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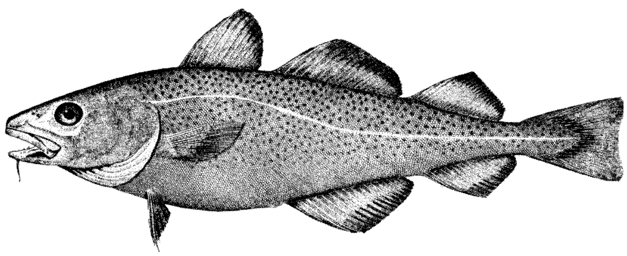
ASSESSMENT OF COD STOCK IN THE NORTHERN GULF OF ST. LAWRENCE (3Pn, 4RS) IN 2007



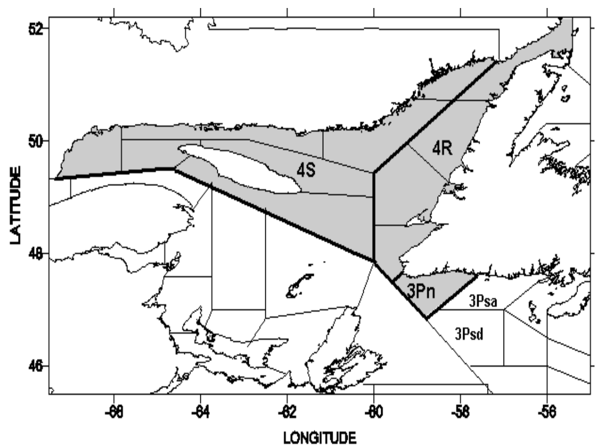


Figure 1. Cod stock management area in the Northern Gulf of St. Lawrence (3Pn, 4RS). For reference, fishing areas 3Psa and 3Psd are also indicated.

Context

The assessment of cod stock in the Northern Gulf (3Pn, 4RS) (Figure 1) is conducted annually based on commercial fishery data and on four abundance indices, three from sentinel fisheries and the other from the Department's research mission. Resource status is measured chiefly by a sequential population analysis model completed by risk analysis in the context of the precautionary approach but also based on results from a tagging program. Resource management is mainly done by imposing annual TACs (total allowable catches) and a series of other management measures (closing areas during the spawning period, presence of observers, minimal size of catches, controlling bycatches, etc).

SUMMARY

- The 2007 total admissible catches (TAC) were established at 7,000 tons. Preliminary landings available in January 2008 totalled 6,406 tons.

- Even though there was a recreational fishery in 2007, there is no available data.

- Sentinel fishery performance (longline and gillnet) peaked in 2006. However, the four abundance indices for this stock dropped from 2006 to 2007.

- Performance as well as geographic range observed by the commercial and sentinel fisheries suggest to fishermen that abundance and biomass are much more significant than what was estimated by this assessment.

- The results from the two sequential population analyses indicate that spawner abundance and biomass levels remained low and have not increased since 1997. The results from the sequential population analysis formulation, which estimated natural mortality (*M*), indicated that the spawning stock biomass would be 26,000 tons in 2008 compared to 37,000 tons for the formulation where *M* was set.

- A 7,000 ton fishery in 2008 would not cause any increase in spawning stock biomass based on the formulation accepted last year. According to the other model which estimates natural mortality, there would be no spawning stock biomass increase if catches exceed 5,000 tons in 2008. Without the fishery, the spawning stock biomass would increase by 22 or 20% respectively. Exploitation rates reached 21 to 28% in 2007 based on the model used; this will not enable the stock to recover.

- Estimates indicate that the spawning stock biomass is under the conservation limit.

- Based on the stock's spawning capacity, a reconstruction strategy would require a drop in catch levels for a recovery within the scale of the next decade.

BACKGROUND

The biological characteristics of Northern Gulf cod have varied over the years. Growth, condition, size and age at sexual maturity decreased in the mid-1980s and in the early 1990s, periods when cold oceanographic conditions were unfavourable. These changes had a negative impact on egg production because smaller fish, in poor condition at sexual maturity, produce fewer eggs. In addition, the natural mortality rate has increased, as fish in poor condition have lower chances to survive, particularly after spawning.

Cod growth increased during the second half of the 1990s. Weight and size at age of commercially harvested cod increased, and the observed values since 2000 are similar to those noted in the early 1980s, before the decline in abundance.

Every year, Northern Gulf of St. Lawrence cod (NAFO Divisions 3Pn and 4RS) undertake extensive migrations. In winter, they gather off southwestern and southern Newfoundland at depths of more than 400 m (200 fathoms). In April and May, they move towards the Port au Port Peninsula, on the west coast of Newfoundland (Division 4R), where spawning starts. In 2002, a new zone was established in 4R to protect the spawning stock. It is a sector where any groundfish capture is prohibited between April 1st and June 15. During the summer, fish continue their migration and disperse towards the coastal zones, along the West coast of Newfoundland (Division 4R) and towards Quebec's Middle and Lower North Shore (Division 4S). This migration towards the coasts is associated with warmer water and the presence of capelin (*Mallotus villosus*), the cod's main prey

Based on the results from many tagging experiments, this stock is generally isolated from adjacent stocks (those of Divisions 4TVn, 2J, 3KL and 3Ps). The stock can sometimes mix in the Northwest part of the Gulf, (with 4TVn cod), in the Strait of Belle Isle, (with 2J, 3KL cod), but especially in the Burgeo Bank area (with 3Ps cod). A study determined that 75% of cod present on the Burgeo Bank (3Psa and 3Psd) in winter might come from the Northern Gulf.

Description of the Fishery

Cod landings in the Northern Gulf of St. Lawrence totalled more than 100,000 tons in 1983 (Figure 2). They then regularly decreased until 1993. During the decline, boats using mobile gear usually caught their allocation, whereas those using fixed gear did not. The fishery was under moratorium from 1994 to 1996. Since 1997, catches and TACs have varied from 3,000 tons to 7,500 tons (Table 1), except in 2003 when the fishery was closed again. Currently, it is the only Atlantic coast stock where the directed fishery is only conducted with fixed gear (longlines, gillnets and hand lines).

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

Year	*1977-1993*	*1994-1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
TAC	*70.4*[1]	*0*[1]	*6*	*3*	*7.5*	*7*	*7*	*7*	*0*	*3.5*	*5*	*6*	*7*
Landings	*70.2*[1]	*0.3*[1]	*4.8*	*3.3*	*7.1*	*6.8*	*7.1*[3]	*6.3*[4]	*0.4*	*3.3*	*4.5*	*5.4*[5]	*6.4*[2]

[1] *Mean*
[2] *Preliminary data*
[3] *Includes 253 t from the recreational fishery*
[4] *Includes 34 t from the recreational fishery*
[5] *Includes 75.3 t from the recreational fishery*

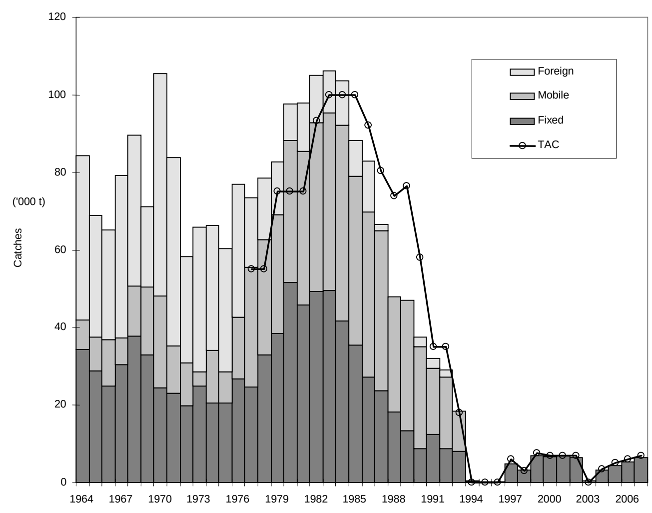


Figure 2. Landings and total allowable catches (TACs).

RESOURCE ASSESSMENT

Biological Data

The direct influence of the condition factor on cod fertility has helped develop a multiple regression model describing the relation between size, condition and potential fertility of northern Gulf cod. This model has helped estimate the changes in fertility for this cod stock since 1984. Fertility at size and age has dropped significantly between the early and mid 90s. A gradual increase has been observed since this period, and current levels are comparable to those in the mid 80s.

The assessment of cod condition conducted within the framework of the sentinel fisheries program demonstrates an annual cycle. This cycle shows significant seasonal variations, with a maximum in the fall and a minimum in the spring. Energy reserves accumulated in late fall are critical for cod and must be sufficient to survive winter and the spawning period in spring. In 2006, fall values (September to November) from the Fulton condition index and the hepato-somatic index were below the values from the eight previous years. However, the 2007 condition assessment did not show this condition decrease from September to November.

Sources and Trends

Logbooks have been mandatory since 1997 for commercial fishing boats under 35' directed on cod in areas 3Pn and 4R, and for boats under 45' since 1999 in area 4S. Gillnet and longline catch rates dropped in each area from 2006 to 2007.

The sentinel fisheries were implemented in 1994 in order to develop a partnership between the industry and the Department of Fisheries and Oceans (DFO). The sentinel fisheries are conducted within a well defined framework and provide among other things indices of resource abundance. 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

Fixed gear sentinel fisheries provide two abundance indices. The first index comes from the longline fishery, and the second from the gillnet fishery. The catch per unit effort (CPUE) data are standardized using a multiplicative model, which establishes an index that reflects annual trends regarding cod abundance since 1995.

The abundance index of gillnet sentinel fisheries in 4R and 4S revealed catch rate variations between 1995 and 2001 (Figure 3), but they more than doubled from 2001 to 2003, and reached a high in 2006. The abundance index of longline sentinel fisheries in 3Pn, 4RS showed a CPUE increase between 1995 and 2001, followed by a drop in 2002 and 2003. Longline CPUEs increased from 2004 to 2006, reaching a high in 2006. Longline and gillnet CPUEs dropped from 2006 to 2007.

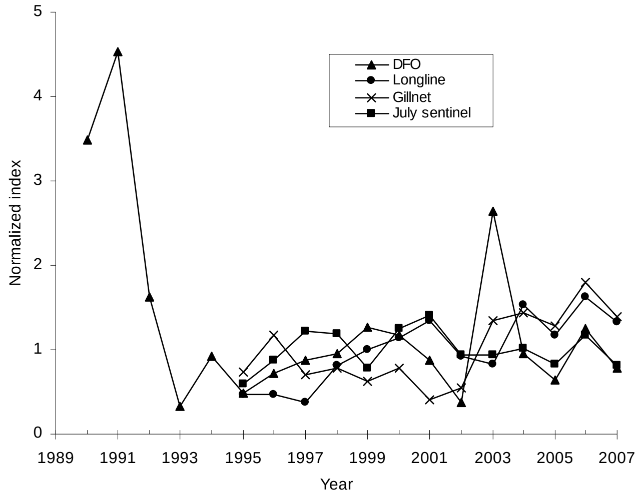


Figure 3. Standardized abundance indices.

Abundance index based on trawl survey catch rates from the sentinel fisheries

Nine trawlers participate in this survey using a stratified random sampling protocol similar to that used by DFO. The gears used were adjusted and standardized in 1997 with the adding of restrictor cables, which maintain a constant trawl opening during fishing operations. The series of July sentinel fishery surveys showed a gradual increase in stock abundance from 1995 to 2001. This abundance index then decreased from 2001 to 2002 and has remained stable from 2002 to 2005, before increasing in 2006 and dropping again in 2007 (Figure 3). All surveys indicate that most of the biomass is found in 4R.

Since July 2003, ten additional trawl tows have been carried out in three new shallow strata (10 to 20 fathoms). Many difficulties were encountered during these tows; unfavourable trawling locations and the presence of fixed gears. Many tows did not reach the targeted 30-minute duration. Given the inconsistency of these 10 tows, confidence intervals of the estimated value of minimal trawlable biomass were very high. Considering that these strata were only sampled five times, it is still too early to include them as an index for adjusting sequential population analysis.

Abundance index based on DFO trawl survey catch rates

The abundance index based on 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 have been done in 2004 and 2005 in order to account for changes in vessels (CCGS *Alfred Needler* and CCGS *Teleost*), gear (URI trawl to Campelen trawl) and tow duration (from 24 to 15 minutes) (Bourdages et al. 2007). The CCGS *Teleost* survey caught around ten times younger and smaller individuals and twice as many large and older individuals than the CCGS *Alfred Needler* survey. To account for these differences, a length conversion for the CCGS *Alfred Needler* historic catches was done in order to obtain a CCGS *Teleost* equivalent. These catchability changes do not affect the estimates for numbers, biomass or exploitation rates in the analytical models.

The DFO survey results indicate that cod abundance increased from 1993 to 1999. Abundance then fluctuated and the 2007 value can be compared to 2001 (Figure 3).

Tagging program from the fixed gear sentinel fisheries

Since 1995, the sentinel fisheries program has tagged more than 74,000 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); the tag return rate (by using high cost tags and by a telephone survey). So far, nearly 4,500 tags have been recovered. This program helps identify the main migration corridors and local stocks (Yvelin *et al*. 2005), but can also be used to assess the exploitation rates independently from the sequential population analysis.

Resource Status

Natural mortality (*M*)

As recommended during the 2007 workshop on natural mortality for the two cod stocks in the Gulf (DFO, 2007), a formulation was made for estimating natural mortality (*M*) in 2007 and 2008 using ADAPT. The first model uses fixed values for *M* (solid line in Figure 4), whereas model 2 estimates two values of *M*, the first for the 1997-2001 period and the second for the 2002-2007 period (two point estimates in Figure 4). Results showed an increase in natural mortality estimates for the more recent period, 2002-2007 (Figure 4). It was impossible to determine the best formulation for SPA and therefore the risk analysis presents both models.

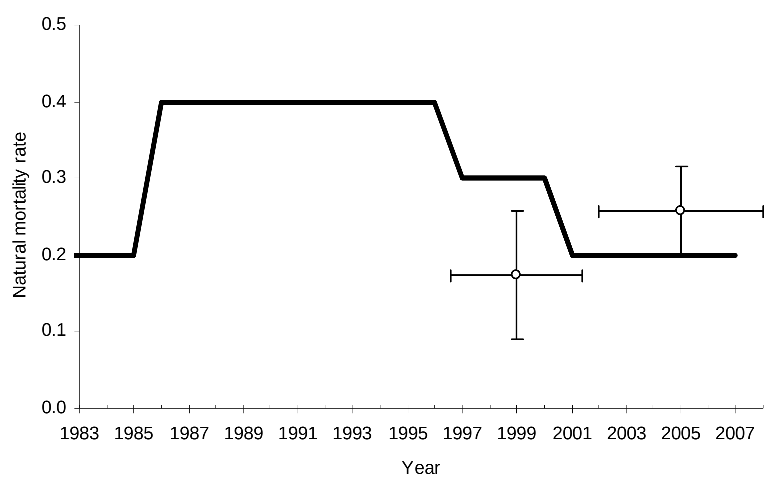


Figure 4: Natural mortality (M) estimates including fixed values and estimates, +/- two standard errors.

Total population estimates

Sequential population analysis (SPA) is an analytical model that provides population estimates per year class by taking into account natural mortality (*M*) and fishing mortality (*F*). The analysis is based on catches at age estimated from the commercial fishery. It is calibrated using indices from the fixed gear sentinel fisheries in coastal waters (longline and gillnet), from the mobile gear sentinel fisheries, and from the scientific survey conducted by DFO.

Stock abundance and biomass estimates as of January 1st, 2008 were based on 3+ year-old individuals, mean weight at age and maturity ogives (2005-2007).

SPA results with established *M* values indicate that the abundance of 3+ year-old individuals dropped from 559 millions in 1980 to 40 millions in 1994, before slowly increasing to 33 million individuals in 2003. The total population increased slightly to 43 million individuals in early 2008.

The proportion of spawners according to size or year-class is used to establish spawning stock biomass (SSB). The number of spawners decreased from 223 million in 1982 to 10 million in 1994. It reached 21 million individuals in 2008.

The exploitation rate of 7-10 year-old individuals calculated by SPA was high (around 30%) from 1999 to 2002; this value was very low in 2003 due to the moratorium (Figure 5). The exploitation rate associated with catches totalling 6,400 tons in 2007 was 21%.

Figure 5. Exploitation rate of 7-10 year-old cod.

Population numbers were converted to biomass using average weights-at-age calculated annually from commercial fishery. Total biomass for 3+ year-old fish declined from 603,000 tons in 1983 to 26,000 tons in 1994. It increased to 50,000 tons at the beginning of 2006 (Figure 6). Spawning stock biomass declined from 378,000 tons in 1983 to 11,000 tons in 1994, to reach 37,000 tons at the beginning of 2008.

The 2004 cohort estimated by the two mobile surveys (sentinel fisheries and DFO) at 2 years of age in 2006 appeared promising. However, because the four abundance indices decreased in 2007, estimates therefore dropped. It is now lower than the 1993 estimate (Figure 7). This age-class will not likely contribute to the 2008 fishery at 4 years old given the small size and selection pattern of the gillnets and longlines. It will probably start contributing to the fishery around 2010.

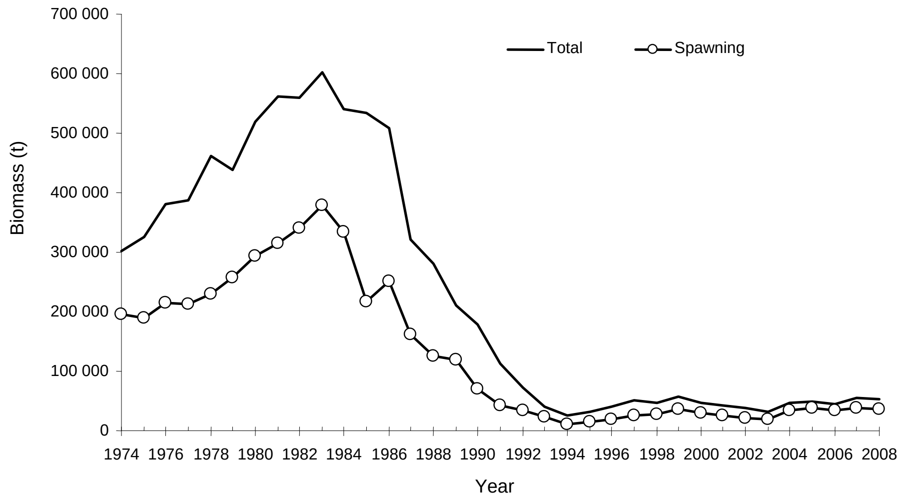


Figure 6. Estimated biomass of 3+ year-old individuals and biomass of mature individuals.

Numbers at age, the sex ratio, the proportion of mature females at age and fertility at age were used to calculate the total production of eggs for the stock, the probability of survival between hatching and recruitment at age 3 and the potential population increase. Based on natural mortality values used in the sequential population analysis, the maximum annual potential population increase would have dropped significantly between the mid 80s and 90s. The average reproductive characteristics observed since the end of the first moratorium (1997) favour maximum population increase rates between 9% and 12% per year without any fishing. However, the average mortality caused by the fishery since the end of the first moratorium did not yield any population increase. Maintaining the current fishery mortality rate would only provide maximum potential population increase rates between 0 and 5% per year.

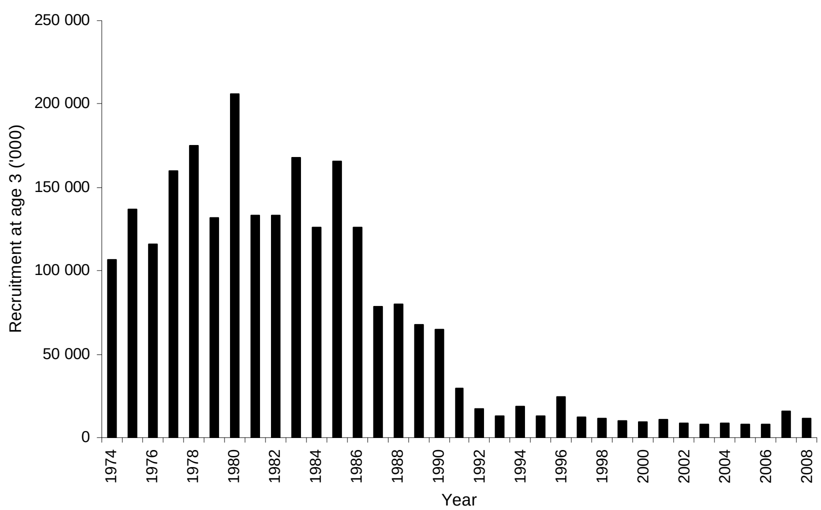


Figure 7. Estimated number of 3 year-old recruits.

Annual exploitation rate estimates from the tagging program

The tagging program helped evaluate the annual exploitation rates independently from those provided by the SPA. Results were generally slightly higher than those recorded by the SPA (Figure 5) but show the same trends (Figure 8). Two factors can explain these differences:

1) recaptures from 3Ps are included in mortality rate estimates and represent 10% of the total catches;
2) recaptures were significant in area 3Pn and show a higher exploitation than in 4R and 4S.

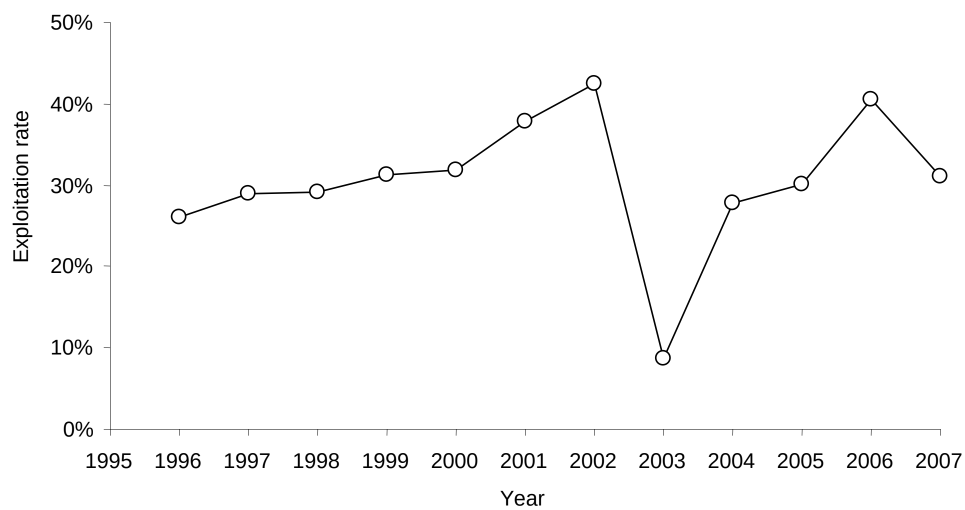


Figure 8: Annual exploitation rates according to the tagging program.

Sources of Uncertainty

The issue of winter migration of northern Gulf cod in 3Ps has been frequently discussed in the past. Since 1999, to prevent northern Gulf cod from being captured during the winter fishery in the western part of 3Ps, a portion of the Burgeo Bank (3Psd, Figure 1) has been closed to the cod fishery from November 15th to April 15th. This sector would correspond to a fraction of the mixing area between the 3Pn, 4RS stock and the 3Ps stock. Several research projects have been carried out over recent years in order to better describe the extent of the mixing (tagging, seasonal evolution of maturity and otolith microchemistry; counting fence) (Bérubé and Fréchet 2001; Méthot et al. 2005). A workshop on this issue took place in October 2000. The conclusion was that a significant portion of captured cod in winter in areas 3Psa and 3Psd came from the northern Gulf stock.

The use of the fixed gear sentinel fishery activities as an abundance index is based on the hypothesis that the resource's abundance is directly proportionate to the catch rate. However, there could be a bias if the fishing gear became saturated, i.e. if the gear reaches a catch level that doesn't allow for anymore catches regardless how abundant the resource is. Correspondingly, the probability that a fish will be caught drops and the catch rate is no longer proportionate to abundance. This aspect of fishing gear saturation is evaluated annually for the activities of the longline sentinel fishery program. With the increase of catch rates since the program's inception, the mean annual saturation level has risen from 6% in 1995 to 25% between 1995 and 2006. The CPUE drop for longlines in 2007 resulted in a saturation decrease to a level equal to 2003.

ADDITIONAL STAKEHOLDER PERSPECTIVES

For the eleventh consecutive year (no survey in 2004 due to moratorium in 2003) the *Regroupment of 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 3Pn, 4R Sentinel Program since its inception in 1994. The 2007 survey collected information from 40 fish harvesters in 3Pn, 71 in 4R and 61 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.

For comparison between 2007 and 2006 seasons, respondents noted that cod size (overall length) and condition was the same or had increased and was in recent years extremely positive. On the size, as a percentage of the catch the last two years have produced more very large (> 28 inches standard length, 83 cm fork length) than anytime in the past two decades. With respect to migration, the majority of the respondents indicated minimal change in migration time, however, in 2007 as per 2006, a higher percentage of 4R and 4S respondents noted an earlier migration in spring / early summer. With respect to fishing depth, fishers have generally maintained activity on the same grounds, however, in 2007 a higher percentage of 4R and 4S respondents noted fishing in much shallower waters during the traditional summer period while 3Pn respondents reported fishing in relatively deeper waters during the traditional autumn period versus 2006.

With respect to catch rates, 2007 noted a slight decline for 3Pn while the trends for 4R and 4S were still increasing (Figure 9). The absolute value for all three zones has declined in 2007. In summary, catch rates are still very high and the positive trend in catch rates both in terms of level and the extensive geographic area observed continue to indicate to harvesters that the abundance of this stock is much higher than what the current assessment indicates.

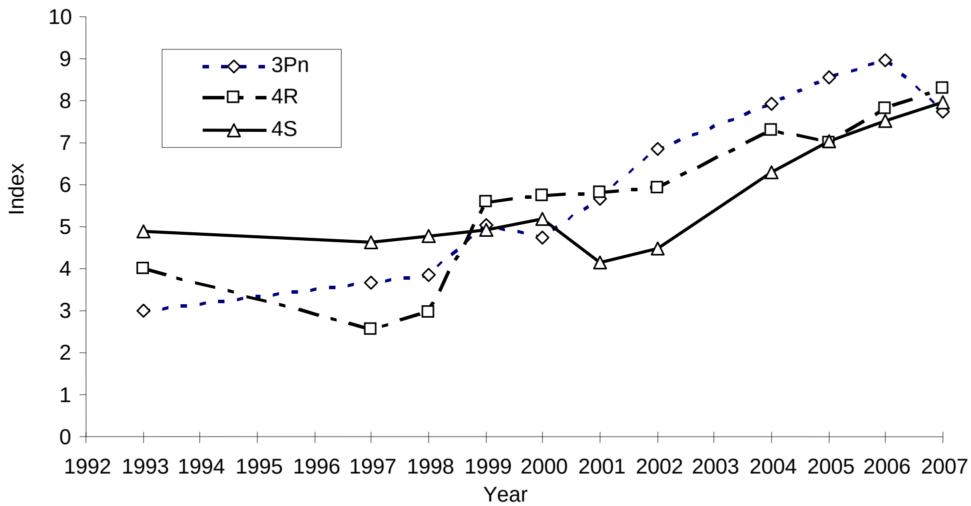


Figure 9. Performance index from a survey with fixed gear fishermen.

CONCLUSIONS AND ADVICE

Based on current productivity, the pressure exercised by the fishery between 2000 and 2007 was too high (except for 2003 which was under moratorium) to allow for this stock to rebuild.

The risk analysis from the formulation that estimates *M* indicates that the spawning stock biomass would have 50% probability of dropping for catches over 5,000 tons (Figures 10 and 11). With regards to the retained formulation that establishes the *M*, except for the 2004 year-class, the year-classes produced since 1990 are less abundant than average over the medium and long term. The current small size of the stock combined with weak recruitment would mean that catches exceeding 7,000 tons in 2008 would lead to a drop in spawning stock biomass (Figure 10). A 20% increase target for mature biomass would require a moratorium (Figure 11).

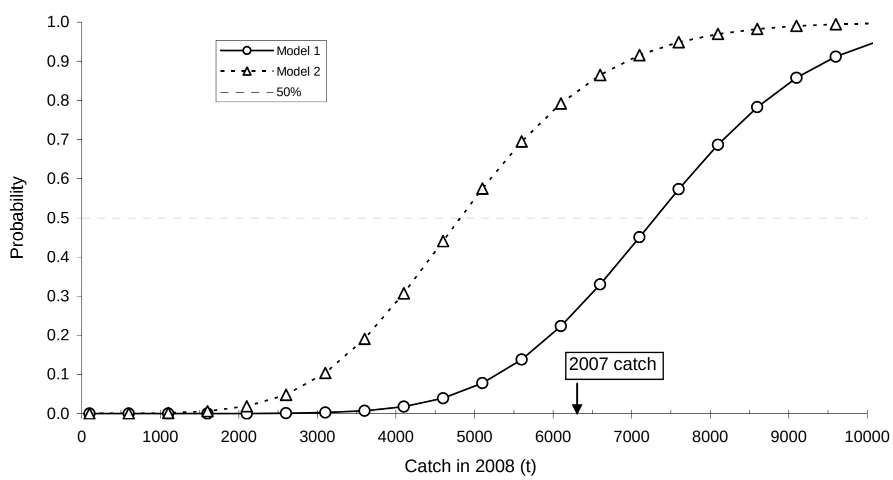


Figure 10. Mature biomass decline probability according to different catch levels for 2008.

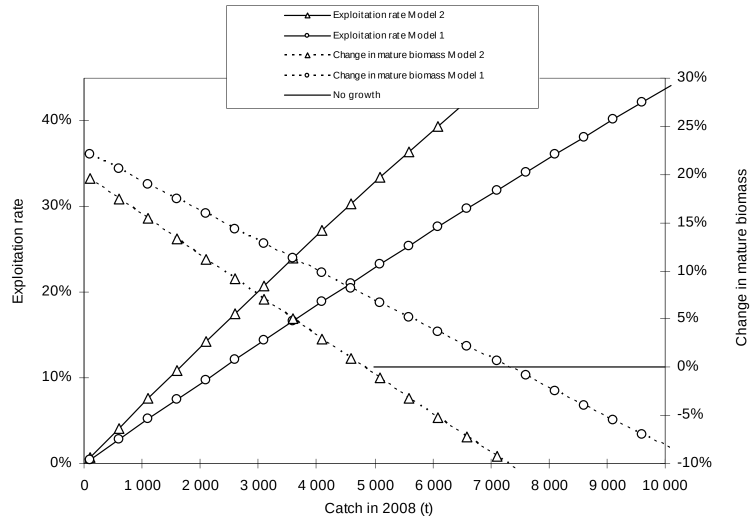


Figure 11. Projected mature biomass harvesting rate compared with various catch rates for 2008.

In order to reach a spawning stock biomass of 100,000 t in 10 years at current productivity conditions a reduction in fishing mortality of 50% would be necessary.

Spawning stock biomass is estimated to be below the conservation limit. When a stock is in such a situation, it is highly likely that its productivity has already been seriously reduced. The conservation limit for this stock is between 85 to 110 thousand tons of spawning stock biomass. The 2008 spawning stock biomass is well below this level.

Landings since 1994 have affected the annual changes in mature biomass (Figure 12). Based on the SPA, mature biomass increased from 30 to 65% for each moratorium year (1994 to 1996 as well as 2003) for an average exploitation rate of 3%. Landings exceeding 5,500 tons recorded between 1999 and 2002 and in 2007 resulted in a 16% drop of mature biomass for exploitation rates reaching 29%, which was well under the old target exploitation rate $F_{0.1}$ which was around 17%. Such exploitation levels are inconsistent with a rebuilding strategy.

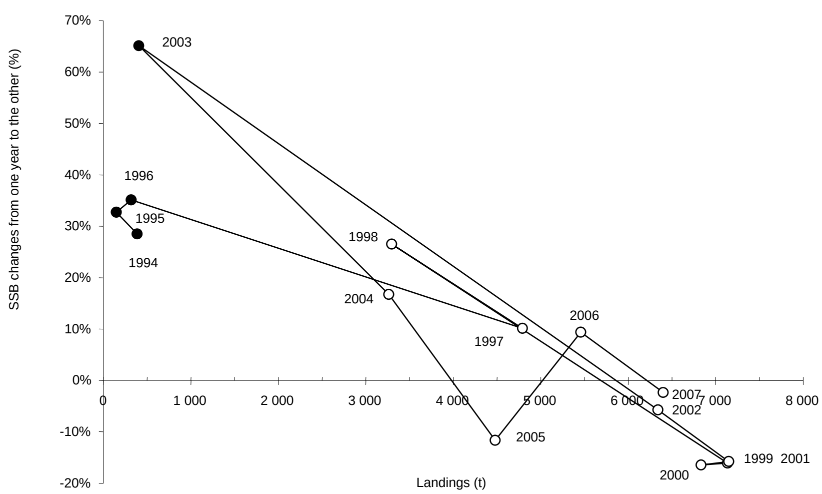


Figure 12. Relation between landings since 1994 and the recovery of cod stocks. Solid circles represent the four moratorium years.

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FOR MORE INFORMATION

Contact : Alain Fréchet
Maurice Lamontagne Institute
850, route de la Mer
P.O. Box 1000
Mont-Joli (Quebec)
G5H 3Z4
Tel: (418) 775-0628
Fax: (418) 775-0679
E-Mail: Alain.Frechet@dfo-mpo.gc.ca
Internet address: http://www.osl.gc.ca/pse/fr/

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Center for Science Advice (CSA)
Quebec Region
Fisheries and Oceans Canada
Maurice Lamontagne Institute
P.O. Box 1000, Mont-Joli
Quebec (Canada)
G5H 3Z4

Telephone: (418) 775-0825
Fax: (418) 775-0679
E-Mail: Bras@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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