



## ASSESSMENT OF COD IN THE SOUTHERN GULF OF ST. LAWRENCE

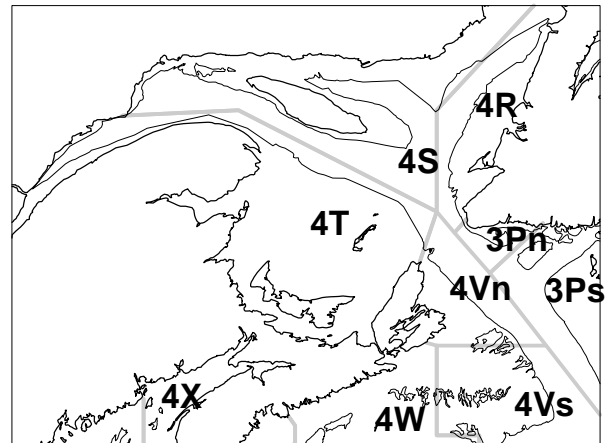
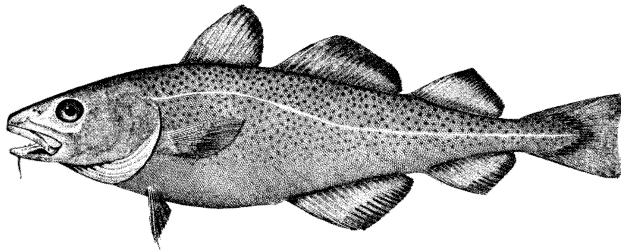


Figure 1: Map of the Gulf of St. Lawrence showing NAFO divisions.

### Context

Southern Gulf cod have been exploited commercially since at least the 16th century. Landings varied between 20,000 and 40,000 t annually between 1917 and 1940 and then began to increase, peaking at over 100,000 t in 1958. Landings remained relatively high in the 1960s and early 1970s at close to 60,000 t. TACs were first imposed in 1974 and became more restrictive as the stock declined in the mid-1970s. The fishery was closed in September 1993 due to low abundance. A 3,000-t index fishery was allowed in 1998, and a TAC of 6,000 t was in effect from 1999 to 2002. The directed fishery was closed again in 2003 due to a lack of recovery but reopened at a TAC of 3,000 t in 2004, 4,000 t in 2005 and 2006 and 2,000 t in 2007 and 2008.

Since 1999, the management year for the fishery runs from May 15 of the current year to May 14 of the following year. The management unit for this stock includes all of 4T and catches in 4Vn from November to April. In some years, catches in 4Vs in January to April are also attributed to this stock.

The present assessment is the result of a request for science advice from the Fisheries and Aquaculture Management (FAM) Branch (Gulf Region). The main objectives 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 five 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 of provincial governments, fishing industry members, external experts and academia.

## SUMMARY

- In 2008-2009, the total allowable catch (TAC) was 2,000 t. Landings in 2008 were 1,648 t, 121 t landed from 4Vn in January – April and 1527 t in the 2008-2009 fishing season up to December 31.
- In a telephone opinion survey of fishers on the status of the stock, 43% considered abundance in 2008 to be the same as in 2007, 33% considered it to be higher, and 24% considered it to be lower.
- The 2005-2008 abundance indices from the annual DFO research vessel survey are at the lowest levels observed in the 1971-2008 time series.
- Mean catch rates in the longline sentinel survey declined each year after 2004 and since 2005 have been at the lowest levels observed in the 1995-2008 time series.
- The abundance index from the sentinel trawl survey declined in 2005 and has remained below the 2003-2004 level since then.
- Year-classes produced since the late 1980s have been much weaker than those produced from the mid 1970s to the mid 1980s. The most recent year-classes (2003-2006) are estimated to be the lowest in the time series.
- Natural mortality in recent years is estimated to be high (about 0.6) and increasing. Predation by seals is considered to be a significant component of natural mortality. At such rates of natural mortality, sustainable exploitation rates must be very low. Stock growth is not likely unless productivity increases well above levels observed in the past decade.
- The exploitation rate in 2008 is estimated at 6% (fishing mortality of 0.08), a small fraction of natural mortality, but still high and unsustainable given current stock productivity.
- A conservation limit reference point (LRP) has been established for this stock, based on the spawning stock biomass (SSB) below which the probability of poor recruitment is high. The LRP is estimated to be 80,000 t.
- SSB is at the lowest level observed in the last 60 years. The estimate of SSB at the beginning of 2009 is 28,000 t, which is well below the LRP. SSB has been below the LRP since 2002.
- SSB is well below the LRP. The application of the precautionary approach would require catches in 2009 to be at the lowest possible level. This would include no directed fishing and measures to reduce cod by-catch in other fisheries. Catches not exceeding 300 t are considered to be a low attainable catch level.
- Given the high natural mortality and low recruitment in recent years, SSB is expected to decline in 2009 even with no catch, and there is a high probability (about 95%) of a decline of 5% or more. The probability of a decline of 10% or more is 54%.

## BACKGROUND

### Species biology

Atlantic cod (*Gadus morhua*) is a demersal species that occurs on both sides of the North Atlantic. Southern Gulf of St. Lawrence cod are relatively long-lived and may reach ages of 20 years or more when mortality is low. Cod from the southern Gulf of St. Lawrence are slow-growing compared to neighboring cod populations. Individual fish growth declined in the late 1970s and has remained low since. They begin to reach commercial size (43 cm) at about age 5 and are fully available to the commercial fishery by age 8. They start to mature at ages 4-5, (i.e. below the commercial size) and by age 7 most fish in the population are sexually mature. It is estimated that the natural mortality of southern Gulf of St. Lawrence cod started to increase in the 1980s and has been high in the 1990s and 2000s.

Southern Gulf cod are highly migratory. Spawning occurs in the Shediac Valley and around the Magdalen Islands from late April to early July. During the summer, the cod are widely distributed while they feed heavily on krill, shrimp, and small fish, primarily herring, American plaice, and capelin. The fall migration begins in late October, and cod become concentrated off western Cape Breton in November as they move into 4Vn. The stock overwinters in 4Vn and northern 4Vs, along the edge of the Laurentian Channel. The return migration usually begins in mid-April, although this can be delayed if breakup of winter ice is late.

### Fishery

A TAC of 2,000 t was in place for 2008-2009. This included an allowance of 200 t for sentinel and scientific surveys. Cod were caught in cod-directed fisheries and as bycatch in fisheries directed at other species, mainly flatfish. Directed fisheries for cod remained closed until June 24, 2008. Bycatch of cod in other fisheries was restricted to between 5 and 25%, depending on the target species. A recreational fishery for cod was permitted in 2008. Estimated landings from the recreational fishery are 10 t.

*Table 1: Landings and TACs by management year (thousands of tonnes) for southern Gulf of St. Lawrence cod. Starting in 1999, the TAC applies from May 15 of the current year to May 14 of the following year.*

Year	Average 1981-1990	Average 1991-1995	Average <sup>1</sup> 1996-2002	2003 - 2004	2004 - 2005	2005 - 2006	2006- 2007	2007- 2008	2008- 2009 <sup>2</sup>
Landings	60.8	19.7	4.1	0.3	2.3	2.8	3.2	1.5	1.5
TAC	57.5	20.8	3.4	0	3.0	4.0	4.0	2.0	2.0

1. Including the allowance of 3,000 t for an index fishery in 1998.  
2. Preliminary data up to 31 December.

In 1999, the fishery management year changed from the calendar year to the period from May 15 of the current year to May 14 of the following year. This stock assessment is based on calendar year, consistent with past practice. Total reported **landings** in the 2008 calendar year were 1,648 t (Figure 2). As of December 31, landings in the 2008-2009 fishing season (Table 1) included 1,483 t caught in cod-directed and bycatch fisheries. Sentinel surveys, which are used to obtain additional indices of stock abundance, caught 44 t (36 t in longline surveys and 8 t in the trawl survey). Catch reporting in the recent commercial fishery is considered reliable. The 2008-2009 TAC has not yet been reached because little effort has been directed for the 4Vn

allocation, and some other allocations were not reached (e.g., French reserve, sentinel allocation, certain fixed gear allocations). Additional landings (less than 150 t) are expected from the 4Vn area in January to April 2009.

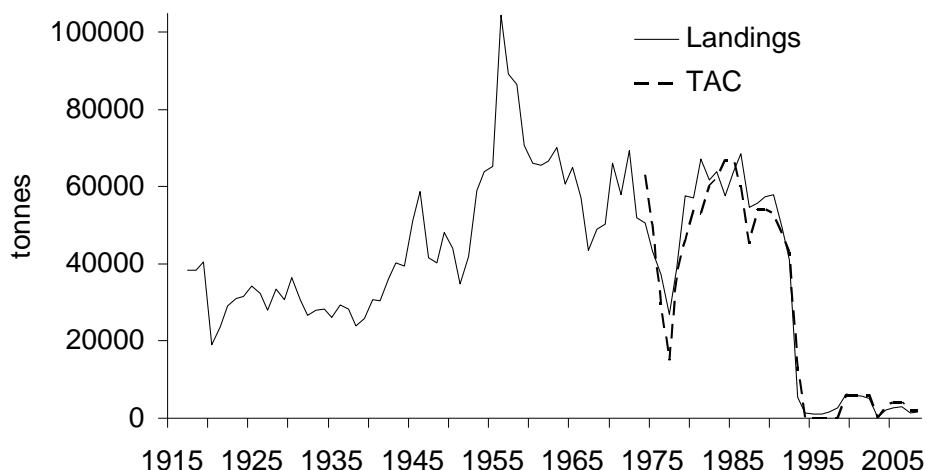


Figure 2: Landings and TAC (t) for the southern Gulf of St. Lawrence cod stock. Landings are for the calendar year; the TAC is for the management year which changed to the period from May 15 of the current year to May 14 of the following year starting in 1999.

Ages 7 and 8 were dominant in the 2008 landings. The **average weights** at age in the catch and in the annual research vessel survey remained low in 2008 relative to the period before 1980 (Figure 3).

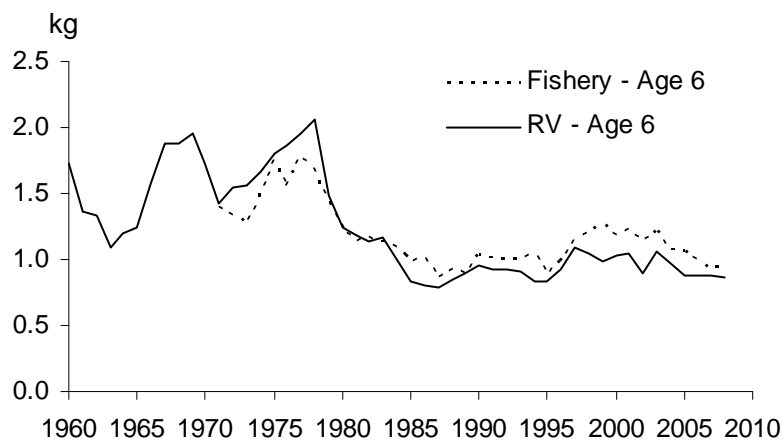


Figure 3: Average weight (kg) of age 6 cod in fishery catches and from the annual research vessel survey.

## Ecosystem

The ecosystem in the southern Gulf of St. Lawrence has changed dramatically in recent decades. Abundances of many large-bodied demersal fishes (e.g., Atlantic cod, white hake, American plaice, skates) have declined to very low levels, and continue to decrease. These fishes appear to currently have elevated natural mortality at adult sizes. In contrast, many small fishes (e.g., shannies, sculpins) have increased dramatically in abundance. Most important prey

of cod are at high levels of abundance. Grey seals (year-round residents) and harp seals (present in winter and early spring) are also at high levels of abundance.

Environmental conditions have also varied in recent decades. Bottom waters were colder than normal from the late 1980s to late 1990s but then increased to normal or warmer than normal levels in the 2000s. Surface water temperatures have also generally been normal or above normal since the late 1990s, with exceptionally warm temperatures in 1999 and 2006.

## ASSESSMENT

### Sources of information

The information used in this assessment includes the annual research vessel survey (1971-2002 and 2004-2008), landings data from 1917 to 2008, commercial catch at age data from 1950 to 2008, sentinel survey data from 1995 to 2008, otter trawl catch rate data from 1982 to 1993, and the views of industry expressed in the annual telephone survey from 1997 to 2002 and in 2004 to 2008.

### Stock Trends

Since 1997, an index of the state of the resource has been calculated based on a telephone survey of active cod fishers. In 2006, for the first time since the survey began, the average opinion of fishers was that abundance had declined compared to the previous year, and in 2007, they were of the opinion that the abundance of the stock was similar to 2006 (Figure 4).

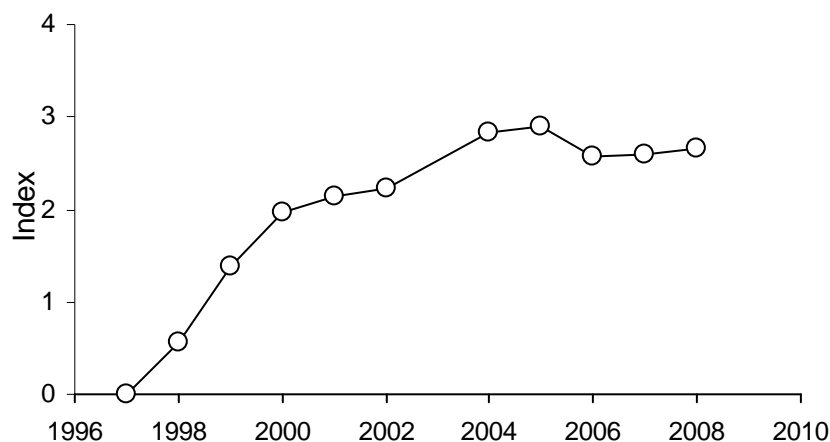


Figure 4: Relative index of cod abundance based on the opinion of fishers who indicated cod as the first or second most important species targeted.

Of the 117 fishers interviewed in 2008 who indicated that cod was the first or second most important species they harvested and who had an opinion, 43% considered abundance in 2008 to be the same as in 2007, 33% considered it to be higher, and 24% considered it to be lower.

An **annual research vessel (RV) survey** has been conducted each year in September since 1971 and covers most of the stock area. The research vessel used to conduct the survey changed in 1985, 1992 and 2004. In each case, comparative fishing experiments were

conducted to calibrate the fishing efficiency of the new vessel relative to the old vessel. In 2003, the survey was conducted by an uncalibrated vessel, the survey started late, and coverage was incomplete. For these reasons, the results in 2003 were not used here as an indicator of stock status.

The RV survey index indicated that the abundance of cod was low in the early to mid-1970s, and then increased to the early 1980s (Figure 5). Abundance was high until the late 1980s, but declined rapidly to low levels by 1992. With the closure of the fishery in 1993, the decline was arrested but the abundance index has remained low. The abundance index has declined further in recent years. Since 2005, the indices of abundance and biomass have remained at the lowest levels observed.

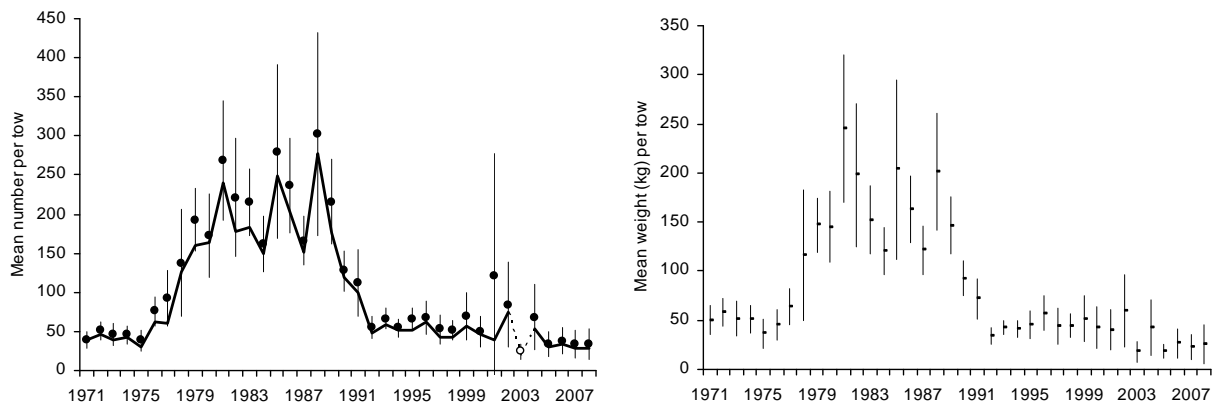


Figure 5: September research survey abundance and biomass indices for cod (2003 is not considered a comparable indicator). Circles are the indices for all ages combined and the line is the abundance index for ages 3 and older. Vertical bars indicate approximate 95% confidence intervals.

In 2004, the abundance of cod aged 2 and 3 years was significantly higher than that observed in the surveys conducted between 1996 and 2003. These fish were from the 2001 and 2002 year-classes, and those year-classes accounted for about one-third of the estimated abundance in the 2007 and 2008 surveys. More recent year-classes, particularly the 2003 and 2005 year-classes, appear to be very weak.

The geographic distribution of cod was similar to that observed in recent years. The highest concentrations were found in the Shediac Valley, the north coast of Prince Edward Island, near Banc des Américains, and off northwestern Cape Breton (Figure 6). While a number of large catches were made along the edge of the Laurentian Channel, catches were as usual very low (mostly zero) along the offshore margin of the survey in the Laurentian Channel.

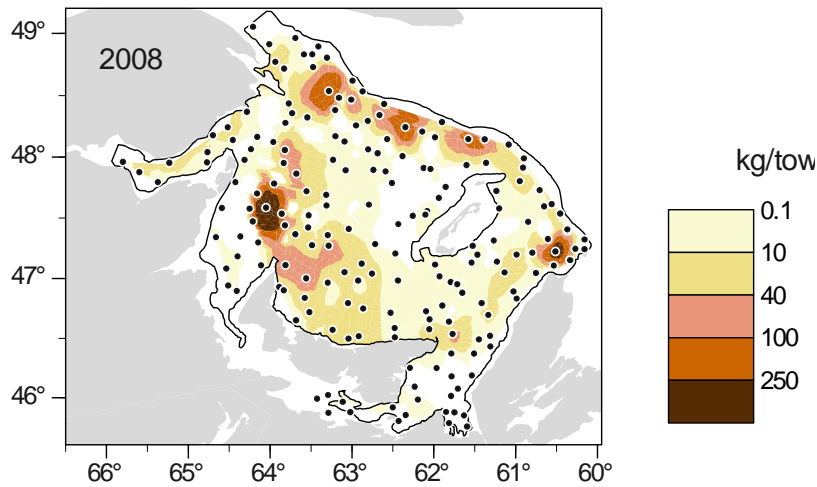


Figure 6: Distribution of cod (kg per tow) in the September 2008 research vessel survey.

The August **sentinel trawl survey** started in 2003 and covers most of the stock area. Abundance indices from this survey declined in 2005 and remained below the 2003-2004 level since then (Figure 7). Biomass indices steadily declined from 2003 to 2006 and then increased somewhat, though they remained below the 2003-2004 level. The increase in the 2008 index was due to the catch in a single tow; omitting this tow, the index was near the record-low 2006 level.

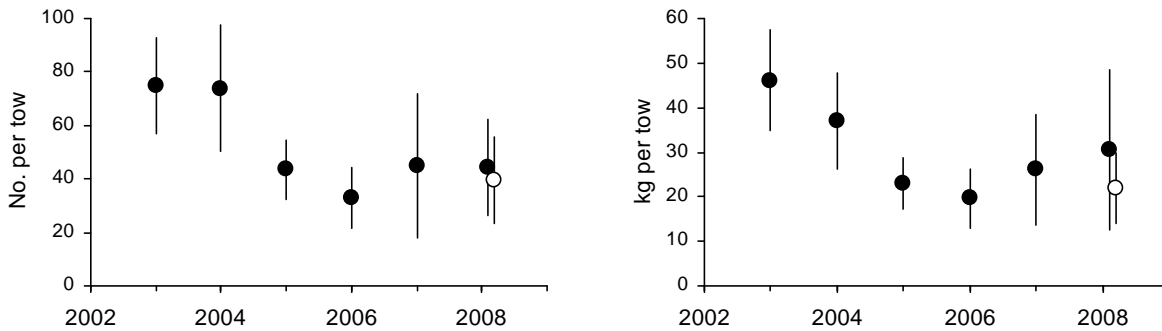


Figure 7: August sentinel trawl survey indices. The open circle shows the 2008 index omitting a single large tow. Vertical bars indicate approximate 95% confidence intervals.

Geographic distribution of cod was similar to that observed in the September RV survey, with the highest cod densities located in the Shediac Valley and in the area between the Magdalen Islands and Cape Breton (Figure 8). Relative density was lower north of PEI and to the northwest of the Magdalen Islands in the sentinel trawl survey than in the RV survey.

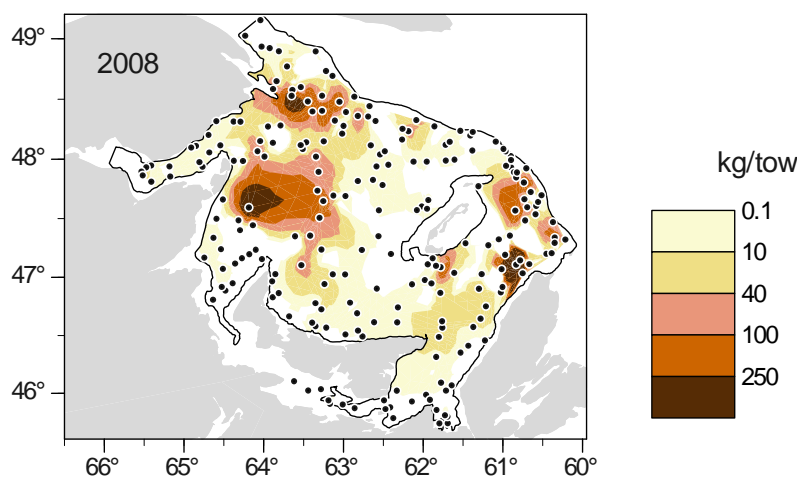


Figure 8. Distribution of cod (kg per tow) in the August 2008 sentinel trawl survey.

In the **sentinel longline survey**, 17 vessels fished at 38 reference sites during July to November. After 2004 standardized catch rates have declined each year and have been at the lowest levels observed in the 1995-2008 time series (Figure 9).

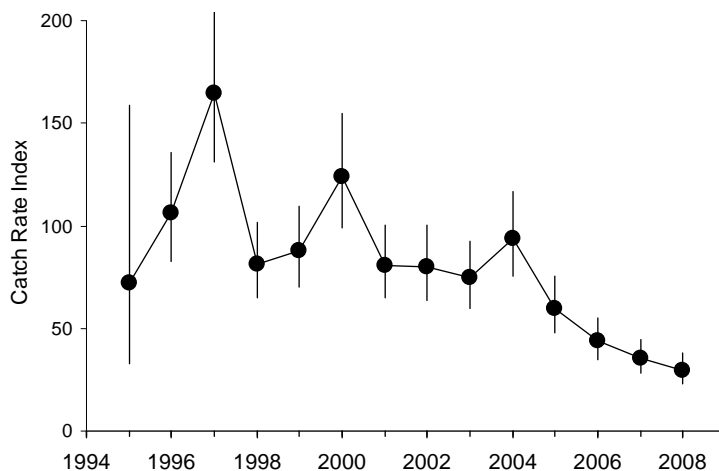


Figure 9: Longline sentinel catch rate index. Vertical bars indicate approximate 95% confidence intervals.

In summary, indices from the September RV survey, the August sentinel trawl survey and the longline sentinel survey all indicate that the stock is at or near a record-low level and is declining.

### **Biological information**

Size-at-age of southern Gulf cod decreased sharply in the late 1970s and early 1980s (Figure 3). This decline is thought to reflect a decrease in **growth rate** due to increasing competition for food as cod density increased, and an increase in the selective harvesting of fast-growing fish by the fishery. Size-at-age has remained low, even though conditions for growth now appear to be good: temperatures experienced by cod during the feeding season are relatively warm, cod density is low, and prey abundance is high. The continued slow growth of southern Gulf cod may reflect a genetic response to the strong selection against fast growth that was inflicted by fisheries in the 1980s and early 1990s.



Previous work has indicated an increase in the **natural mortality** rate ( $M$ ) of this cod stock. This would include unaccounted mortalities due to factors such as poor environmental conditions, predation, unreported catches and changes in life history characteristics. Estimates of  $M$  from population analyses increased in the 1980s and have not declined appreciably since the late 1980s. Estimates from survey data also suggest that  $M$  was near 0.4 or higher during the moratorium from 1994 to 1997. Recent estimates of total mortality based on data from the RV, sentinel trawl and sentinel longline surveys are very high, suggesting that  $M$  may now be increasing to even higher levels.

The contribution of each of the potential causes of the recent high estimates of  $M$  cannot be partitioned. Consumption estimates of cod by grey and harp seals in 2000 for this stock ranged from 19,000 to 39,000 t (all ages), depending on diet assumptions. Cod consumption by grey seals is estimated to exceed that by harp seals in the southern Gulf. Changes in estimated natural mortality of cod are consistent with trends in grey seal abundance in the southern Gulf of St. Lawrence.

## **Current Status**

The population model used in this assessment estimates natural mortality over four periods (Figure 10). Natural mortality is high and increasing.

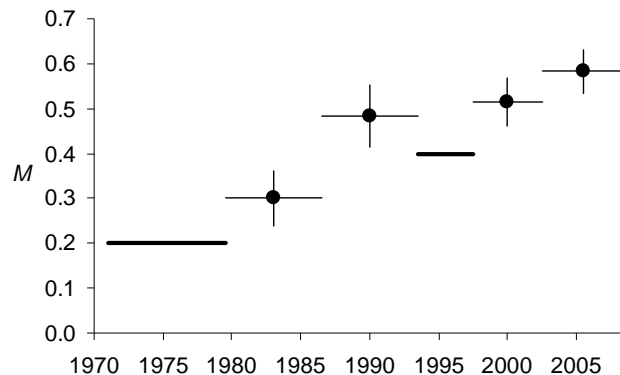


Figure 10: Natural mortality estimated by the model. Heavy lines are assigned values, and circles are values estimated by the model with their 95% confidence intervals (vertical lines). Horizontal lines indicate the period for which  $M$  is either assigned or estimated.

Total biomass (ages 3 and older) and spawning stock biomass (SSB) were high in the 1950s, but declined throughout the 1960s, to reach a minimum in the mid-1970s (Figure 11). SSB increased sharply with the recruitment of strong year-classes (1974-1975 and 1979-1980), but then declined just as rapidly, reaching a new low in 1993 (Figure 11). SSB has been low since the early 1990s and has declined further in recent years. The SSB at the beginning of 2009 was 28,000 t.

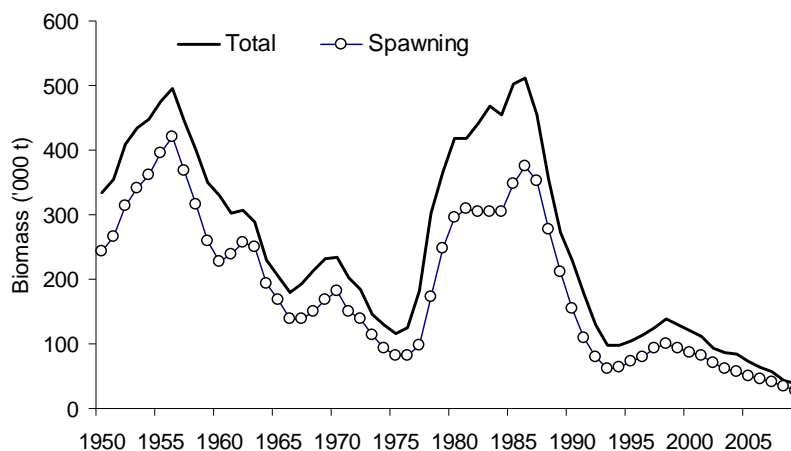


Figure 11: Total (ages 3+) and spawning stock biomass estimates derived from population models for cod in the southern Gulf of St. Lawrence.

The trend in total abundance (Figure 12) is similar to that of biomass (Figure 11), except that abundance was greater in the 1980s than in the 1950s, whereas biomass was similar between the two periods. This difference reflects the lower weights at age in the 1980s than in the 1950s and the younger age composition. Abundance was roughly stable at a low level from the mid 1990s to the early 2000s, but has declined further since then.

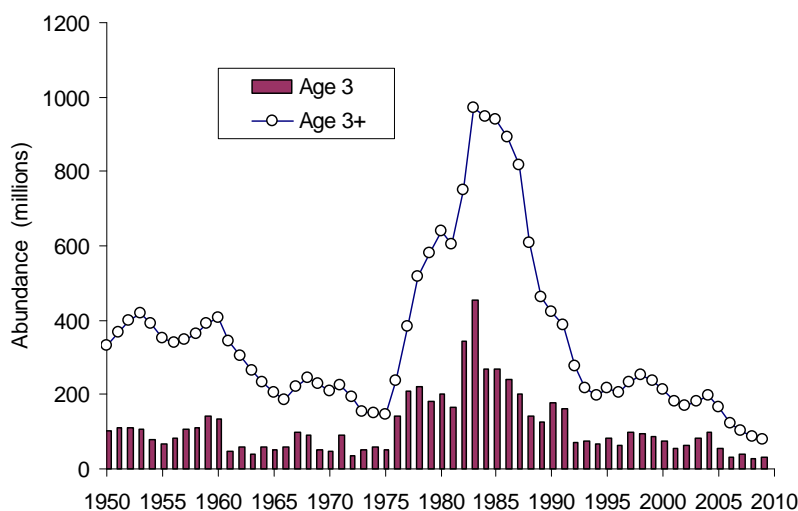


Figure 12: Abundance (ages 3+) and recruitment (age 3) estimates for southern Gulf of St. Lawrence cod.

Recruitment in the 1990s was considerably lower than the high values observed in the late 1970s and the 1980s and comparable to the lower values observed from the 1950s to the early 1970s. Average recruitment of 3-year-old cod was slightly higher in 1994-2004 than the average in the 1960s and early 1970s. However, the most recent year-classes (the 2003-2006 year-classes) are the weakest observed in the 60-year record.

Analyses indicate that the high production of recruits from the mid-1970s to early 1980s may have resulted from the low abundance of pelagic fish species (herring and mackerel). Herring

and mackerel feed on small prey including the early life stages of cod (eggs and larvae). Herring biomass in the southern Gulf has been at a relatively high level since the mid-1980s.

The exploitation rate by commercial fisheries on southern Gulf cod generally increased from the early 1950s to the mid-1970s, with an extremely high value in 1959 (Figure 13). There was a decrease following the extension of fisheries jurisdiction in 1977. The exploitation rate increased sharply in the late 1980s, peaking over 60% in 1992.

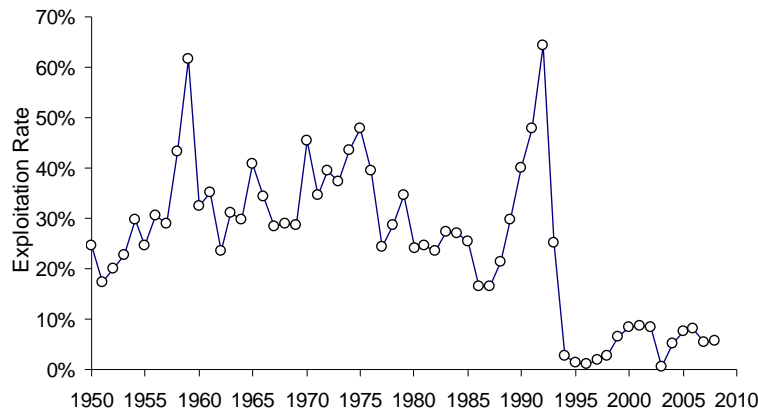


Figure 13: Exploitation rate (ages 7+) for southern Gulf of St. Lawrence cod.

Fishing effort was reduced markedly in 1993 with the closure of the directed fishery. Exploitation rates were 1 to 3% during the moratorium. In 2008, the exploitation rate was estimated at about 6% (fishing mortality,  $F = 0.08$ ).

Surplus production is the gain in biomass due to recruitment and growth minus the losses to natural mortality. Estimated surplus production was substantial in most years from 1950 to the mid 1980s, and then appeared to drop sharply (Figure 14). The apparent suddenness of this drop may be an artifact of a possible increase in discarding or unreported catch in the late 1980s and early 1990s, because the production lost to any unreported catch is not incorporated in these estimates. There was a small amount of surplus production in the early to mid 1990s (average 8,400 t), but production has been consistently negative since 1998. This indicates that the population is expected to continue to decline even in the absence of fishing unless productivity improves.

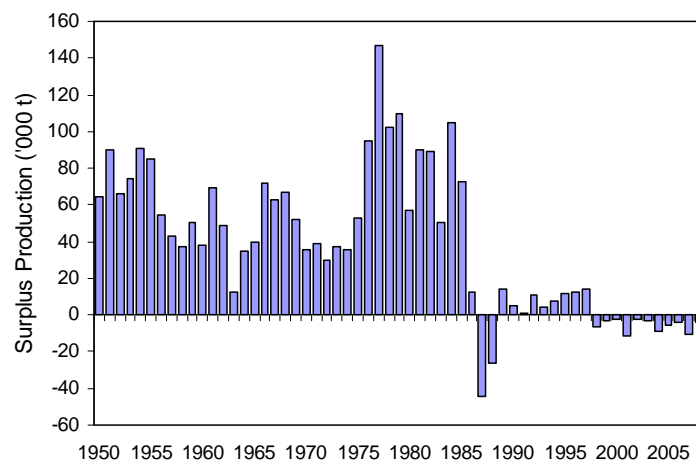


Figure 14. Surplus production (ages 3+) for southern Gulf of St. Lawrence cod.

## Sources of Uncertainty

The changes in natural mortality (M) in recent years remain a source of uncertainty in the assessment. Predation by seals is considered to be a significant component of M, and analyses suggest that changes in M are consistent with grey seal abundance trends. Recent analyses indicate that seal predation is higher than previously estimated; however, there is considerable uncertainty about seal diets in the southern Gulf. Diet analyses rely on the presence of hard parts (such as otoliths) from prey species in seal stomachs. Conclusions about diet composition would be affected if it is shown that seals tend not to eat the heads of larger cod.

The causes of the continued low weights at age, despite high prey abundance, are also uncertain. If the reduced growth rate is a genetic consequence of past fishing, then recovery of weights at age to the higher values observed historically may be slow.

## CONCLUSION AND ADVICE

The estimated conservation limit reference point for this stock is a spawning stock biomass (SSB) of 80,000 t (DFO 2003). Below the limit reference point, 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 give priority to promoting stock growth, and removals by all human sources should be kept to the lowest possible level (DFO 2006b).

The outlook for this stock continues to be very pessimistic and further declines are expected in the short term. The productivity of the stock has been low for more than a decade because of poor growth and natural mortality that is high and may still be increasing. Recent year-classes are the weakest in the 60-year record. Production has been negative since the late 1990s, indicating that this stock will continue to decrease at its current level of productivity.

**Projections** indicate that the SSB will decrease by 11% in 2009 even with no catch (Figure 15). Catches of 1,650 t (the level of the catch in 2008) in 2009 would result in a 15% decline in SSB.

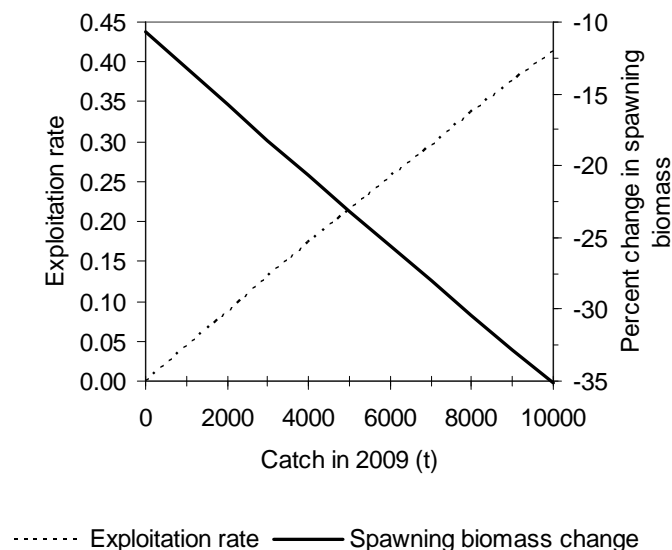


Figure 15: Estimates of the exploitation rate and changes in spawning stock biomass for various catch levels in 2009.

**Risk analyses** indicate that, even with no catch in 2009, SSB is almost certain to decline, with a 94% probability of a decline of 5% or more and a 54% probability of a decline of 10% or more. With a catch of 2,000 t, there is a 99% probability of a decline of 5% or more and a 93% probability of a decline of 10% or more (Figure 16). These risk analyses include uncertainties in population estimates and the estimate of natural mortality but not those associated with weight at age and partial recruitment. Risk was calculated for the calendar year, whereas TACs are set for the period from May 15 to May 14.

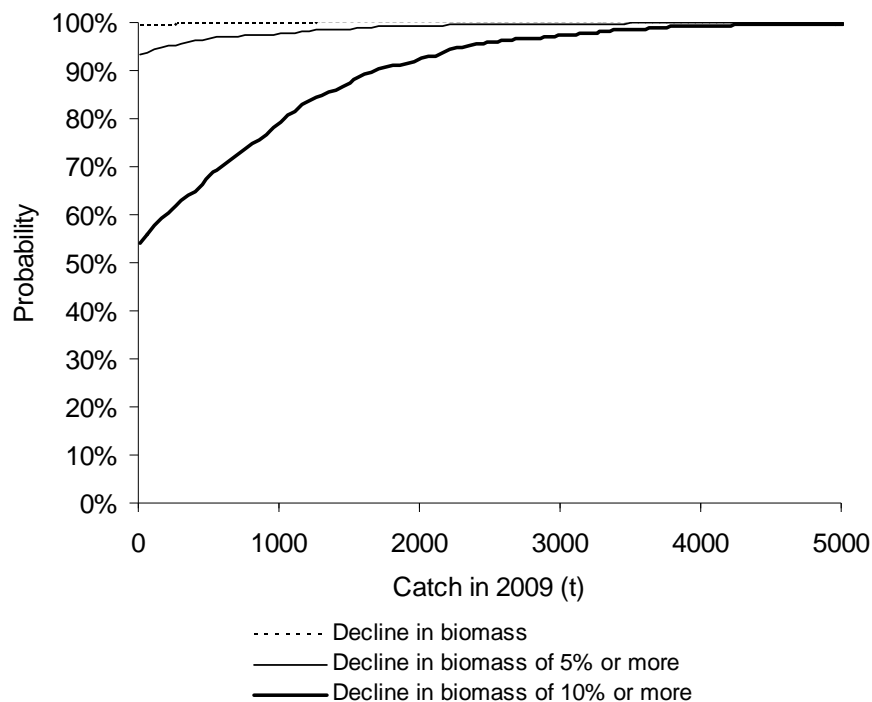


Figure 16: Risk analyses of the decline in spawning stock biomass at various catch levels in 2009.

The current estimate of SSB of southern Gulf cod (28,000 t) is the lowest observed and is well below the limit reference point. Given the current status of the stock relative to the limit reference point and the declining trend foreseen for the next year, if the stock is managed to be compliant with the Precautionary Approach catches should be limited to the lowest possible level. This would include no directed fishing and measures to reduce cod by-catch in other fisheries. Based on historical by-catch data from other southern Gulf fisheries, a catch of 300 t is considered to be a low attainable catch level (DFO 2006a) for this stock.

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