2016 4X5Yb ATLANTIC COD (*GADUS MORHUA*) STOCK STATUS UPDATE

Context

Although Atlantic Cod (*Gadus morhua*) in the 4X5Yb area have supported a commercial fishery since the 1700s, their abundance has declined in number and biomass since 1980. In 2003, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the Maritimes Designatable Unit (DU) of Atlantic Cod as Special Concern (COSEWIC 2003). In 2010, COSEWIC re-assessed Atlantic Cod, and split the Maritimes DU into two new DUs, the Laurentian South DU and the Southern DU, and assessed the Southern DU as Endangered due to significant decline in abundance and evidence of an unexplained increase in natural mortality in 4X (COSEWIC 2010).

A Recovery Potential Assessment (RPA) was carried out by Fisheries and Oceans Canada (DFO) Science in 2011 to provide the information and scientific advice required to meet various requirements of the *Species at Risk Act* (SARA). The RPA used data (1980-2008) from the most recent peer reviewed stock assessment (DFO 2009) to explore the consequences of particular productivity assumptions and catch scenarios (DFO 2011a). The last 4X5Yb Atlantic Cod stock status update was in 2014 (DFO 2015) and the present Science Response is the result of a request for a stock status update from Fisheries Management (Maritimes Region) using most recent DFO Summer Research Vessel surveys (2015-2016) and fishery landing data up to 2015.

This Science Response Report results from the Science Response Process of December 2, 2016, on the Stock Status Update of 4X5Y Cod.

Background

Atlantic Cod is a bottom dwelling North Atlantic fish that ranges from Georges Bank to Northern Labrador in the Canadian Atlantic, including the southern Scotian Shelf and Bay of Fundy (4X5Yb) (Figure 1).

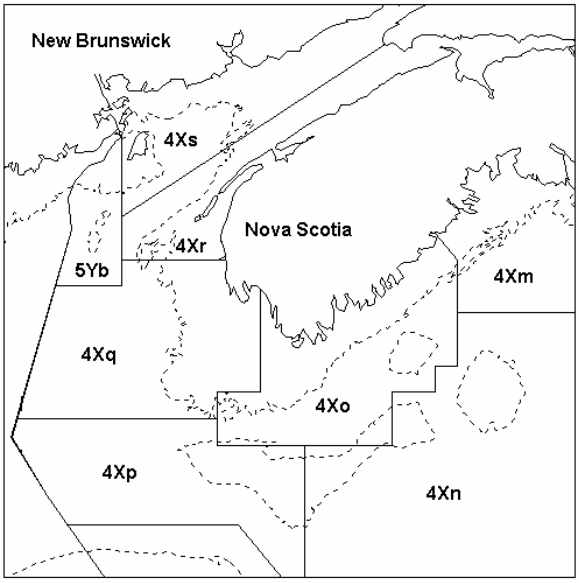

Figure 1. Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Yb.

Atlantic Cod in Divisions 4X5Yb are caught as part of a mixed species fishery including Haddock, Pollock, Winter Flounder, redfish and other species. Landings increased in the 1960s as domestic and foreign otter trawl fleets joined the fishery, and then dropped in 1970 due to restrictions on Haddock fishing. Total landings averaged 20,000 tonnes (t) for several decades, but have recently declined along with restrictive Total Allowable Catch (TAC) (Figure 2). In 2015, landings decreased to 705t.

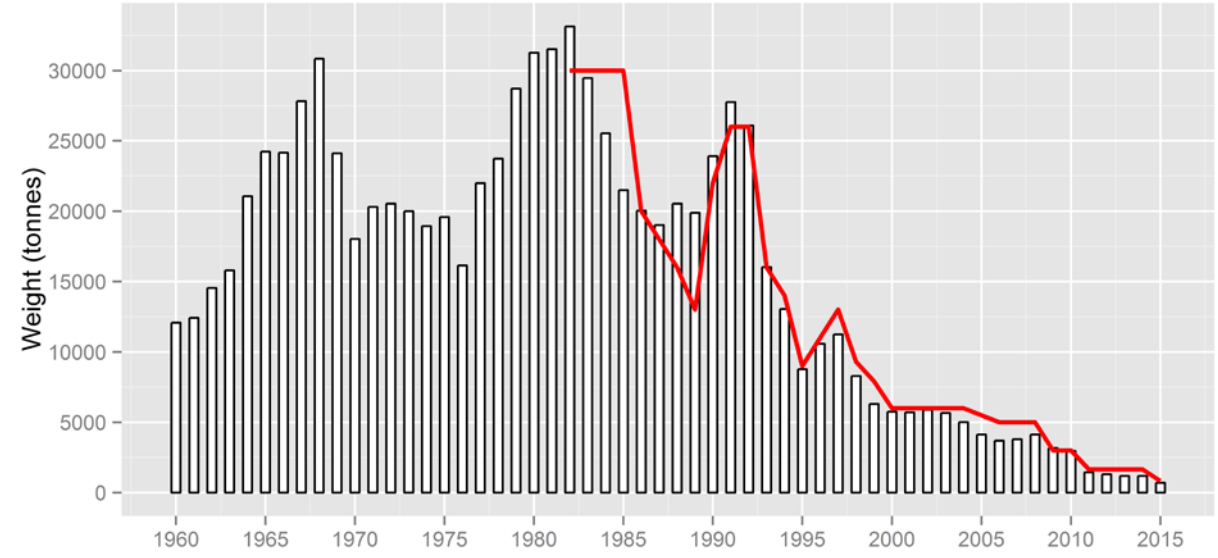

Figure 2. Landings and Total Allowable Catch (solid red line) for 4X5Yb Atlantic Cod by quota year.

The most recent stock assessment showed that the stock had declined in abundance since the early 1990s and revealed a trend of continuing decline (DFO 2009). Natural mortality was estimated to be unusually high for Atlantic Cod aged 4 years and older (0.76 for 1996-2008) and average recruitment had declined to less than half of the pre-1992 level. A conservation Limit

Reference Point (LRP) was calculated for the Spawning Stock Biomass (SSB) based on a Beverton-Holt stock recruitment model as B_{lim} = 24,000t and the target fishing mortality (F_{ref}) was 0.2. At the time, the SSB was estimated based on a Virtual Population Analysis (VPA) model to be below the LRP since 2002 and was estimated to be 10,600t at the beginning of 2009.

Annual fishing mortality (F) has been variable and high, ranging between 0.4 and 0.5 in the 1980s, then rising to a peak over 1.0 in 1991 before declining to lower levels. From 1995 to 2008, F has been above the reference level 0.2, ranging between 0.2 and 0.4 (DFO 2011a). In 2011, as a result of science advice provided in a RPA, the TAC was reduced by 45% to 1650t, which was the fishing level expected to result in approximately F=0.11, or 55% of F_{ref}, a value deemed to meet rebuilding and preventable decline requirements and to balance rebuilding requirements with socioeconomic considerations. The TAC remained stable at 1650t from 2011-2014. Due to information presented in the last update, the TAC was further reduced by 50% to a total of 1650t over two years (2015/2016 and 2016/2017) (DFO 2015).

The VPA formulation from the most recent stock assessment estimated that natural mortality (M) for Atlantic Cod Age 4+ was 0.76 from 1996 to 2008, which is much higher than the value of 0.2 historically used as an estimate of M at all ages for Atlantic Cod. Major sources of mortality for the stock are natural mortality (including seal predation), fishing, discards and bycatch. The possibility that a change in the emigration rate of Atlantic Cod from 4X5Yb has contributed to declining survey trends has not been fully assessed, although the fact that adjacent stocks are also very low and/or declining suggests that this is unlikely.

Analysis and Response

Survey station coverage and Atlantic Cod catches from the 2015 and 2016 annual DFO Summer RV survey are shown in Figure 3. Details of survey design and results are available in DFO (2016). In 2015 and 2016, Atlantic Cod survey biomass increased (3722t in 2015 and 5195t in 2016) from the all-time low in 2013 (2058t) but remained among the lowest in the series (Figure 4).

The trends in total (Age 1+) and adult (Age 3+) biomass estimates from the most recent VPA model run (DFO 2009) generally track the survey biomass index, particularly for the past two decades of declining abundance. The high survey index in 2009 appears to have been anomalous relative to the declining trend of the stock. The trend in the survey biomass index suggests that the stock has been gradually declining since approximately 1980, particularly since the late 1990s, and has been at the lowest level in the time series since 2010, showing no sign of recovery (Figure 4). This stock was concluded to be in the critical zone in the 2011 RPA (Clark et al. 2015) and the biomass index has remained at this low level since then.

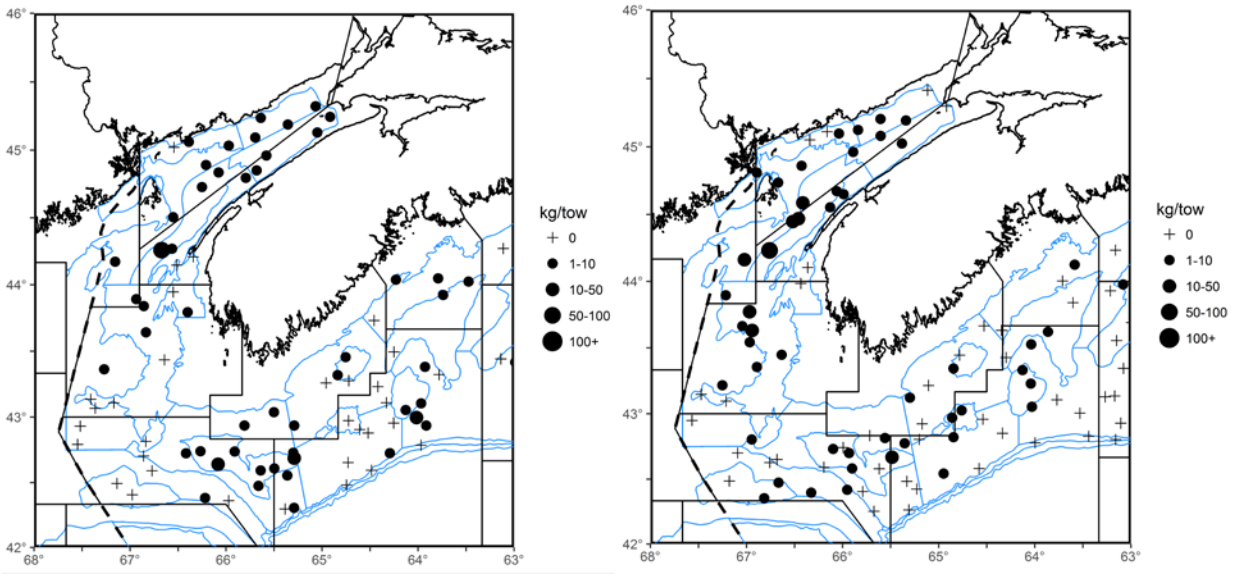

Figure 3. Distribution of Atlantic Cod catches during the 2015 (left) and 2016 (right) DFO Summer Research Vessel surveys in 4X5Yb. Zero catch is represented by the + symbol. Black circles represent catches. The circle area is proportional to the catch size. Blue lines represent survey strata areas and black lines represent NAFO divisions.

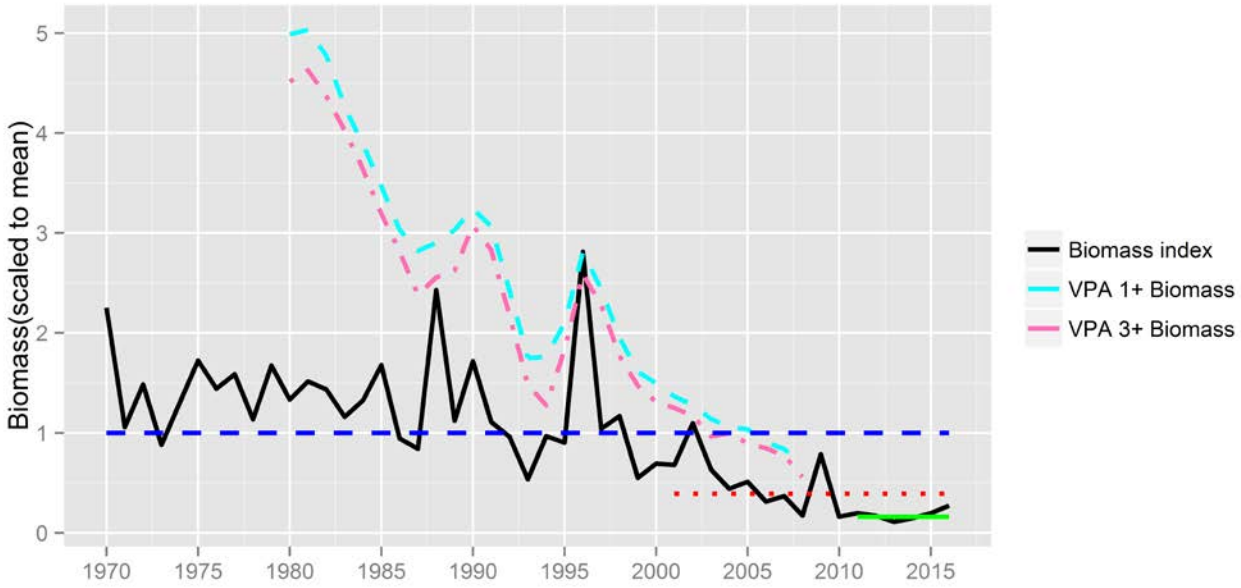

Figure 4. Scaled biomass index of Atlantic Cod in 4X5Yb from the DFO Summer Research Vessel survey from 1970 to 2015. Age 1+ and Age 3+ Virtual Population Analysis scaled biomass estimates from 1980-2008 are also shown (DFO 2011a). The dashed dark blue line represents the scaled long-term average (1970-2015), the red dotted line represents 15-year scaled average (2001-2015), and the green solid line represents 5-year scaled average (2011-2015).

In general, the instantaneous rate of fishing mortality calculated from the VPA tracks variation in relative fishing mortality (relF) quite consistently. Relative fishing mortality declined around 1994 and has been variable at a lower level since then (Figure 5). However, as a result of the

low TAC and more or less constant survey biomass in recent years, the 2015 relF is the lowest in the time series. Overall, the total mortality (natural mortality, mortality from reported fishery landings and discards and other unaccounted for mortality) of Age 4-5 (Z4-5) has been quite variable over the time series. However, this variability appears to have increased since 2003 with values ranging from -0.06 to 2.78. This high variability indicates that Atlantic Cod (Age 4 and 5) are only sporadically being seen as older Cod (Age 5 and 6) in following years. Moreover, there have been very few Atlantic Cod older than Age 5 in survey and fishery catches since 2010 (Figure 6), which suggest that natural mortality of Age 4+ Cod from recent VPA model runs remains elevated or has further increased.

The unexplained increase in mortality in the mid-1990s has been observed in other Atlantic Cod stocks (e.g. TRAC 2016). The reason for the elevated rate of mortality in this and other stocks is not fully understood; however, it may include:

- Predation by seals. The Canadian Grey Seal population continues to increase at approximately 4% per year (DFO 2014).
- Un-estimated discarded bycatch from Lobster fisheries and other fisheries (Gavaris et al. 2010 and Pezzack et al. 2014).

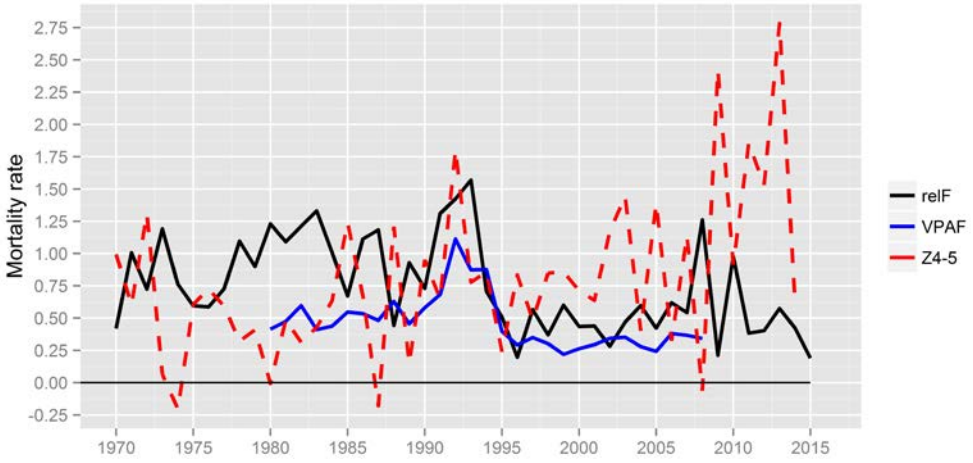

Figure 5. Relative fishing mortality (relF), instantaneous fishing mortality from the most recent Virtual Population Analysis model run (VPA F) and total mortality from annual DFO Summer Research Vessel survey catches-at-age (Z4-5). Virtual Population Analysis F is for Ages 4-5 and relF is based on landings/survey biomass.

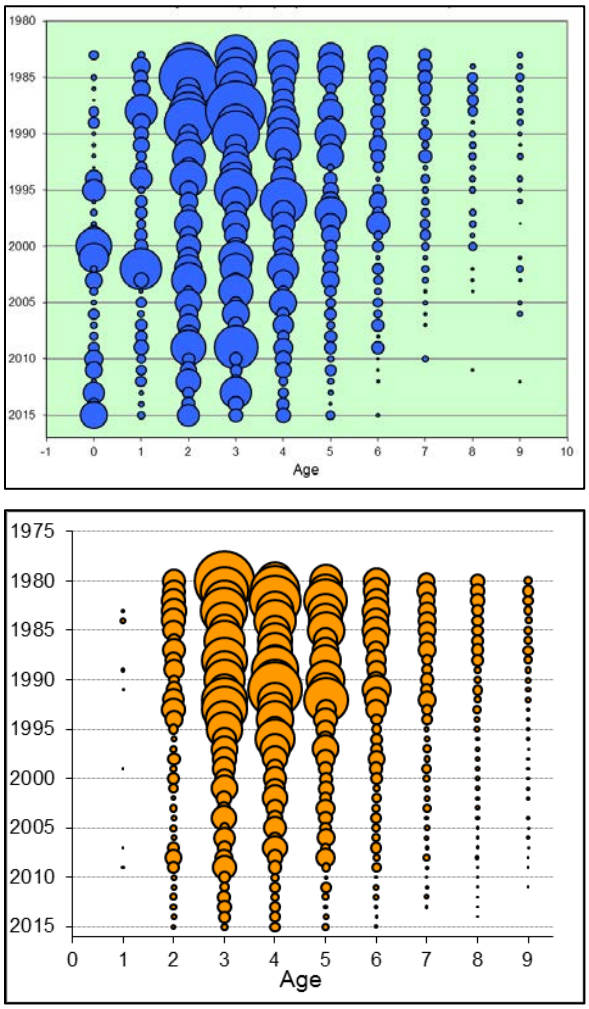

Figure 6. DFO Summer Research Vessel survey indices-at-age (top) for 4X Atlantic Cod and fishery catch-at-age (bottom). The size of the bubble is proportional to the number-at-age.

Age 1 recruitment index for 2015 remains among the lowest on record. Years of exceptionally high recruitment have been less frequent in the past two decades than they were in the 1970s and 1980s, and there has only been one strong year-class (2001) since 1995 (Figure 7).

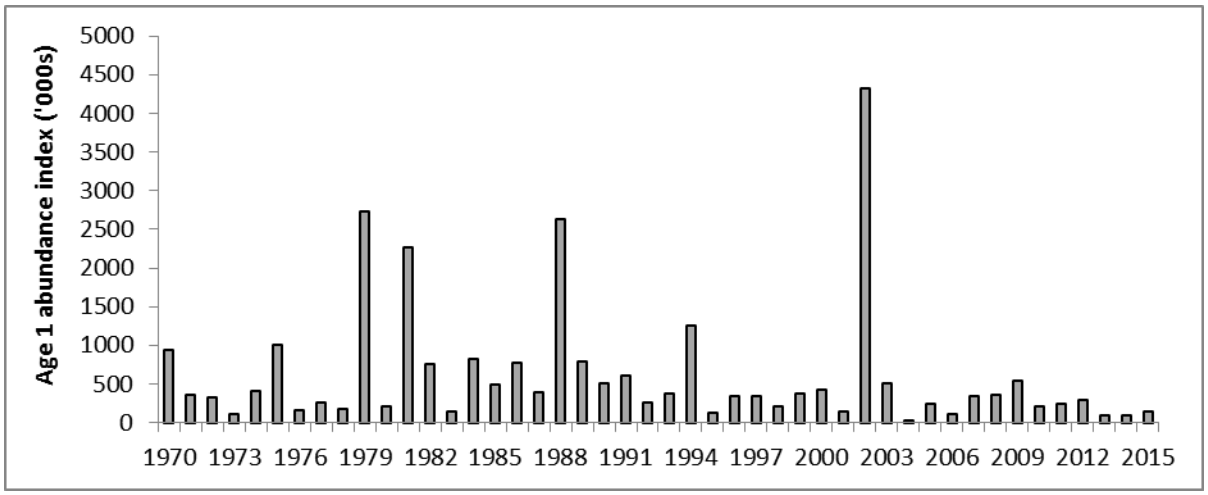

Figure 7. Age 1 recruitment index from DFO Summer Research Vessel survey.

The stratified total estimates of Atlantic Cod abundance by length in 2014, 2015 and 2016 were well below the average from 1970-2014, except for Atlantic Cod less than 10 cm (likely Age 0), which were very abundant in 2015, and close to the long term average in 2014 and 2016 (Figure 8).

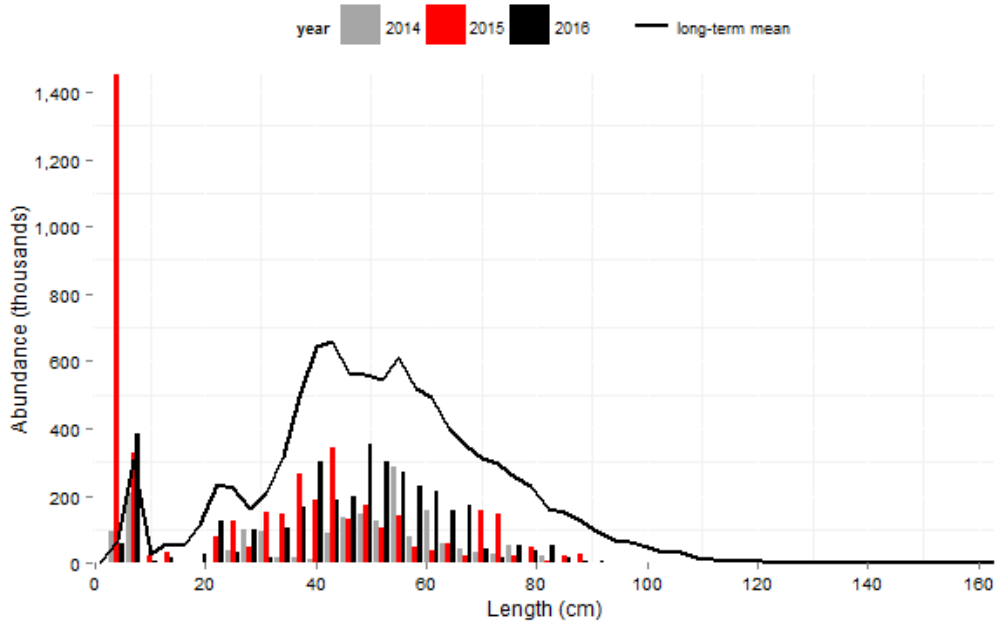

Figure 8. Length frequency indices for Atlantic Cod in 4X from the DFO Summer Research Vessel survey. Bars represent the number in thousands at length from the 2014 (grey), 2015 (red) and 2016 (black) survey. The solid black line represents the average number in thousands at length for the time period 1970-2014.

Conclusions

The survey biomass index remains at very low level since 2010. The recruitment index for this stock has also remained very low in recent years, with the 2013 value being the second lowest

on record. Although the survey length frequencies suggest that the abundance of Age 0 Atlantic Cod was well above average in 2015, this high abundance was not observed for Age 1 in the 2016 survey.

Recent assessment work on adjacent Eastern Georges Bank, Eastern Scotian Shelf, Southern Gulf of St. Lawrence, and Gulf of Maine stocks confirm that productivity have been unusually low due to persistent low recruitment and high total mortality across the entire area (DFO 2011b, Mohn and Rowe 2012, Palmer 2014, Swain et al. 2012, TRAC 2016). In 4X, total mortality of Age 4+ Atlantic Cod was elevated from 2009 to 2013.

Given the very low biomass, low productivity due to low recruitment, truncated age structure and high natural mortality, the current outlook for this stock is extremely poor. This stock was concluded to be in the critical zone in the 2011 RPA (Clark et al. 2015) and the biomass index has remained at this low level since then. This outlook indicates that removals of Atlantic Cod from all fisheries should be at the lowest possible level.

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Sources of Information

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