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Canadian Science Advisory Secretariat
Science Response 2021/023

Maritimes Region

STOCK STATUS UPDATE OF ATLANTIC COD (*GADUS MORHUA*) IN NAFO DIVISIONS 4X5Yb FOR 2020

Context

Although Atlantic Cod (*Gadus morhua*) in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Yb have supported a commercial fishery since the 1700s, their abundance has declined in number and biomass since the 1990s. 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 split the Maritimes DU into two new DUs, the Laurentian South DU and the Southern DU, and re-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 2008 stock assessment (DFO 2009) to explore the consequences of particular productivity assumptions and catch scenarios (DFO 2011a). The last 4X5Yb Atlantic Cod stock assessment was in 2018 (DFO 2019), and the present Science Response is the result of a request for a stock status update from Fisheries Management (Maritimes Region) using the most recent DFO Summer Research Vessel (RV) surveys (2019–2020) and fisheries landing data up to 2019.

This Science Response Report results from the Regional Science Response Process of December 1-2, 2020, on the Stock Status Updates of Groundfish Stocks in the Maritimes Region.

Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

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).

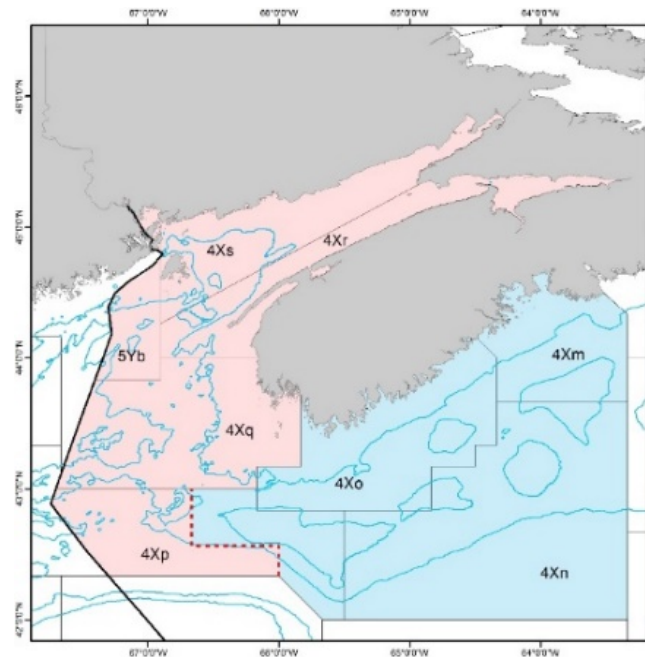


Figure 1. Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Yb. The colours identify approximate spatial division of 4X5Yb into Bay of Fundy (pink) and Scotian Shelf (blue) components.

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 metric tonnes (mt) for several decades but have declined since the 1990s along with restrictive Total Allowable Catch (TAC) (Figure 2). Landings for the 2018–19 and 2019–20 fishing-years (FY) amounted to 542 mt and 555 mt, respectively, with the 2018–19 FY representing a new low in the time series.



Figure 2. Landings (white vertical bars) and Total Allowable Catch (solid red line) for 4X5Yb Atlantic Cod by calendar year (January 1st–December 31st). After 1999, landings and TAC are reported by fishing-year (April 1st–March 31st).

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The most recent framework and stock assessment (2018) showed that the stock had declined in abundance since the early 1990s, and revealed a trend of continuing decline (DFO 2019; Andrushchenko et al., In prep.¹; Wang and Irvine, In prep.²). Natural mortality (M) was estimated to be unusually high for Atlantic Cod aged 5 years and older, with M exceeding 1.4 since 2011, which is consistent with the truncation of the age structure for the population. Recruitment has remained low with the most recent estimate of the 2016 year-class (1.9 million fish) being the lowest on record. A conservation Limit Reference Point (LRP) was calculated for the Spawning Stock Biomass (SSB) based on the $Sb_{50/90}$ method as $B_{lim} = 22,193$ mt. With further declines expected even in the absence of fishing, no fishing mortality reference point was proposed. At the time, the SSB was estimated based on a Virtual Population Analysis (VPA) model to be below the LRP since 2008, with the most recent estimate of SSB being 10,298 mt at the beginning of 2018.

Annual fishing mortality (F) has been variable throughout the time series, ranging between 0.20 and 0.31 in the 1980s, rising to a peak over 0.45 in 1992, then declining to lower levels since then. Following the 2011 RPA, the TAC was reduced by 45% to 1,650 mt; a fishing level expected to result in approximately $F = 0.11$, or 55% of F_{ref} (0.2), at the time. This value was deemed to meet both rebuilding and preventable decline requirements, and it was expected to balance rebuilding requirements with socioeconomic considerations. Following the information presented in the 2014 update (DFO 2015a), the TAC was further reduced by 50% to a total of 1,650 mt over two years (2015–16 and 2016–17), with a carry-forward of no more than 15% of final quota amounts between years. The same arrangement was renewed for the 2017–18 and 2018–19 fishing-years. Directing for cod in 4X5Yb was prohibited in the 2019–20 FY and, since then, the TAC has been 825 mt annually for bycatch only, with the 15% carry forward provision still in place.

The VPA formulation from the most recent (2018) stock assessment estimated natural mortality (M) for Atlantic Cod Age 5+ as at or above 1.0 since 1998. Currently, the high estimate of natural mortality includes mortality from natural sources (e.g., predation, disease, etc.), as well as unaccounted-for fishing mortality (e.g., discards and bycatch from all fisheries operating in NAFO 4X5Yb) experienced by this stock. 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 cod stocks are also either very low, or declining, suggests that this is unlikely.

Analysis and Response

Survey-station coverage and Atlantic Cod catches from the 2019 and 2020 annual DFO Summer RV surveys are shown in Figure 3. Details of survey design and 2019 results are available in the survey report (DFO 2020).

The 2018 assessment identified a number of conditions that, if met, would signify a substantial change has occurred and trigger an assessment in the following year (DFO 2019):

1. The 3-year median abundance for ages 7 through 9 is above 0 for all three ages.

¹ Andrushchenko, I., D. Clark, F. Irvine, E. MacEachern, R. Martin, and Y. Wang. (In prep.). 2018 4X5Y Atlantic Cod Framework Data Inputs. DFO Can. Sci. Advis. Sec. Res. Doc. Presented and reviewed in March 2018 at the Framework Part I meeting.

² Wang, Y. and F. Irvine. (In prep.). 2018 4X5Y cod stock assessment modelling framework. DFO Can. Sci. Advis. Sec. Res. Doc. Presented and reviewed in November 2018 at the Framework Part II meeting.

2. The q-adjusted 3-year median survey biomass index falls outside of the 95% confidence interval of the projection of 2020.
3. The 3-year q-adjusted median of the Age 7+ group abundance index falls outside of the 95% confidence interval of the projection of 2020.
4. The q-adjusted 3-year median survey biomass index exceeds B_{lim} .

None of these four trigger conditions were met in 2020. However, the model projections used to evaluate the trigger conditions expire in 2020, so a 4X5Yb cod stock assessment will occur in December 2021 to provide updated projections for evaluation of triggers in 2021–2023.

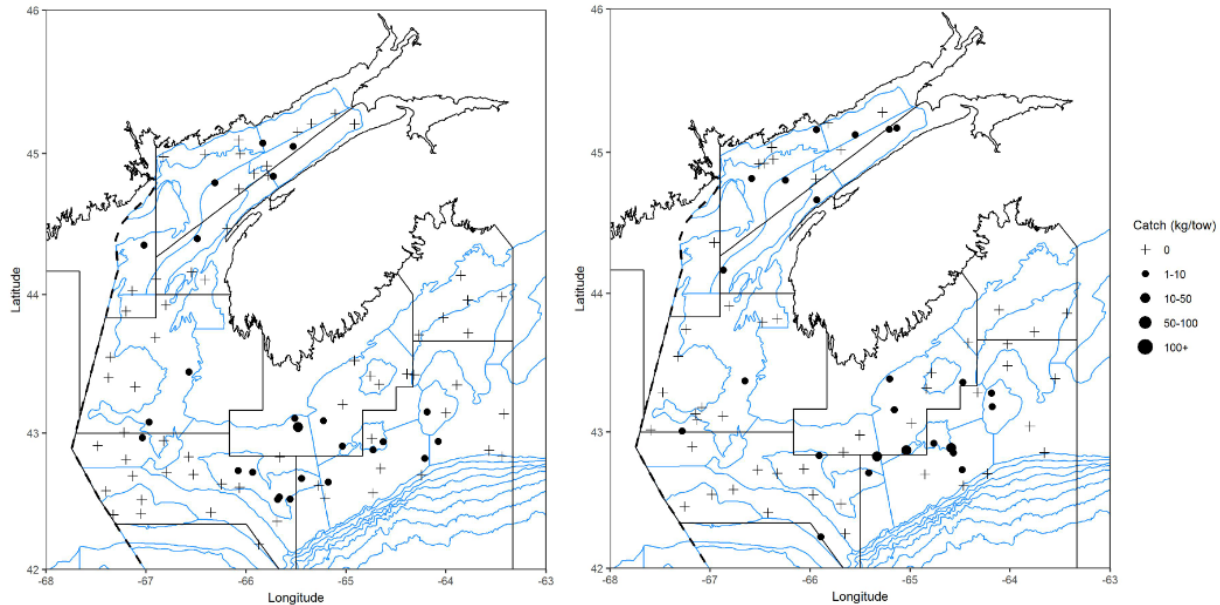


Figure 3. Distribution of Atlantic Cod catches during the 2019 (left) and 2020 (right) DFO Summer Research Vessel surveys in 4X5Yb. Zero catch is represented by the + symbol. Black circles represent catches. The circle area is proportional to the catch size. Blue lines represent survey strata, black lines represent NAFO divisions.

Total Atlantic Cod survey biomass was 1,443 mt and 1,669 mt in 2019 and 2020, respectively, with 2019 representing a new low in the time-series. The trends in total Age 1+ and adult (Age 4+) biomass estimates from the most recent VPA model run (DFO 2019) generally track the survey biomass index, particularly for the past two decades of declining abundance (Figure 4). The trend in the survey biomass index suggests that the stock has been gradually declining since the 1990s, and it has stabilized at a low level since 2010 (Figure 4). This stock was assessed as being in the Critical Zone during the 2011 RPA (Clark et al. 2015) and has shown no signs of recovery since then.

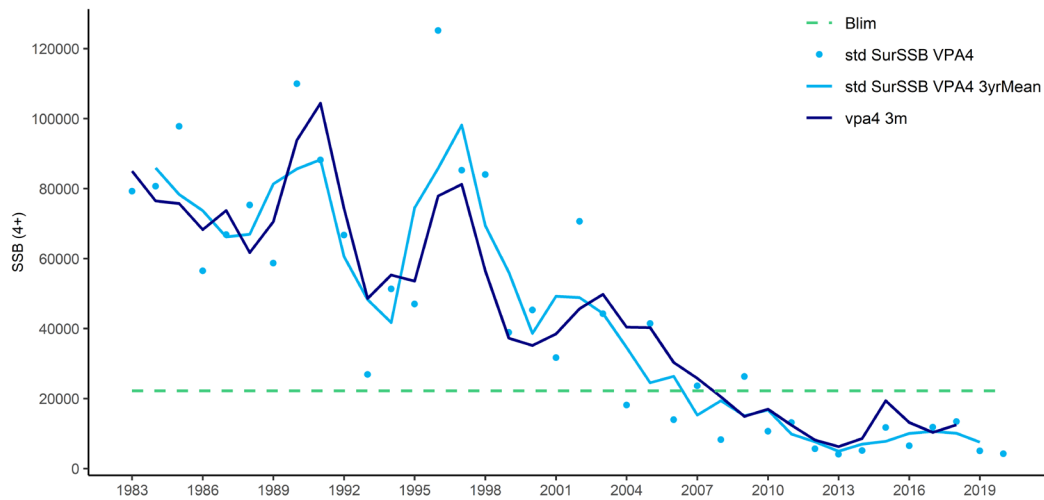


Figure 4. Comparison of scaled Spawning Stock Biomass (SSB) (Age 4+) index of Atlantic Cod in 4X5Yb from the DFO Summer Research Vessel Survey (light blue points), scaled-survey SSB 3-year mean (light blue line), and Virtual Population Analysis for the 3Mfirst method scaled-SSB estimates (dark blue line) from 1983 to 2020 (DFO 2019). The green dashed line represents B_{lim} (22,193 mt).

Since no fishing reference value was provided at the 2018 framework, a proxy value was selected at the 2019 Advisory Committee meeting and defined as the mean value of Relative F between 2015 and 2018, with the expectation that annual relative F will be compared against this proxy in the update years (SFGAC 2019). Given the high inter-annual variability in the survey biomass for Atlantic Cod, it is being proposed that annual Relative F is calculated as Catch in a given year (Y) over average survey biomass in years Y, Y-1 and Y+1. This will effectively dampen some of the annual noise coming from the survey component of Relative F, while retaining the inter-annual changes in landings.

To allow for comparisons between annual Relative F, smoothed Relative F, proxy Relative F and the VPA F, while retaining the absolute values of VPA F, all four were standardized to their respective series means from 1983–2017, then raised to the mean VPA F over the same time period (Figure 5). In general, the instantaneous rate of fishing mortality coming from the VPA (VPA F) tracks the variation in relative fishing mortality (RelF) fairly closely. The trend shows fishing mortality for the stock declined around 1994, remained at that lower level until the early 2010s, and decreased again in 2014–2015 with the 50% decreases in TAC. Since 2015, annual relative F has fluctuated at a low level, with 2018 falling below the proxy RelF and 2019 increasing above it. The smoothed RelF shows a slow increase from the series low in 2015, though the last five years continue to remain below the pre-2015 level (Figure 5).

Total mortality (Z) on mature fish (ages 4–7) increased in the 2000s and has remained at a high level since then. Moreover, there have been very few Atlantic Cod older than Age 6 in survey and fishery catches since 2010 (Figure 7), which suggests that natural mortality on older fish remains elevated, or has further increased (Figure 6).

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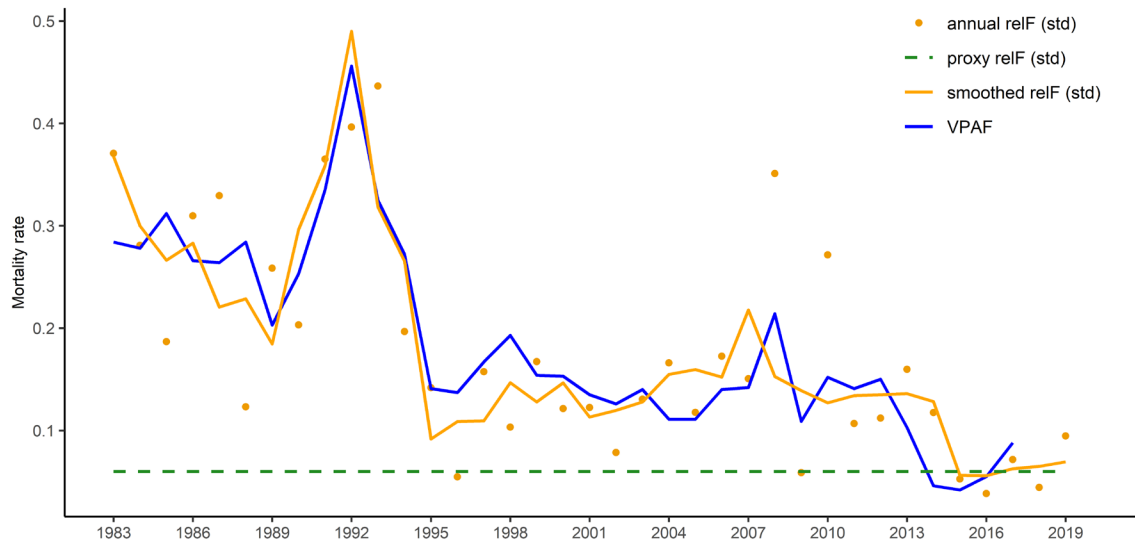


Figure 5. Comparison of VPA F (ages 4–7; blue line), standardized annual relative F (orange points) and standardized smoothed relative F (annual catch / 3-year mean survey biomass; orange line). Note that relative F estimates have been standardized to the VPA F values (Annual RelF / Mean RelF 1983–2017 * Mean VPA F 1983–2017) to allow for comparisons in trend while retaining absolute values of VPA F . Green dashed line shows the RelF proxy set in 2019 (0.19), if it were standardized to the VPA F .

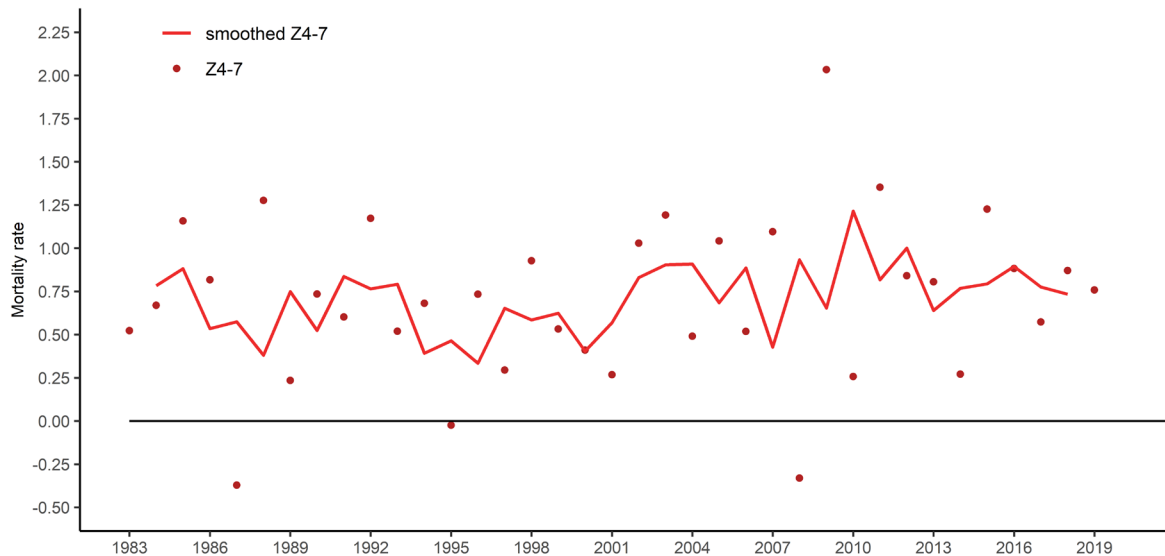


Figure 6. Total mortality (Z4–7, red points) and 3-year mean total mortality (red line) from annual DFO Summer Research Vessel Survey catches-at-age.

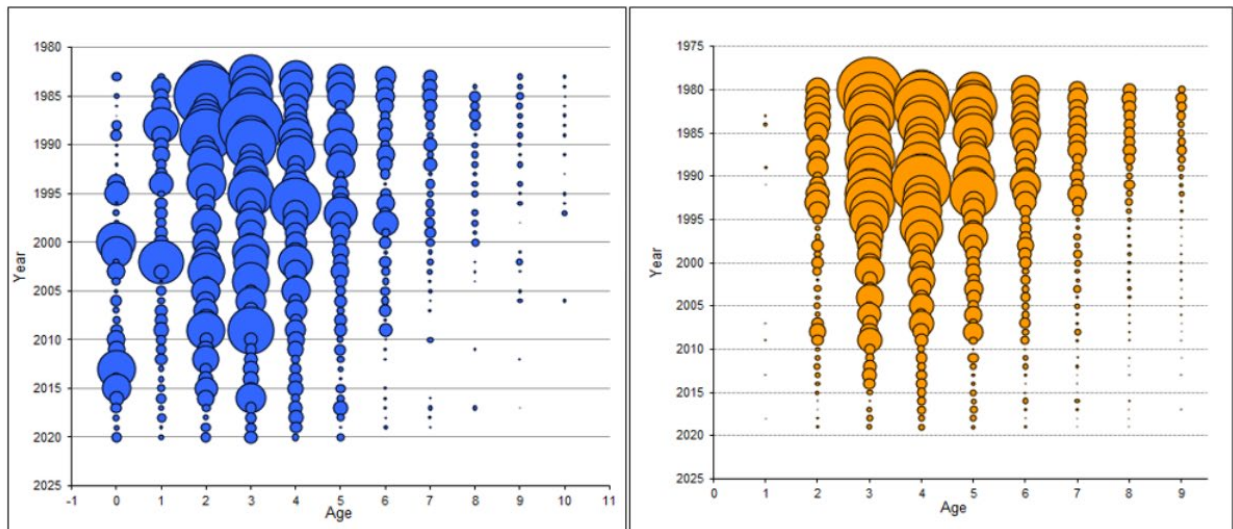


Figure 7. DFO Summer Research Vessel Survey indices-at-age (left, 1983–2020) for 4X5Yb Atlantic Cod and fishery catch-at-age (right, 1980–2019). The size of the bubble is proportional to the number-at-age.

The increase in total mortality since the mid-1990s has been observed in other Atlantic Cod stocks (e.g., TRAC 2016). The reasons for the elevated rate of mortality in this and other stocks are not fully understood; however, they may include changes in the productivity, trophic interactions and structure of the Scotian Shelf ecosystem (DFO 2015b), unreported bycatch from non-groundfish fisheries (Gavaris et al. 2010, Pezzack et al. 2014, DFO 2019), and increased predation pressure with the substantial increase in the abundance of Grey Seals (*Halichoerus grypus*) on the Scotian Shelf (DFO 2017).

The Age 1 recruitment index for 2020 is comparable to those seen since 2013, but it remains low relative to the remainder of the time-series (Figure 8). There has only been one strong year-class (2001) seen since 1995, which is a contrast to the higher frequency of strong year-classes seen prior to 1995 (Figure 8).



Figure 8. Age 1 recruitment index from DFO Summer Research Vessel Survey from 1970–2020.

The stratified total estimates of Atlantic Cod abundance by length in 2018, 2019, and 2020 were well below the average from 1983–2019, except for Atlantic Cod 8–13 cm (Figure 9). These small fish (likely Age 0) were abundant in 2020 but were absent from the survey catch in 2018 and 2019.

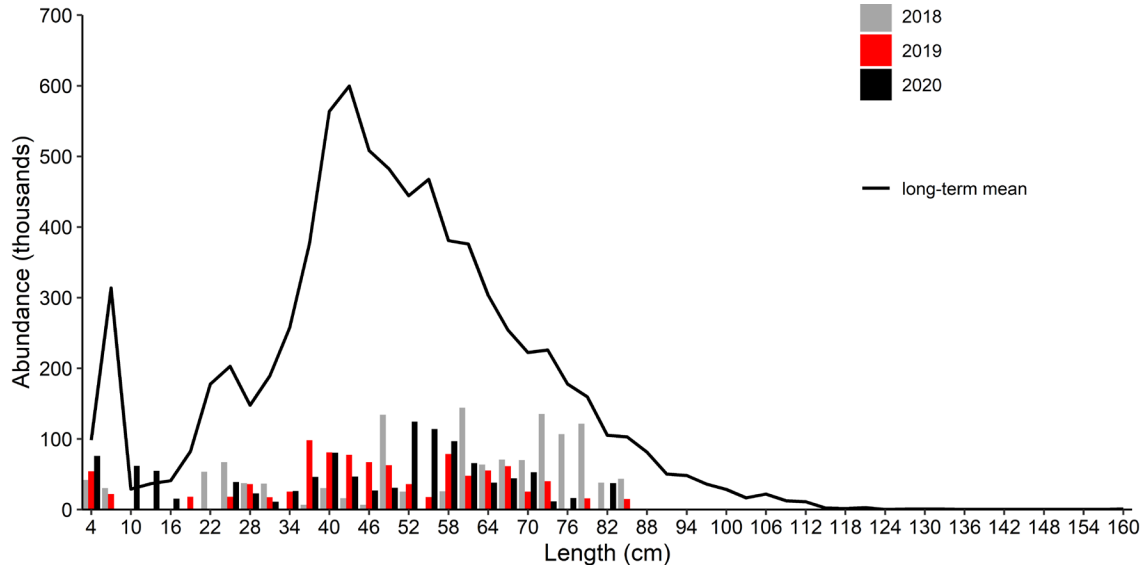


Figure 9. Length frequency indices for Atlantic Cod in 4X5Yb from the DFO Summer Research Vessel Survey. Bars represent the number in thousands at length from the 2018 (grey), 2019 (red), and 2020 (black) survey. The solid black line represents the average number in thousands at length for the time period 1983–2019.

Conclusions

The survey biomass index has remained at a very low level since 2010. The recruitment index for this stock has also remained low in recent years, with second-, third-, fourth-, fifth- and sixth-lowest years in the time-series occurring in the last 8 years of the time-series. Although most of the survey length-frequencies remained well below the long-term mean, the abundance of 8–13 cm (Age 0) Atlantic Cod was above average in 2020.

Previous assessment work on adjacent Eastern Georges Bank, Eastern Scotian Shelf, Southern Gulf of St. Lawrence, and Gulf of Maine stocks confirm that productivity has 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).

Given the very low biomass, low productivity and recruitment, truncated age structure, and high total 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

- Clark, K.J., D.S. Clark, I.V. Andrushchenko, and D.P. Swain. 2015. [Recovery Potential Assessment \(RPA\) for the Southern Designatable Unit \(NAFO Divisions 4X5Yb and 5Zjm\) of Atlantic Cod \(*Gadus morhua*\)](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2015/069. v + 58 p.
- COSEWIC. 2003. COSEWIC Assessment and Update Status Report on the Atlantic Cod *Gadus morhua* in Canada. Committee on the Status of Engangered Wildlife in Canada. Ottawa. Xi +76 pp.
- COSEWIC. 2010. COSEWIC Assessment and Update Status Report on the Atlantic Cod *Gadus morhua* in Canada. Committee on the Status of Engangered Wildlife in Canada. Ottawa. Xi +105 pp.
- DFO. 2009. [Cod on the Southern Scotian Shelf and in the Bay of Fundy \(Div. 4X/5Y\)](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/015.

Maritimes Region

- DFO. 2011a. [Recovery Potential Assessment \(RPA\) for the Southern Designatable Unit \(NAFO Divs. 4X5Yb and 5Zjm\) of Atlantic cod \(*Gadus morhua*\)](#). DFO Can. Sci. Advis. Sec. Advis. Rep. 2011/034.
- DFO. 2011b. [Recovery Potential Assessment for the Laurentian South Designatable Unit of Atlantic cod \(*Gadus morhua*\)](#). DFO Can. Sci. Advis. Sec. Advis. Rep. 2011/028.
- DFO. 2015a. [2014 4X5Yb Atlantic Cod Stock Status Update](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/010.
- DFO. 2015b. [Assessment of Nova Scotia \(4VWX\) Snow Crab](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/034.
- DFO. 2017. [Stock assessment of Canadian Northwest Atlantic Grey Seals \(*Halichoerus grypus*\)](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/045.
- DFO. 2019. [Stock Assessment of Atlantic Cod \(*Gadus morhua*\) in NAFO Divisions 4X5Y](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/015.
- DFO. 2020. [Maritimes Research Vessel Survey Trends on the Scotian Shelf and Bay of Fundy](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/019.
- Gavaris, S., K.J. Clark, A.R. Hanke, C.F. Purchase, and J. Gale. 2010. Overview of Discards from Canadian Commercial Fisheries in NAFO Divisions 4V, 4W, 4X, 5Y and 5Z for 2002–2006. Can. Tech. Rep. Fish. Aquat. Sci. 2873: vi + 112 p.
- Mohn, R.K. and S. Rowe. 2012. [Recovery Potential Assessment for the Laurentian South Designatable Unit of Atlantic Cod \(*Gadus morhua*\): The Eastern Scotian Shelf Cod Stock \(NAFO Div. 4VsW\)](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/138: vii + 71 p.
- Palmer, M.C. 2014. Assessment update report of the Gulf of Maine Atlantic cod stock. US Dept. Commer. Northeast Fish. Sci. Cent. Ref. Doc. 14-14: 119 p.
- Pezzack, D.S., C.M. Denton, and M.J. Tremblay. 2014. [Overview of By-catch and Discards in the Maritimes Region Lobster Fishing Areas \(LFAs\) 27-33 based on Species at Risk Act \(SARA\) At-sea Sampling 2009-2010](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2014/040. v + 27 p.
- SFGAC. 2019. Scotia-Fundy Groundfish Advisory Committee October meeting minutes.
- Swain, D.P., L. Savoie, and E. Aubry. 2012. [Recovery Potential Assessment for the Laurentian South Designatable Unit of Atlantic Cod \(*Gadus morhua*\): the Southern Gulf of St. Lawrence cod stock \(NAFO Div. 4T-4Vn \(Nov-Apr\)\)](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/052. iii + 51 p.
- TRAC. 2016. Eastern Georges Bank Cod. TRAC Status Report 2016/01.

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