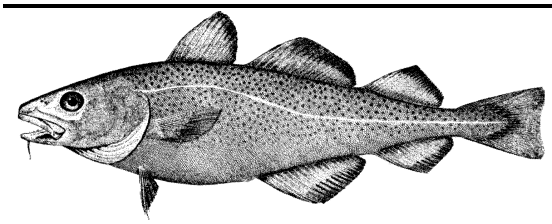

The Northern Gulf of St. Lawrence cod (3Pn, 4RS) in 2000

Background

Each year, the northern Gulf of St. Lawrence cod (Divisions 3Pn, 4RS) undertakes long-distance migrations. During winter, the stock gathers in the Newfoundland south-west area at water depths exceeding 400 m (200 fathoms). In April and May, the stock moves towards the Port au Port Peninsula on the west coast of Newfoundland (Division 4R), where spawning begins. During summer, the cod disperses towards inshore areas, along the west coast of Newfoundland and the Middle and Lower North Shore of Quebec (Division 4S). This inshore migration has been attributed to the warmer waters near the coast and the presence of capelin, the main prey of cod.

Based on the results of many tagging experiments, this stock is generally isolated from neighbouring cod stocks, that is, those of divisions 4TVn, 2J, 3KL and 3Ps. Mixing may sometimes occur in the north-western Gulf area (with the Division 4TVn stock), in the Strait of Belle-Isle (with the 2J, 3KL stock) and on Burgeo Bank (with the 3Ps stock). A recent study estimated that a large proportion of the northern Gulf cod stock may be present on Burgeo Bank (3Ps) during winter (reaching 75% of the catches from November to April).

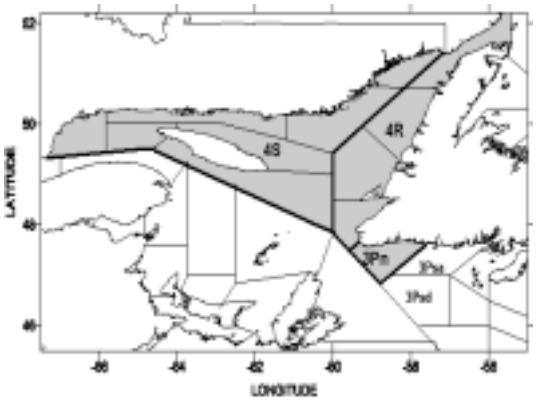

Figure 1. Management units of cod stock in the northern Gulf of St. Lawrence. For reference, fishing areas 3Psa and 3Psd are also shown.

Landings (in thousands of tonnes)

Year	*77-93*	*94-96*	*1997*	*1998*	*1999*	*2000*[1]
TAC	*70.4*	*0*	*6.0*	*3.0*	*7.5*	*7.0*
Landings	*70.2*	*0.3*	*4.4*	*3.0*	*6.7*	*5.8*

[1]*Preliminary data*

Summary

- Population numbers for this stock increased from a minimum of 50 million 3 years old and over fishes in 1994 to 98 million fishes at the beginning of 2001. This figure is considerably less than the average (1977 – 1993 period) of 382 million fishes.
- The adult biomass reached a minimum of 18 000 t in 1994 - the year the moratorium on cod fishing began - before increasing to reach 77 000 t at the beginning of 2001. This increase stems in part from recruitment of the 1995 and 1996 year-classes and from an improvement in the growth rate and condition of cod. The adult biomass still remains much smaller than the average (1977 – 1993) of 248 000 t and the maximum of 467 000 t observed in 1983.
- A substantial improvement of growth and condition (size at age and weight at length) is observed over the last few

years. However, the age at maturity has shown a significant decrease in the last few years, perhaps as a response of the population to a low abundance.

- The index of the DFO trawl survey dropped from 1991 to 1993 and has increased at a mean rate of 14% since 1993. The abundance indices from sentinel surveys for July and October have risen at a rate of 10% and 8% respectively over the last six years. The catch rates for longlines have climbed by 22% on the average since 1995 whereas gillnets have not shown any increase since 1995.
- Following a recommendation from a workshop on stocks mixing held October 2000, a scenario where 75% of the catches from 3Psa and 3Psd would come from the Gulf stock between November and April was examined. The estimation of population numbers is less variable with the inclusion of these catches in the analysis. The adult biomass at the beginning of 2001 would be 6% higher than the current management units (3Pn, 4RS) and would stand at 82 000 t. This scenario should be considered as a contribution to the iterative consultation process between scientists, fisheries managers and the industry as recommended in the workshop report and in the 3Ps stock status report.
- Projections for 2001 do not show any increase compared to 2000 for both population numbers and adult biomass. Catches over 4 000 t in 2001 would not allow the adult biomass to increase by 10%. A catch of 7 000 t (the TAC for 2000) would have a small probability of increasing the adult biomass. For both scenarios, the probability of increasing the adult biomass by 10% is nil. A target increase of 10% of the adult biomass would essentially require the re-establishment of the moratorium.

The fishery

Landings for this stock reached a maximum of 100 000 t in 1983 and have declined up to 1993 (Figure 2). Mobile gear boats would reach their allocation while the fixed gear sector could not. Before the moratorium in 1994, landings from the directed fishery came from a winter mobile gear fishery off Port aux Basques, while the fixed gear sector did not reach its allocation for a number of years. The fishing was under moratorium from 1994 to 1996. In 1997, a TAC of 6 000 t was authorised and landings totalled 4 400 t. The TAC was reduced to 3 000 t in 1998, and 3 029 t of cod was landed. In 1999, the TAC was raised to 7 500 t and landings amounted to 6 683 t. Finally, the TAC for 2000 was 7 000 t of which preliminary landings available for the assessment were 5 823 t.

Fishery profile has changed considerably further to the moratorium. Since fishery reopened in 1997, directed fishing has been authorised solely for fixed gear (longlines and gillnets). In 1999 and 2000, fishing effort is spread over several months as a result of monthly allocations. Limits were imposed on fishing effort in 1999. Whereas on the west coast of Newfoundland (4R and 3Pn), a total of 2 000 hooks or 6 gillnets could be used per fishing trip, on the Lower North Shore of Quebec (4S), up to 25 gillnets were permitted per trip. Fishermen aboard small vessels carried out the fishery and landings were made at several designated ports along the coast that have dockside monitoring services in 1999 and 2000. Fishermen aboard vessels under 45’ in Quebec were not required to complete logbooks, nor were fishermen aboard vessels under 35’ in Newfoundland. Logbooks were distributed in Newfoundland (3Pn, 4R) in 1997 and in Quebec (4S) in 1999. The information from the logbooks are used to assess the performance of fishery. Trawler landings were made solely within the

context of sentinel fisheries or scientific fishing projects.

One component of the commercial fishery is done within the sentinel fisheries that started in 1995 to develop a partnership between fishermen and the Department of Fisheries and Oceans. The sentinel fisheries are conducted according to a strict protocol and allow to establish indices of abundance. Three types of fisheries are conducted every year: a gillnet fishery along the Lower North Shore of Quebec (Division 4S) and along the West Coast of Newfoundland (Division 4R), a longline fishery and an otter trawl survey for all the stock area (3Pn, 4RS). Landings done in the sentinel fisheries are accounted with the landings of the commercial fishery. Sentinel fisheries had an allocation of 400 t in 2000 of which 274 t were landed.

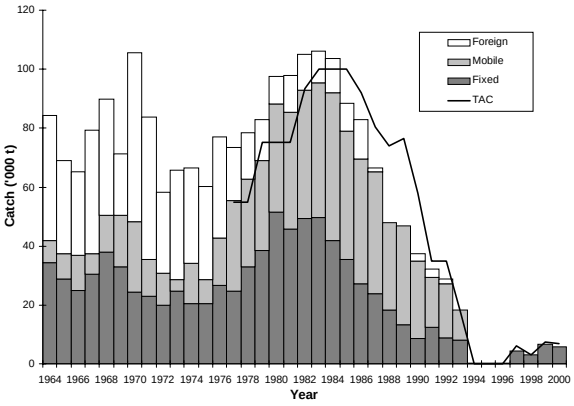

Figure 2. Landings and total allowable catches (TAC).

The industry

For a third consecutive year, the Quebec Lower North Shore Fishermen's Associations (Regroupement des Associations de Pêcheurs de la Basse Côte-Nord du Québec, RAPBCN) and its counterpart on the west coast of Newfoundland (Fish, Food and Allied Workers, FFAW), which are responsible for the sentinel fisheries in these regions, conducted **telephone surveys**. For the 2000 survey, 59 fishermen responded in 3Pn, 88 fishermen in 4R and 53 fishermen in 4S. The questionnaire was intended to obtain information on the fishery, including comments in catch rates. Respondents noted that there had been an increase or a stabilisation in cod size and condition in 2000. They also said that the cod had leaved earlier 3Pn in the spring and left 4R later. Essentially, cod spent more time in the Gulf in 2000 compared to 1999. In 4R, catch rates had risen between 1998 and 1999, but declined in 2000. The 3Pn late October / early November fishing allocation was hampered by bad weather, and many fishermen decided to go to Codroy (4R), where good catch rates were occurring. In last year's telephone survey, fishermen from 4S indicated that catch rates had declined in 1999 relative to 1998. This year, the situation improved with the majority of fishermen indicating catch rates for the 2000 season higher than last year. It is interesting to note that 51% of fishermen from 4S have observed spawning in July 2000, compared to only 40% in 1999. Respondents in 4R and 3Pn noted the occurrence of spawning activity in May and June.

Biological characteristics of the resource

The biological characteristics of cod from the northern Gulf varied in time, and some changes occurred when the stock abundance declined due to cold oceanographic conditions which were unfavourable for cod. Growth, condition, size and maturity at age declined in the 1980's and early 1990's. These changes may have had a negative impact on egg production as a small fish in poor condition and with smaller size at maturity produces fewer eggs. The natural mortality rate may have increased as fish in poor condition has less chance to survive, especially after spawning when conditions

are unfavourable. However, we have noted improvements in some biological characteristics over the last few years, which improve the stock status.

After reaching a record low level in 1992, the **weight** of 6 years old cod gradually rose (Figure 3). The weight value recorded in 2000 is the highest of the last 16 years. This observation also holds for other age groups, whether it is in the commercial fishery or from the three mobile gear surveys (*Needler*, sentinel surveys in July and October).

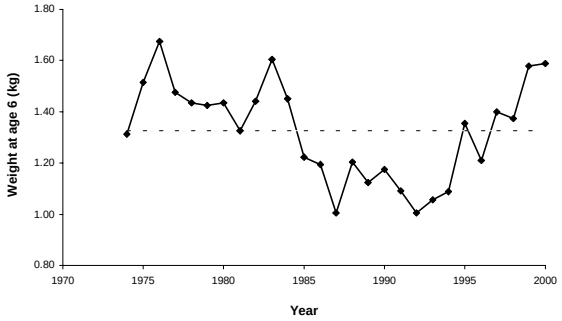

Figure 3. Mean weight of 6 years old cod from commercial fishery. The dotted line is the average for the 1974 – 2000 period.

The indeces of **condition** provides information on the capacity for cod to survive and spawn. Fish in good condition will have better chances to survive and a better spawning success, especially in poor environmental conditions. Since 1994, a monitoring program has been carried out to assess the condition of cod. The indices obtained shed light on the capacity of the fish to reproduce and survive. They include the Fulton Index (the weight to length relationship), which provides a snapshot on the health of fish, and three indices for energy reserves (hepato-somatic index, which is the weight of the liver compared to the fish weight less the stomach content and gonads, water content in the liver and muscles). In the early 1990's, some cod sampled at sea were found to be in an as poor condition as those of experimental cod held in tanks without food and dying.

In general, it has been noted that the condition indices for cod have improved since the early 1990's. All the indices now reflect a good and stable condition. The water content analyses done on samples taken during the *Needler* research survey of August indicate that the reserves of lipids (liver) and proteins (muscles) are good. Since 1995, the indices for cod condition obtained from mobile gears operated offshore have been lower than, but exhibited the same general trend as, the corresponding indices for cod taken near the coast. This situation may point to more favourable environmental conditions for cod offshore.

The size of cod at sexual maturity declined between 1985 and 1995. In 1985, 50% of mature females measured 50 cm compared to 50% of mature females at 37 cm in 1995. Such changes in size at maturity and changes in mean size at age impact on changes in the age of maturity for females. While 50% of females were mature between 5 and 6 years old in 1985, this percentage was reached between 3 and 4 years old in 1995. More recent data collected during the spring of 1998 shows that the size at which 50% of females are mature had slightly increased and established at 40 cm. However, no sampling activity has occurred to monitor changes in size at maturity since 1998.

Resource status

Abundance indices

Catch rates from sentinel fixed gear fisheries

The standardised **catch rates for sentinel fisheries using gillnets** in 4R and 4S show little inter-annual changes (Figure 4). This may be due to their narrow range of selectivity, which varies little from year to

year, and because the gillnets catch large individuals which are not very abundant. The index provides a means of tracking the year-classes and thus has been included in the analysis.

Catch rates for gillnets for the overall territory have increased since 1997, with large variations in 1995 and 1996. In June of 2000, gillnet fishermen in the Blanc-Sablon area (eastern part of 4S) realised exceptional catch rates.

The standardised **catch rates for sentinel fisheries using longlines** have been rising since 1995. The largest figures were for 2000. The increased catch rates recorded in 1999 and 2000 in the sentinel fisheries using longlines is due to harvesting of the 1993 year-class, at the age of 6 and 7 years respectively.

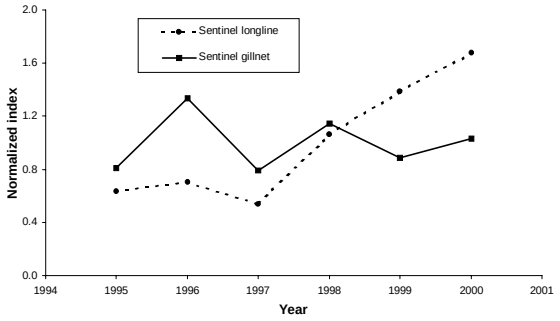

Figure 4. Cod abundance indices derived from fixed gear.

Trawl surveys

The **mobile gear sentinel fishery** program began in 1994 in the northern Gulf of St. Lawrence, but the study only covered the entire stock since 1995, from the coast to the offshore area. The surveys are carried out by nine trawlers twice a year, in July and October, using a stratified random sampling protocol similar to that applied by DFO aboard the *Needler*. The gear types were standardised in 1997 by adding a restrictor cable to maintain a constant trawl opening during fishing operations.

The 1995-2000 data series suggests a slight upward trend in the cod stock abundance for the July series (an average increase of 10% over the period) (Figure 5). The abundance indices derived from the October survey indicate a very slight increase (8%) since 1995. According to both surveys, most of the biomass is located in Division 4R. Cod distribution does not differ significantly between July and October.

The ***Needler*** (DFO) surveys, initiated in 1990, were originally aimed to assess the shrimp stock and some groundfish species in the Gulf. Some adjustments were made later to increase coverage of the geographic region frequented by the northern Gulf of St. Lawrence cod; this was achieved by extending the surveys to 3Pn and adding some depth strata between 37 m and 100 m (20 to 50 fathoms). As the spatial coverage has varied over time, only the strata consistently sampled since 1991 were considered in this assessment. The abundance index from the *Needler* surveys suggests an average increase of 14% since 1993 (Figure 5).

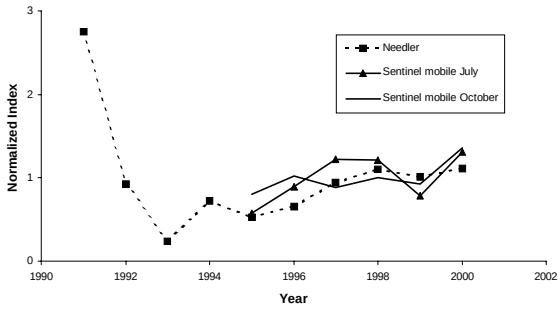

Figure 5. Cod abundance indices derived from research surveys.

The estimated abundance of the 1997 year-class (2 years old) derived from the 1999 *Needler* survey would be the highest value in the 10-year data series. In 1999, 2 years old cod were very abundant, and in 2000, 3

years old cod were very abundant . The same year class is also abundant in both sentinel mobile surveys. The abundance index for age three is included in the sequential population analysis, but the few observations makes its estimation inaccurate.

Estimation of stock size

The **SPA** (sequential population analysis) is an analytical model that allows estimating stock abundance while taking into account natural mortality and fishing mortality. The analysis is based on catches at age estimated from the commercial fishery and calibrated with the indices derived from fixed gear sentinel fisheries in inshore waters, those derived from the mobile gear sentinel fisheries offshore and those derived from the *Needler* survey.

To account for the degradation of environmental conditions, the increased wasteful fishing practices and the growing predation on cod, it was decided during a zonal meeting in winter of 1998 that the **natural mortality** (M) coefficient should be increased from 0.2 to 0.4 as of 1986 in the sequential analyses for several cod stocks. Environmental conditions appear to have improved recently, as indicated by the better condition of the fish, for example; however, predation by seals continued to increase until at least 1996. In view of this, the coefficient was kept at 0.4 for the entire period 1986-2000 in order to take account of the combined effect of these factors.

The maturity ogives, or proportion of fish sexually mature by size or age, are used to estimate from results of the sequential population analysis the adult abundance or biomass. Previously, results from winter surveys were used (1983 to 1994) to evaluate maturity at age. The ogive of 1983 was used for 1983 and years prior. The ogive of 1994 was applied for 1995 and years later. Last year, the maturity ogives at age were replaced by maturity ogives at length in order to take into account changes in growth. This year, more recent information on spawning aggregations in 1994, 1995 and 1998 were appended. As a consequence, it is difficult to compare adult population numbers and biomass from this assessment to those calculated in earlier assessments. It should be noted that female maturity is used to estimate both male and female maturity.

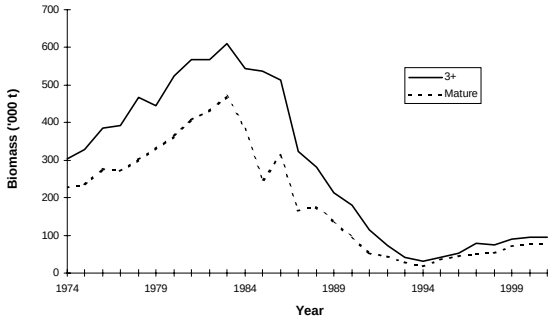

Figure 6. Estimates of the total biomass of individuals of 3 years old and more and the biomass of adult individuals.

The results of the SPA indicate that the **abundance** of fish of 3 years old and more dropped from 537 millions in 1983 to 50 millions in 1994, and then rose to 98 millions at the beginning of 2001 (Figure 6). The abundance has only increased by 3% between 1999 and 2000. The abundance of adult fish declined from 311 million individuals in 1982 to 21 millions in 1994. It has increased to 65 millions in 2000 with an increase of 10% between 1999 and 2000.

Population numbers are converted to **biomass** using average weights at age. The total biomass (fish of 3 years old and over) has dropped from 610 000 t in 1983 to 31 000 t in 1994 (Figure 6). It climbed to 95 000 t at the beginning of 2001, following an increase of 6% between 1999 and 2000. The adult biomass declined from 468 000 t in

1983 to 18 000 t in 1994 to increase afterwards to 77 000 t in early 2001. The increase in adult biomass between 1999 and 2000 is 7%.

Projections for stock abundance and biomass for 2001 were based on average observed recruitment at 3 years old of the last five years (1996-2000), mean weights at age and maturity of the last three years (1998-2000). Projections indicate a marginal increase in abundance and biomass in 2001. The total abundance and adult abundance would increase by 3%, whereas the total biomass and adult biomass would not increase.

Fishing mortality for fully recruited cod was 20% (F=0.28) in 2000. This value is much higher than the target $F_{0.1}$ level, previously estimated at 15% (F=0.2). However, given the changes in cod growth, selectivity of fixed gear and maturity, the reference level has probably changed. Considering the collapse of the cod stock, it would be imprudent to calculate a new target of the $F_{0.1}$ type.

There are no important signs of recruitment over the last 10 years (Figure 7); only the 1993 year class has sustained the fisheries in the last two years. It should be noted that this year class was produced prior to the moratorium.

Mixing of stocks from the northern Gulf and Burgeo Bank

The issue of influx of Gulf cod into 3Ps has been frequently discussed in the past. In order to avoid catches of cod from the Gulf stock in the winter fishery of the western part of 3Ps, the area around Burgeo Bank (3Psd) was closed in 1999 and 2000. This sector is a fraction of the area of **mixing** of Gulf cod (3Pn, 4RS) in Burgeo Bank. Many research programs were initiated over the last years to address the importance of this mixing (tagging, otolith microstructure). A specific workshop was held on October 2000 to examine this question (Chouinard, G. A., 2000). A conclusion of this workshop was that a significant proportion of the cod caught in winter in areas 3Psa and 3Psd were incursions of Gulf cod. As recommended, we examined the impact of reallocating 75% of the catches occurring between November and April in 3Psa and 3Psd to the catches of 3Pn, 4RS in the SPA.

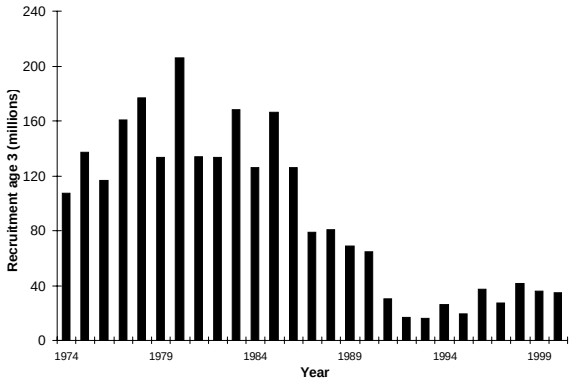

Figure 7. Estimates of the number of cod recruited at 3 years old.

Landings between November to April in fishing areas 3Psa and 3Psd peaked at 9 945 t in 1992 and dropped to very low levels since (Figure 8). This is partly due to the moratorium in 3Ps as well as to seasonal closures in 3Psd since 1999.

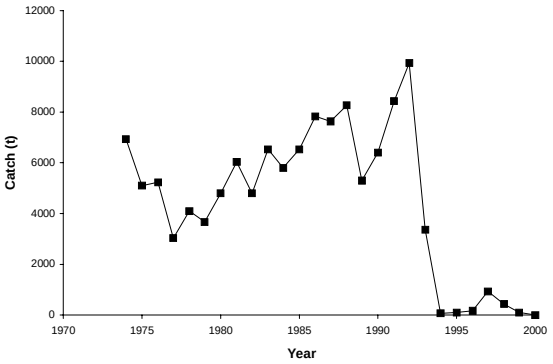

Figure 8 : Landings accounting for 75% of the total from fishing areas 3Psa and 3Psd between November and April.

In the proposed scenario, the catch at age for the Gulf cod would thus be modified to take the **mixing** into account. An exploratory analysis was undertaken to assess the impact of such mixing on the assessment of Gulf cod. It is important to note that the analysis was conducted with the same formulation as in the current advice, using all five indices of abundance that are not affected by this mixing. Model fit (residual sum of squares) was improved by 3% with the addition of 75% of the catches at age from 3Psa and 3Psd between November and April for the 1974 to 2000 period. The estimate of adult biomass for Gulf cod at the beginning of 2001 would be 6% higher than the current estimate at 82 000 t. As there are still uncertainties regarding the potential catches of 3Ps cod in the Gulf, this analysis was not retained in the final formulation for the northern Gulf cod stock assessment.

Sources of uncertainty

In last year's report, the issue of **catchability** (number of fish estimated from a survey compared to population abundance from VPA) was considered as a source of uncertainty. This year, only one out of the 22 data points from the surveys has a population estimate higher than the sequential population analysis, the July sentinel estimate in 1997 (Figure 9). The observations suggest that high catchability levels are not as important as mentioned last year.

Since 1995, sentinel fishermen have **tagged** more than 43 000 cod; however, only 1 132 tagged cod have been recaptured. This suggests that the exploitation rate is very low, and well below the rate of 20% (F = 0.28) estimated in this assessment report. Two experiments on post-tagging survival were carried out in 1999 and 2000 under the sentinel fishery programs, in fishing areas 4R and 4S. They indicated that the mortality rate associated with tagging is very low, about 1%. The loss of tags, the small number of tag returned by fishermen or emigration from the population might explain the low level of recapture. In the FFAW's telephone survey with fishermen in 1999, it was estimated that fishermen returned 56% of the tags they retreived.

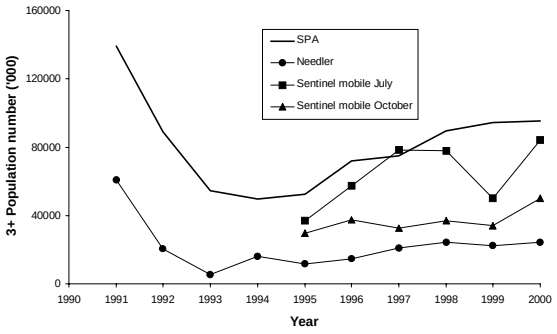

Figure 9. Comparison of abundance of fish from the surveys to those estimated from the sequential population analysis (SPA).

Despite the sources of uncertainty in this assessment, a number of factors appear to show that the resulting analysis provides an accurate reflection of the stock's current situation. The total mortality rate for 1997 to1999 was 21%, a figure that is consistent with the rapid disappearance of the year-classes in the surveys. A natural mortality value of M=0.4 is sufficient to account for the consumption of cod by seals as determined from available estimates. Finally, the abundance indices used to calibrate the SPA are generally consistent with one another and indicate marginal increases in population size in recent years.

Outlook

The 1995 and 1996 year-classes are the largest ever seen in this stock over the past decade; however, this recruitment remains well below the mean recruitment values of about 100 millions that existed prior to the 1990's. These year-classes were mature in

2000 and have contributed to the increase of the adult biomass (Figure 10). However, given the small stock size, landings of about 7 000 t (the TAC for 2000) would be equal to 12% of the harvestable biomass, which only gives a small probability (less than 5%) of an increase in adult biomass. A 10% target level for growth of the adult biomass would only be possible by reinstituting the moratorium (Figure 11).

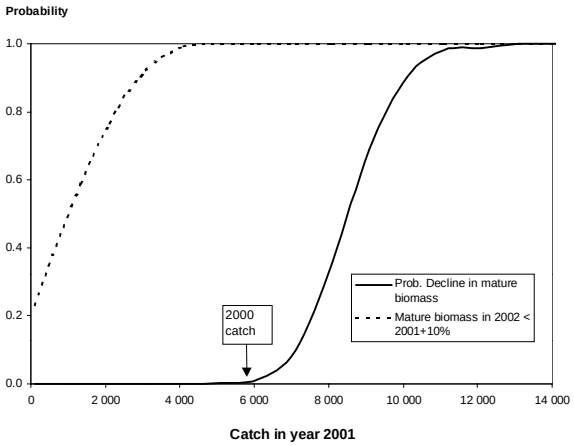

Figure 10. Probability of a decline and increase in the adult cod biomass relative to various catch levels for 2001.

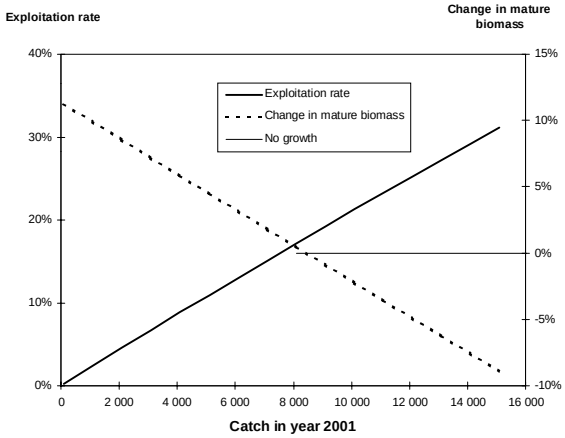

Figure 11. Harvesting rate and projected variation in adult cod biomass relative to various catch levels for 2001.

Management considerations

Based on this assessment, 3 years old cod is immature and not yet recruited, whereas almost all individuals reach full maturity at four years of age. Gillnets and longlines have a selectivity that targets mainly fish of 6 years old and over. This means that cod can spawn at 4 and 5 years old before it become vulnerable to these fisheries. In spite of the FRCC recommendation to avoid concentrating fishery on this age category, the 1993 year-class was heavily fished with gillnets and longlines in 1999 and 2000 in both commercial fisheries as well as in sentinel fixed gear fisheries. The situation did not improve in 2000, the 1993 year class was also the most important in the gillnet and longline landings.

The FRCC recommended last year to increase mesh size for gillnets from 5½ " to 6 " for the 2000 fishing season. In a news release from DFO on May 12th, 2000 (NR-HQ-00-21E), we can note « *In response to industry concerns, a limited fishery in 4RS3Pn using 5 ½" mesh gillnets has been authorized for the 2000 fishery. This will allow the Department and industry to carry out a comparative study on the conservation impacts between 5 ½" and 6" meshes. Given the present age structure of this stock, rebuilding may be optimized by permitting 5 ½" mesh gillnets, at least for the year 2000.* » Sentinel fisheries thus initiated a study in 2000 to assess the impact of such a mesh change. Ten sentinel sites used both gears simultaneously (6 in 4R, 4 in 4S, there is no gillnet fishery in 3Pn) (Figure 12A). Results varied according to fishing areas.

We note that currently, gillnets with 5½" mesh select the largest fish of all gears available (longline, trawl, traps, hand lines). An increase to 6" would select mostly fish of 72 cm, corresponding to fish of more than 10 years old, which represented less than 1% of the adult fish at the beginning of 2001.

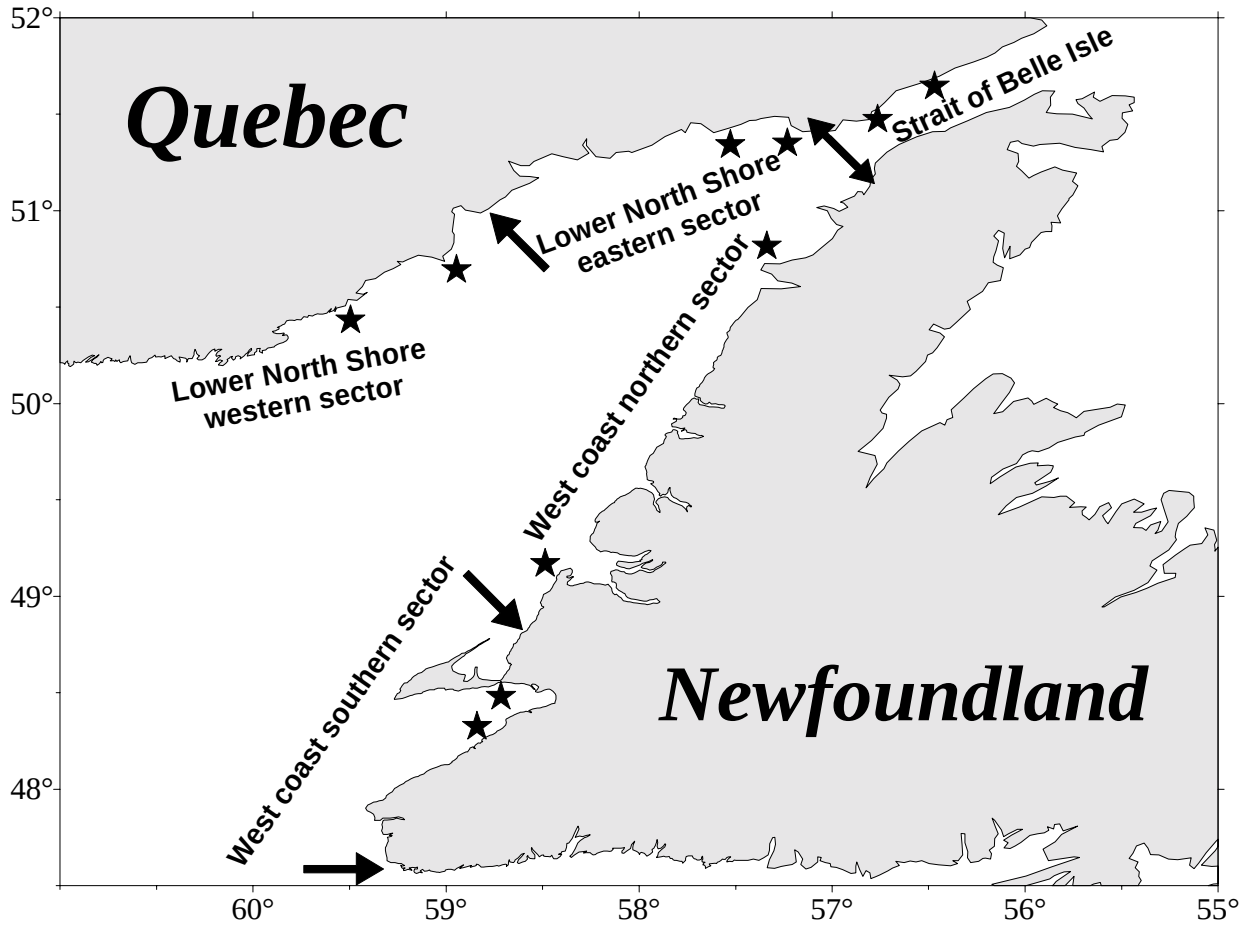

Figure 12A. Map of fishing areas and specific sites (identified by star).

An added fishing pressure on these individuals could be detrimental given their importance to the reproductive potential of the stock.

The largest impact would occur along the western part of the Lower North Shore of Quebec, 6" mesh catch rates would be four times lower than for the 5½" mesh (Figure 12B). For the eastern part of the lower North Shore of Quebec, catch rates for the 6" mesh would be almost half of the 5½" mesh. In the Strait of Belle Isle and in the northern part of 4R, the catch rates for 6" mesh would be about 25% less than for the 5½" mesh. Finally, for the southern part of 4R, catch rates for the 6" mesh would be 25% superior to the 5½" mesh. According to the length frequencies, it seems to be a greater abundance of larger size cod in southern 4R that could explain the efficiency of the 6" mesh in that area.

Other considerations

A precautionary approach must be adopted for this stock over the coming years. Targets and limits should be set with respect to the adult cod biomass and fishing mortality. Figure 13 illustrates the path that this stock has followed since 1974. It should be noted that the biomass doubled between 1974 and 1982 in spite of exploitation rates that were twice the target of $F_{0.1}$=0.2. Afterwards, the biomass contracted and fishing effort increased up to 1993, just before the

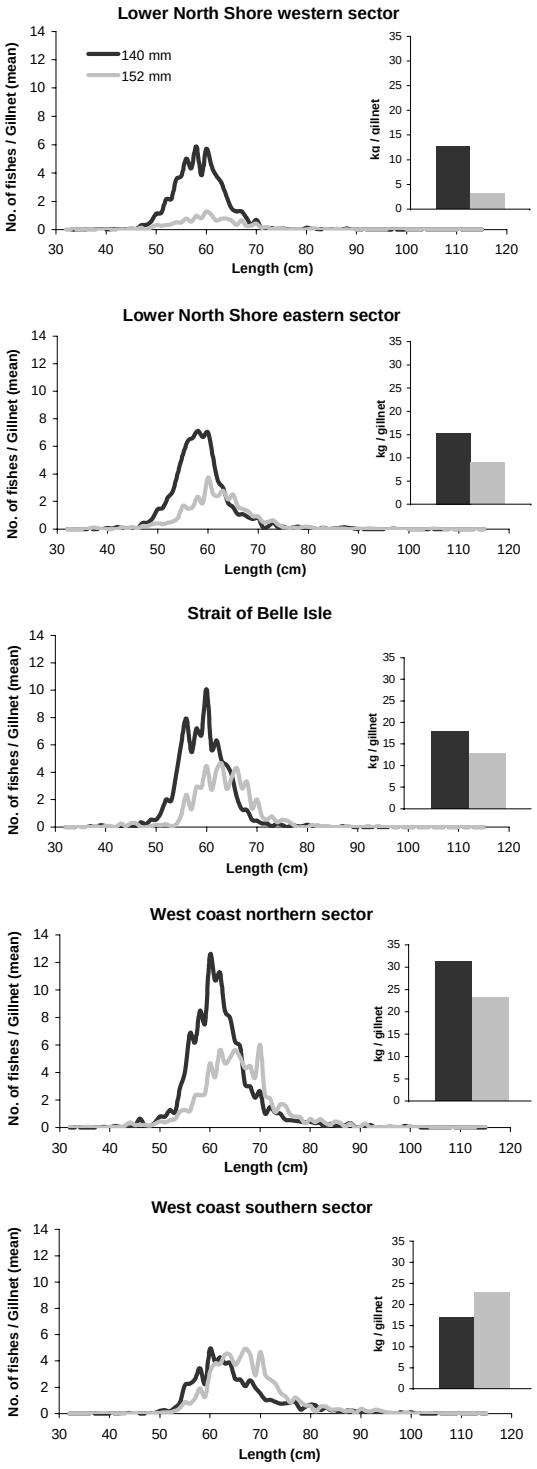

Figure 12B. Length frequencies and catch rates of gilnets with 5½" and 6" mesh from selectivity study conducted by sentinel fishermen in 2000.

moratorium was imposed. Since then, fishing mortality has increased with the reopening of the fishery, but the spawning stock biomass has not grown substantially.

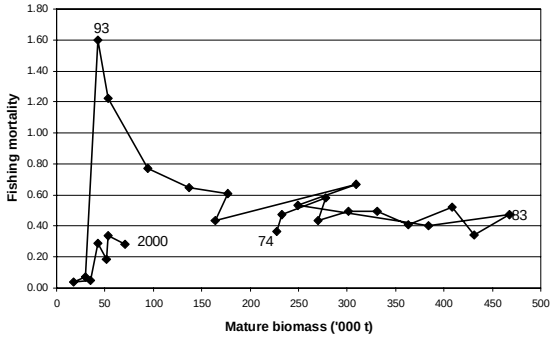

Figure 13. Precautionary approach for the cod stock.

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