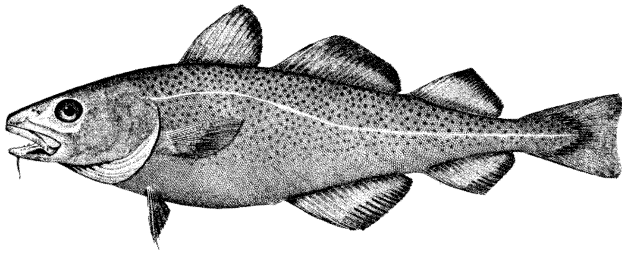
ASSESSMENT OF COD IN THE SOUTHERN GULF OF ST. LAWRENCE



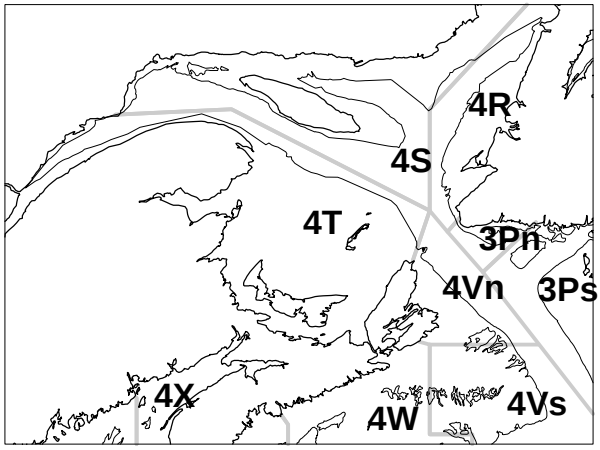


Figure 1: Map of the Gulf of St. Lawrence showing NAFO divisions.

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.

The management year for the fishery now 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.

Given the fragile state of the stock and the high level of interest in exploiting it, stock assessments and science advisory reports are requested annually by DFO Resource Management. The information base available for assessing this stock is extensive, dating from 1950. The data are used to assess and interpret recent trends. Reference points that are consistent with the precautionary approach have been established for this stock (DFO 2006a). Under the precautionary approach, when a stock is below the limit reference point, management actions must promote stock growth, and removals by all human sources must be kept to the lowest possible level (DFO 2006b).

SUMMARY

- In 2007-2008, the TAC was 2,000 t. As of December 31, 2007, 1,442 t had been landed.
- All abundance indices indicate that this stock is at, or near a record-low level and is declining.
- A telephone opinion survey of fishers on the status of the stock indicates that they consider the state of the resource to be similar to that of 2006.
- Spawning stock biomass is at the lowest level observed in the last 59 years. The current estimate of spawning stock biomass at the beginning of 2008 is 36,000 t.
- Spawning stock biomass has been estimated to be well below the limit reference point for this stock (80,000 t) since 2004. Below the limit reference point, a stock is considered to have suffered serious harm because the probability of poor recruitment is high.
- Recruitment of year-classes of the late 1980s and 1990s has been significantly below the long-term average. The 2003 and 2005 year-classes are estimated to be the lowest in the time series and less than half the strength of any other recent year-class.
- Natural mortality in recent years is high (0.5 or higher) and seems to be increasing. Predation by seals is considered to be a significant component of natural mortality. The exploitation rate in 2007 is estimated at 5% (fishing mortality of 0.07), a fraction of natural mortality.
- Given the high natural mortality and low recruitment in recent years, the spawning stock biomass is certain to decline. Even with no catch in 2008, it is almost certain to decline by at least 10%, and there is a 53% probability of a decline of 15% or more.
- A study shows that, under current productivity conditions, the stock is headed for extinction. Unless productivity increases, spawning stock biomass will fall to close to 0 (<1,000 t) in 20 years with annual catches of 2,000 t and in 40 years with no commercial catch.
- Given the current stock status, removals in 2008 should be set at the lowest possible level. Catches of 300 t are considered to be a low attainable catch level.

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 relatively slow-growing compared to other cod populations. Individual fish growth is estimated to have 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 a size below the commercial size of 43 cm (ages 4-5) 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 increased in the mid-1980s.

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 by the late breakup of winter ice.

Fishery

A TAC of 2,000 t was in place for 2007-2008. 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, 2007. 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 2007. Estimated landings from the recreational fishery are 15 t, but this estimate is probably incomplete.

Table 1: Landings and TACs (thousands of tonnes) for southern Gulf of St. Lawrence Cod.[1]

Year	Average 1981-1990	Average 1991-1995	Average[1] 1996-2001	2002	2003	2004	2005	2006	2007[2]
Landings	60.8	19.7	4.0	5.1	0.3	2.3	2.8	3.0	1.4
TAC	57.5	20.8	3.6	6.0	0	3.0	4.0	4.0	2.0

[1] Including the allowance of 3,000 t for an index fishery in 1998.

[2] Preliminary data up to December 31, 2007

(Note: Starting in 1999, the TAC applies from May 15 of the current year to May 14 of the following year.)

Total reported **landings** were 1,442 t in 2007 (Table 1, Figure 2). Catches in the cod-directed and bycatch fisheries amounted to 1,380 t. Catch reporting in the commercial fishery is considered reliable. The TAC was not reached because little effort was directed for the 4Vn allocation, and some other allocations were not reached (e.g., French reserve, sentinel allocation, fixed gear allocations). There was also a winter fishery in 4Vn starting on January 1, 2008. Preliminary landings in 4Vn in 2008 were roughly 110 t at the end of February 2008.

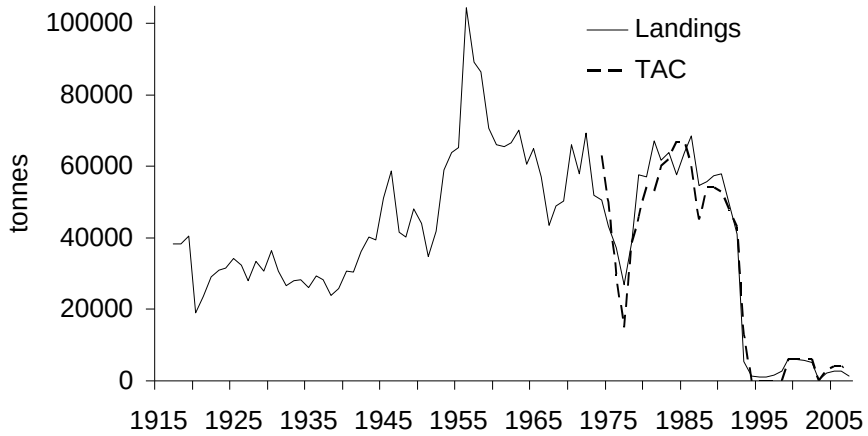


Figure 2: Landings and TAC (t) for the southern Gulf of St. Lawrence cod stock.

[1] Table 1 was revised in April 2008.

Sentinel surveys, which are used to obtain additional indices of stock abundance, caught 63 t (56 t in longline surveys and 7 t in trawl surveys).

The dominant age groups in 2007 landings were ages 6 to 8. The **average weights** at age of cod in the catch and in the annual research vessel survey remained low in 2007 relative to the period before 1980 (Figure 3).

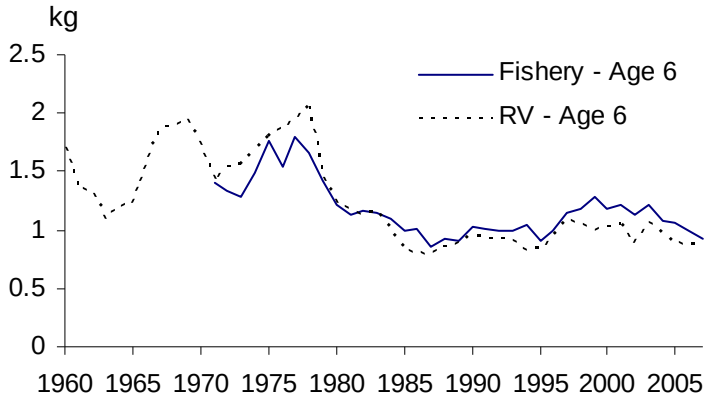


Figure 3: Average weight (kg) of age 6 cod in fishery catches and from the annual research vessel survey.

ASSESSMENT

Stock Trends and Current Status

The information used in this assessment includes the annual research vessel survey (1971-2002 and 2004-2007), landings data from 1917 to 2007, commercial catch data from 1950 to 2007, sentinel survey data from 1995 to 2007, 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 and 2007.

Since 1997, the **views of fishers** on the state of the resource have been obtained through a telephone survey of active cod fishers. In 2006, for the first time since the survey began, fishers had a negative view, and in 2007, they were of the opinion that the abundance of the stock was similar to 2006 (Figure 4).

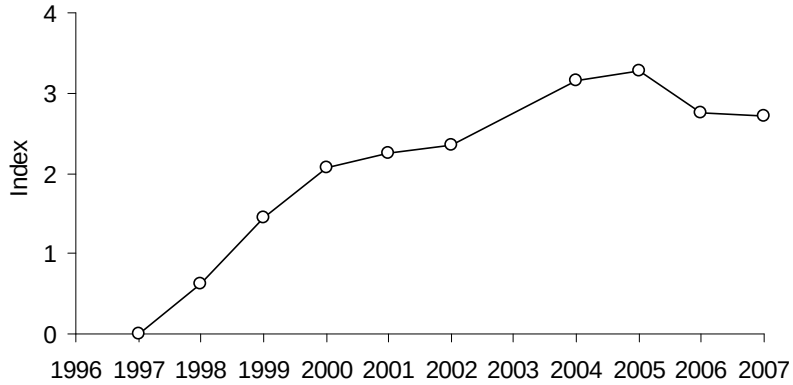


Figure 4: Relative index of cod abundance based on the opinion of fishers who indicated cod as the first or second most important species targeted.

Of the 108 fishers interviewed who indicated that cod was the first or second most important species they harvested and who had an opinion, 32% felt that cod abundance was lower or much lower than in 2006, 44% felt that it was similar to the 2006 level and 24% felt that it was higher or much higher than in 2006.

The **annual research vessel (RV) survey** has been conducted each year in September since 1971. The survey index indicates that the abundance of cod was low in the early to mid-1970s, then increased to the early 1980s. 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.

There have been changes in the research vessels used in recent years for the survey. In 2003, the CCGS *Alfred Needler* was replaced by the CCGS *Wilfred Templeman*. Because no comparative fishing experiments were conducted, the results in 2003 were not used here as an indicator of stock status. Starting in 2004, the CCGS *Teleost* was employed for the survey using the same Atlantic Western IIA trawl as used previously. In both 2004 and 2005, comparative fishing experiments were conducted between the CCGS *Teleost* and the CCGS *Alfred Needler* while conducting the annual survey. The analysis of paired tows by the two vessels indicated no significant difference in catchability between these two for cod in the southern Gulf. Data from both vessels have been used to calculate abundance estimates for 2004 and 2005. In 2007, the survey was once again conducted from the CCGS *Teleost*.

The 2007 estimates of abundance and biomass were among the lowest seen in the time series (Figure 5). The 2007 abundance estimate is approximately 11% lower than that of 2006.

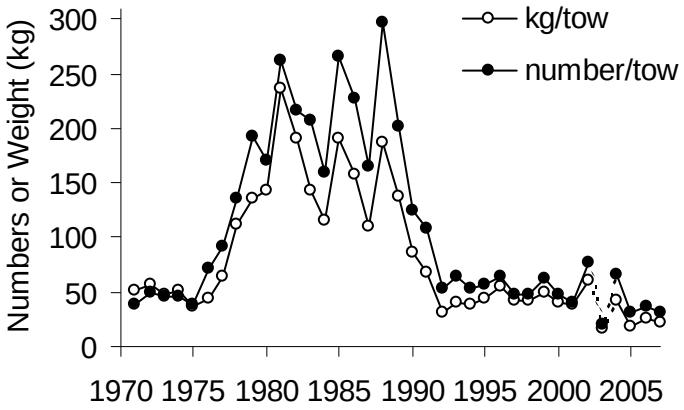


Figure 5: September research survey abundance indices for cod 2 years and older (2003 is not considered a comparable indicator).

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 are the 2001 and 2002 year-classes, and they accounted for over one-third of the estimated abundance in the 2007 survey. Abundance of the 2003 year-class remained relatively low in the 2007 survey. Abundance of the 2004 year-class is low, and the first abundance estimate of the 2005 year-class is very low and comparable to that of 2003.

The geographic distribution of cod was, however, virtually identical to that of 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).

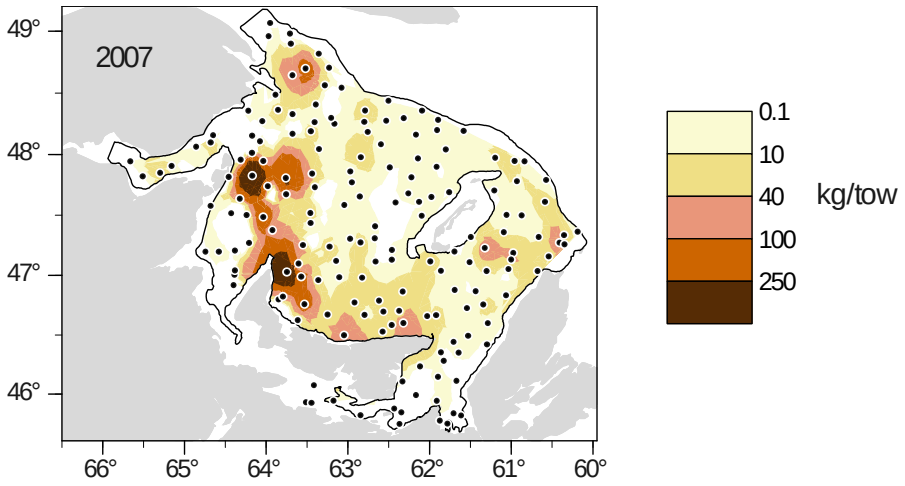


Figure 6: Distribution of cod (kg per tow) in the September 2007 research vessel survey.

The **sentinel survey** program continued in 2007. Two types of surveys are conducted: a trawl survey in August and a sentinel longline survey from July to November. The **synoptic sentinel trawl survey** was started in 2003. Abundance and biomass estimates from the 2007 trawl survey were higher than the 2006 estimates, which had reached the lowest level in the 5-year time series (Figure 7).

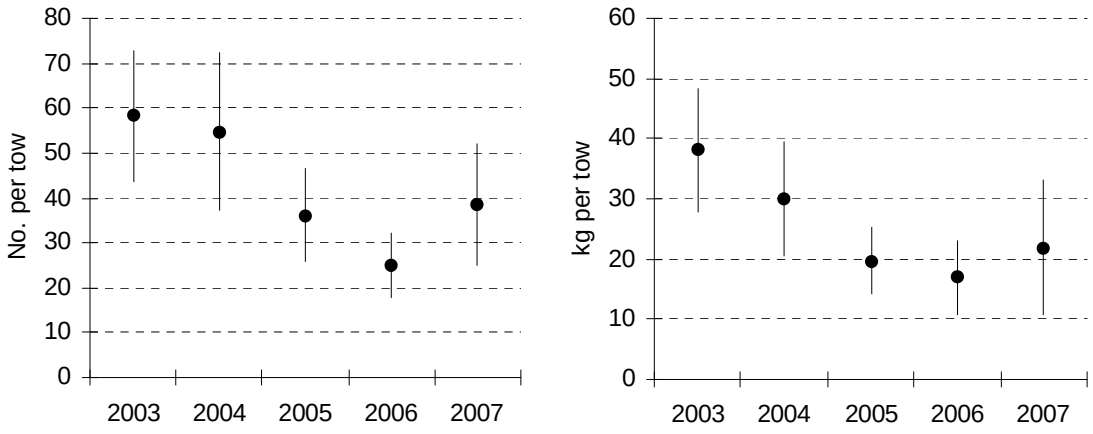


Figure 7: August sentinel trawl survey indices. Vertical bars indicate approximate 95% confidence intervals.

The length frequency distribution in the sentinel trawl survey differed somewhat from that obtained in the September research vessel survey (Figure 8). The large catches in one tow (tow 26 of the sentinel survey) seem to be the cause of this difference. Fewer fish less than 20 cm were caught in the sentinel survey owing to the larger mesh size of the liner used in the sentinel trawl.

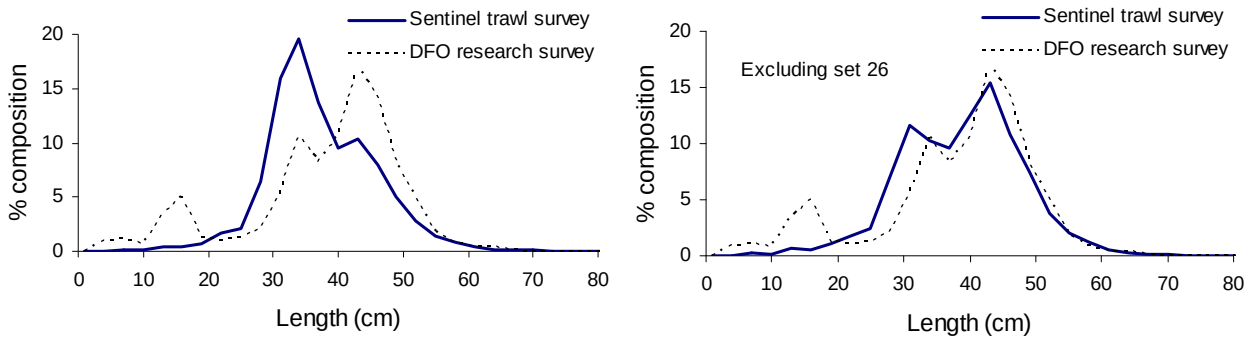


Figure 8: Length frequency distribution of cod caught in the August 2007 sentinel trawl survey and the September 2007 research vessel survey for all tows (left) and excluding tow 26 of the sentinel survey (right).

Geographic distribution of cod in the sentinel trawl survey was similar to that observed in the September research vessel survey, with the highest cod densities located in the Shediac Valley and in the area between the Magdalen Islands and Cape Breton (Figure 9). Relative density was lower north of PEI in the sentinel trawl survey than in the research vessel survey.

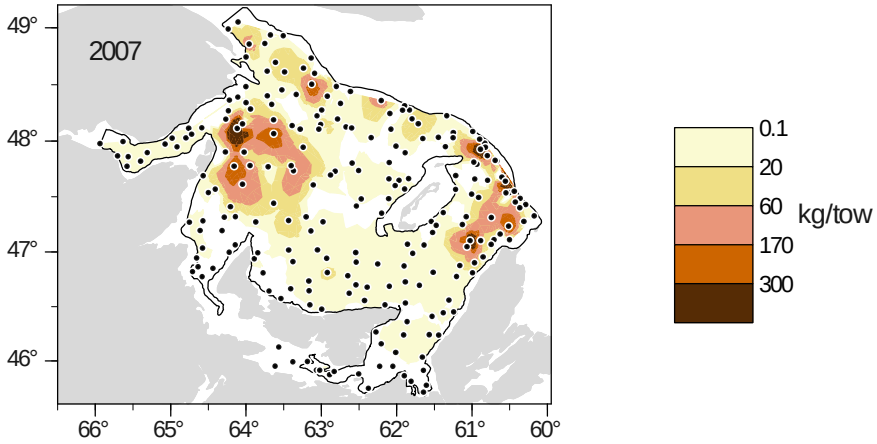


Figure 9. Distribution of cod (kg per tow) in the August 2007 sentinel trawl survey.

In the **sentinel longline survey**, 17 vessels fished at 38 reference sites. Standardized catch rates have decreased in recent years (Figure 10).

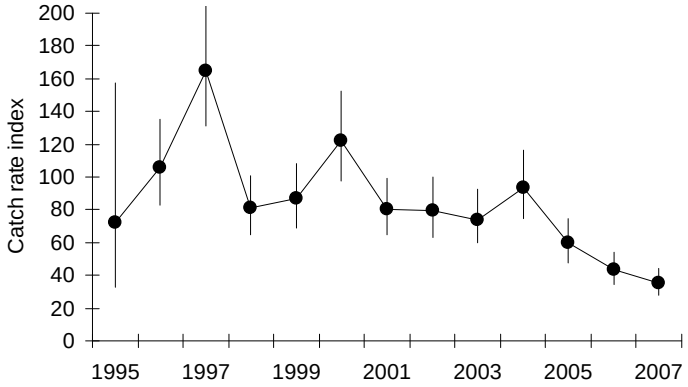


Figure 10: Longline sentinel catch rate index. Vertical bars indicate approximate 95% confidence intervals.

The 2007 catch rates are the lowest in the time series and are significantly lower than the catch rates prior to 2005.

In summary, all abundance indices indicate that the stock is at or near a record-low level and is declining.

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 natural mortality from population analyses indicated that *M* increased in the 1980s and has not declined appreciably since the late 1980s. Total mortality estimates (*Z*) 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 the RV and sentinel trawl survey data are very high, suggesting that *M* may now be increasing to values above 0.4.

The contribution of each of the potential causes of the recent high estimates of *M* is undetermined. Consumption estimates of cod by grey and harp seals in 2000 for this stock range from 19,000 to 39,000 t (all ages), depending on diet assumptions. The higher estimates were produced using diet compositions from outside the stock area. Cod consumption by grey seals is estimated to exceed that by harp seals in the southern Gulf. Although diet samples suggest that most cod consumed by seals appear to be less than 35 cm in length, diet analyses cannot account for cod that may be killed but not consumed totally (heads are not eaten). Changes in natural mortality estimates for cod are consistent with trends in grey seal abundance in the southern Gulf of St. Lawrence.

The population model used in the assessment of this stock estimate natural mortality over four periods (Figure 11) and reveal that it is high (0.59) for the period 2003 to 2007 and has increased in recent years.

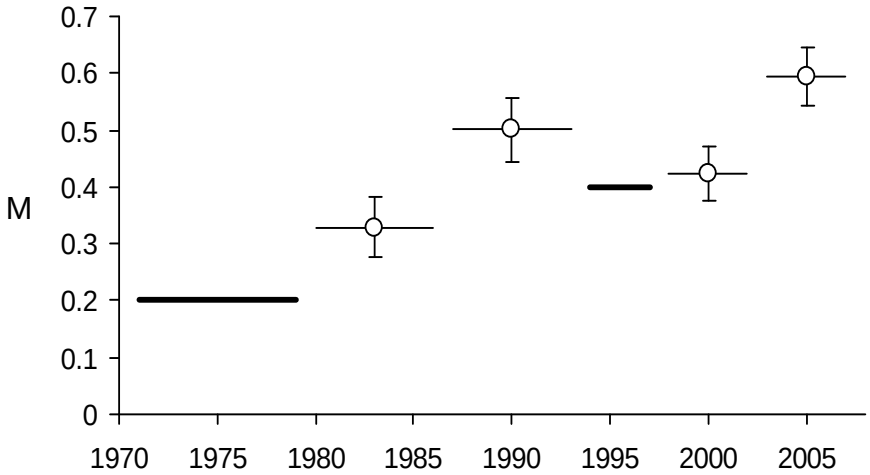


Figure 11: Natural mortality (age 3+) estimated by the model. Heavy lines are fixed values, and circles are values estimated by the model with their 95% confidence intervals (vertical lines). Horizontal lines indicate the period for which M is either fixed or estimated.[2]

Total biomass (ages 3 and older) and spawning stock biomass were high in the 1950s, but declined throughout the 1960s, to reach a minimum in the mid-1970s (Figure 12). Spawning biomass increased sharply with the recruitment of strong year-classes (1974-1975 and 1979-

[2] Figure 11 was revised in June 2008.

1980), but then declined just as rapidly, reaching a new low in 1993 (Figure 12). Spawning stock biomass has been low since the early 1990s and has declined since 2002. The estimate of spawning stock biomass at the beginning of 2008 is 36,000 t.

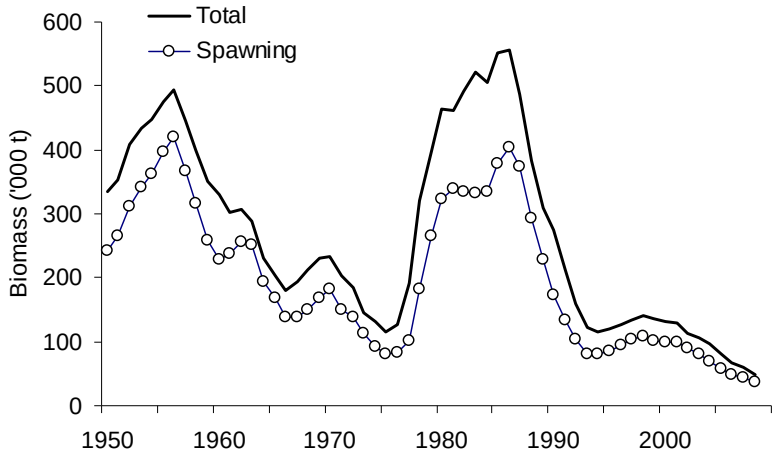


Figure 12: Total (ages 3+) and spawning stock biomass estimates derived from population models for cod in the southern Gulf of St. Lawrence.

The trend in total abundance (Figure 13) is similar to that of biomass (Figure 12), 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 stable at a low level in the mid to late 1990s, but declined further in the early 2000s. Abundance increased somewhat in 2003 and 2004 because the 2000 and 2001 year-classes are more abundant than those of the preceding several years. Abundance declined after 2005 because of the weak 2003 year-class.

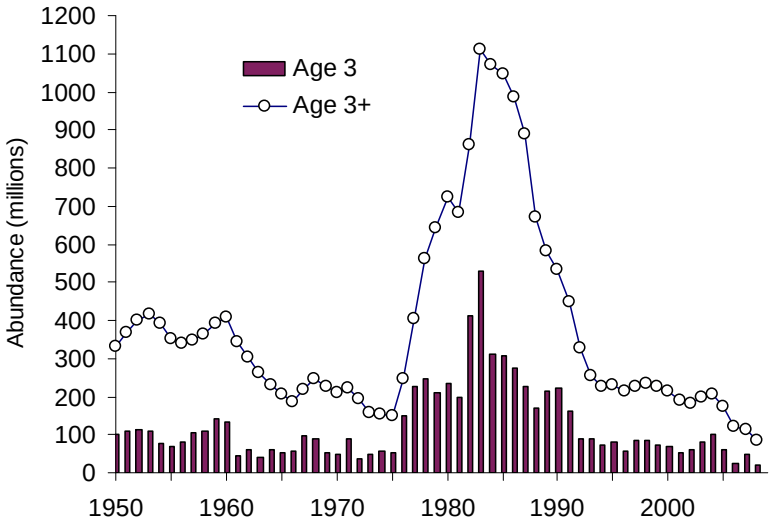


Figure 13: Abundance (ages 3+) and recruitment (age 3) estimates for southern Gulf of St. Lawrence cod.

Recruitment of year-classes produced since the late 1980s has been significantly below the long-term average. The 2001 and 2002 year-classes are estimated to be slightly more abundant than the weak year-classes preceding them. However, the estimates of the 2003 and 2005

year-classes are very low, less than half the strength of other recent year-classes, which are themselves low.

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 and has been increasing since the mid-1990s.

The exploitation rate of commercial fisheries on southern Gulf cod increased from the early 1950s to the mid-1970s, with the exception of a high value in 1959 (Figure 15). There was a decrease following the extension of fisheries jurisdiction in 1977. The exploitation rate increased sharply in the late 1980s, peaking near 60% in 1992.

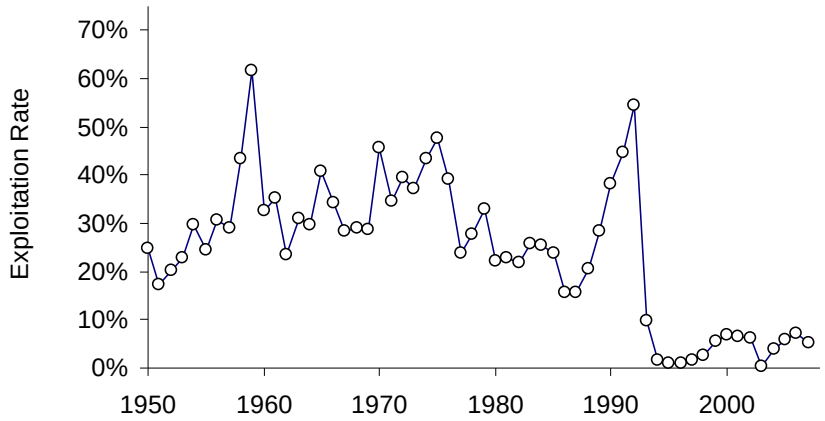


Figure 14: Exploitation rate (ages 7+) for southern Gulf of St. Lawrence cod.

Fishing effort was reduced markedly in 1993 with the closure of the directed fishery. Exploitation rates were 1 to 2% during the moratorium. In 2007, the exploitation rate was estimated at about 5% (F = 0.07).

Sources of Uncertainty

The level of natural mortality in recent years remains a source of uncertainty in the assessment. Predation by seals is considered to be a significant component of natural mortality, and analyses suggest that changes in natural mortality 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.

CONCLUSION AND ADVICE

The estimated limit reference point for this stock is 80,000 t (DFO 2003). Below this 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 must promote stock growth, and removals by all human sources must be kept to the lowest possible level (DFO 2006b).

The productivity of the stock has been low for more than a decade because of poor growth and high natural mortality. The estimates of the 1998, 1999 and 2000 year-classes are amongst the lowest on record. While the estimates of the 2001 and 2002 year-classes are slightly higher, the 2003 and 2005 year-classes are estimated to be much weaker than any other year-class observed, and the 2004 year-class is also low. Natural mortality remains high and may be increasing to even higher levels. The outlook for the stock continues to be very pessimistic and further declines are expected in the short term.

Projections based on the point estimates of stock size predict that the spawning biomass will decrease by 15% in 2008 even with no catch (Figure 15). Catches of 1,500 t (approximately level of the catch in 2007) in 2008 would result in an 18% decline in spawning stock biomass.

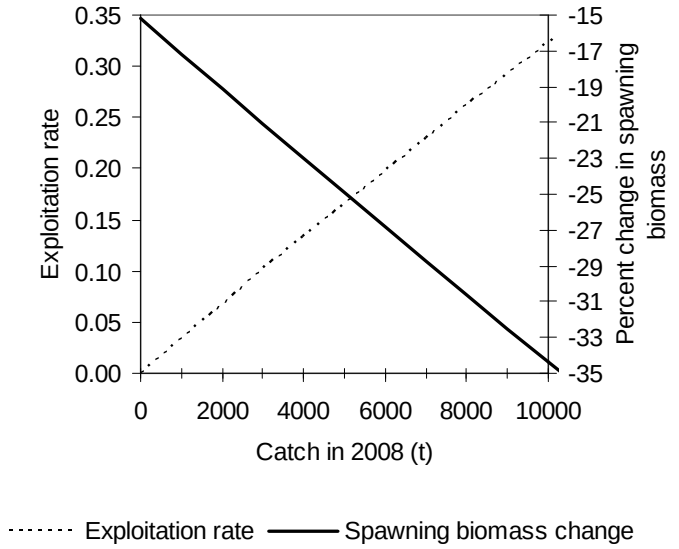


Figure 15: Estimates of the exploitation rate and changes in spawning stock biomass for various catch levels in 2008.

It is also possible to estimate the uncertainties regarding stock size (and natural mortality, if it is estimated in the population model) and then use these in **risk analyses**. These risk analyses include uncertainties in the population estimates but not those associated with weight at age and partial recruitment (or natural mortality if its value is assumed). It should be noted that risk was calculated for the calendar year, whereas TACs for this stock are set for the period from May 15 to May 14.

The analyses indicate that, even with no catch in 2008, spawning stock biomass is almost certain to decline by 10%, with a 53% probability of a decline of 15% or more. With a catch of 1,500 t, there is a 100% probability of a 10% decline and an 89% probability of a 15% decline (Figure 16).

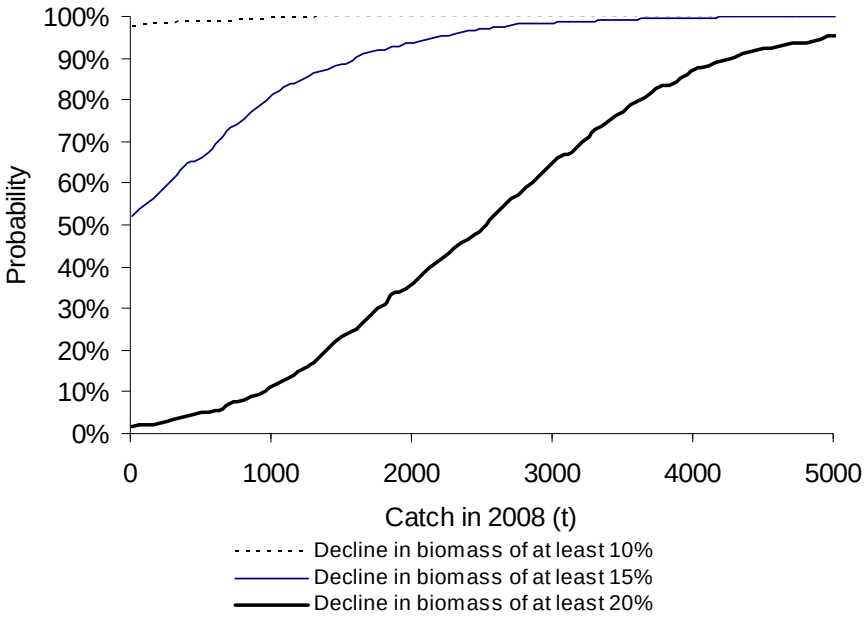


Figure 16: Risk analyses of the decline in spawning stock biomass at various catch levels in 2008.

An analysis of the viability of the stock indicates that the stock is destined for extinction if the low productivity conditions (high natural mortality, low growth and recruitment) persist (Figure 17). Unless productivity increases, spawning biomass will fall to close to 0 (<1 000 t) in 20 years with a TAC of 2,000 t (catches equal to the TAC or at a maximum exploitation rate of 80%) and in 40 years with no commercial catch. A closure of the fishery would delay this eventuality and would increase the chances of recovery if productivity conditions improve.

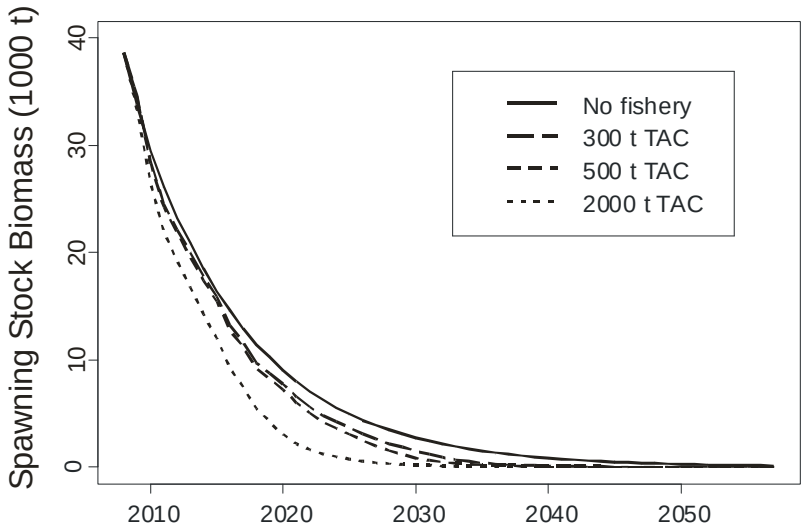


Figure 17: Southern Gulf of St. Lawrence cod biomass projections for four different annual catch levels on the assumption that stock productivity remains at the current level. The projections assume that catches are equal to the TAC or to a maximum exploitation rate of 80%.

The current estimate of spawning stock biomass of southern Gulf cod (36,000 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, the lack of improvement anticipated for the next few years,

and the possibility of the extinction of the stock if the poor productivity conditions persist, it would be advisable to limit catches to the lowest possible level in order to minimize expected declines and to be compliant with the principles of the precautionary approach. Based on historical bycatch 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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[3] Citation updated June 2008.

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This report is available from the:

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ISSN 1480-4913 (Printed)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2008. Assessment of Cod in the Southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/004 (revised).