



ASSESSMENT OF THE COD STOCK IN THE NORTHERN GULF OF ST. LAWRENCE (3Pn,4RS) IN 2008

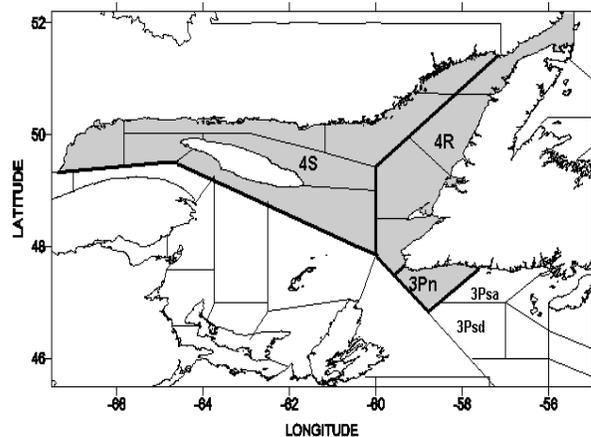
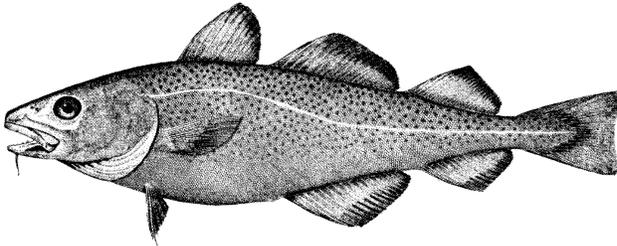


Figure 1. Cod stock management area in the Northern Gulf of St. Lawrence (3Pn,4RS). For reference, fishing areas 3Psa and 3Psd are also indicated.

Context

Landings during 1974 to 1993 were from a mixture of fixed and mobile gears by Canadian fleets, as well as from foreign fleets using mobile gear. Since the reopening of the fishery in 1997, all landings are from fixed gear fisheries (handlines, longlines and gillnets). The first TAC was introduced in 1977 and was set at 55,000 t. The fishery management followed the calendar year until 1998, after which the management year was May 15 of the current year to May 14 of the following year.

The assessment of the cod stock in the Northern Gulf (3Pn,4RS) (Figure 1) is conducted annually using commercial fishery data and abundance indices from sentinel fisheries and a DFO research survey. Resource status is primarily estimated using a population model, but results of tagging programs are also used to estimate exploitation rates. Stock projections are conducted and risk of decline in spawning stock biomass is examined for various catch levels. Advice is also provided in the context of the precautionary approach. The resource is managed mainly by annual TACs (total allowable catches) and a series of other management measures (closing areas during the spawning period, presence of observers, dockside monitoring, minimal size of catches, controlling by-catches, etc).

The present assessment is the result of a request for science advice from the Fisheries and Aquaculture Management Branch. The main objectives of the review were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

The current evaluation of the stock was conducted through a zonal assessment process where the status of 5 cod stocks in Atlantic Canada (2J3KL, 3Ps, 3Pn 4RS, 4TVn and 4X/5Y cod) was assessed. The meeting was held February 24 to March 6 2009 in St. John's (NL). Participants included DFO scientists, fisheries managers, officials from provincial governments, fishing industry members, external experts and academia.

SUMMARY

- The 2008/2009 total allowable catch (TAC) was 7,000 tonnes (t). Preliminary landings available as of January 2009 totalled 6,183 t.
- The recreational fishery landings in 2008 were estimated to be 67 t in 3Pn, 4R. There was no recreational catch estimate in 4S.
- Sentinel catch rates for both longlines and gillnets peaked in 2006. These indicators of biomass and abundance have declined over the past two years but remain above average.
- The DFO research vessel (RV) survey and the mobile gear sentinel survey abundance indices increased from 2007 to 2008 to about average values observed since the moratorium, but DFO survey indices were substantially below the values in the early 1990s.
- The DFO survey indicates that the abundance of age classes that support the fisheries have remained at about the same level since 2004, and slightly above the levels observed during the moratorium.
- DFO RV and sentinel survey estimates of fish at age 2 (2006 year-class) are the highest since the 1990s and this year-class appears widespread in 4R and 4S. However, it will not contribute to the fishery before 2011 and 2012.
- Growth, condition, and maturity-at-age and size declined in the late 1980s to reach their lowest levels in the early 1990s. Growth (of fish 6 years and younger) and condition have returned to levels observed in the 1980s.
- Surplus production was positive from 1974 to 1988 but has remained marginal thereafter. Current levels of total mortality and reproductive rates impede increase in population size.
- Majority of harvesters reported a decline in catch rates in 2007 and 2008, but they still feel the stock is in better condition than is indicated by the assessment.
- Total mortality of fish of age 4 and older remains high (54% annual).
- The exploitation rate estimated by the sequential population analysis (SPA) has increased since 2004 to reach 30% in 2008.
- Estimates of exploitation rates from tagging studies were 40% in 2007 and 21% in 2008.
- The limit reference point (LRP) for this stock has been recalculated, using new maturity data, as 140,000 t spawning stock biomass (SSB). The rationale is that, below this level, recruitment is substantially impaired.
- SSB is estimated at 32,000 t at the beginning of 2009, well below the LRP. To be consistent with the precautionary approach, management should have fishing mortality at the lowest possible level. This requires no directed fishery and measures to reduce by-catch of cod in other fisheries.
- Over the past decade, each time fishery catches exceeded 5,000 to 6,000 t, most indicators of total stock status suggested declines in mature biomass (spawning stock biomass). Hence, catches above that level do not seem sustainable at stock productivity over the past decade.
- If the management goal is to ensure continued growth in SSB then projections indicate that the catch should be less than 9,000 t in 2009. This catch implies an exploitation rate of 39% for fish of ages 7 and older, well above medium term sustainable levels.

- At status quo catch the SSB will increase by 10%. The catch at status quo fishing mortality is 7,000 t.
- With no fishery removals in 2009 and assuming current productivity and natural mortality (M), the spawning stock biomass would increase by 30% by 2010
- Fisheries in 2009 and beyond should be managed to protect the relatively strong 2006 year-class until those fish mature.

BACKGROUND

Species Biology

Northern Gulf of St. Lawrence cod (NAFO Divisions 3Pn and 4RS) undertake an extensive annual migration. In winter, they are found off southwestern (3Pn) and southern Newfoundland (3Ps) at depths of more than 366 m (200 fathoms). In April and May, they migrate towards the Port au Port Peninsula, on the west coast of Newfoundland (Division 4R), where spawning begins. During the summer, fish continue their migration and disperse in the coastal zones, along the West coast of Newfoundland (Division 4R) and towards Quebec's Middle and Lower North Shore (Division 4S). This migration to the coast is associated with warmer water and the presence of capelin (*Mallotus villosus*). Based on the results from numerous tagging experiments, this stock is generally isolated from adjacent stocks particularly the 4TVn, and the 2J,3KL stocks. There can be occasional mixing in the northwest part of the Gulf, (with 4TVn cod), in the Strait of Belle Isle, (with 2J,3KL cod), but mixing in the Burgeo Bank area (with 3Ps cod) is considered to occur every year during winter. A study determined that 75% of cod present on the Burgeo Bank (3Psa and 3Psd) in winter might come from the northern Gulf.

Growth, condition, size and age at sexual maturity decreased in the mid-1980s and in the early 1990s, periods when oceanographic conditions were unfavourably cold. These changes had a negative impact on fecundity and the reproductive rate of the population. In addition, the natural mortality rate (M) has increased. The reasons for this increase are unclear but appear, in some years, to be related to poor fish condition, particularly after spawning. Growth and reproductive characteristics improved after the mid-1990s to the levels of the early 1980s. However the mean length-at-age for older fish and age and size at maturity remained at lower levels than in the 1980s. Cod start maturing at age 4 and size at 50 % maturity is currently about 45 cm (age 5).

Ecosystem status

In the northern Gulf of St. Lawrence, 2008 was a cold year with water temperature in the cold intermediate layer similar to 2003. Zooplankton abundance in the Gulf was above average in 2007. The trends in the main species caught in the northern Gulf of St. Lawrence DFO research vessel (RV) survey during 1990 to 2008 indicate that turbot, halibut, and shrimp increased during the last 10 years and are currently at relatively high abundance levels. Redfish remains at low abundance following intensive fishing in the 1980s and early 1990s. Pelagic species (herring and capelin) abundance seems relatively healthy although their assessments are uncertain. Simulations using abundance data from RV surveys and diet data from various sources suggest that intensive fishing during the 1980s & early 1990s removed most of the large piscivorous fish trophic level (i.e., cod and redfish), which has left marine mammals as the dominant top predators in the northern Gulf during the 2000s.

Fishery

Cod landings in the northern Gulf of St. Lawrence exceeded 100,000 tonnes in 1983 (Figure 2). Landings declined continuously until 1993. During the decline, vessels using mobile gear generally caught their allocation, whereas those using fixed gear failed to do so. The fishery was under moratorium from 1994 to 1996. It reopened in 1997 and catches and TACs have varied between 3,000 to 7,500 tonnes since (Table 1), except in 2003 when the fishery was closed again. Currently, it is the only Atlantic coast cod stock where the directed fishery is only conducted with fixed gears (longlines, gillnets and hand lines). In 2002, a new management zone was established in 4R off St. George's Bay to protect the spawning stock. In this area, the groundfish fishery is prohibited between April 1st and June 15th.

The 2008 total directed cod fishery allocation was caught. The difference between the TAC and the landings in 2008 (Table 1) was due to non transferable allocations (sentinel, by-catch, recreational and France allocations). The recreational catch in 2008 (hand lines only) was estimated to be 67 t in 3Pn, 4R. There was no estimate of recreational catch for 4S but it is considered unlikely that the recreational 80 t allocation in 3Pn,4RS was exceeded.

Table 1. Cod landings and TACs (in thousands of tonnes) in divisions 3Pn,4RS

Year	1977-1993	1994-1996	1997	1998	1999-2002	2003	2004	2005	2006	2007	2008
TAC	70.4 ¹	0 ¹	6	3	7.1 ¹	0	3.5	5	6	7	7
Landings	70.2 ¹	0.3 ¹	4.8	3.3	6.8 ^{1,3}	0.4	3.3	4.5	5.7 ⁴	6.5	6.2 ^{2,5}

¹ Average

² Preliminary data

³ Includes landings from the recreational fishery, 253 t in 2001 and 34 t in 2002

⁴ Includes 75 t from the recreational fishery

⁵ Includes 67 t from the recreational fishery

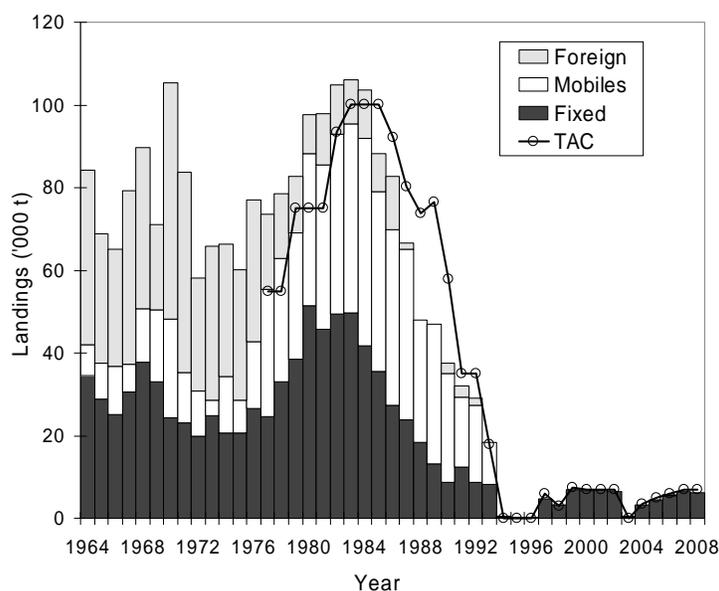


Figure 2. Annual landings and total allowable catches (TACs) for the management years.

Logbook data

Logbooks have been mandatory since 1997 for commercial fishing boats under 35 feet directing on cod in NAFO Divisions 3Pn and 4R, and for boats under 45 feet since 1999 in NAFO Division 4S. Those logbooks are analyzed to assess the performance of fixed gear commercial fleets. Landings from these fleets represent around 70 % of the annual landings in the cod directed fishery. For all area combined, gillnet and longline commercial catch rates were fairly stable until 2002. Catch rates have increased after the 2003 moratorium for both gear types, and the maximum value was observed in 2004 for gillnets and in 2006 for longlines. Those catch rates have decreased after 2006 and in 2008 they were comparable to values observed in the 1997 to 2002 period (Figure 3). The trends are quite similar in each NAFO Division and the decrease in catch rates from 2006 to 2008 has been observed in 3Pn, 4R, and 4S.

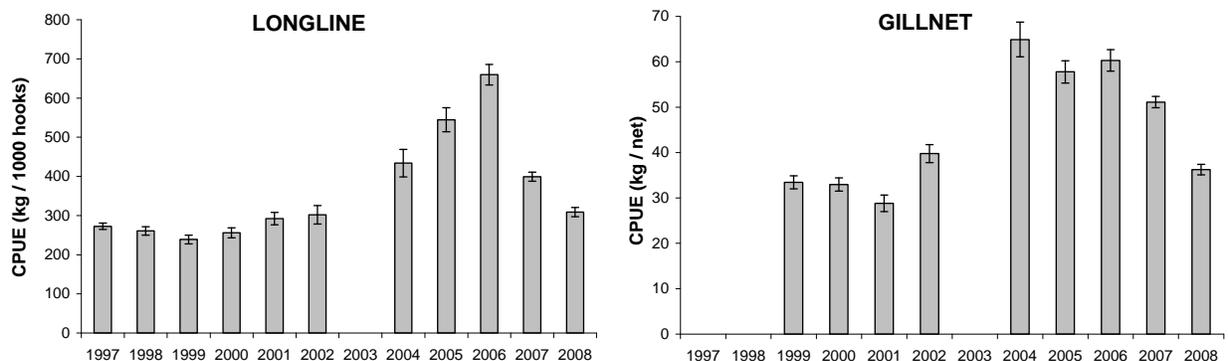


Figure 3. 3Pn,4RS cod commercial logbook catch per unit of effort (CPUE) for vessels less than 45 feet (1997-2008). Error bars are 95% confidence intervals.

ASSESSMENT

Sources of information

Stock status was updated using data from commercial landings and abundances indices based on fixed gears sentinel fishery (1995 to 2008), a sentinel otter trawl survey (1995 to 2008), and an annual DFO research vessel (RV) survey (1990 to 2008). Catch rate data from logbooks for vessels less than 35 feet in 3Pn,4R (1997 to 2008) and less than 45 feet in 4S (1999 to 2008) were also examined. Annual exploitation rates were estimated from tagging experiments conducted in different regions of 3Pn,4RS during 1997 to 2008.

Biological Data

Yearly estimates of maturity at age were re-calculated. The new maturity schedules represent a slight increase in the age at maturity and a corresponding decrease of about 7 to 10% in spawning stock biomass (SSB) for 1983 and 1984. Maturity ogives for 1985 onward remained largely unchanged from previous estimates.

A regression model describing the relation between size, condition and potential fecundity of northern Gulf cod was developed. This model was used to estimate the changes in fecundity

since 1984. Fecundity at size and age has dropped significantly between the early and mid 1990s. A gradual increase has occurred since the mid 1990s, and current levels are comparable to those in the mid 1980s.

Cod condition information from the sentinel fisheries program indicates an annual cycle. Condition is maximum in the fall and minimum in the spring. Energy reserves accumulated in late fall are critical for cod and must be sufficient for fish to survive winter and the spawning period in the spring. Seasonal condition cycle in 2008 is similar to the 1998 to 2007 average.

Stock trends

The sentinel fixed- and mobile-gear fishery programs were implemented in 1994 in order to monitor the abundance of the stock and develop a partnership between the industry and the Department of Fisheries and Oceans. The sentinel fisheries are conducted within a well defined protocol and provide indices of resource abundance and other data. All catches that are made within the framework of the sentinel fisheries are accounted for in the TAC.

Abundance indices based on catch rates from fixed gear sentinel fisheries

The fixed gear sentinel program provide abundance indices derived from gillnets and longlines. Catch per unit effort (CPUE) data are standardized to provide an index of annual trends of cod abundance since 1995.

The gillnet abundance index for 4R and 4S showed variations without much trend between 1995 and 2001 (Figure 4), it doubled from 2001 to 2003 with a maximum in 2006. The longline abundance index in 3Pn,4RS showed an increase between 1995 and 2001, followed by a decrease in 2002 and 2003. The longline index increased from 2004 to a maximum in 2006. Sentinel longline and gillnet abundance indices decreased from 2006 to 2008 but are still above average.

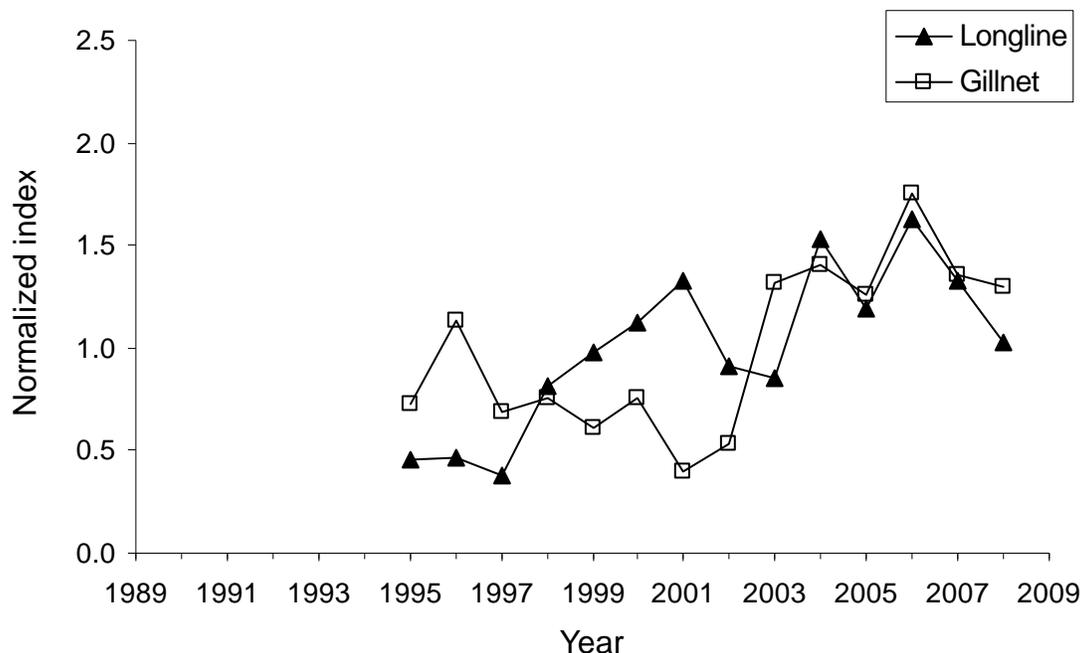


Figure 4. Standardized abundance indices from the fixed gear sentinel program.

Abundance index based on the July mobile sentinel survey

Nine trawlers participate in the July sentinel mobile survey. They use the same gear, a Star Balloon 300. A restrictor cable is used to maintain a constant and comparable trawl opening during fishing operations.

This survey follows a depth-stratified random sampling protocol similar to that used in the DFO RV survey. In July 2003, three new shallow strata with depths ranging between 10 to 20 fathoms were added in the 4R Division. The information from these additional strata has been included in this assessment. To do so, the survey index was divided into two periods. A 1995 to 2002 index based on the sampling of strata of 20 fathoms and more, and a 2003 to 2008 index including all strata i.e. 10 fathoms and more.

The normalized abundance index increased from 1995 to 2001 and then decreased in 2002 (Figure 5). The new abundance index including all strata varied little during 2003-2008.

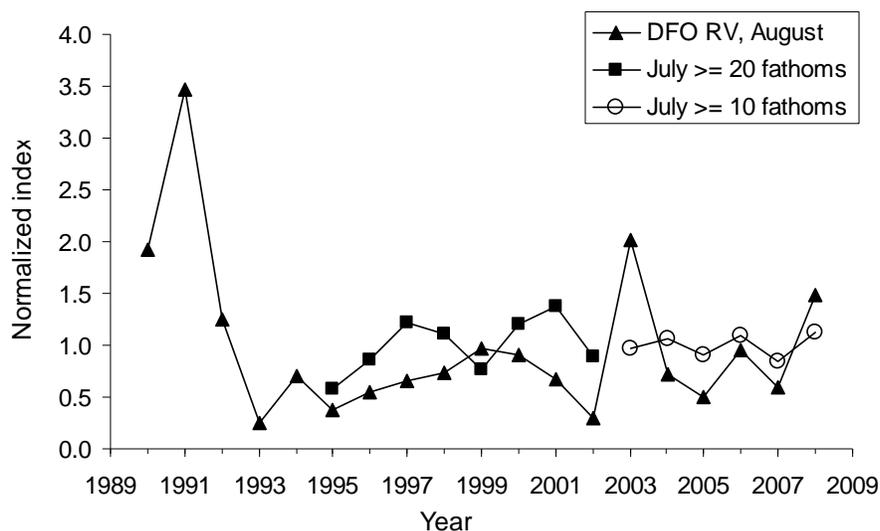


Figure 5. Standardized abundance indices for the August DFO RV and the July sentinel mobile surveys.

Abundance index based on the DFO RV survey

The DFO trawl survey began in 1990 on the CCGS *Alfred Needler*. Since 2004, this survey has been carried out on the CCGS *Teleost*. Inter-calibrations were conducted in 2004 and 2005 in order to account for changes in vessel, gear (URI trawl to Campelen trawl) and tow duration (from 24 to 15 minutes) (Bourdages et al. 2007). The CCGS *Teleost* survey is about 10 times more efficient at catching small cod and twice as efficient for larger cod than the CCGS *Alfred Needler* survey. To account for these differences, a conversion factor based on length is used to adjust historic catches from the CCGS *Alfred Needler* to make them comparable to those of the CCGS *Teleost* survey.

The results indicate a sharp decline in cod abundance during 1991 to 1993 followed by an increase until 1999. The timing of the increase corresponded to the period of the first moratorium during 1994 to 1996 (Figure 5). Abundance then fluctuated with little trend from 2001 to 2007. An abnormal low value occurred in 2002 and a high value occurred in 2003.

These year effects were seen for other species in the surveys. The index showed a substantial increase in cod abundance from 2007 to 2008. This increase is largely due to the presence of age 2 fish from the 2006 cohort (Figure 6). The proportion of age 2 fish increased from 17 % to 38 % of the total survey abundance from 2007 to 2008.

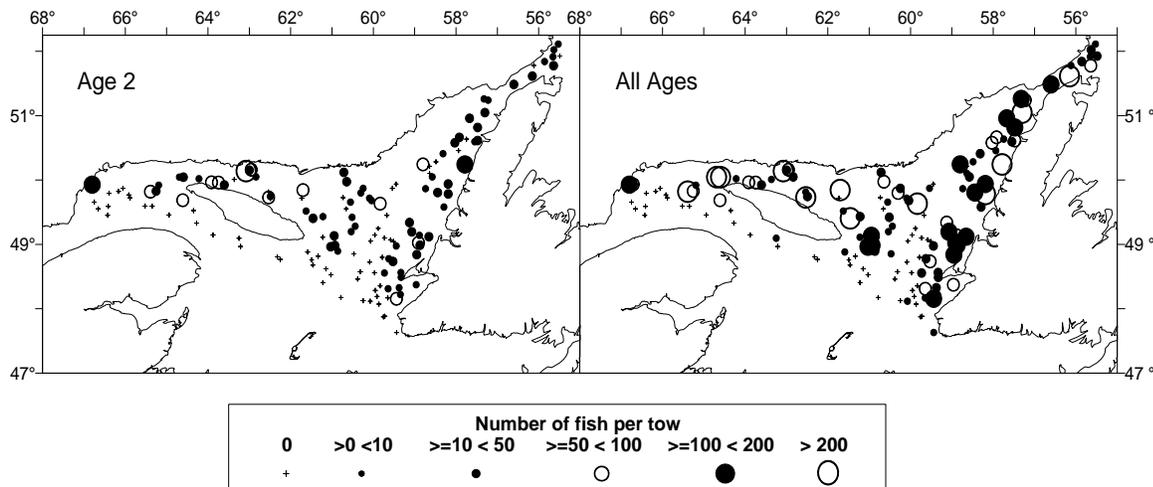


Figure 6. 2008 DFO RV survey distribution of cod (number per tow) of age 2, the 2006 cohort (left) and all age groups (right).

Current Status

The population model used in this assessment to integrate information on stock status was sequential population analysis (SPA).

Natural mortality (M)

As recommended at the 2007 workshop on natural mortality for both cod stocks in the Gulf of St. Lawrence (DFO, 2007), natural mortality values (M) were fixed for earlier period and estimated in the SPA for the recent time. Values of M for all ages were fixed to 0.2 prior to 1986 and to 0.4 from 1986 to 1996. They were estimated for two periods: 1997 to 2002 ($M = 0.20 \pm 0.033$ standard error) and 2003 to 2008 ($M = 0.28 \pm 0.024$ standard error).

Total population estimates

SPA provides estimates of population abundance by year and age taking into account natural mortality (M) and fishing mortality (F). The analysis is based on reported catches at age for the commercial fishery. It is calibrated using sentinel longline (ages 3 to 13) and gillnet (ages 4 to 13) indices, mobile gear sentinel indices (ages 2 to 11), and indices from the DFO RV survey (ages 2 to 11).

According to the SPA, total abundance (ages 3+) declined from 559 million in 1980 to 32 million in 1994, then slowly increasing to attain 43 million individuals in 2008. Abundance increased to 76 million in 2009. This is due to the strong 2006 year class at age 3 in 2009. This year class is poorly estimated as it was first observed at age 2 in both mobile-gear surveys conducted in 2008. Future surveys will improve its estimation. The number of spawners estimated from the

population numbers and maturity ogives decreased from 200 million in 1983 to 7 million in 1994. It has increased to 20 million individuals in 2009.

The exploitation rate of 7 to 9 year-old individuals, estimated by the population model, was high (around 30%) from 1999 to 2002. Exploitation rate was very low in 2003 due to the moratorium (Figure 7). The exploitation rate associated with the 2008 fishery totalling 6,200 tonnes was 30%.

Since 1995, the Sentinel Fisheries Program has tagged more than 76,000 cod. The program includes components aimed at assessing initial mortalities caused by tagging (with the use of traps); the loss of tags (by double tagging); and the tag reporting rate (by using high-reward tags and a telephone survey). So far, more than 5,000 tags have been recovered. The tagging program is independent from the population model; therefore, it is a useful and complementary method to estimate annual exploitation rates. Exploitation rate from both sources show similar trends until 2007 (Figure 7). The 2008 exploitation rate from tagging is preliminary and may change if additional tags are reported in 2009, as has occurred in the past.

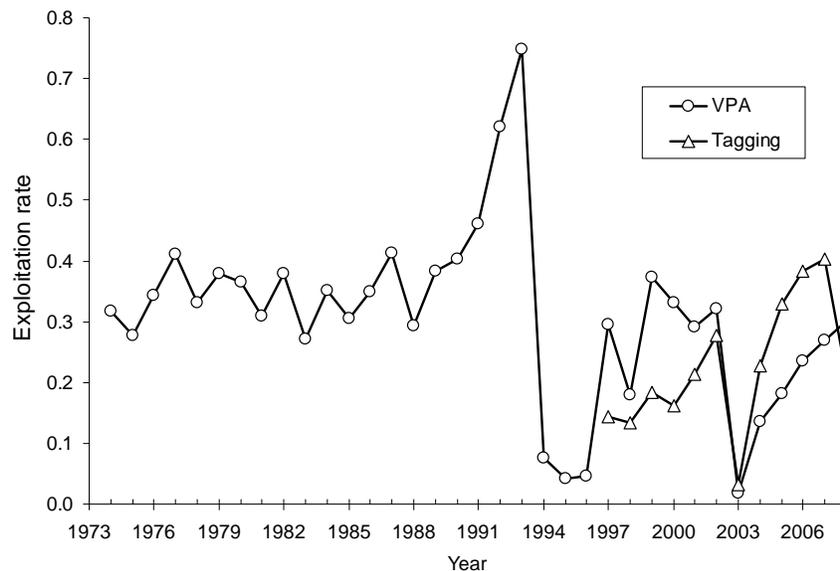


Figure 7. Exploitation rates of 7 to 9 year-old cod estimated by the population model and by tagging experiments for fish 40 to 80 cm long.

According to SPA, total biomass (ages 3-12) declined from 602,000 tonnes in 1983 to 22,000 tonnes in 1994. It increased to 46,000 tonnes at the beginning of 2006 (Figure 8).

SSB declined from 350,000 tonnes in 1983 to 8,000 tonnes in 1994 then increased to about 38,000 tonnes in 1999. SSB has fluctuated since and is estimated at 32,000 tonnes at the beginning of 2009.

The 2004 cohort was previously estimated to be relatively abundant at age 2 in 2006. However, subsequent estimates from surveys have resulted in a downward revision. This year-class is now estimated to be of similar abundance to the 1993 year-class (Figure 9). This age-class will contribute to the 2009 fishery at 5 years old.

The 2006 year-class at age 2 in 2008 also appears to be abundant but is poorly estimated. It is not expected to contribute to the 2009 fishery at age 3. Future surveys will improve this estimate.

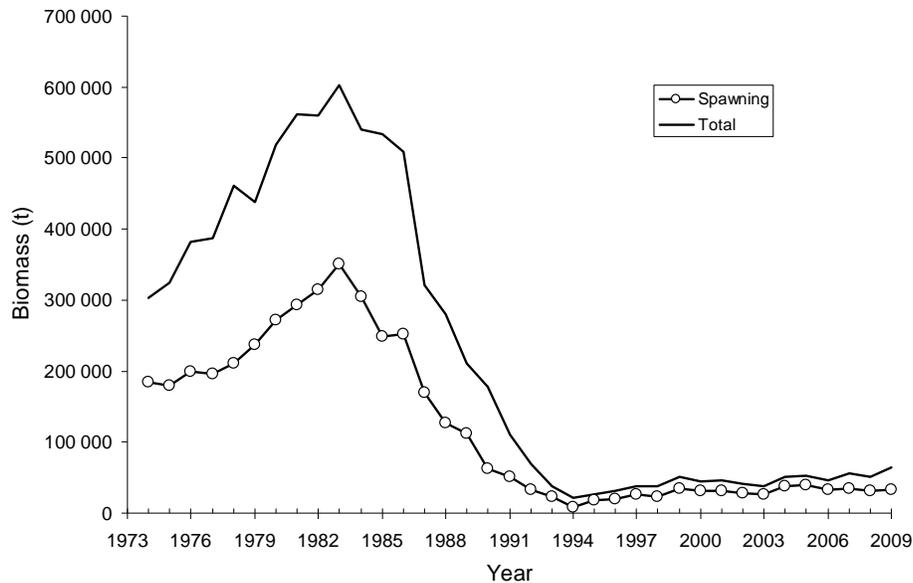


Figure 8. Estimated total (ages 3 and older) and mature biomass (spawning stock biomass).

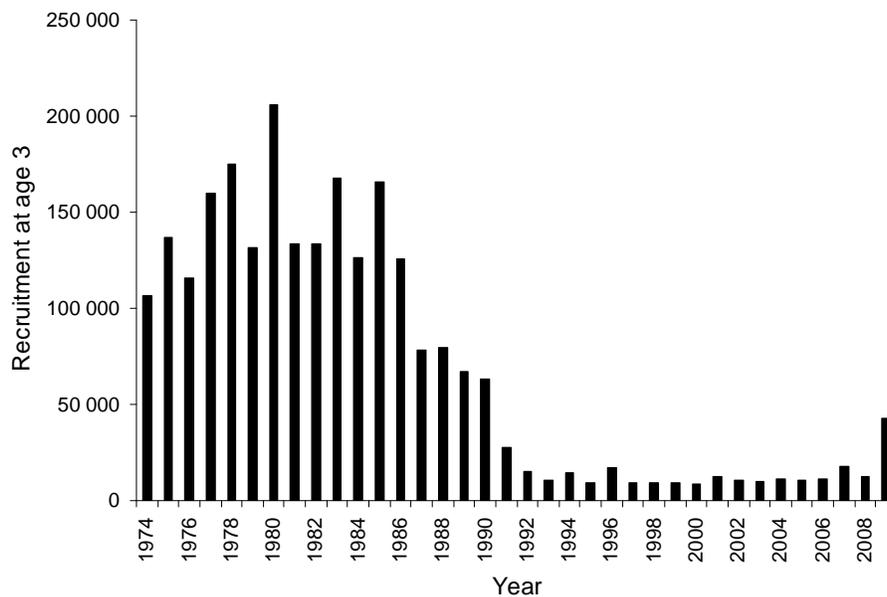


Figure 9. Estimated number of 3 year-old recruits.

Total production of eggs for the stock, the probability of survival between hatching and recruitment at age 3 and the potential population increase were estimated. Based on values of natural mortality from the population model, estimates of the rate of population growth (r) in the 1986 to 1995 period were either low or negative indicating that over that period the biomass of

the stock would have decreased even without fishing. In the recent period, maximum rate of population growth is estimated to be in the range of 5 to 15% per year without fishing. Taking account of fishing mortality, maximum rate of population growth fluctuated between -10% and 10% since 1998 with a negative trend in the years when fisheries were open after the 2003 moratorium.

Sources of Uncertainty

Northern Gulf cod are known to migrate to 3Ps in winter (Méthot *et al.* 2005). Since 1999, a portion of Burgeo Bank (3Psd, Figure 1) has been closed to the cod fishery from November 15th to April 15th to prevent northern Gulf cod from being captured during the winter fishery in the western part of 3Ps. This sector would correspond to a fraction of the mixing area between the 3Pn,4RS stock and the 3Ps stock. It is possible that historical estimates of catches from the stock may have been affected by this mixing and as such constitutes a source of uncertainty.

The use of the fixed gear sentinel fishery activities as an abundance index is based on the assumption that the resource's abundance is proportional to the catch rate. However, this assumption can be incorrect if the fishing gear becomes saturated, (i.e. if the gear reaches a catch level that doesn't allow for anymore catches). This aspect of fishing gear saturation is evaluated annually for the activities of the longline sentinel fishery program. Both catch rates and saturation have decreased in sentinel longlines from 2006 to 2008. In addition, these fixed gear sentinel surveys cover a small part of the stock area and are sensitive to changes in the spatial distribution of the stock. They may reflect local stock densities more than overall stock size.

ADDITIONAL STAKEHOLDER PERSPECTIVES

For the tenth consecutive year (no survey in 2004 due to the 2003 moratorium), the Lower North Shore Fishermen's Associations of Quebec and the Fish, Food, and Allied Workers Union of Newfoundland and Labrador have conducted telephone surveys of fixed gear cod license holders based on a random sampling design. These organizations are the sponsors of the 4S, and 4R, 3Pn, Sentinel Program since its inception in 1994. The 2008 survey collected information from 45 fish harvesters in 3Pn, 84 in 4R and 53 in 4S. The objective of the survey was to review various aspects of the fishery including biological information and abundance via trends in catch rates.

In comparison with the previous years, respondents in all three areas noted more smaller fish than anytime within the last decade. Respondents did not note any change in fish condition and as in recent years, their observations suggested that condition was very good. With respect to spring and summer migration, the majority of the respondents indicated minimal change in 2008 compared to 2007. However, in 2008 a higher percentage of 4R and 4S respondents noted an earlier migration out in the fall. There was little or no change in fishing depth from 2007.

Comparing 2007 to 2008, interviewed harvesters noted a decrease in catch rates for 4R and 4S, while 3Pn remained stable (Figure 10). In summary, catch rates are still considered very high by the respondents and the trend in catch rates both in terms of level and the extensive geographic area continue to indicate to harvesters that the abundance of this stock is much higher than what the current assessment indicates.

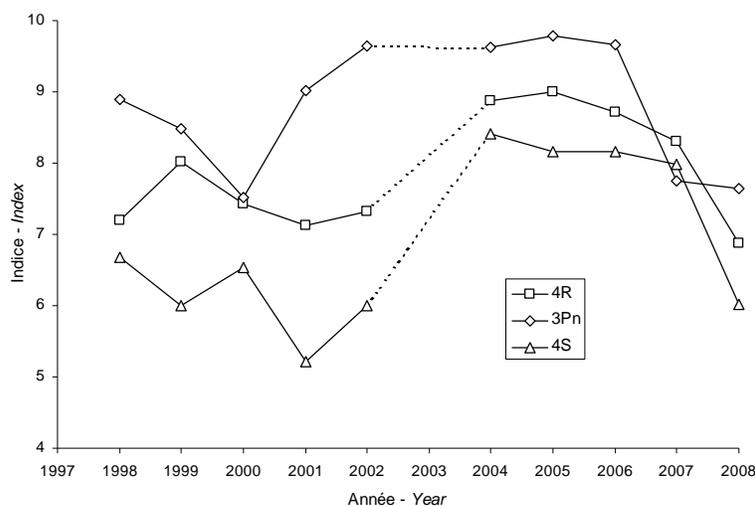


Figure 10. Performance index from a telephone survey with fixed gear fishermen.

CONCLUSIONS AND ADVICE

Using new maturity data, the limit reference point (LRP) for this stock has been recalculated. The new estimate is 140,000 t of spawning stock biomass (SSB), an estimate based on improved information that is ecologically comparable to and replaces the previous estimate of 100,000 t. Below this LRP, a stock is considered to have suffered serious harm because the probability of poor recruitment is high. Under the precautionary approach, when a stock is below this level, fishery management actions should promote stock growth, and removals by all human sources should be kept to the lowest possible level (DFO, 2006). SSB is estimated at 32,000 t, well below the LRP. If the stock is managed to be consistent with the Precautionary Approach, this would require no directed fishery and measures to reduce by-catch of cod in other fisheries.

Based on current productivity, the exploitation rates that have been observed in the period 2000 to 2008 have been too high (except for 2003 which was under moratorium) to allow for any rebuilding of this stock. At current productivity conditions, in order to reach an SSB of 100,000 t in 10 years a moratorium for all that period would be necessary.

Projections indicate that SSB is expected to decline if catches exceed 9,000 tonnes in 2009 (Figure 11). This catch implies an exploitation rate of 39% for fish age 7 and older, well above medium term sustainable levels. At the 2008 level of catch, SSB is expected to increase by 10%. The catch at status quo fishing mortality is 7,000 t. With no fishery removals in 2009 and assuming current productivity and natural mortality (M), SSB is expected to increase by 30%.

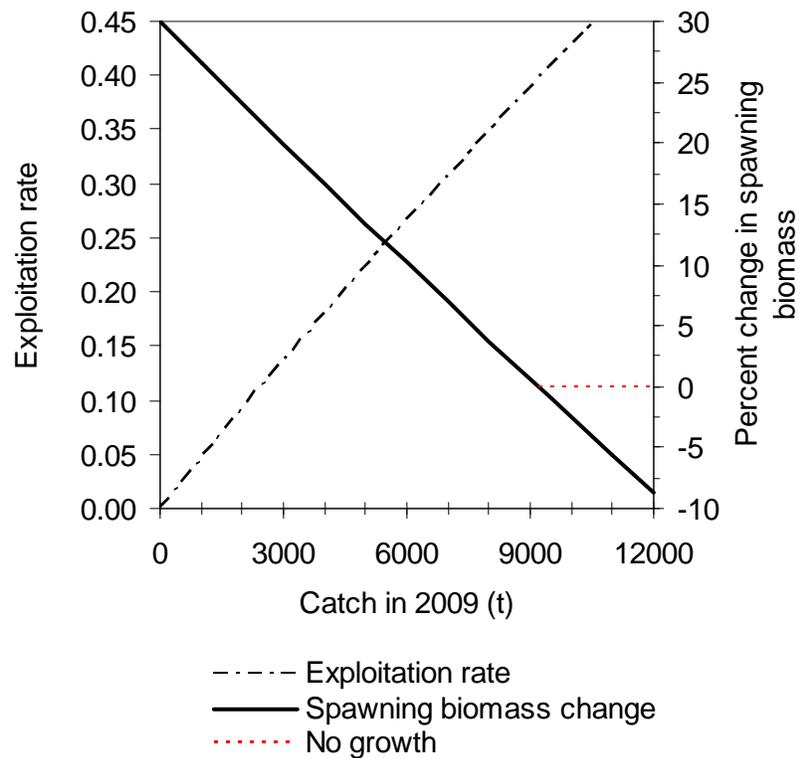


Figure 11. Projected mature biomass harvesting rate compared with various catch levels for 2009.

Landings since 1994 have affected the annual changes in SSB (Figure 12). Based on the SPA, SSB increased from 30 to 55% for each moratorium year (1995 to 1996 as well as 2003) for an average exploitation rate of 3%. Landings exceeding 5,500 tonnes between 1999 and 2002, and between 2006 and 2008 resulted in an average 8% drop in SSB with exploitation rates reaching 30%. This value was well above the old target exploitation rate $F_{0.1}$ which corresponds to an exploitation rate of 17%. Such exploitation levels are not sustainable at present productivity, and are inconsistent with a rebuilding strategy.

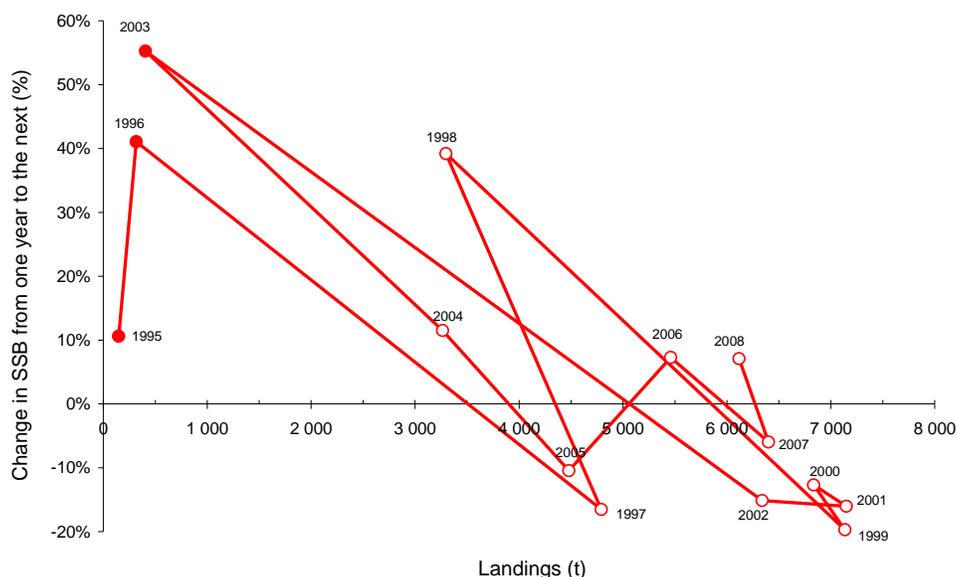


Figure 12. Relation between landings since 1995 and SSB growth. Full circles represent the moratorium years.

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