



ASSESSMENT OF THE NORTHERN GULF OF ST. LAWRENCE (3Pn, 4RS) COD STOCK IN 2011

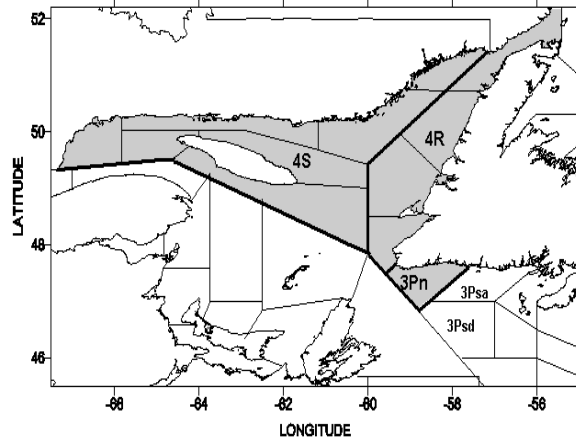
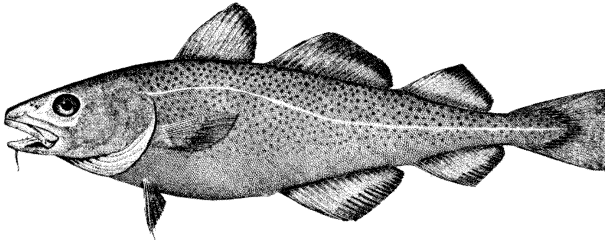


Figure 1. Cod stock management area in the Northern Gulf of St. Lawrence. For reference, fishing areas 3Psa and 3Psd are also indicated.

Context

Landings associated with this stock for the 1974-1993 period were from fixed and mobile gear fisheries carried out by Canadian fleets, as well as from foreign fleets using mobile gear. The first TAC was introduced in 1977 and was set at 55 000 t. Since the reopening of the fishery in 1997, following the first moratorium between 1994 and 1996, all landings have been from fixed gear fisheries (handlines, longlines and gillnets). 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 every two years using commercial fishery data and abundance indices from sentinel fisheries and a DFO research survey. Resource status is primarily estimated using a population model. The tagging program is an independent source of information also used to estimate exploitation rates. This Advisory Report takes into account the precautionary approach. The resource is managed mainly by annual TACs (total allowable catches) and a series of other management measures (number and types of gear, closing areas during the spawning period, presence of observers, dockside monitoring, minimal size of catches, monitoring by-catches, etc.).

This 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 provide scientific advice concerning conservation outcomes related to various fishery management options for the 2012–2013 and 2013–2014 fishing seasons.

SUMMARY

- The 2010–2011 total allowable catch (TAC) was 4 000 t and 3 567 t were landed. The 2011–2012, TAC was 2 000 t and 1 742 t were landed (preliminary). Recreational fishery landings are unknown.
- Commercial fishery performance estimated from longline fishermen logbooks shows a decrease from 2006 to 2010, followed by a slight increase in 2011. Gillnet fishermen performance decreased from 2004 to 2009, then increased in 2010 and 2011. A similar pattern was observed from the telephone survey.
- Sentinel fishery catch rates (longline and gillnet) peaked in 2006. They both dropped until 2010 and gillnet rates increased significantly in 2011.
- Catch rates from the DFO trawl survey have been low and have shown no trend since 1994. The sentinel trawl survey has shown no trend since it began in 1995. However, the 2011 value is the highest of the series.
- The natural mortality parameter estimated by sequential population analysis (SPA) has increased over the last 15 years. Possible causes are an increase in seal predation and an increase in unaccounted fishing mortality as a result of increased discards or recreational fishing.
- The exploitation rate estimated by the SPA for 7–9-year-old cod has increased since 2004 to reach 38% in 2008. It dropped to 9% in 2011. This is confirmed by tagging analysis that shows exploitation rates of 23% in 2006 and 5% in 2011.
- The proportion of fish older than 7 years of age has dropped by half since 2008. Estimates of the population's growth potential in the absence of fishing was 17% in the early 2000s, and has declined to 3% per year since 2008.
- The spawning stock abundance for 2012 and projected to 2014 is well below the limit reference point. The stock has remained in the critical zone for the last 23 years. Catches in recent years have not allowed the stock to grow and similar catches in 2012 and 2013 will prevent any growth.
- According to the precautionary approach, landings in 2012 and 2013 should be as low as possible, the directed commercial fishery and the recreational fishery should be prohibited and by-catches should not increase.

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. There can be occasional mixing in the northwest part of the Gulf (with 4TVn cod) and in the Strait of Belle Isle (with 2J,3KL cod). However, 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 (Figure 1).

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, reproductive and M characteristics improved after the mid-1990s to the levels of the early 1980s, but have again declined over the last five years. In addition, 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 DFO research survey in the northern Gulf of St. Lawrence indicates that, during the 1990–2008 period, turbot, halibut, and shrimp increased over 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 there are some uncertainties in their assessments. However, mackerel abundance has decreased. Simulations using abundance data from DFO research surveys and diet data from various sources suggest that intensive fishing during the 1980s and 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.

The extent of ice cover during the winters of 2010 and 2011 was among the lowest since 1969, which also contributed to the volume decline of the cold intermediate layer (CIL). Cod must cross the CIL in May to reach shallower waters and feed on capelin in July.

Fishery

Cod landings in the northern Gulf of St. Lawrence exceeded 100 000 tonnes in 1983 (Figure 2). Landings then 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 2 000 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 gear (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 1 and June 15.

The 2011 total cod directed fishery allocation was not caught. Catch data from the 2010 and 2011 recreational fishery are unknown.

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

Year	1997	1998	1999-2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
TAC	6	3	7.1 ¹	0	3.5	5	6	7	7	7	4	2
Landings	4.8	3.3	6.8 ^{1,3}	0.4	3.3	4.5	5.7 ⁴	6.5	6.2 ⁵	4.7 ^{2,6}	3.6 ^{2,6}	1.7 ^{2,6}

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

⁶ No data from the recreational fishery available

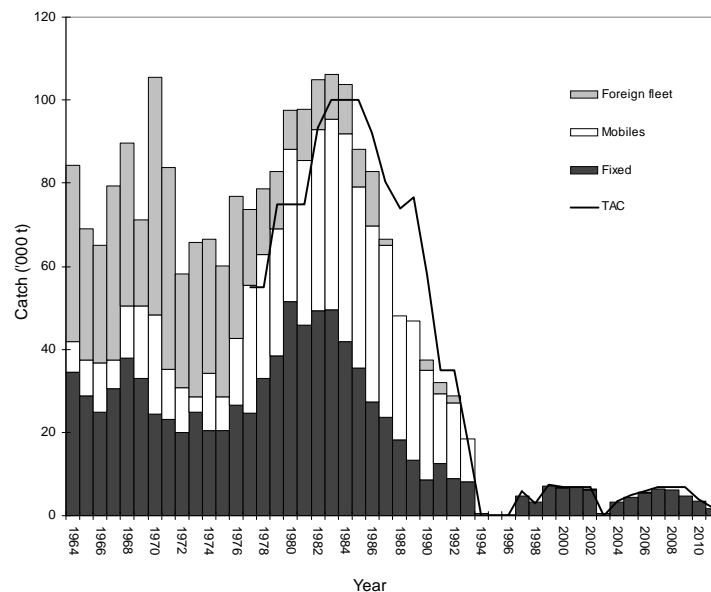


Figure 2. Annual landings and total allowable catches (TACs) for the management years.

Logbook data

Logbooks have been mandatory since 1997 for cod-directed commercial fishing boats under 35 feet in NAFO Divisions 3Pn and 4R, and for boats under 45 feet since 1999 in NAFO Division 4S. Logbook data 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 areas 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 (Figure 3). Catch rates decreased from 2004 to 2009 for both gear types since 2006. The 2011 values increased and are below the series average. The more noticeable increase for gillnets in 2011 was due to high catch rates in 4S.

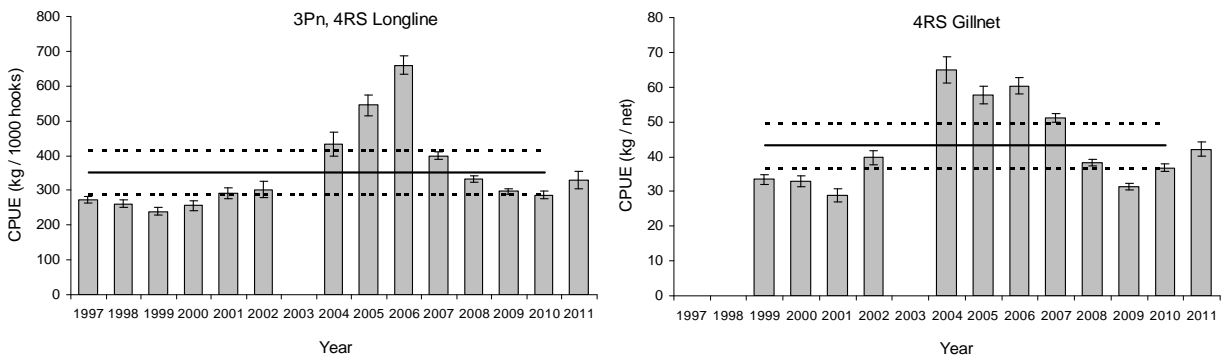


Figure 3. Logbook data from commercial fishing vessels of less than 45 feet (1997-2009). Catch per unit effort (CPUE) \pm 95% confidence interval. The solid line represents the series average (1997–2010) and the dotted lines \pm 1/2 standard deviation around the average.

ASSESSMENT

Sources of Information

Stock status was updated using data from commercial landings and abundance indices based on the fixed gear sentinel fishery program (1995 to 2011), a trawl survey conducted in the context of sentinel fisheries (1995 to 2011) and an annual DFO research survey (1990 to 2011). Catch rate data from vessels of less than 35 feet in 3Pn,4R (1997 to 2011) and less than 45 feet in 4S (1999 to 2011) were also examined. Annual exploitation rates were estimated from tagging experiments conducted in different regions of 3Pn,4RS between 1997 and 2011. Finally, a survey to estimate the reproductive potential (fecundity and maturity) has been conducted in April and May since 2002 (except 2003).

Biological Data

Maturity at age estimates have had a see-saw pattern since 2008. The 2011 survey was only partial due to several technical problems (number of vessels, number of stations, number of fish sampled). The proportion of mature fish at 4 years of age increased from 14% in 2010 to 49% in 2011, the highest value of the series (1974+).

Fecundity at size and age decreased between 1984 and 1994. A gradual increase in fecundity at age has been observed since 1994 and current levels are comparable to those in the mid-1980s.

The monitoring of cod condition conducted as part of the sentinel fisheries program shows 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. The seasonal condition cycle in 2011, expressed by the Fulton index, is similar to the 1998–2010 average.

Stock Trends

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

Abundance indices based on catch rates from fixed gear sentinel fisheries

The fixed gear sentinel fisheries program provides abundance indices derived from gillnets and longlines. Catch per unit effort (CPUE) data have represented an index of annual trends of cod abundance since 1995.

The longline abundance index in 3Pn,4RS (Figure 4) showed a general upward trend starting in 1997 and peaking in 2006. It then decreased until 2010 to a level below the series average. The index increased in 2011 to a level near the series average. The gillnet abundance index for 4R and 4S (Figure 4) varied at low levels between 1995 and 2002 and more than doubled in 2003 and peaked in 2006. It remained high and well above the average until 2008 and then decreased to a level below average in 2009 and 2010. This index shows a strong and significant increase in 2011. This increase is largely attributable to very high catch rates on the Lower North Shore, in the northeastern part of Division 4S.

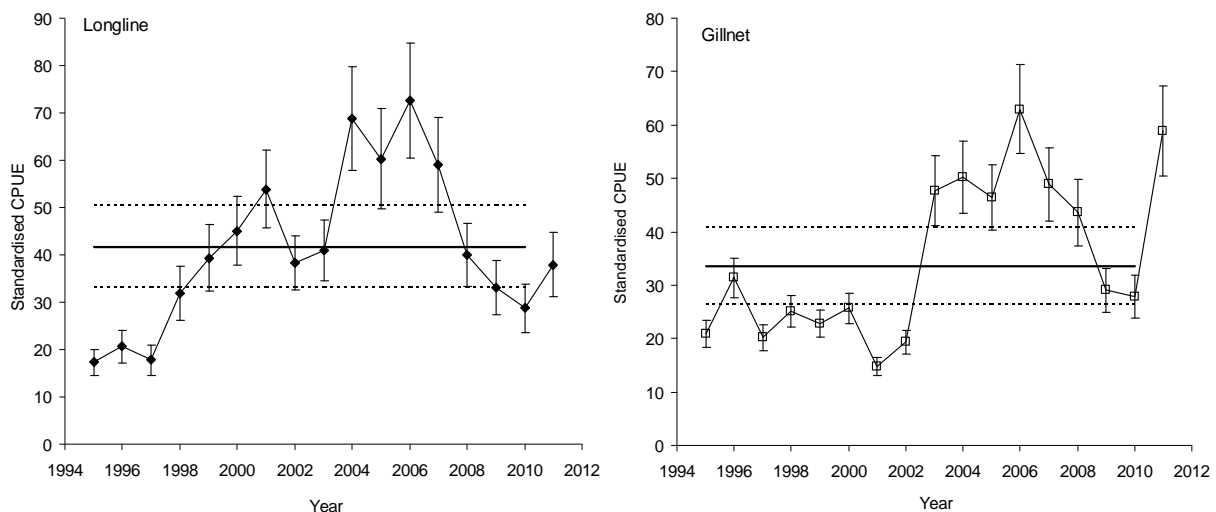


Figure 4. Catch rates from the fixed gear sentinel fisheries program. The solid line represents the series average (1995–2010) and the dotted lines $\pm \frac{1}{2}$ standard deviation around the average. The error bars indicate the 95% confidence interval.

Abundance index based on the July mobile gear sentinel fisheries survey

Nine trawlers participate in the July mobile gear sentinel fisheries survey and they all use a Star Balloon 300 trawl. A restrictor cable is used to maintain a constant and comparable trawl opening during fishing activities.

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

The July mobile gear sentinel fisheries survey index shows no trend between 1995 and 2011. The average number of cod per tow varied between 17 and 43 individuals (Figure 5). However, the mean number of cod per tow in 2011 is the highest in the series.

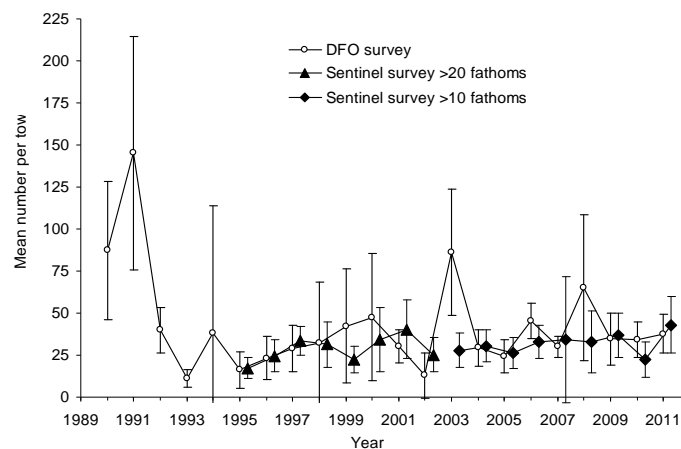


Figure 5. Mean number of cod per tow from the DFO research vessel annual surveys in August and from commercial vessels in the July mobile gear sentinel fisheries survey. The error bars indicate the 95% confidence interval.

Abundance index derived from the DFO research survey

The DFO trawl survey began in 1990 with the CCGS *Alfred Needler*. Since 2004, this survey has been carried out by 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* and make them comparable to those of the CCGS *Teleost*.

The DFO trawl survey (Figure 5) indicates a sharp decline in cod abundance between 1991 and 1993, followed by an increase until 2000. The increase corresponds to the period of the first moratorium (1994 to 1996). Abundance then fluctuated with little trend from 2001 to 2011. Two years showed abnormal values: a low value in 2002 and a high value in 2003. These annual effects were observed for other species in these surveys.

Current Status

A sequential population analysis (SPA) model was used to integrate all the information on the status of cod in the Northern Gulf of St. Lawrence.

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 set for the period prior to 1997 and estimated in the SPA for the recent period. The M values for all ages were set at 0.2 prior to 1986 and 0.4 for the 1986–1996 period. They were estimated for three periods: 1997 to 2001 ($M = 0.186 \pm 0.036$), 2002 to 2006 ($M = 0.308 \pm 0.025$) and 2007 to 2011 ($M = 0.404 \pm 0.039$).

Total population estimates

The sequential population analysis (SPA) provides estimates of population abundance per 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 based on indices from fixed gear sentinel fisheries in coastal waters, longline fisheries (ages 3 to 13) and gillnet fisheries (ages 4 to 13), mobile gear sentinel fisheries (ages 2 to 11), and from the DFO research survey (ages 2 to 11).

According to the SPA, the abundance of individuals ages 3+ declined from 559 million in 1980 to 31 million in 1994, then it slowly increased to 55 million individuals in 2009 and dropped to 41 million in 2012 (Figure 6). The number of spawners (mature) estimated from the population numbers and maturity ogives decreased from 200 million in 1983 to 7 million in 1994. It has increased to reach a projected value of 20 million individuals in 2012 (Figure 6).

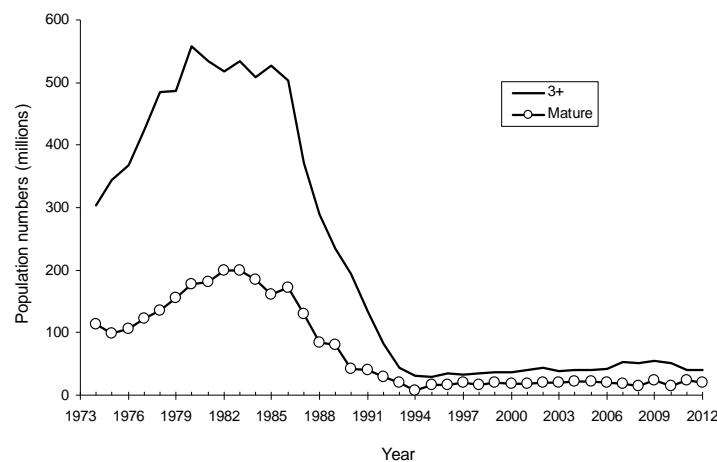


Figure 6. Estimated population numbers (ages 3+) and mature population.

The exploitation rate of 7–9-year-old individuals, estimated using the SPA, was high (around 36%) from 1999 to 2002. The exploitation rate was very low in 2003 due to the moratorium (Figure 7). The 2011 exploitation rate associated with a fishery totalling 1 742 tonnes was 9%.

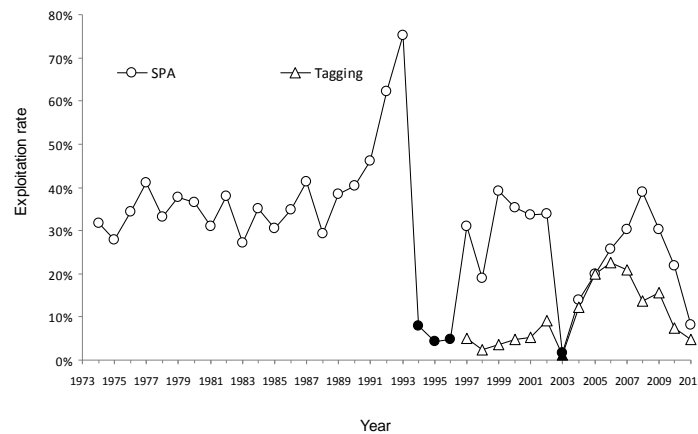


Figure 7. Exploitation rates of 7–9-year-old cod estimated by the sequential population analysis (SPA) and by tagging experiments for fish 40 to 80 cm long. Full circles represent the moratorium years.

Since 1995, the sentinel fisheries program has tagged 81 226 cod. One of the tagging program's major objectives is to estimate the exploitation rate independently of the sequential population analysis. To achieve this, initial mortality caused by tagging (with the use of traps); loss of tags (by double tagging); and the tag reporting rate (by using high-reward tags and a telephone survey) are included in the analysis.

To date, 6 799 tags have been recovered from fishermen. The exploitation rate has trended downward since 2006, reaching 7.4% in 2010 and 4.8% in 2011. These values are close to those estimated by the sequential population analysis (22.0% in 2010 and 9.2% in 2011). Analysis of tagging data therefore confirms the exploitation rate estimate by the sequential population analysis.

The 2004 and 2006 year-classes were the strongest of the last 21 years (Figure 8). The 2004 cohort will be 8 and 9 years of age in 2012 and 2013, whereas the 2006 cohort will be 6 and 7 in 2012 and 2013. These year-classes will all be exploitable in 2012 and 2013.

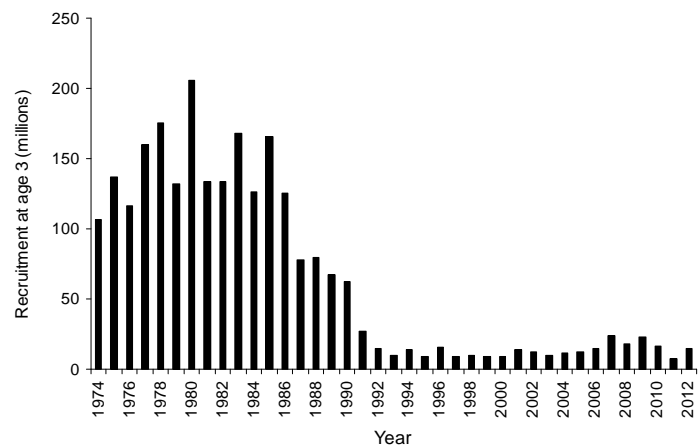


Figure 8. Estimated number of 3-year-old recruits.

The updated time series of the different life cycle characteristics of northern Gulf of St. Lawrence cod indicates a significant change in the stock's age structure. Fish older than 7 years of age now account for only 13 to 19% of adult fish older than 4 years of age. An apparent decrease in age at 50% maturity for females is associated with this lower proportion of older fish. The decrease in egg production per mature female and low recruitment would also negatively affect the stock's reproductive potential. In addition, the higher natural mortality rate observed in recent years has a significant impact on the population's potential growth rate. While the population's potential growth rate in the absence of fishing was estimated at about 17% annually in the early 2000s, it is now estimated at only 3% per year with a negative trend since 2008. Projections of this stock's dynamics over a 36-year period using a population model derived from life tables and age-specific reproduction indicate a very slow progression of the spawning biomass in the absence of fishing and a zero progression of the stock should the fishing mortality level increase or remain the same as observed in 2011. In all scenarios, the spawning biomass never reaches the limit reference point of 116 000 tonnes established for this stock.

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 15 to April 15 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 catch estimates from this stock may have been affected by this mixing and, as such, constitutes a source of uncertainty.

The use of **fixed gear sentinel fishery activities** to establish an abundance index is based on the assumption that the resource's abundance is proportional to the catch rates. 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 any more catches). This aspect of fishing gear saturation is evaluated annually as part of the longline sentinel fisheries program activities. Both catch rates and saturation decreased in the longline sentinel fisheries from 2006 to 2009 and increased slightly in 2010 and 2011. In addition, fixed gear sentinel fisheries program surveys cover only a small part of the stock's distribution area and could be sensitive to changes in the stock's spatial distribution. These surveys may reflect local stock densities more than overall stock size. Saturation leads to an underestimation of CPUE at high densities, thus an underestimation of a stock growth rate or a stock decline rate, as seen presently.

The reproductive potential survey shows a high variability in the assessment of cod **maturity**. Maturity at age estimates have had a see-saw pattern since 2008. The 2011 survey was only partial due to several technical problems (number of vessels, number of stations, number of fish sampled). Only 50% of planned stations were completed and the number of female cod evaluated for maturity (n=263) is the lowest since this survey was introduced. The proportion of mature fish at 4 years of age increased from 14% in 2010 to 49% in 2011, the highest value of the series (1974 +). In addition, should a different spatial distribution exist for immature cod compared to mature individuals, the survey which focuses off St. George's Bay where spawning occurs may overestimate maturity at age.

OTHER CONSIDERATIONS

For the thirteenth consecutive year (no survey in 2004 due to the 2003 moratorium), the Lower North Shore Fishermen's Association 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 have been the proponents of the 4S and 3Pn,4R sentinel fisheries since their inception in 1995. The objective of the survey is to review various aspects of the fishery including biological information and abundance via catch rates.

Respondents from all regions noted that sizes observed in 2011 were larger than in 2009 and 2010. In 2009 and 2010, there were more smaller fish (in catch percentage) compared to the last decade. Respondents did not note any change in fish condition and their observations have been extremely positive in recent years. With respect to spring/summer migration, the majority of the respondents indicated minimal change for the migration period in the time series.

Respondents from all regions have seen a significant increase in catch rates since 2009. Respondents indicate that yields in 4S are the highest of the series and respondents from 3Pn and 4R noted significant increases in 2011 compared to 2009 and 2010. Respondents are also encouraged by signs of recruitment, combined with higher catch rates recorded recently, suggesting that a TAC increase would allow for stock growth.

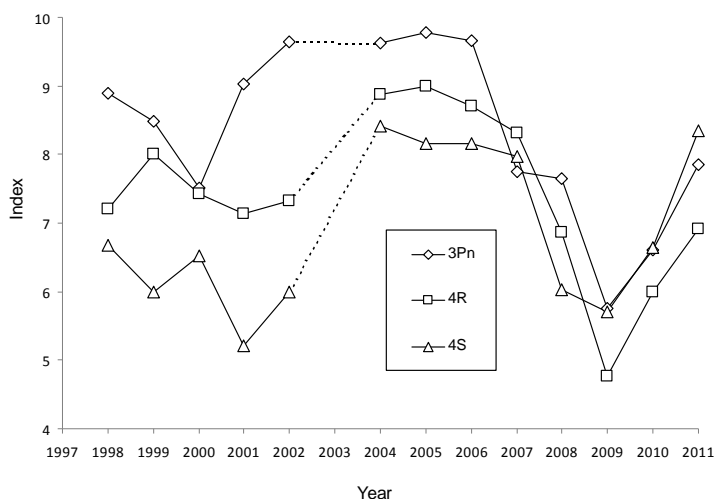


Figure 9. Performance index from a telephone survey with fixed gear fishermen.

CONCLUSIONS AND ADVICE

Given the stock's current productivity, the exploitation rates between 1997 and 2011 were too high (except for 2003 when the second moratorium was in effect) to allow for any significant rebuilding of this stock.

Natural mortality estimated by the SPA has increased over the last 15 years. Possible causes are an increase in seal predation and an increase in unaccounted fishing mortality as a result of increased discards or recreational fishing.

The exploitation rate estimated by the SPA has increased since 2004 to reach 38% in 2008, but it dropped to 9% in 2011. This is confirmed by tagging studies that show exploitation rates of 23% in 2006 and 5% in 2011. The spawning stock abundance for 2012 and projected to 2014 is well below the limit reference point. The stock has remained in the critical zone for the last 23 years.

In 2010, Laurentian North cod (NAFO Areas 3Pn, 4RS and 3Ps, Figure 1) was designated Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (compared with a less severe status of Threatened in 2003) due to the significant decline in abundance, mainly due to overfishing. DFO conducted a recovery potential assessment of Laurentian North cod in 2011 (DFO, 2011).

Maintaining the 2012 and 2013 catches at the same level as in 2011 would result in zero growth for this stock until 2014. To promote stock rebuilding, the 2012 and 2013 catches should be maintained at the lowest possible level. This implies closing commercial and recreational cod-directed fisheries and developing measures to stabilize or reduce cod by-catches in other fisheries.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 8 and 9, 2012 regional peer review meeting on the Assessment of the northern Gulf of St. Lawrence (3Pn, 4RS) Cod. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at: <http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm>

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