussion paper on 3Pn 4RS, Sentinel Fishery Tagging program.	J. Spingle M. Bérubé

CSAS WP	TITLE	AUTHOR(S)
99/10	A mark-recapture estimate for 3Pn 4RS cod. Addendum #1	G.H. Winters D.Decker J. Spingle M. Bérubé G. Winters
99/11	Results of a telephone survey of 1998 fixed gear groundfish licence holders, NAFO divisions 3Pn 4RS.	J. Spingle
99/12	Overview of Meteorological and Sea Ice Conditions off Eastern Canada during 1998.	K.F. Drinkwater R. Pettipas L. Petrie
99/13	Physical oceanographic conditions on the Scotian Shelf and in the Gulf of Maine during 1998	K.F. Drinkwater R. Pettipas L. Petrie
99/14	Oceanographic Conditions in the Gulf of St. Lawrence in 1998	D. Gilbert C. Lafleur P. Galbraith K. Drinkwater D. Swain
99/15	Meterology - Newfoundland	E. Colbourne
99/16	Oceanographic conditions in NAFO Division 2J3KLMNO during 1998, with comparisons to the long-term (1961-1990) average	E. Colbourne
99/17	Partitioning the Total Mortality of Atlantic Cod Stocks: A progress Report	D. D'Amours
99/18	An assessment of the cod stock in NAFO subdivision 3Ps Addendum to 3Ps cod	J. Brattey N. Cadigan G. Lilly E. Murphy P. Shelton D. Stansbury
99/19	Integrated catch analysis (ICA) of 3Ps cod	G. Winters
99/20	The 1998 French cod fishery in subdivision 3Ps	J.C. Mahé D. Briand
99/21	An assessment of subdivision 3Ps cod using extended survivor analysis (XSA)	J.C. Mahé
99/22	A description of the 1998 Atlantic cod fishery in NAFO division 3Ps from port sampling and fishery observer records.	D. Kulka T. Inkpen F. Mowbray
99/23	Assessment of cod in the southern gulf of St. Lawrence, march 1999 Addendum 1	G. Chouinard B. Parent G. Poirier D. Swain
99/24	Results of the sentinel surveys for cod conducted in the southern gulf of St. Lawrence 1994-1998	G. Chouinard B. Parent D. Daigle

CSAS WP	TITLE	AUTHOR(S)
99/25	Tag loss and reporting rates for 1997 and 1998 tagging experiments in 3Ps & 3KL	N. Cadigan J. Brattey
99/26	Estimation of 3Psc and 3KL coarse exploitation and migration rates in 1997 and 1998 from tagging experiments in these regions Addendum 1	N. Cadigan J. Brattey
99/27	An examination of the bias associated with estimating cod density acoustically in near bottom distribution	D.S. Miller
99/28	An assessment of the cod stock in NAFO Divisions 2J+3KL. Addendum #1 [Spatial Patterns in the fall RV data relative to recolonization of the shelf] Addendum #2 [Consumption by harp seals]	G.R. Lilly P.A. Shelton J. Brattey N.G. Cadigan E.F. Murphy D.E. Stansbury D. Stansbury P. Shelton G.R. Lilly
99/29	Alimentation de la morue du nord du golfe du St-Laurent, 1993-1998	D. Chabot R. Miller L. Girard M. F. Beaulieu J. Guérin I. D'Auteuil
99/30	Total mortality estimates, 3Pn 4RS cod	A. Sinclair
99/31	4S fixed gear cod fish questionnaire results for lower north shore Quebec in 1998	F. Collier (RAPBCN)
99/32	Comparison of ADAPT and QLSSPA for two SPA formulations based on 3Ps cod.	N. Cadigan D. Stansbury
99/33	Analysis of mark-recapture data for northern cod	G. Winters
99/34	Stock status report 2J 3KL cod draft 1	DFO Nfld
99/35	Standardization of sentinel catch rates in NAFO divisions 3KL	DFO Nfld
99/36	Draft 1 subdivision 3Ps cod	DFO Nfld
99/37	Standardization of sentinel catch rates in NAFO subdivision 3Ps	DFO Nfld