



ASSESSMENT OF COD STOCK IN THE NORTHERN GULF OF ST. LAWRENCE (3PN, 4RS) IN 2006

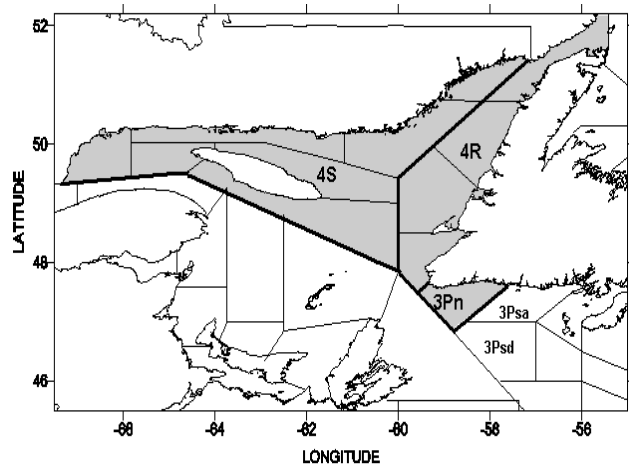
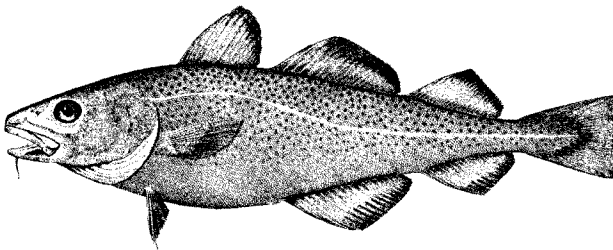


Figure 1. Cod stock management area in the Northern Gulf of St. Lawrence. For reference, fishing areas 3Psa and 3Psd are also indicated.

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 by a sequential population analysis model completed by risk analysis in the context of the precautionary approach. 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.). A new process for setting TACs is being developed in collaboration with the industry.

SUMMARY

- The 2006 total admissible catches (TAC) was established at 6,000 tons. Preliminary catches available in January 2007 totalled 5,459 tons.
- The four abundance indices for this stock increased at the same rate from 2005 to 2006. Catch rates from the sentinel fisheries (longline and gillnet) are the series' highest (1995-2006).

- Catch rates as well as the geographical 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.
- Significant migrations of northern Gulf cod (3Pn, 4RS) in 3Ps in winter remains an important issue which is not satisfactorily addressed according to the industry.
- During a zonal meeting held in January 2007, it was concluded that the natural mortality values used during the last two assessments were adequate.
- During the same meeting, it was recommended that the 2007 assessments of cod stocks in the northern and southern Gulf be consistent with respect to the methods used to evaluate natural mortality using the sequential population analysis.
- Natural mortality values (M) estimated with the sequential population analysis was 0.2 for the 1997-2001 period and 0.21 for the 2002-2006 period, while in the two previous assessments, they were established at 0.3 for the 1997-2000 period and at 0.2 since 2001. Although the results from both methods are presented, a change to the formulation will not likely improve the assessment. Nevertheless, both formulations will be examined in the future.
- Sequential population analysis results indicate that the abundance and spawning biomass remains at a low level. Spawning biomass reached a maximum of 378,000 tons in 1983 and dropped to 11,000 tons in 1994. After the first moratorium in 1998, this stock's biomass reached 29,000 tons. Since the fishery was reopened in 1997, the spawning stock biomass varied from 24,000 tons to 44,000 tons without any real sign of recovery. The spawning stock biomass increased by 6% between 2006 and 2007. Exploitation rates rose by 11% in 2004 to 13% in 2005 and to 16% in 2006 in relation with the increase in annual landings.
- The results from the sequential population analysis formulation, which estimated natural mortality, indicated that the spawning stock biomass would be 35,000 tons in 2007 compared to 44,000 tons where M was fixed.
- The abundance of the 2004 year-class at two years of age estimated on both mobile surveys (DFO and sentinel) is the second most important in the temporal series. This year-class is the most significant at three years of age since 1990, according to the sequential population analysis. This estimate must be confirmed by future surveys.
- Spawning stock biomass estimates are below the conservation limit for this stock. Recruitment contribution towards stock productivity is also concerning.
- According to the risk analysis made using the 2006 formulation (*status quo* – with M established), it is expected that without the fishery, the spawning stock biomass should increase by 20% at the end of 2007. An 8,300 tons fishery in 2007 would produce a drop (with a 50% probability) of the spawning stock biomass.
- In order to promote the increase of the stock's biomass, it is recommended that captures remain at a very low level.

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. On the other hand, the natural mortality rate may have increased, as fish in poor condition have lower chances to survive, particularly after reproduction.

Cod growth increased during the second half of the 1990s. Weight and size at age of commercially harvested fish increased, and the observed values since 2000 are similar to those noted in the early 1980s, before the decline in abundance. Fish in good condition have a better chance of surviving.

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.

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
TAC	70,4 ¹	0 ¹	6	3	7,5	7	7	7	0	3,5	5	6
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	5,5 ^{2,5}

¹ Mean

² Preliminary data

³ Includes 253 tons from the recreational fishery

⁴ Includes 34 tons from the recreational fishery

⁵ Includes 75.3 tons from the recreational fishery

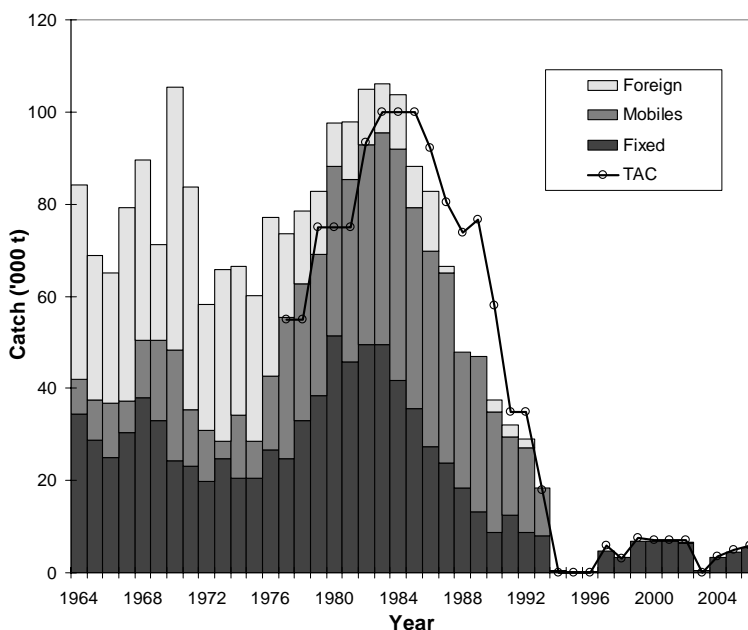


Figure 2. Landings and total allowable catches (TACs).

RESOURCE ASSESSMENT

Sources and Trends

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 and 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 changing catch rates 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. CPUEs increased from 2004 to 2006, reaching a high in 2006.

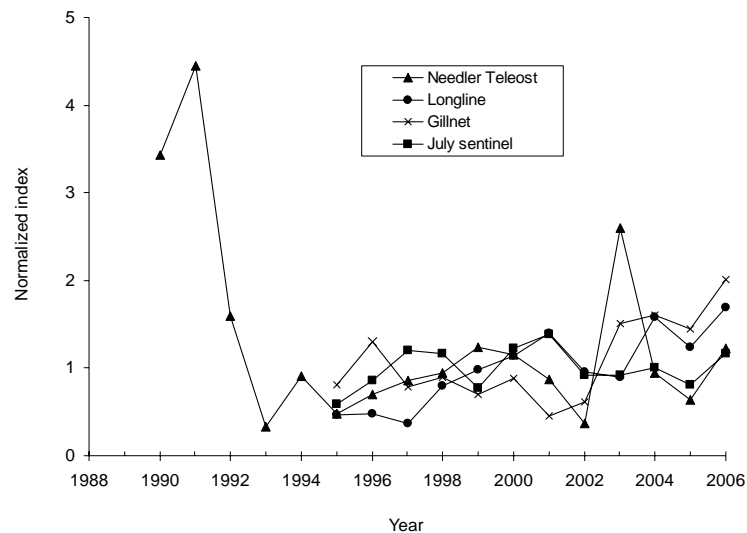


Figure 3. Standardized abundance indices.

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

The mobile gear sentinel fisheries program began in 1994 in the Northern Gulf of St. Lawrence, but only since 1995 have surveys covered Division 4S. 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 show 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 (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 are very high. Considering that these strata were only sampled four 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 DFO trawl survey catch rates began in 1990 with the CCGS *Alfred Needler*. Since 2006, this survey is carried out by the CCGS *Teleost*. Inter-calibrations have been made 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). The CCGS *Teleost* survey caught around ten times more young 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 has increased from 19943 to 1999. Abundance then fluctuated and the 2006 value can be compared to 1999 (Figure 3).

Resource Status

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, from the mobile gear sentinel fisheries in offshore waters, and from the scientific survey conducted by DFO.

To account for the deterioration of environmental conditions, the increase of poor fishing practices and the increase of seal predation, it was decided in 1998 to increase the value of M used in the model from 0.2 to 0.4 beginning in 1986. Environmental conditions have improved recently, which has led to renewed growth and an improvement in fish condition. Furthermore, wasteful fishing practices stated in the past are not as prevalent because of strict monitoring of the fishery (new log books, presence of observers, dockside monitoring, quality control, etc.). Nevertheless, seal predation remains significant.

Total mortality rates (Z) of fully-recruited Northern Gulf cod (ages 4-12 years old) during the 1990-2003 period were assessed using the DFO and sentinel fishery survey catch rates from July. The two surveys show a gradual decrease of the total mortality value (Grégoire and Fréchet, 2005). In 2005, the natural mortality value was re-evaluated and reduced from 0.4 to 0.3 for the 1997-2000 period and from 0.3 to 0.2 since 2001.

A new formulation was recommended during a zonal workshop on the natural mortality of both Gulf cod stocks. This formulation recommended that the M value be estimated in two five-year blocks (1997 to 2001 and 2002 to 2006). Estimated M values were 0.2 and 0.21 respectively. The formulation used to estimate M results in lower estimates for numbers, spawning stock biomass and estimated a higher fishing mortality rate than the other formulation that established M . This is due to the low estimated value for M for the 1997-2001 period (0.2), compared with the 1997-2000 established value (0.3).

The differences between the M values found in the formulation from previous years and the estimates from the new model are not sufficiently different to justify changing the formulation. Nevertheless, both formulations will be examined and presented in the future.

Stock abundance and biomass estimates on January 1st, 2007 were based on 3+ year-old individuals, mean weights at age and maturity ogives (2002 to 2006).

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 44 millions in 1999. Thereafter, total population decreased to 41 million individuals in early 2006. The occurrence in 2007 of the strong 3 year-old 2004 cohort resulted in an increase in numbers from 41 millions in 2006 to 62 millions in 2007.

The proportion of sexually mature fish according to size or year-class is used to establish spawning stock biomass (SSB). The number of sexually mature fish decreased from 223 millions in 1982 to 10 millions in 1994. It increased to 25 million individuals from 2005 to 2007. The exploitation rate of 7-10 year-old individuals calculated by SPA was stable (around 30%) from 1999 to 2002; this value was very low in 2003 due to the moratorium (Figure 4). The exploitation rate associated with catches totalling 5,459 tons in 2006 is 16%.

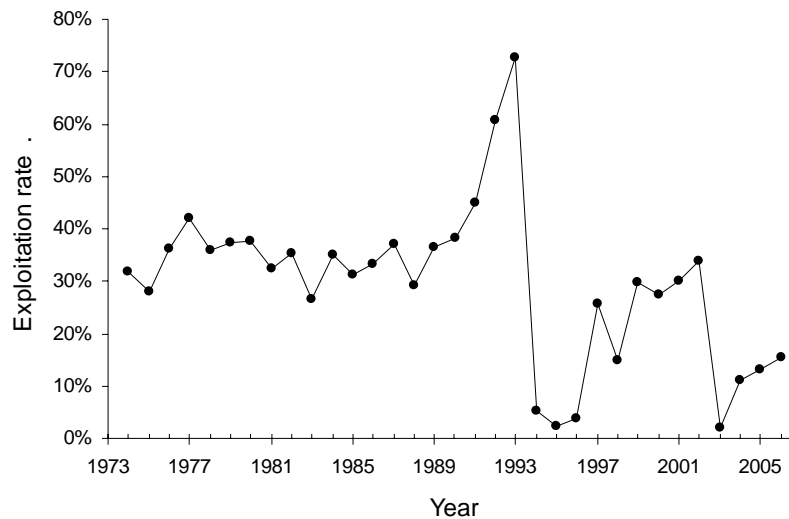


Figure 4. Exploitation rate of 7-10 year-old cod.

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 53,000 tons at the beginning of 2006 (Figure 5). Reproductive biomass declined from 378,000 tons in 1983 to 11,000 tons in 1994, to reach 44,000 tons at the beginning of 2007.

The 2004 cohort estimated by the two mobile surveys (sentinel fisheries and DFO) at 2 years of age in 2006 is promising. It is the second most significant in the temporal series from these two surveys (1990 to 2006 for the DFO survey and 1995 to 2006 for the sentinel fisheries). Based on the SPA, it is the most significant since 1991 (Figure 6). This estimate must be confirmed by future surveys. This age-class will not likely contribute to the 2007 fishery given the small size

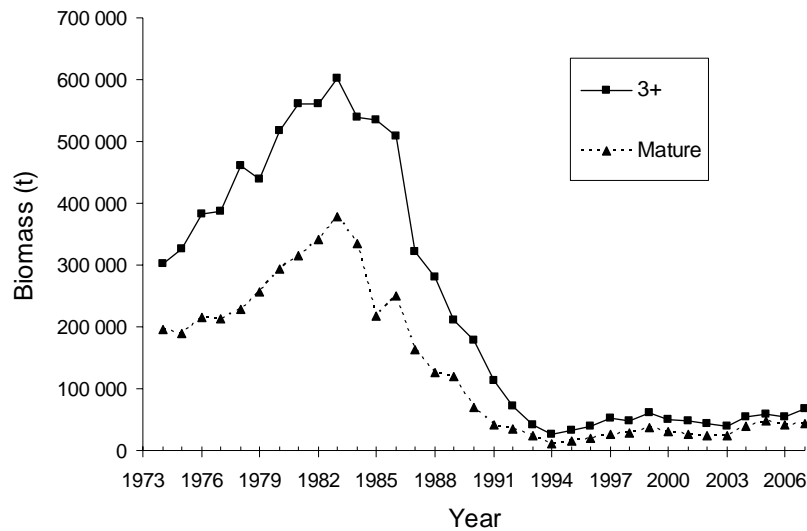


Figure 5. Estimated biomass of 3+ year-old individuals and biomass of mature individuals.

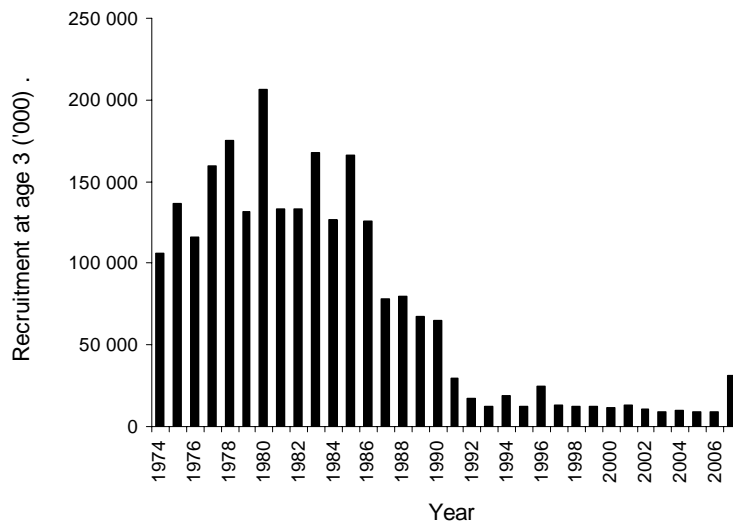


Figure 6. Estimated number of 3 year-old recruits.

and selection pattern of the gillnets and longline. It will probably start contributing to the fishery around 2010.

Numbers at age, the proportion of mature females at age and egg production 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 potential population increase would have dropped significantly between the mid 80s and 90s. The average reproductive characteristics of recent years would favour average population increase rates between 6% and 16% per year without fishing. However, average total mortality conditions maintained since the end of the first moratorium (1997) and 2003 did not allowed any increase of the population, while maintaining the total mortality conditions followed since 2004 would create potential increase rates between 0 and 5% per year.

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. Egg production at size and age has dropped significantly between the early and mid 90s. A gradual increase has been observed since this period, and the 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) for the Fulton condition index and the hepatosomatic index were below the values from the eight previous years. We cannot however confirm that these condition levels are critical. Condition assessment will continue in 2007.

Sources of Uncertainty

The issue of migration of the 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) 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, otolith trace elements) (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 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% in 2006. In 1995, only 1% of longline activities showed a saturation level above 30% compared with 35% in 2006. This increase in saturation rates is considered significant and will undergo additional analyses in the next assessment.

ADDITIONAL STAKEHOLDER PERSPECTIVES

For the tenth 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 2006 survey collected information from 50 fish harvesters in 3Pn, 78 in 4R and 57 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 2006 and 2005 seasons, respondents noted that cod size (overall length) and condition was the same or had increased and was in recent years extremely positive, particularly with respect to condition. With respect to migration, the majority of the respondents indicated minimal change in migration time, however, in 2006 a higher percentage of 4R and 4S respondents noted an earlier migration in spring / early summer. With respect to fishing depth, fishers have maintained activity on the same grounds; however, in 2006 this percentage increased to 67 % of respondents in all three (3) Divisions reported fishing in relatively deeper waters, notably in the Strait of Belle Isle.

With respect to catch rates, the recent trend has been an increasing one for all Divisions, with the most optimistic perception in 2006 (Figure 7). The most optimistic view remains in 3Pn, followed by 4R and 4S, a trend that has been consistent for most of the time series. In summary, 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.

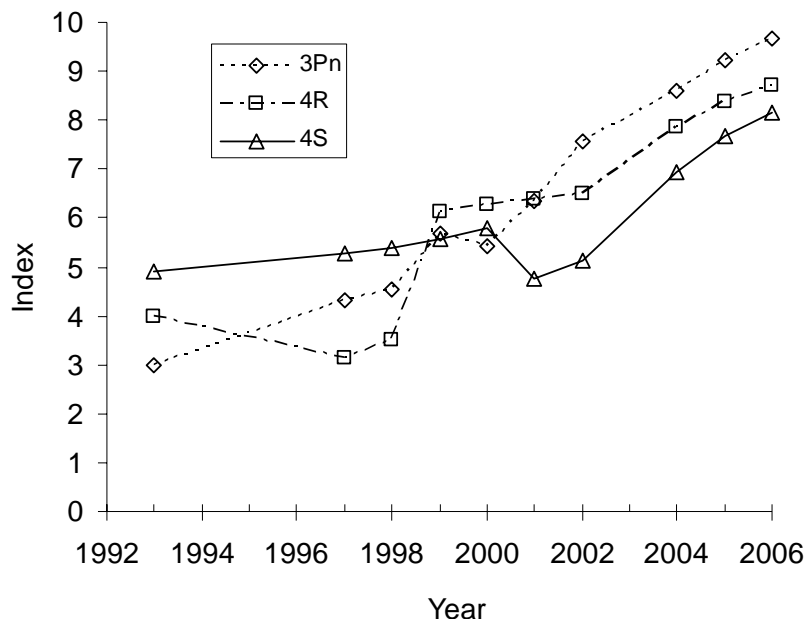


Figure 7. Performance index of a survey conducted with fixed gear fishermen.

CONCLUSIONS AND ADVICE

Based on current productivity, the pressure exercised by the fishery between 2000 and 2006 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 6,000 tons (Figures 8 and 9).

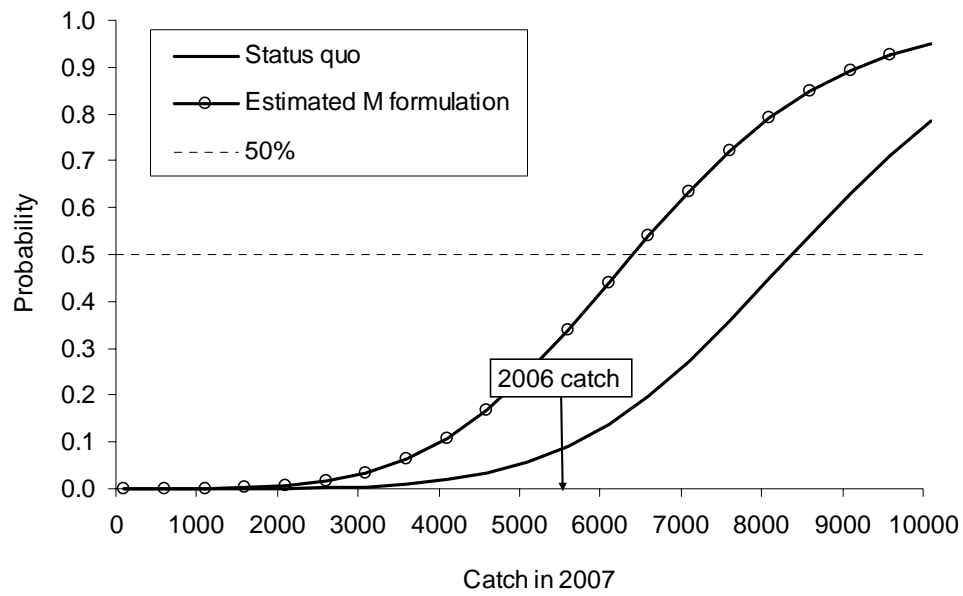


Figure 8. Mature biomass decline probability according to different catch levels in 2007.

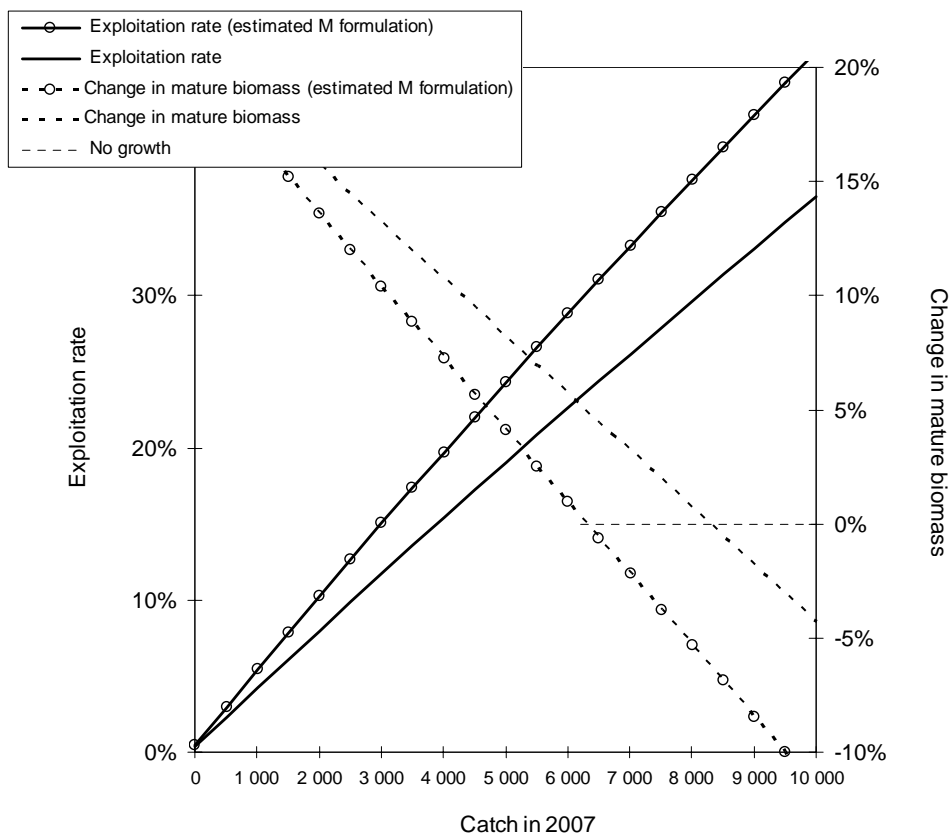


Figure 9. Harvesting rate and projected variation of mature biomass according to different catch levels in 2007.

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 long term. Catches over 8,300 tons in 2007 will lead to a reduction in spawning stock biomass due to the current small size of the stock combined with weak recruitment (Figure 8). A 20% increase target for mature biomass would require a moratorium (Figure 9).

The mid-term outlook appears to show stability for spawning stock biomass.

Spawning stock biomass is estimated to be below the conservation limit reference points for this stock. 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 2007 spawning stock biomass is well below this level.

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