Fisheries and Oceans Canada | Pêches et Océans Canada
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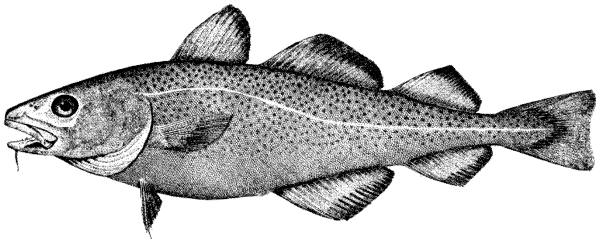
Canadian Science Advisory Secretariat
Gulf Region **Science Advisory Report 2015/061**

ASSESSMENT OF ATLANTIC COD (*Gadus morhua*) IN THE SOUTHERN GULF OF ST. LAWRENCE (NAFO DIV. 4T-4VN(NOV. – APRIL)) TO 2014



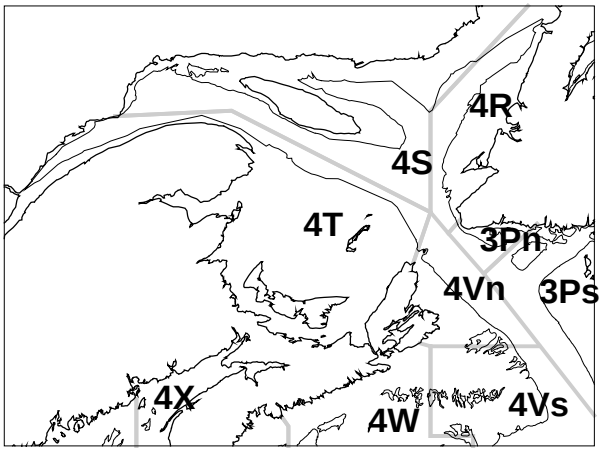


Figure 1. Map of the Gulf of St. Lawrence showing NAFO divisions.

Context:

The stock of Atlantic cod in the southern Gulf of St. Lawrence (sGSL) has 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. The directed fishery has been under moratorium since 2009 and a 300 t bycatch TAC has been set.

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.

This assessment was conducted in support of DFO Ecosystems and Fisheries Management multi-year management approach and request for advice for a TAC decision for May 2015 to May 2019 for the southern Gulf of St. Lawrence stock of Atlantic Cod. A regional peer review meeting was held March 12, 2015 to address the request for science advice. Participants included DFO Science personnel from Gulf and Maritimes regions, DFO Fisheries Management, and fishing industry members.

SUMMARY

- The cod-directed fishery has been closed since 2009, with a 300 t TAC in place to cover by-catch in other groundfish fisheries, a limited recreational fishery, scientific purposes, and negotiated Aboriginal food, social and ceremonial agreements.
- Annual landings since 2009 have varied between 103 and 172 t.
- Since 2009, the exploitation rate has averaged 0.2% for ages 5-8 and 0.7% for ages 9+. These low levels have a negligible impact on the population trajectory.
- The biomass index for commercial-sized cod (≥ 42 cm) from the annual DFO research vessel survey was at the lowest level observed in the 44-year record in 2011 and 2012. The 2011 and 2012 indices were about 10% of the already low values in 1995-2002. The 2013 and 2014 indices were marginally higher, about 20% of the 1995-2002 level.
- The biomass index from the sentinel trawl survey was at the lowest level observed in 2012 and 2013, averaging 17% of the level at the start of this time series in 2003. The index in 2014 increased to 34% of the 2003 value, but was highly uncertain.
- The biomass index from the sentinel longline program steadily declined from 2004 to 2011. The 2011 value was 19% of the 1995-2004 average. The index remained low in 2012-2014.
- Over the past 15 years, cod have progressively moved out of shallow inshore waters and into deeper offshore waters during their feeding season in the sGSL. This appears to result from the high and increasing risk of predation by grey seals in inshore waters in summer.
- Estimated spawning stock biomass (SSB) declined steadily between 1997 and 2014. SSB at the beginning of 2014 was 28,700 t, 28.7% of the level in 2000 and 9% of the level in 1985. SSB in 2015 was slightly higher at 34,000 t, 29.2% of the level in 2000.
- A limit reference point (LRP), the level below which the stock is considered to have suffered serious harm to its productivity, was estimated in 2003 to be 80,000 t. The SSB in 2015 is estimated to be 42% of the LRP. There is no chance that the stock is at or above the LRP.
- Year-class strength has been declining since the mid-1980s due to declining SSB. Year-classes produced since 2002 have been the weakest on record, except for the 2011 year-class. The 2011 year-class is estimated to be nearly twice the average size of other year-classes produced since 2002.
- Extremely high natural mortality of cod 5 years and older is the reason for the lack of recovery of this stock. Natural mortality of about 18% annually (M = 0.2) is considered normal for adult cod. In this population, natural mortality of adults has increased over the past 35 years and is now estimated to be 52 - 58% annually (M = 0.74 – 0.88). Predation by grey seals is considered to be a major component of this mortality.
- Given the relatively strong 2011 year-class, SSB is expected to increase slightly in 2016. It is then expected to decline below the 2015 level by 2020 due to the high level of natural mortality.
- At the current level of natural mortality, recovery of this stock is highly improbable, even in the absence of fishing.

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 normally 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 between the late 1970s and mid-1980s and has remained low since then. They begin to reach commercial size (43 cm) at about age 5 and are fully available to the commercial fishery by age 8. Historically, southern Gulf cod began to mature at 5-6 years of age and most were mature by age 9. However, age-at-maturation declined in the 1950s and 1960s, and since the early 1970s most fish in the population have been mature by age 6. 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 the overwintering grounds. The stock overwinters along the edge of the Laurentian Channel in eastern 4T and in 4Vn, in some years extending into 4Vs. The return migration usually begins in mid-April, although this can be delayed if breakup of winter ice is late.

Fishery

The directed fishery for southern Gulf Atlantic cod has been under moratorium since 2009. A TAC of 300 t has been in place since then for bycatch in fisheries directed at other species, mainly flatfish, for scientific sampling, for a limited recreational fishery and for allocations in aboriginal fishery agreements for food, social and ceremonial purposes.

Table 1. Reported landings (in tonnes) of Atlantic cod by fishing component, 2009 to 2014. NR means not reported.

Fishing component	2009	2010	2011	2012	2013	2014
Bycatch in groundfish fisheries	117	77	96	146	90	95
Sentinel fisheries	32	26	19	26	21	19
Charter boat catch [1]	6	8	12	16	14	13
Recreational [2]	NR	NR	NR	NR	NR	NR
Aboriginal FSC fisheries [3]	NR	NR	NR	NR	NR	NR

[1] Includes harvested and released cod (75-80% of the reported catch was released in 2012 – 2014)
[2] Estimated to be in the range of 5 t annually
[3] No reports of fishing having taken place

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. Landings since the closure of the cod-directed fishery in 2009 have been very small, averaging 6% of the landings by the small directed fisheries in 2004-2008 and 0.2% of the landings in the five years prior to the first closure of the cod fishery in 1993 (Fig. 2). Total reported landings in the 2009 to 2014 calendar years in commercial and sentinel fisheries ranged from 103 t to 172 t (Table 1). Sentinel programs, conducted in collaboration with the fishing industry to obtain additional indices of stock

abundance, accounted for 15-25% of the reported landings, 13-22% by the sentinel longline program and 2-4% by the sentinel trawl survey. The research vessel survey caught an additional 0.9 to 3.7 t annually between 2009 and 2014.

The general recreational fishery for groundfish is open for five weeks or less with a daily bag limit of five cod and/or white hake. Landings are not reported but DFO Fisheries Management Gulf Region indicated these to be about 5 t annually. In addition, charter boat recreational fishing with rod and reel operate in management zones 4T2b and 4T8. Reported catches (kept and released fish) by charter boats were 6 – 16 t annually, with 75 – 80% of the catch released at sea. The total cod catch by charter boats in 2014 was 13.2 t, with 2.8 t landed and 10.4 t released.

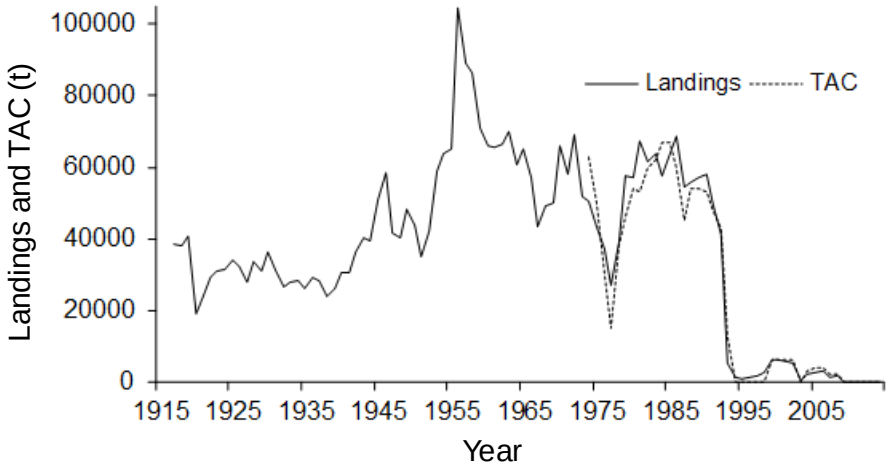


Figure 2. Reported landings and TAC (t) for the southern Gulf of St. Lawrence cod stock, 1917 to 2014. Landings are for the calendar year; the TAC is for the management year which changed to the period from May 15 of the current year to May 14 of the following year starting in 1999.

Ages 6 to 9 were dominant in the 2009 to 2014 landings. Average weight-at-age in the fishery catch declined in the early to mid-1980s but returned to a higher level in recent years (Fig. 3). This may reflect the increased proportion of the landings taken as by-catch in the halibut fishery after 2009. Weight-at-age in the annual research vessel survey has remained low since the mid-1980s.

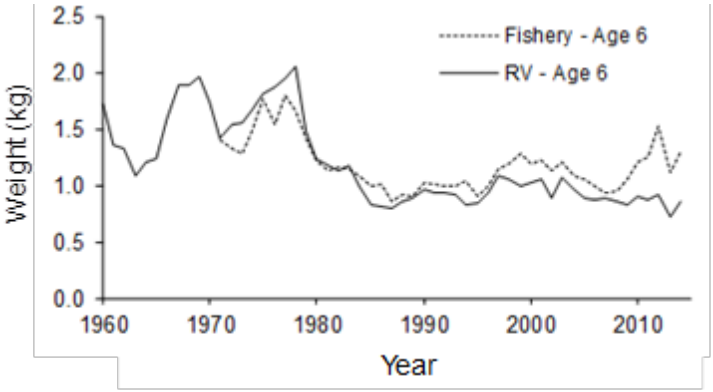


Figure 3. Average weight (kg) of a 6-year-old cod in fishery catches and from the annual research vessel survey.

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 currently have elevated natural mortality at adult sizes. In contrast, many small fishes (e.g., shannies, sculpins) have increased dramatically in abundance. Most of the 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.

ASSESSMENT

Sources of information

The information used in this assessment includes the annual research vessel survey (1971-2002 and 2004-2014), landings data from 1950 to 2014, commercial catch at age data from 1950 to 2014 and sentinel survey data from 1995 to 2014.

Stock Trends

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 biomass of pre-commercial and commercial sizes of cod was low in the early to mid-1970s, and then increased to the early 1980s (Fig. 4). 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 for commercial sizes of cod, but these cod declined further after 2002. The index for commercial-sized cod was at the lowest level observed in 2011 and 2012, when the index was about 10% of the already low values in 1995-2002. The 2013 and 2014 indices were marginally higher, about 20% of the 1995-2002 level.

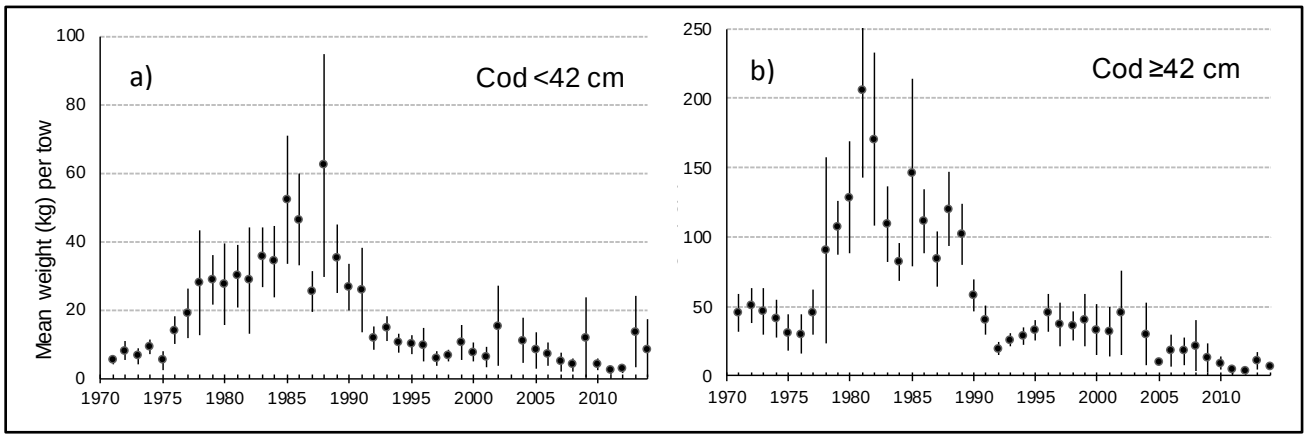


Figure 4. September research survey biomass indices (kg per tow; mean and approximate 95% confidence intervals) for cod less than the commercial length of 42 cm (left panel, a) and of commercial length (≥ 42 cm; right panel b).

The index for pre-commercial sizes continued to decline at a slow rate after 1992. The decline was interrupted by high but uncertain values in 2002, 2004, 2009, 2013 and 2014. The high catch rates at small sizes in 2002, 2004 and 2009 did not result in subsequent increases in abundance at larger sizes.

The geographic distribution of cod in September has changed dramatically over the past 20 years (Fig. 5). Over this period there has been a progressive shift in distribution out of inshore areas and into deeper water along the slope of the Laurentian Channel. This appears to represent a response to increased risk of predation by grey seals, with cod shifting out of areas where predation risk is now high and into low risk areas.

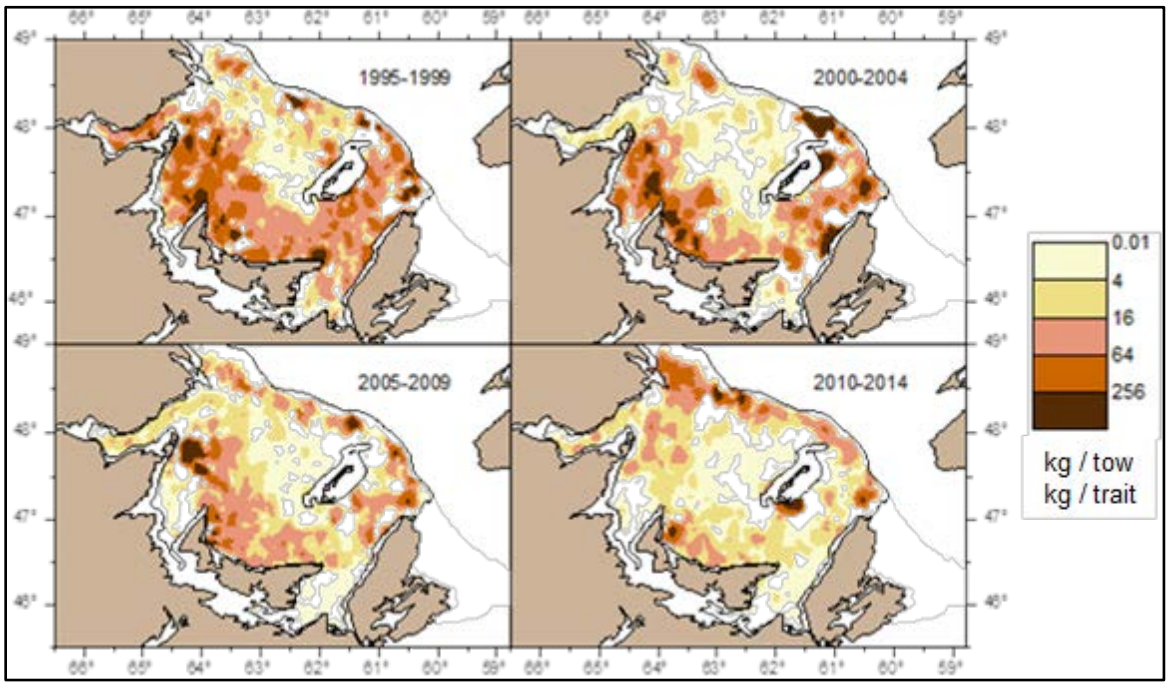


Figure 5. Changes in the distribution of cod in September over the past 20 years as indicated by the spatial distribution of biomass indices (kg per tow) by five year groups, 1995 to 2014.

The August sentinel trawl survey started in 2003 and covers most of the stock area. Two of the four vessels conducting the survey in 2014 were new to the sentinel program. The estimated relative fishing efficiencies of these new vessels were higher than the efficiencies of the other vessels currently or previously participating in this program. The abundance and biomass indices from this survey showed a declining trend from 2003 to 2013, with the 2003 and 2004 indices the highest in the time series and the 2012 and 2013 indices the lowest in the time series, about 20% of the 2003-2004 level (Fig. 6). Without standardizing for differences in fishing efficiency, the abundance and biomass indices in 2014 are at the 2003-2004 level, but uncertainty in these indices is extreme. The standardized indices are at a low level in 2014.

The geographic distribution of catches in the sentinel trawl survey indicated an offshore shift in cod distribution in August similar to that observed in the September survey (Fig. 7). In the 2003-2005 August surveys, cod catches were relatively high in a band extending from Miscou, off the north coast of PEI and between the Magdalen Islands and Cape Breton. By the 2012-2014 surveys, cod densities had declined to very low levels in these areas, with the highest catches occurring between Miscou and the American Bank area off the Gaspe coast. This change is also consistent with a shift in cod distribution out of areas where risk of predation by grey seals is now high and into lower risk areas.

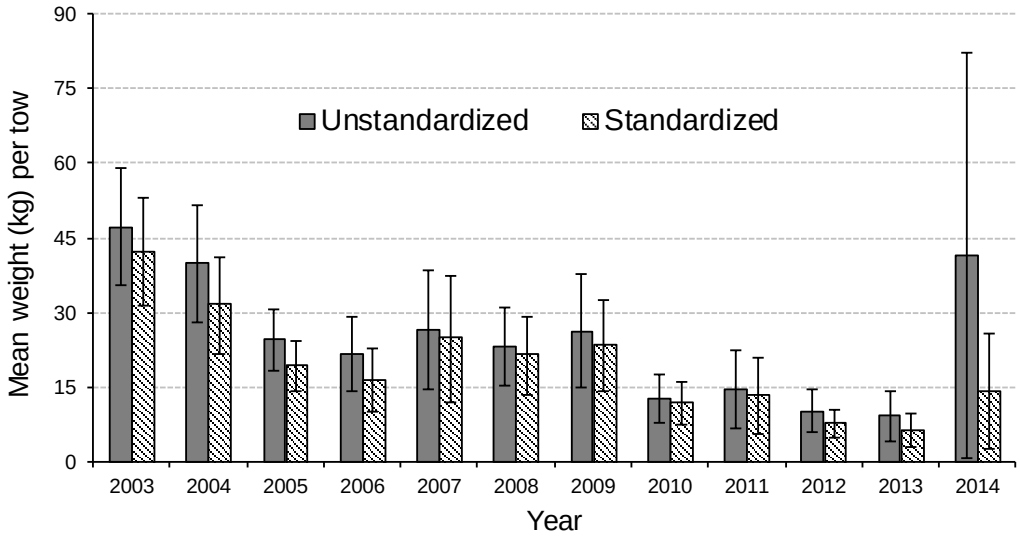


Figure 6. Biomass indices (kg per tow; mean and approximate 95% confidence intervals) from the August sentinel trawl survey. Indices are shown as standardized (hatched bars) and unstandardized (solid bars) for differences in fishing efficiency between vessels.

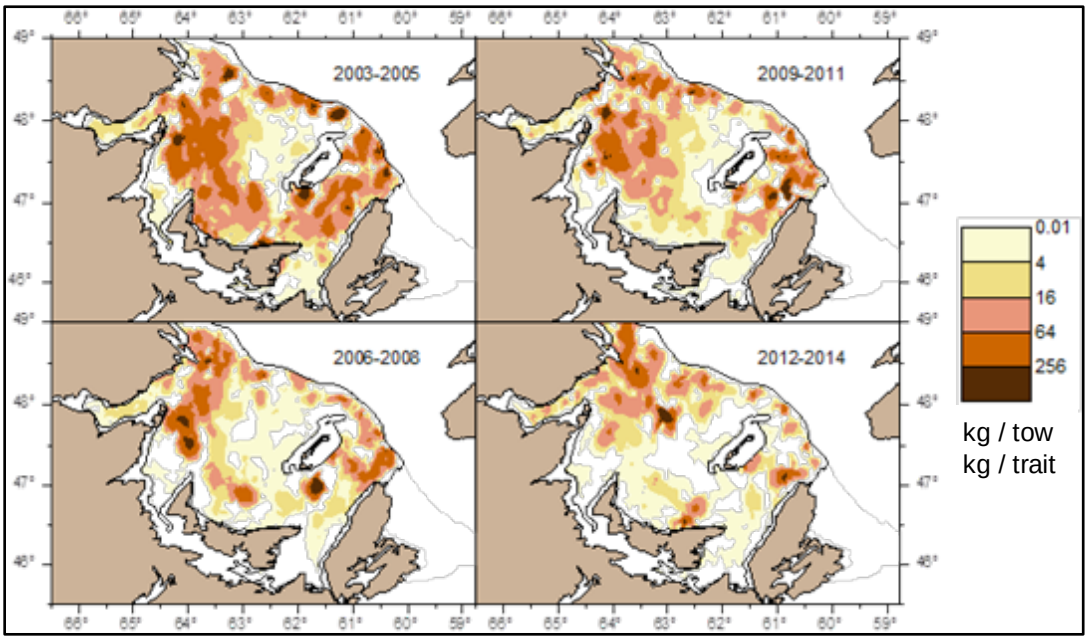


Figure 7. Changes in the distribution of cod in the August sentinel trawl surveys over the past twelve years as indicated by the spatial distribution of biomass indices (kg per tow) by three year groups, 2003 to 2014.

Since 1996, vessels participating in the sentinel longline program have each fished at two traditional fishing sites up to 18 times in July to November using standardized protocols. Currently, 36 sites are fished. Standardized catch rates in this program declined steadily between 2004 and 2011 (Fig. 8). Catch rates remained near this low level in 2012-2014, averaging 26% of the 1995-2004 level.

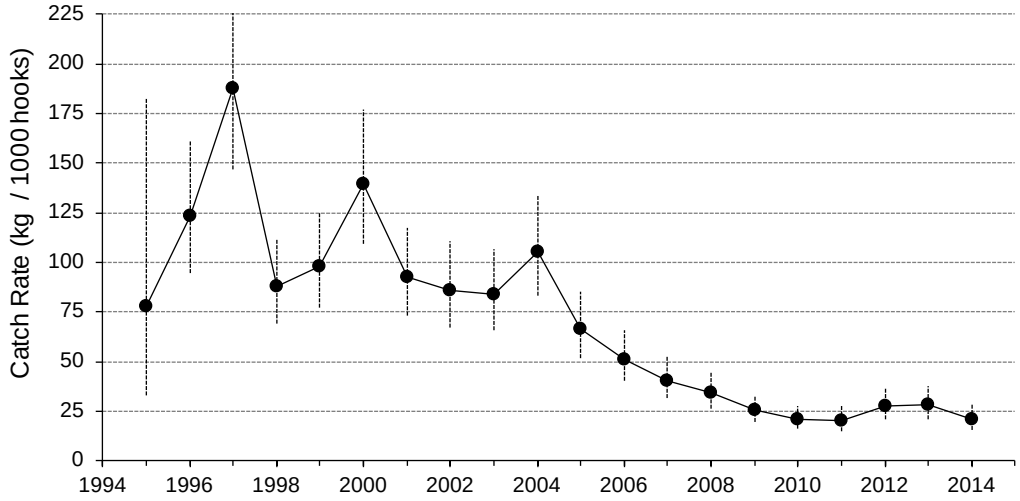


Figure 8. Longline sentinel catch rate index (kg per 1000 hooks; mean and approximate 95% confidence intervals), 1995 to 2014.

In summary, indices from the September RV survey, the August sentinel trawl survey and the longline sentinel program all indicate that the stock is at or near a record-low level and is declining. All three indices have declined by 75-80% from the already low levels in the late 1980s and early 2000s.

Biological information

Previous work has indicated an increase in the instantaneous rate of natural mortality rate (*M*) of this cod stock. Natural mortality of about 18% annually (*M*=0.2) is considered normal for adult cod. Results from early studies using data from the 1960s and 1970s were consistent with *M* near 0.2 for adult cod in this population at that time. Estimates of *M* from population models and from analyses of the catch rates at age in the surveys indicate that *M* began to increase in the 1980s, reaching very high levels in recent years (see below). Possible causes of these elevated estimates for *M* include unreported catch and increased natural mortality due to disease, contaminants, poor fish condition as a result of harsh environmental conditions, life-history change (early maturation, early senescence), heavy parasite loads, or increased predation mortality. The weight of evidence most strongly supports the hypothesis that predation by grey seals is a major cause of the increases in natural mortality. While unreported catch and early maturation combined with harsh environmental conditions may have contributed to increases in *M* between the late 1970s and mid-1990s, there is no support for these factors as important causes of the increases in *M* since then.

Size-at-age of southern Gulf cod decreased sharply in the late 1970s and early 1980s (Fig. 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 most 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:

1. a genetic response to the strong selection against fast growth that was inflicted by fisheries in the 1980s and early 1990s,

2. size-selective natural mortality (e.g., higher predation mortality of individuals that are less risk averse and thus forage more actively) and/or
3. behavioural responses to increased risk of predation by grey seals (e.g., reduced foraging activity, increased use of safer but less profitable habitats).

Age and size at maturation of sGSL cod decreased sharply over time in cohorts produced in the 1950s and 1960s, but has changed little since then (Fig. 9). When mortality is high, individuals that mature early tend to be at an advantage over those maturing later in life. The decline in age and size at maturity between the late 1950s and the early 1970s is thought to reflect an evolutionary response to increasing fishing mortality in the 1950s and 1960s. The continued early maturation following the sharp reduction in fishing mortality in the early 1990s is thought to reflect the current high natural mortality. These changes in maturation schedule have resulted in large changes in the characteristics of the spawning stock, from one consisting of large older fish to one dominated by smaller young fish.

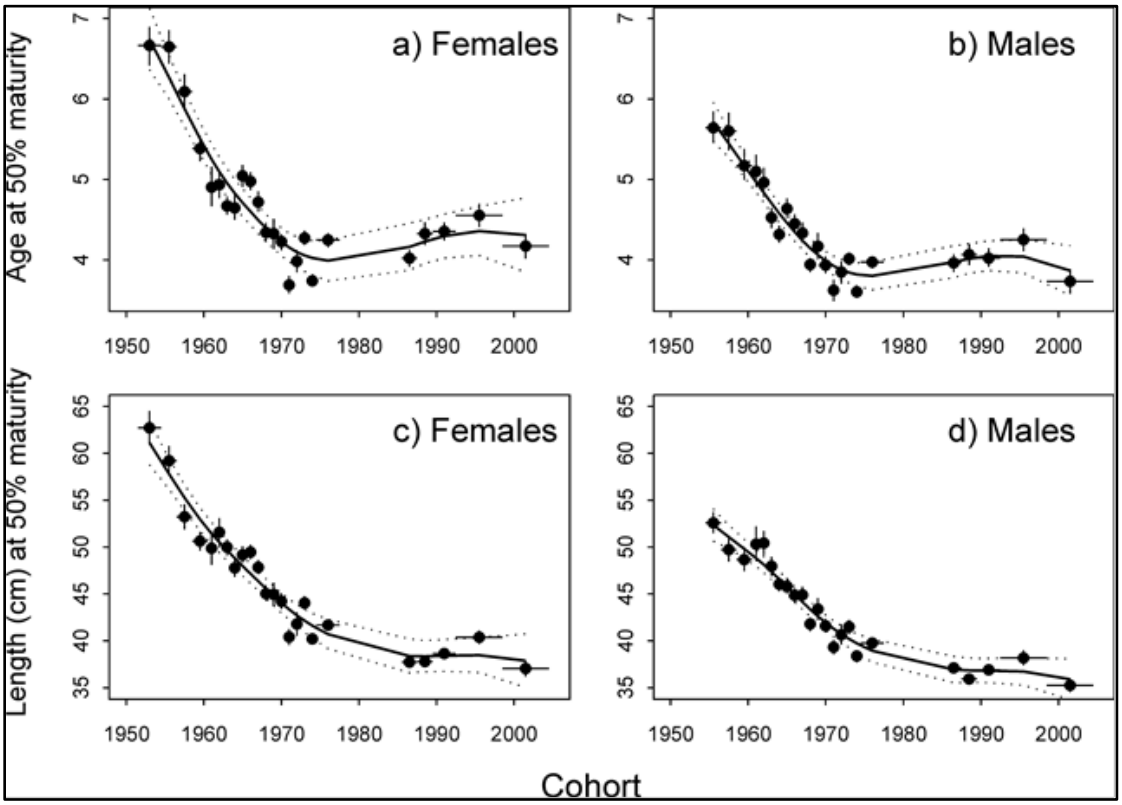


Figure 9. Age and length at 50% maturity for female and male cod in the southern Gulf of St. Lawrence (from Swain 2011). Vertical lines are 95% confidence intervals. Horizontal lines indicate the range of cohorts grouped together for an estimate. Time trends are summarized by a smoothing spline (heavy line) ± 2 SE (dotted lines). Lengths have been adjusted to September values.

Current Status

The statistical Catch at Age model used in this assessment estimates time trends in natural mortality for three age groups, cod aged 2-4, 5-8 and 9+ years (Fig. 10). For adult cod (ages 5+), *M* began to increase in the 1970s, reaching very high levels in recent years (age 5-8: *M*=0.74 in 2014, 52% annually, age 9+ *M*=0.875 or 58% annually in 2010). Predation by grey seals is considered to be a major component of this mortality. In contrast to adults, there is no indication of an increase in *M* for younger cod (ages 2-4 years).

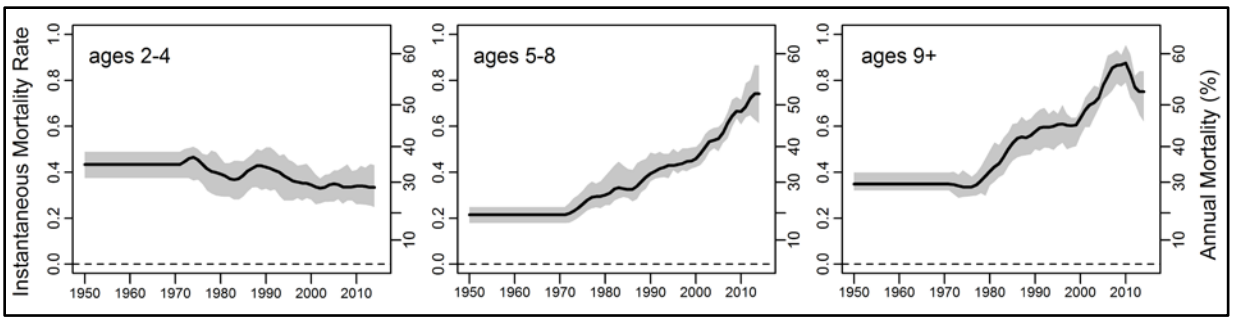


Figure 10: Estimated natural mortality of southern Gulf of St. Lawrence cod aged 2-4, 5-8 and 9+ years. Shading shows 95% confidence intervals.

Spawning stock biomass (SSB) and the biomass of cod 5 years and older declined from the 1950s to the mid-1970s (Fig. 11). The difference in trend between the two measures of biomass reflects the changing maturation schedule during this period. Biomass recovered rapidly in the late 1970s due to strong recruitment but rapidly collapsed in the late 1980s and early 1990s due to high adult mortality. The decline halted with the closure of the directed cod fishery in September 1993. Biomass recovered little following the fishery closure and resumed its decline in the early 2000s. Both SSB and 5+ biomass are currently at their lowest levels in the 65-year record.

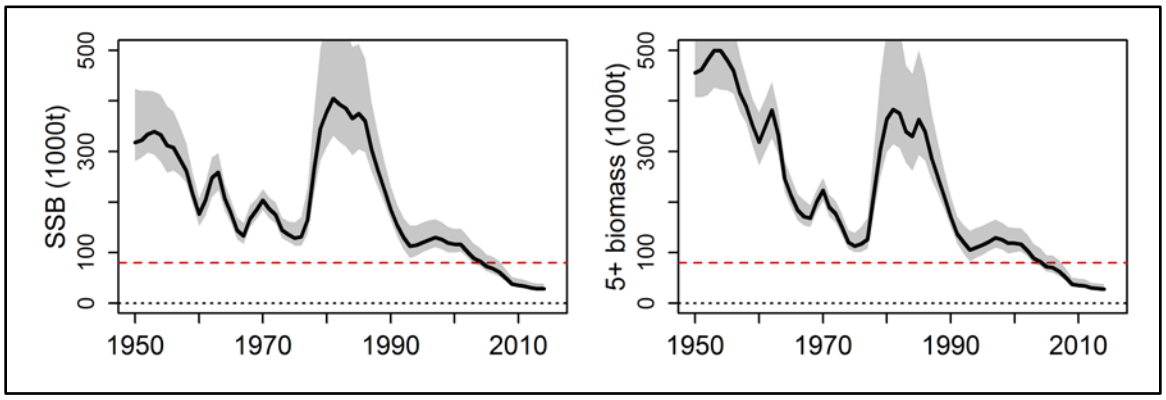


Figure 11. Estimated spawning stock biomass (SSB 1000 t; left panel) and biomass of Atlantic cod 5 years and older (right panel) in the southern Gulf of St. Lawrence. Shading shows 95% confidence intervals. The red dashed line is the Limit Reference Point (LRP), estimated to be 80,000 t of SSB.

The limit reference point (LRP) for this stock, the level below which the stock is considered to have suffered serious harm to its productivity, was estimated in 2003 to be 80,000 t of SSB. Estimated SSB has been below this level since 2005. SSB at the beginning of 2014 is estimated to be 28,700 t, the lowest on record at 28.7% of the level in 2000 and 9% of the level in 1985. SSB is estimated to be slightly higher at the start of 2015 at 34,000 t, 42% of the LRP. The probability that SSB at the start of 2015 was at or above the LRP is less than 0.0002.

Population abundance (ages 2+) dropped sharply in the early 1960s (Fig. 12a) following a steady rise in fishing mortality throughout the 1950s (Fig. 13). Abundance recovered rapidly in the late 1970s, reaching levels considerably higher than the level at the start of the time series in 1950. This recovery resulted from a series of strong year-classes produced in the mid to late 1970s (Fig. 12a). These year-classes, the strongest on record, were produced by relatively low SSB. Recruitment rate, the number of recruits produced per unit of SSB, was unusually high during this period (Fig. 12b). These high recruitment rates have been attributed to reduced predation on early life stages of cod by collapsed pelagic fish stocks (herring and mackerel).

Pelagic fish stocks recovered in the early to mid-1980s and cod recruitment rates returned to a more normal level. Population abundance decreased rapidly from the mid-1980s to the mid-1990s and has declined at a slower rate since then. Population abundance reached its lowest level in 2009, at 36% of the abundance in 1993 when the directed cod fishery was first closed, 12% of the average level in 1980-1985 and 19% of the level in the 1950s. Since 2011, population abundance has increased slightly due to improved recruitment, reaching 45% of the 1993 level in 2014.

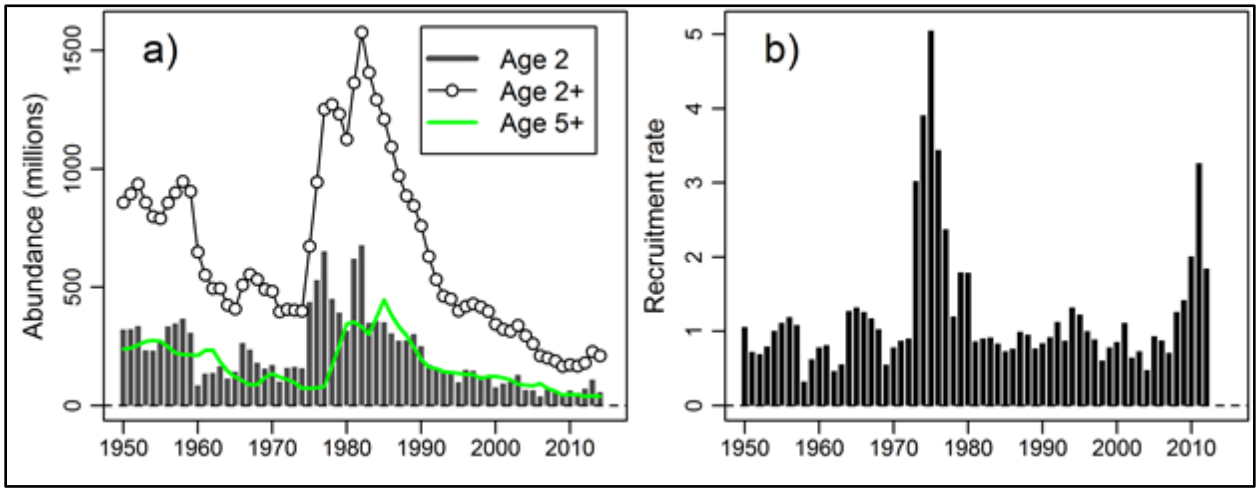


Figure 12. Estimates of abundance (number in millions; left panel a) by year of sampling (1950 to 2013) and recruitment rate at age 2 (thousands of age-2 recruits per ton of spawning stock biomass; right panel b) of Atlantic cod by year class (1950 to 2012) from the southern Gulf of St. Lawrence.

The abundance of age-2 recruits declined between the mid-1980s and the mid-2000s (Fig. 12a). Recruit abundances from 2004-2012 (2002-2010 year-classes) were the lowest on record. These low recruit abundances reflected low SSB, not poor spawning success or pre-recruit survival. Recruitment rates during this period have been near or above those estimated for earlier periods (the 1950s to early 1970s). More recently, recruitment rates have been unusually high, particularly for the 2011 year-class which is estimated to be the strongest on record since 2003.

The instantaneous rate of fishing mortality F increased more than 4- (ages 9+) or 5-fold (ages 5-8) from the early 1950s to the early 1970s (Fig. 13). F then declined to a lower level with the brief reduction in landings and the rapid increase in biomass in the late 1970s. However, F increased rapidly as stock biomass collapsed in the late 1980s and early 1990s, reaching a peak near 0.4 (ages 5-8) or over 0.5 (ages 9+). Estimated F was very low during the 1994-1997 moratorium (0.7% and 1.8% annually for ages 5-8 and 9+, respectively). During the fishery openings in 1999-2002 and 2004-2008, the annual exploitation rate on 9+ cod averaged 8.6% and 6.4% respectively, a small fraction of natural mortality but unsustainable given the low stock productivity. During the moratorium since 2009, annual exploitation rates on 5-8 year-old and 9+ cod have been negligible, averaging 0.2% and 0.7% respectively.

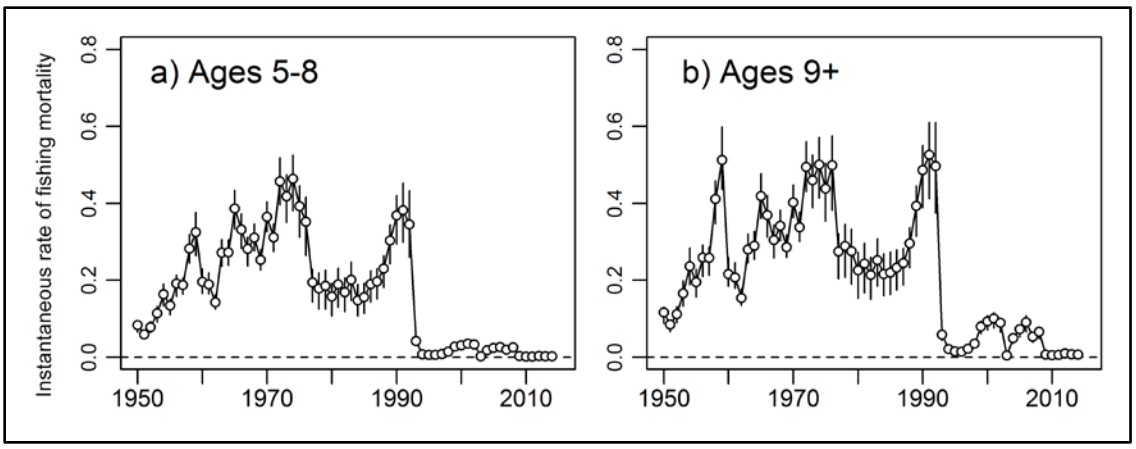


Figure 13. Estimated instantaneous rate of fishing mortality F for southern Gulf of St. Lawrence Atlantic cod aged 5-8 and 9+ years.

Surplus production is the gain in biomass due to recruitment and growth minus the losses to natural mortality. It is the production that can be used to grow the stock and/or support a fishery. Estimated surplus production was substantial in most years from 1950 to the mid-1980s (Fig. 14). Since then surplus production has been very low in most years. There has been a production deficit in most years since 1998. In this situation, the stock will decline even with no fishery removals. While there was some surplus production in 2013, this production is based on young fish not yet exposed to the elevated natural mortality at ages 5 and older.

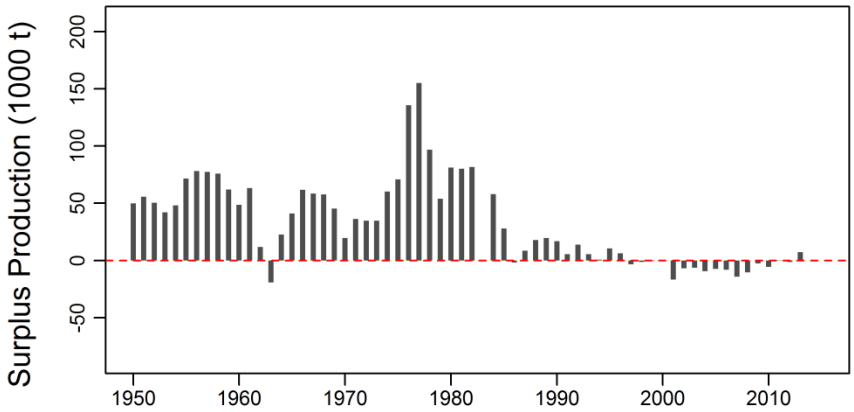


Figure 14: Estimated surplus production (ages 2+) of southern Gulf of St. Lawrence Atlantic cod.

Sources of Uncertainty

The causes of the increases in natural mortality (*M*) of adult cod since the 1970s are uncertain. Based on the weight of evidence, predation by grey seals is considered to be a significant component of *M*, and the estimated changes in *M* are consistent with the trends in grey seal abundance. Recent data and analyses indicate that seal predation on cod is higher than previously estimated. However, there is considerable uncertainty about annual average seal diets in the southern Gulf due to wide spatial, seasonal and individual variation in diet. Furthermore, diet analyses rely on the presence of hard parts (such as otoliths) from prey species in seal digestive tracts. Estimated consumption of adult cod would be underestimated if seals tend not to eat the heads of larger cod, a behaviour consistent with foraging strategies observed in some other predators.

The causes of the continued low weights at age, despite high prey abundance, favourable water temperatures and little size-selective fishing mortality, 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). Estimated SSB at the start of 2015 is 34,000 t, 42% of the LRP (Fig. 15). There is only a 0.02% probability that SSB was at or above the LRP at the start of 2015.

The outlook for this stock continues to be very pessimistic and further declines are expected over the next five years. The productivity of the stock has been low for the past 25 years, with a production deficit in most years since the late 1990s (Fig. 14). During the fishery openings in 1999-2002 and 2004-2008, the annual exploitation rate on 9+ cod averaged 8.6% and 6.4% respectively, a small fraction of natural mortality but unsustainable given the current low stock productivity. However, fishing mortality has been at negligible levels (averaging 0.7% annually for ages 9+) since the directed cod fishery was closed again in 2009. The lack of recovery and continued declines are due to elevated natural mortality of adult cod, which has reached levels of 50-58% annually for 9+ cod in recent years. Predation by grey seals is considered to be an important cause of this high mortality.

Recent year-classes are the weakest on record, reflecting the record-low SSB. The 2011 year-class, the strongest since 2003, is an exception, reflecting the unusually high recruitment rate in 2011.

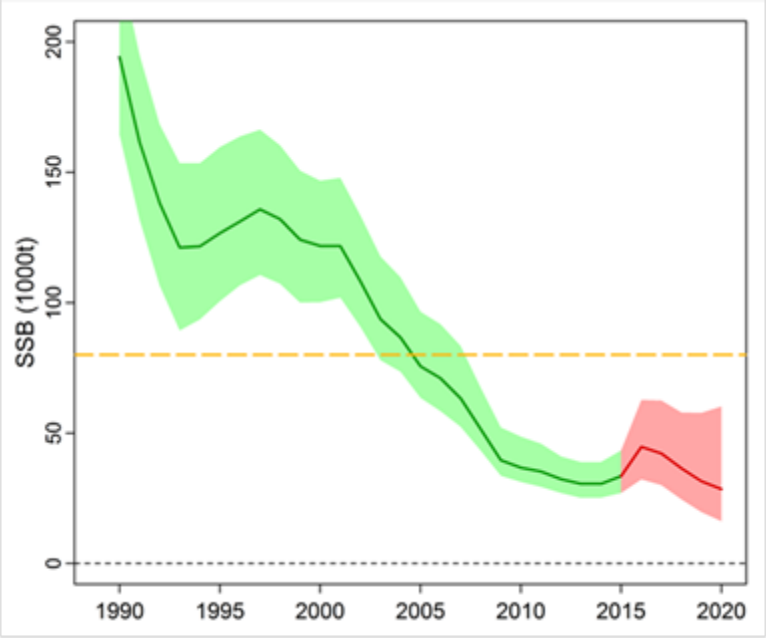


Figure 15. Projected SSB of southern Gulf of St. Lawrence Atlantic cod assuming current productivity and no fishery catch. Lines show the median and shading the 95% confidence band. Green indicates historical values and red the projected values. The dashed line is the LRP value of 80,000 tonnes of SSB.

Projections

The population was projected forward to the start of 2019 assuming that the current productivity conditions would persist until then. SSB is expected to increase slightly in 2016 due to the relatively strong 2011 year-class and then decline as these fish suffer high natural mortality (Fig., Table 2). The probability that SSB in 2019 will be below the 2015 level is estimated to be 79% under current productivity conditions, assuming that there are no fishery removals. Even with no fishery catch, the probability that SSB will remain in the critical zone (i.e., < LRP) over the projection period is 99.9% or more. Fishery by-catch of 300 t is estimated to have a negligible impact on the population trajectory (Fig. 16; Table 2).

Table 2. The probability that SSB will be in the Precautionary Approach critical (< LRP) and cautious zones in projections assuming current productivity conditions and fishery catches of either 0 or 300 t. The proportion SSB in terms of the LRP is also shown.

	Fishery catch = 0 t			Fishery catch = 300 t		
Year	*P* in critical	*P* in cautious[1]	SSB as proportion of LRP[2]	*P* in critical	*P* in cautious[1]	SSB as proportion of LRP[2]
2015	1.0000	< 0.0002	0.477	1.0000	< 0.0002	0.476
2016	1.0000	< 0.0002	0.564	1.0000	< 0.0002	0.561
2017	1.0000	< 0.0002	0.530	1.0000	< 0.0002	0.526
2018	0.9992	0.0008	0.457	0.9992	0.0008	0.453
2019	0.9990	0.0010	0.397	0.9990	0.0010	0.394

[1] The minimum detectable probability is 0.0002.
[2] Based on median values. The maximum likelihood estimate (available for 2015 only) is lower at 0.42.

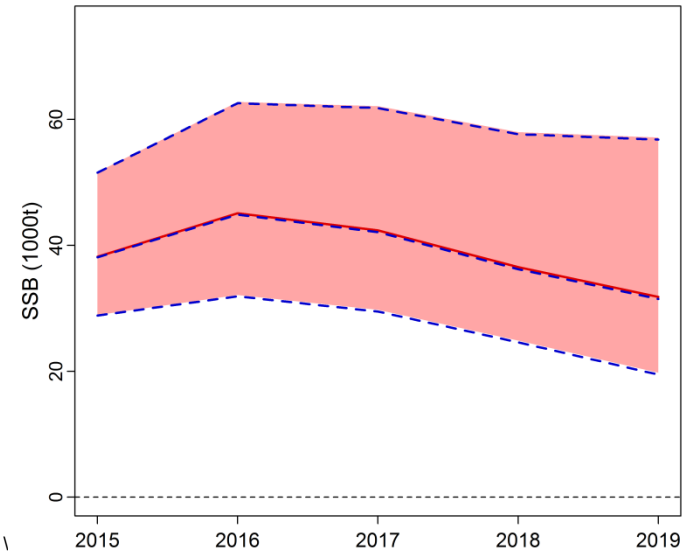


Figure 16. Projected SSB of southern Gulf of St. Lawrence Atlantic cod (median and 95% confidence bands) assuming current productivity and fishery catches of 0 t (solid red line and shading) or 300 t (dashed lines).

OTHER CONSIDERATIONS

Procedure for interim year updates

The three-year moving average of the RV survey biomass indices for adult (commercial-sized) cod will be used as the indicator of stock status in the interim years of the multi-year management cycle. Commercial-sized cod will be approximated by cod 42 cm and longer, because of the 3-cm grouping used prior to 1985. This index will be compared to the LRP value adjusted to the scale of the biomass index which is not corrected for catchability. The re-scaled LRP is 47,200 t of trawlable biomass in September.

An assessment before the scheduled four-year cycle would be recommended if the three-year moving average of the RV biomass index for cod 42 cm and longer exceeds the re-scaled LRP of trawlable biomass. In 2014, the RV biomass index for cod 42 cm and longer was 26% of re-scaled LRP (Fig. 17).

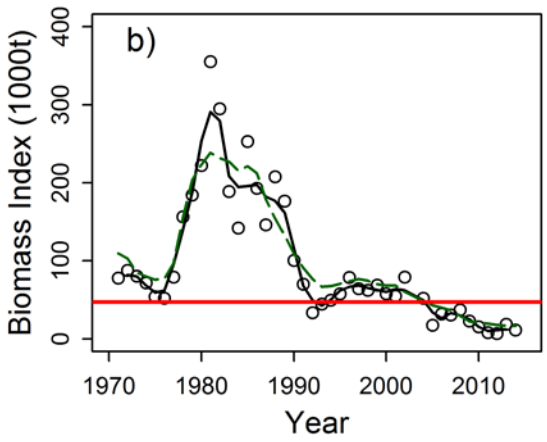


Figure 17. Time trend in the observed biomass index (circles), the index predicted from SSB (dashed green line), and the 3-year moving average of the observed index (solid black line). The horizontal red line is the value of the limit reference point (LRP) at the scale of the biomass index, expressed as trawlable biomass.

An interim year update will be provided mid-way in the four-year assessment cycle, i.e. in early December 2016, to allow sufficient time to complete a full assessment and plan the peer review if the indicators signal that a re-assessment is warranted in winter 2017.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 12, 2015 meeting on Assessment of Atlantic Cod (*Gadus morhua*) of the southern Gulf of St. Lawrence (NAFO Div. 4T-4Vn (Nov. – April)). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Aussi disponible en français :

MPO. 2016. Évaluation de la morue franche (Gadus morhua) du sud du golfe du Saint-Laurent (Div. de l'OPANO 4T-4Vn (nov. – avril)) jusqu'en 2014. Secr. can. de consult. sci. du MPO, Avis sci. 2015/061.