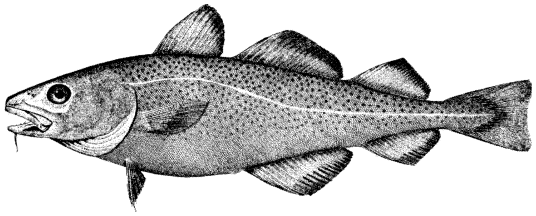

Northern Gulf of St Lawrence cod (3Pn, 4RS)

Background

The northern Gulf of St Lawrence cod (divisions 3Pn, 4RS) undertake distant annual migrations. In winter, the fish gather southwest of Newfoundland at water 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 has been attributed to the warmer waters near the coast and the presence of capelin, the main prey species of cod.

Based on the results of many tagging experiments, this stock is clearly isolated from neighbouring cod stocks, that is, those of divisions 4TVn, 2J, 3KL and 3Ps. Mixing may sometimes occur mix in the northwestern Gulf (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 in winter (3Ps).

Landings (in thousands of tonnes)

Year	*77-93*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*[1]
TAC	*70*	*0*	*0*	*0*	*6*	*3*	*7.5*
Landings	*70*	*0.4*	*0.2*	*0.3*	*4.4*	*3*	*6.7*

[1] *Preliminary data*

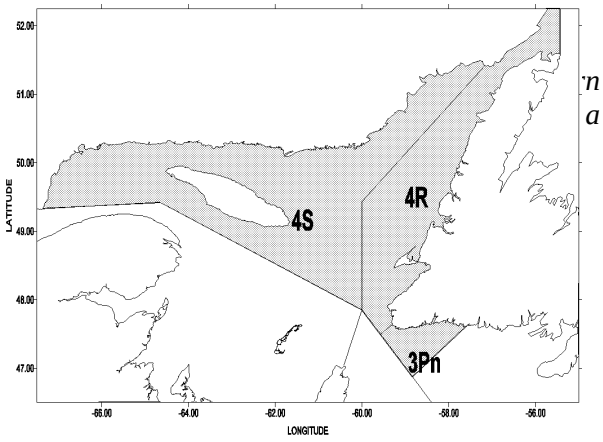

Figure 1. Range of the cod stock in the northern Gulf of St Lawrence

Summary

- This assessment is based on a sequential population analysis calibrated with five routine indices; three bottom trawl research surveys (*Needler*, sentinel fishery surveys of July and October) and two sentinel fishery surveys using longlines and gillnets.
- According to estimates, the adult biomass has been growing since the all-time low level of 16 000 t recorded in 1994–the year the moratorium on cod fishing began–and it stands at 62 000 t at the beginning of 2000. This increase stems in part from recruitment of the 1995 and 1996 year-classes and from an improvement in the growth rate of cod. Nonetheless, the adult biomass remains well below the highest level estimated at 467 000 t in 1983.
- Fishing activities in 1999 generated landings of 6 683 t and an exploitation rate of 26% (F = 0.38).
- If in the year 2000, cod landings reach a level of about 7 500 t (the TAC of 1999), this could prevent growth of the adult

biomass. Alternatively, if a biomass growth target of 10% were established, this would basically require reinstitution of the moratorium on cod fishing. By contrast, with catches of around 4 500 t, there would be no risk of decline in the adult biomass in 2000. However, there would be nil probability of 10% growth in this biomass.

The Fishery

This stock was under a moratorium from 1994 to 1996. In 1997, a TAC of 6 000 t was authorized and landings totalled 4 400 t. The TAC was reduced to 3 000 t in 1998 and 3 029 t of cod was landed that year. In 1999, the TAC was raised to 7 500 t and landings amounted to 6 683 t. The 175 t allocation granted to France was not fished. In 1999, the sentinel fisheries had an allocation of 400 t and their catches totalled 280 t.

The profile of the fishery has changed considerably further to the moratorium. Between 1989 and 1993 most of the landings were made by trawlers during the winter fishery in Cabot Strait, whereas since the fishery reopened in 1997 directed fishing has been authorized solely for fixed gear (longlines and gillnets). Fishing effort is spread throughout the year 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. The fishery was carried out by small vessels and landings were made at several designated ports along the coast that have dockside monitoring services. The fleet of vessels under 45' in Quebec was not required to complete logbooks, nor was the fleet of vessels under 35' in Newfoundland. Logbooks were distributed in Newfoundland (3Pn, 4R) in 1997 and in Quebec (4S) in 1999. Trawler landings were made solely within the context of sentinel fisheries or scientific fishing projects.

The FRCC recommended that fishing activities not be focussed on the 1993 year-class. In 1999, this was the prime year-class in the commercial fisheries and in the sentinel fisheries. It accounted for 33% of catches in number of cod and 27% in weight in the commercial fishery.

During the winter of 1998-1999, the Burgeo Bank area (3Psd) was closed to directed cod fishing in order to minimize catches of Gulf cod. Mixing occurs in this sector between the northern Gulf stock (3Pn, 4RS) and the St. Pierre Bank stock (3Ps).

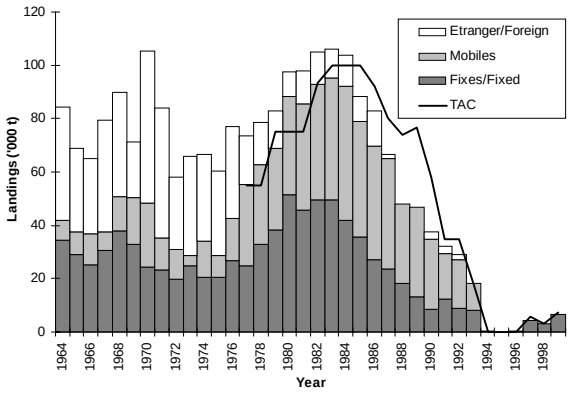

Figure 2. Landings and total allowable catch (TAC) of northern Gulf of St Lawrence cod

The Industry

For the second straight year, the Québec Lower North Shore Fishers' 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. In all, 61 fishers responded to the survey in 3Pn, 103 fishers in 4R and 48 fishers in 4S. The goal of the questions was to develop a profile of the fishers, including their age, their experience in the fishery and the type

of vessel used, and to obtain a description of the 1999 fishing season and comments on catch rates. The respondents said that there had been an increase in cod size and condition in 1999. They also said that the cod had migrated earlier in 4R and left 3Pn later. The catch rates had risen between 1998 and 1999 in 4R and decreased somewhat in 3Pn, except in the case of the November fishing allocation, in which longline fishers had recorded their highest catch rates ever. Most of the fishers interviewed had over 20 years of experience. Fishers using gillnets in 4R made the same comments. In 4S, the fishers mentioned that the catch rates had declined in 1999 from the 1998 level, that is, from 8 to 7 on a scale of 10.

Biology

After hitting a record low level in 1992, the **weight** of 6-year-old cod gradually rose. The weight value recorded in 1999 is the highest of the past 15 years.

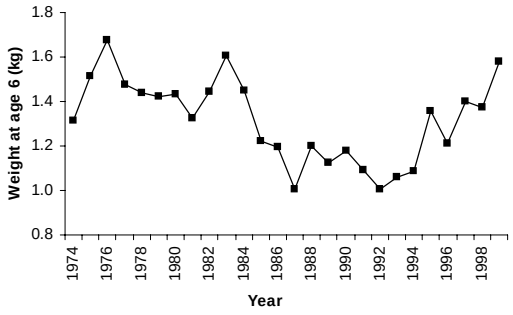

Figure 3. Mean weight of 6-year-old cod taken in the commercial fishery.

The **maturity** ogives used in the past were obtained from winter surveys conducted aboard the *Gadus Atlantica* (1977-1994), with more recent values being extrapolated from the latest observations available (1994). This year, supplementary observations recorded during spring surveys aboard the *Teleost* in 1996 and 1998 provided the opportunity to use real data for more recent years. A model analysing the condition of cod was also applied to the data, making it possible to derive more realistic annual maturity ogives. It was determined that sexual maturity now occurs at a younger age than in the past: in 1998, 93% of 4-year-old cod were sexually mature compared with 8% in 1994. A trend toward earlier maturity has been observed since the late 1980s. This change is partly attributable to the point in time when the maturity of the fish is assessed, that is, whether it is done before or during reproduction. The decrease in age at maturity may also represent the population's response to the decline in its numbers.

Since 1994, a monitoring program has been carried out to assess the **condition** of cod. The indices that are obtained shed light on the capacity of the fish to reproduce and survive. They include the Fulton Index, which provides a snapshot of the health of the fish, and three indices of energy reserves (hepato-somatic index, water content in the liver, and water content in muscle). In the early 1990s, some cod sampled at sea were found to be in a condition as poor as that of experimental cod that had been held in tanks without food and were dying. Fish that are in good condition will have a better chance of survival especially when environmental conditions are unfavourable.

In general, it has been noted that the condition indices for cod have improved since the early 1990s. All the indices now show their condition to be good and stable. The water content analyses done on samples taken during the *Needler* research survey of August indicate that the reserves of lipids (liver) and proteins (muscle) are good (Figure 5). Since 1995, the indices of cod condition obtained from mobile gear operated offshore have been lower than, but exhibited the same general trend as, the corresponding indices for cod taken near the coast. In 1999, for a comparable period, the

two groups showed identical condition values in terms of both the snapshot of health and their energy reserves. This situation may point to more favourable environmental conditions for cod offshore.

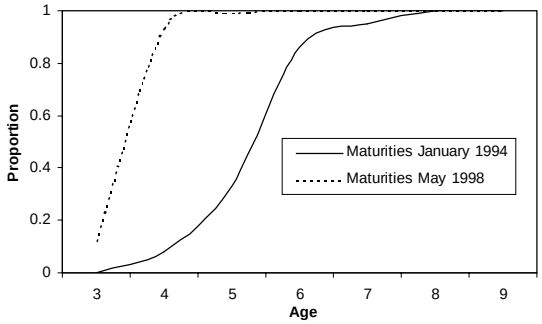

Figure 4. Proportion of mature cod in different age groups.

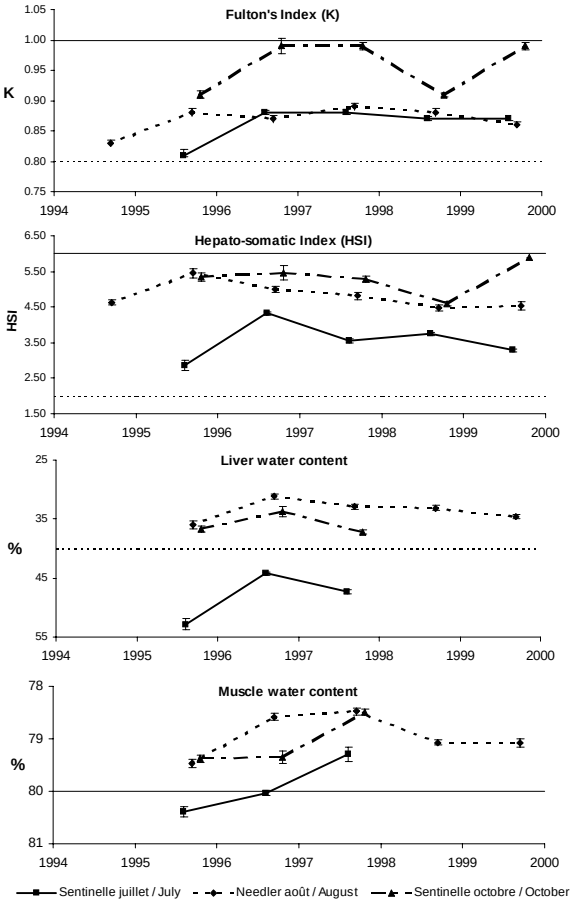

Figure 5. Condition of cod based on research surveys (August) and sentinel fishery surveys.

Research has been done on the consumption of cod by grey **seals** and harbour seals. Grey seals prey mainly on cod aged 2 to 5 and harbour seals on cod aged 1 to 3. The harbour seal population appears to have stabilized in recent years. The quantity of cod eaten by the two seal species stood between 10 000 t and 30 000 t in 1999 and consisted primarily of juveniles not recruited to the fishery.

Resource Status

Abundance Indices

Fixed Gear

The **catch rates for sentinel fisheries using gillnets** in 4R and 4S show little interannual change. This may be because of their narrow range of selectivity, which varies little from year to year and because the gillnets catch large individuals. The index provides a means of tracking the year-classes and so has been included in the analysis.

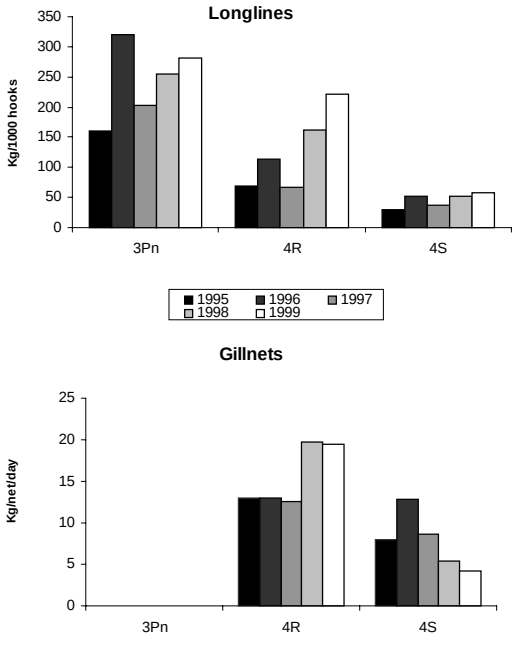

Figure 6. Catch rates for cod in the sentinel fisheries using fixed gear

The yields from gillnets in 4S fell for the fourth year in a row. In 1999, the cod may have moved to the northeastern part of 4R, since sentinel fishers using gillnets recorded good catch rates there.

The **catch rates for sentinel fisheries using longlines** have been on the rise since 1995 (although 1997 is an exception to this trend) with respect to both the gillnet and longline fisheries. The increased catch rates recorded in 1999 in the sentinel fisheries using longlines is due to harvesting of the 1993 year-class, which had reached the age of 6 years.

The **saturation rate** was computed for longlines and gillnets under the sentinel fisheries program from 1994 to 1998. In the case of longlines, saturation is defined by the maximum number of fish that can be caught relative to the number of hooks used in the water. The results show that some 80% of hauls had a saturation rate of less than 20%. For gillnets, about 80% of hauls showed fewer than 24 cod per net. This indicates that the catch rates for these two gear types are not biased by gear saturation. A review of the **soak time** of longlines and gillnets did not reveal any appreciable effect on catch rates. For the most part, soak time totalled 4 to 8 hours for longlines and 19 to 24 hours for gillnets.

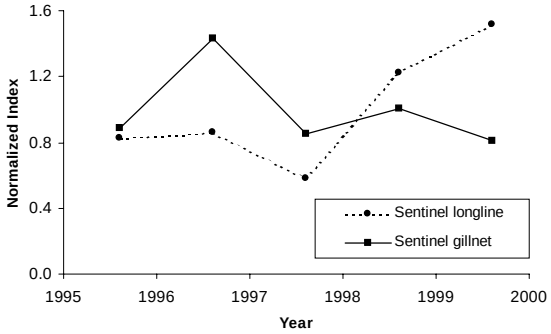

Figure 7. Cod abundance indices derived from fixed gear.

Trawl Surveys

The **mobile gear sentinel fishery** program began in 1994 in the northern Gulf of St Lawrence, but it was only from 1995 that this survey covered the entire stock, 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 standardized in 1997 by adding legs to maintain a constant trawl opening during the fishing operations.

The 1995-1999 data series suggests a slight upward trend in the cod stock's abundance during this period. The abundance indices derived from the October survey indicate a very slight increase 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 ***Alfred Needler*** (DFO) cruises, initiated in 1990, were initially aimed at assessing the shrimp and redfish populations in the Gulf. Certain adjustments were made later on 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 100 m and 37 m (50 to 20 fathoms).

The spatial coverage has varied over time, however. Subdivision 3Pn has been sampled systematically only since 1993, whereas the Strait of Belle Isle was sampled completely only in 1991 and 1992. This situation may cause biases in the annual abundance and age composition estimates for the cod catches. In view of this, we retained only the strata that were carefully sampled. This had an appreciable effect especially in 1991 (- 25% in number, -32% in biomass) and 1999 (-22% in number, -21% in biomass). The abundance index from the *Needler*

nevertheless suggests a slight uptrend since 1993.

The estimated abundance of the 1997 year-class (2 years old) derived from the 1999 *Needler* survey is the highest value in the 10-year data series. The estimates for two-year-old cod are highly variable. This year-class should contribute to the adult biomass in 2002. The surveys done by the sentinel fisheries and the *Needler* in 2000 should provide more details on its abundance.

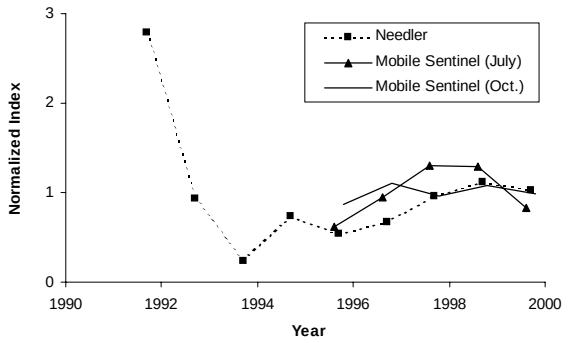

Figure 8. Cod abundance indices derived from research surveys.

Population Analysis

The sequential population analysis is calibrated by using 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.

A more in-depth review showed that the **catch rates of the index fisheries** (1990-1993) using longlines and gillnets were detrimental to the model fit (Figure 9). The two indices corresponding to these gear types did not track the trends in cod number. Since the years 1990 to 1993 are now part of the so-called converged portion, the population size values are not sensitive to the indices for this period. As a result, these two indices were excluded from the analysis.

The population size trend described by the ***Gadus*** survey (1978-1994) does not correspond to the population reconstructed through sequential analysis (Figure 9). It is likely that this survey did not measure population abundance appropriately owing to the increased cod migrations toward 3Ps as of the late 1980s. This situation is already well documented. Hence, this survey was eliminated from the analysis.

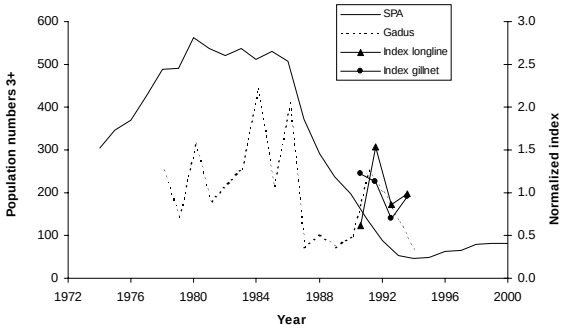

Figure 9. Estimates of the number of cod aged three and over derived from the Gadus survey, index fisheries using gillnets and longlines and sequential population analysis (SPA).

During a zonal meeting in winter of 1998, it was decided 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 to account for degrading of environmental conditions required by cod for its productivity, for increase wasteful fishing pratices and for growing predation on cod. Environmental conditions appear to have improved recently, as indicated by the improved 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 1986-1999 in order to take account of the combined effect of these factors.

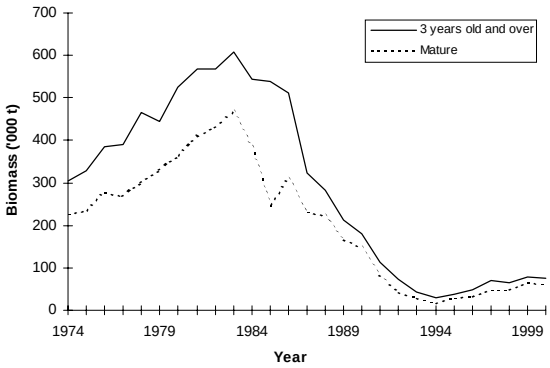

Figure 10. Estimates of the total biomass of individuals aged 3 and over and the biomass of mature individuals using sequential analysis of the cod population.

The results of the sequential population analysis (SPA) indicate that the **abundance** of fish aged three and over dropped from 537 million in 1983 to 47 million in 1994, and then rose to 80 million in 1999. In 2000, the adult **biomass** should be 62 000 t, which represents only 13% of the peak level observed in 1983. The adult biomass is believed to have reached a record low level in 1994, at 16 000 t. **Fishing mortality** for fully recruited cod was 26% (F=0.38) in 1999. 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.

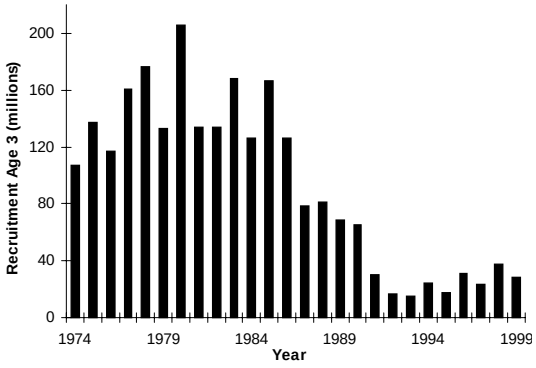

Figure 11. Estimates of the number of cod recruited at age 3.

Sources of Uncertainty

The estimated juvenile **survival** rates at age 3 derived from the SPA for 1993-1995 are considerably higher than the mean survival rate (1974 to 1993). Hence, the SPA generates a recruitment value that is disproportionately large compared to the adult biomass from which it must arise. This is in contradiction with total mortality of 46% (F = 0.38 and M=0.4). During this period, however, there has been some improvement in the condition of the cod and their environment, and this may partly explain the increase in juvenile survival at age 3.

The estimate of cod predation by **seals** is too imprecise to be incorporated into the assessment. It is based on means computed at spatio-temporal scales that are much too broad to be integrated with the SPA. Including this estimate generates even higher juvenile abundance figures, thus amplifying the disproportionate relationship with the adult biomass. In view of this lack of precision and the unrealistic results produced, it was decided not to formally include consumption at age in the analysis. Natural mortality was thus maintained at 20% (M=0.4) to take account of the additional mortality caused by seals.

The **catchability** estimated from the SPA for the sentinel fishery surveys of July and

September is greater than 1. Typically, the catchability estimated from stratified random trawl surveys of other stocks is less than 1. This high catchability may result from the high cod numbers estimated by the sentinel fisheries of July 1997 and 1998 and by the substantial influence that these numbers have on such a short data series (5 years).

Since 1995, sentinel fishers have **tagged** more than 35 000 cod; however, only 934 tagged cod have been recaptured by the fishery. This suggests that the exploitation rate is very low, and well below the rate of 26% (F = 0.38) estimated in the present assessment report. Two experiments on post-tagging survival were carried out in 1999 under the sentinel fishery programs, in fishing areas 4R and 4S. They indicated that the mortality rate associated with tagging is very low, or about 1%. The loss of tags, the small number of tag returns by fishers or emigration from the population might explain this discrepancy. In the FFAW's telephone survey of fishers, it was estimated that fishers returned 56% of the tags in their possession.

A **hydroacoustic** survey done in 4R (west coast of Newfoundland) in May 1998 estimated the spawning stock biomass at 16 800 t . This estimate is much lower than the estimate derived from SPA, which placed the spawning segment of the stock at 49 000 t in 1998. However, the telephone surveys conducted by the Lower North Shore fishers' association (RAPBCN) in 1999 indicated that more than 40% of fishers had observed cod in spawning condition in 4S. Moreover, the sentinel fisheries in 3Pn produced very good catch rates during May, suggesting the presence of mature cod outside the zone covered by the survey. Given that the hydroacoustic survey did not sample 4S and 3Pn, the biomass estimate must be considered as minimal.

Since the discontinuation of the *Gadus* survey, **maturity indices** have not been calculated annually. A major change in age at maturity has been noted since the mid-1980s. Regular sampling of cod during the spawning period (April - May) would provide key benefits in terms of tracking maturity, fecundity and condition. Sampling of this type conducted during a cruise would also permit the collection of hydroacoustic population estimates.

Despite the sources of uncertainty in this assessment, a number of indices 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 surveus. 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 generally agree with one another and indicate marginal increases in population size in recent years.

Outlook

The 1995 and 1996 year-classes are the largest that have been seen in this stock over the past decade; however, this recruitment remains well below the mean recruitment values of about 100 million that existed prior to the 1990s. These year-classes will be mature in 2000. Consequently, there is good potential for growth of the adult biomass in 2000. However, given the small stock size, landings of about 7 500 t (the TAC for 1999) would be equal to 25% of the harvestable biomass; this level of harvesting could prevent growth of the adult segment of the stock. A 10% target level for growth of the adult biomass would essentially require reinstituting the moratorium. By contrast, if catches are in

the order of 4 500 t, there would be no risk of the adult biomass decreasing in the year 2000. However, at this harvesting level, there would be zero probability of 10% growth in the adult biomass.

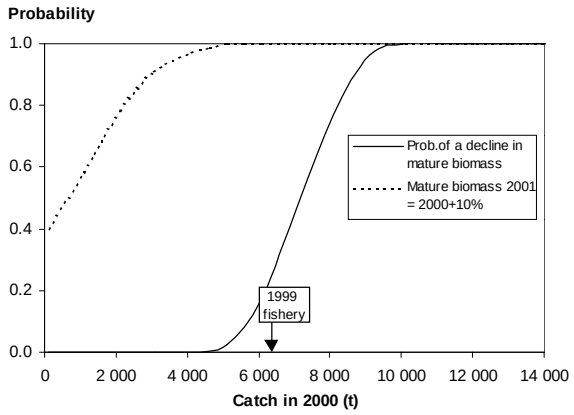

Figure 12. Probability of a decline and of a 10% increase in the adult cod biomass relative to various catch levels for 2000.

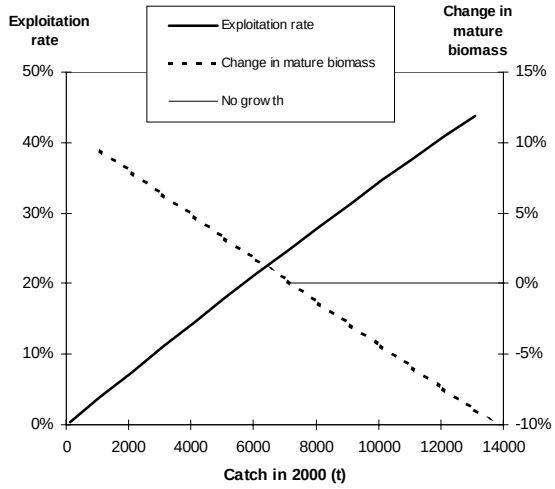

Figure 13. Exploitation rate and projected variation in adult cod biomass relative to various catch levels for 2000.

Management considerations

In spite of the FRCC recommendation to the contrary, the 1993 year-class was heavily fished with gillnets and longlines in 1999. The mesh size increase from 5½ inches to 6 inches planned for all gillnets in 2000 may step up harvesting of this year-class.

Based on this assessment, three-year-old cod are immature and not yet recruited, whereas they reach almost full maturity at four years of age. Gillnets and longlines have a selectivity that targets mainly fish aged six and older. This means that cod can spawn at age four and five before they become vulnerable to these fisheries.

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 14 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. Afterward, the biomass contracted and fishing effort was very high in 1993, just before the moratorium was imposed. Since then, fishing mortality has increased with the reopening of the fishery, but the spawning stock biomass has not grown substantially.

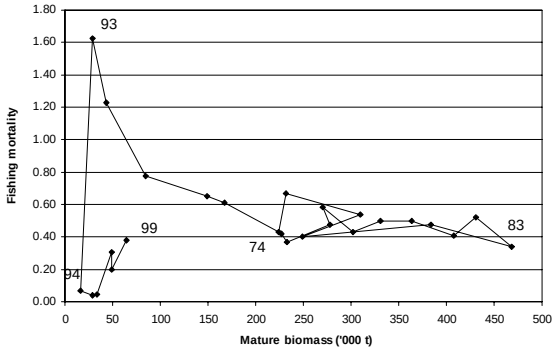

Figure 14. Precautionary approach for the cod stock.

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