Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat
Maritimes Region **Science Response 2021/021**

STOCK STATUS UPDATE OF HADDOCK (*MELANOGRAMMUS AEGLEFINUS*) IN NAFO DIVISIONS 4X5Y FOR 2020

Context

Advice on the status of Haddock (*Melanogrammus aeglefinus*) in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Y (herein referred to as 4X5Y Haddock) is requested annually by Fisheries and Oceans Canada (DFO) Resource Management to help determine a Total Allowable Catch (TAC) that is consistent with the Integrated Fisheries Management Plan (IFMP). The most recent framework and assessment occurred in 2016 (Stone and Hansen 2015, Wang et al. 2017, DFO 2017). A Virtual Population Analysis (VPA) model with natural mortality (M) at ages 10 and older for three 5-year time blocks (2000–2004, 2005–2009, and 2010–2014) fixed at 0.3, 0.6, and 0.9, respectively, was recommended as the model for the 4X5Y Haddock stock assessment. Despite the uncertainties in estimating fishing morality (F) at Maximum Sustainable Yield (F_{MSY}), it was agreed at this Framework meeting that a fishing mortality limit reference (F_{lim}) of 0.25 would be the removal fishing mortality reference when the stock is in the Healthy Zone, and a fishing mortality target reference (F_{ref}) of 0.15 would be an appropriate target when the stock is in the Cautious Zone. Given that the poor stock recruitment relationship precludes the calculation of an appropriate Biomass at Maximum Sustainable Yield (B_{MSY}), a more conservative biomass level from which the stock has been shown to recover ($B_{recover}$; Age 4+ biomass; 19,700 metric tonnes [t]) was recommended as the Limit Reference Point (LRP) for 4X5Y Haddock. In the spring of 2017, Resource Management agreed upon approximately twice the LRP, or 40,000 t, as the Upper Stock Reference (USR; Age 4+ biomass).

In 2019, the standard projection from the 2018 model was not used due to the retrospective pattern that was observed in 2018, and the mismatch between the model results and the survey biomass (DFO 2020). The objectives of this update are to report new information from the DFO Summer Research Vessel (RV) Survey and commercial fishery landings data, provide the most recent data on the length of Haddock captured by the fleet, evaluate the survey biomass index compared to the time-series' 40% and 80% median (1985–2020), as well as provide indicators to increase, maintain, or reduce catch.

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

Biology

Haddock are found on both sides of the North Atlantic and occur in the northwestern Atlantic from southwest Greenland to Cape Hatteras, USA. A major stock of Haddock exists on the western Scotian Shelf and in the Bay of Fundy (NAFO Divisions 4X5Y; Figure 1). Growth rates of Haddock in the Bay of Fundy (Unit Areas 4Xqrs5Y) are higher than those of Haddock on the western Scotian Shelf (Unit Areas 4Xmnop; Hurley et al. 1998); therefore, separate age-length keys are used in the calculation of the fishery Catch-At-Age (CAA) and the survey indices of abundance. Major spawning grounds are found on Browns Bank, and peak spawning occurs annually from April to May, although it can occur as early as February if conditions are favourable (Head et al. 2005).

There has been a declining trend in Weight-At-Age (WAA) and Length-At-Age (LAA) since the early 1990s, and the time-series minimum for most ages occurred in the past five years. While it is not clear what caused the declining trend, the effect on stock productivity is significant and has been discussed in previous assessments (Hurley et al. 2009, Mohn et al. 2010).

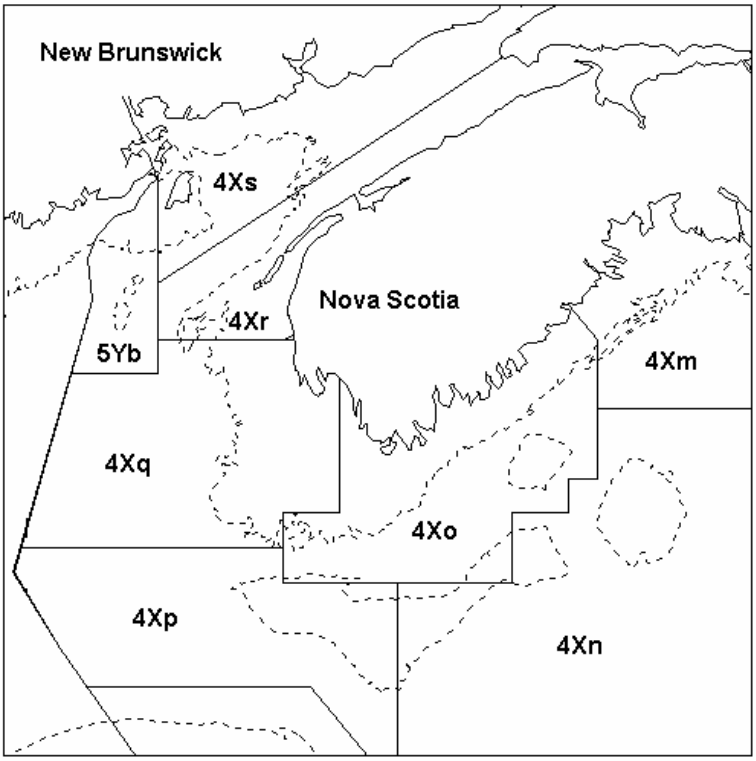

Figure 1. Northwest Atlantic Fisheries Organization Divisions, 4X5Y.

Analysis and Response

The Fishery

Haddock is harvested as part of a mixed groundfish fishery. The TAC for Haddock was 5,100 t for fishing years 2012–13 to 2016–17, it increased to 7,650 t for the 2017–18 and 2018–19 fishing years, 9,000 t for the 2019–20 fishing year, and it was reduced to 6,877 t in 2020–21. Due to challenges related to the COVID-19 pandemic, a carry forward request of 960 t from 2019–20 to 2020–21 was granted by Resource Management to the mobile fleet. Catches have been lower than the TAC since 2002 (Figure 2). The fishing-year landings for 2019–20 were 5,206 t (Table 1). The 2020–21 fishing season is still ongoing, and landing statistics are incomplete.

Table 1. Reported annual and fishing-year catch (t) of 4X5Y Haddock. Annual catch is used for 1970–1999 (January 1st–December 31st); subsequent years use fishing-year catch (April 1st–March 31st).

Year	1970–79 Average	1980–89 Average	1990–99 Average	2000/01–2009/10 Average	2010/11–2015/16 Average	2016/17	2017/18	2018/19	2019/20*
TAC	14,650	21,385	5,050	8,030	5,400	5,100	7,650	7,650	9,000
Landings	18,522	19,851	7,219	6,579	3,719	3,567	5,087	5,294	5,206

**Extracted from MARFIS August 27, 2020*

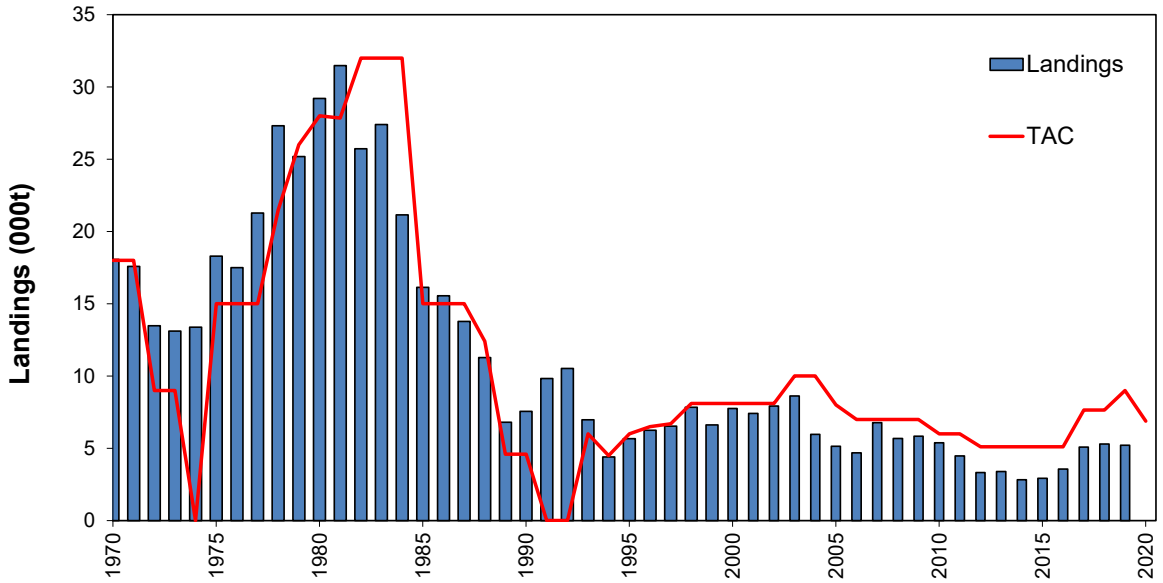

Figure 2. Reported annual and fishing-year landings and Total Allowable Catch (TAC) for the 4X5Y Haddock fishery, 1970–2019. The fishing year changed from Jan 1st–Dec 31st to Apr 1st–Mar 31st in 2000.

The 4X5Y Haddock fishery CAA shows the presence of the strong 2013 year-class (yc) (Figure 3). In the 2019 fishery, the 2013 yc (Age 6) was predominant and represented 64% of the Number-At-Age (NAA) in the catch, followed by the 2014 yc (Age 5) at 19% and the 2015 yc (Age 4) at 7%. Preliminary data for the first half of 2020 suggest the continued availability of the 2013 yc at Age 7 comprising 49% of the CAA in numbers. The 2014, 2015, 2016, and 2017 year-classes make up the remainder of the 2020 catch, representing 17%, 9%, 9%, and 9% percent of the NAA, respectively.

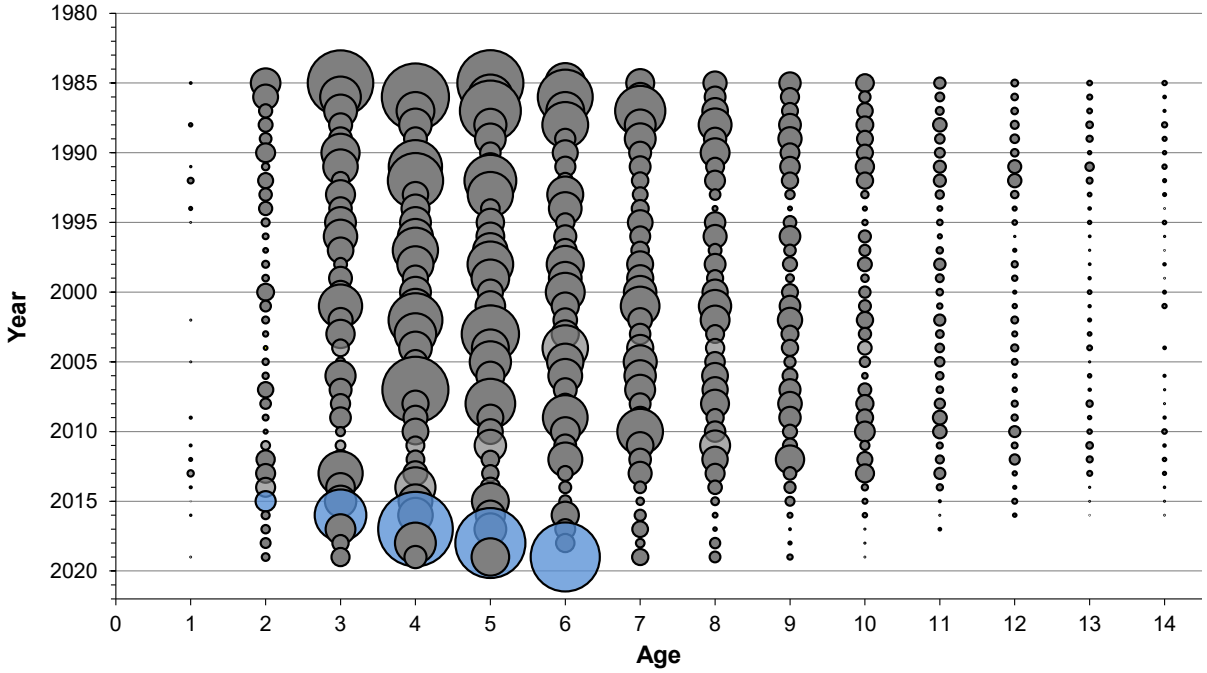

Figure 3. Fishery catch-at-age for 4X5Y Haddock for ages 1–14, 1985–2019. The area of the circle is proportional to the catch in numbers at that age and year. The 2013 year-class is highlighted in blue.

Separate age-length keys are used for the western Scotian Shelf and Bay of Fundy samples to generate NAA, which are then used for weighting the calculations of the overall fishery WAA. In 2019, the fishery-weighted mean WAA for ages 2–7 are the lowest in the time series (Table 2).

Table 2. Fishery- and DFO Summer RV Survey-weighted mean weight-at-age (kg) of 4X5Y Haddock for ages 1–11+ calculated separately for Scotian Shelf strata (470–481) and Bay of Fundy strata (482–495), then combined after weighting. Cells with dashes have no data available.

		Age Group										
Year	**Source**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	8	**9**	**10**	**11+**
2019	Fishery	0.14	0.29	0.41	0.59	0.66	0.78	0.94	0.94	1.29	3.26*	-
1985–2018 Minimum	Fishery	0.11	0.35	0.44	0.65	0.74	0.86	0.96	0.89	1.02	1.12	1.10
2018	Survey	0.08	0.21	0.35	0.51	0.61	0.69	0.83	0.96	1.07	-	-
2019	Survey	0.07	0.21	0.35	0.39	0.58	0.66	0.96	1.03	0.96	1.4	1.68
2020	Survey	0.09	0.23	0.34	0.46	0.63	0.69	0.78	0.88	1.00	1.13	-

**Only 2 samples*

There have been significant changes in the catch-at-size by gear type (mobile versus fixed) and area (Bay of Fundy versus Scotian Shelf) (Wang et al. 2017). The peak length of fish in the catch has decreased from 46.5 cm in 2008 (Wang et al. 2017) to 42 cm in 2019 and 2020 (Figure 4). Catch size composition is characterized using biological measurements collected from observer- and port-sampling programs. The realized observer coverage for the 4X5Y Haddock mobile-gear fishery in 2019 was 4.2% of trips (18 observed trips). Additionally, in 2019, there was a total of 39 port samples completed from the 4X5Y Haddock mobile-gear fishery. In the mobile fleet, three observer samples and five port samples had greater than 30% of small fish (< 38 cm) in the catch. Of the trips that exceeded 30% small fish in 2019, most occurred in 4Xn during the month of March. There were also 12 observer and 12 port-bycatch samples in 2019 from small-mesh gear; one observer and one port sample exceeded 30% small fish in the catch. The bycatch of Haddock from small mesh gear (< 30 mm) made up 10% of the total 2019 Haddock landings (by calendar year).

The preliminary coverage of the 4X5Y Haddock mobile-gear fishery in 2020 consists of 18 observer samples and 40 port samples. The threshold for the percentage of small fish in the catch changed to 40% in 2020–21. Of the available data for 2020, four port samples exceeded 40% small fish in the catch and no observer samples exceeded the threshold. No samples, neither observer nor port, in 2020 had a proportion of small fish between 30% and 40%. All of the trips that exceeded 40% small fish in 2020 occurred in February; most occurred in 4Xn. To date, there are also 5 observer and 6 port-bycatch samples in 2020 from small-mesh gear—none have exceeded 30% or 40% small fish in the catch.

Haddock catches from the fixed-gear fleet are a small proportion of the total Haddock landings in 4X5Y, at < 1% in 2019. There were 4 port samples in 2019 and 8 port samples in 2020 from fixed gear—none of these samples have exceeded 30% or 40% small fish in the catch.

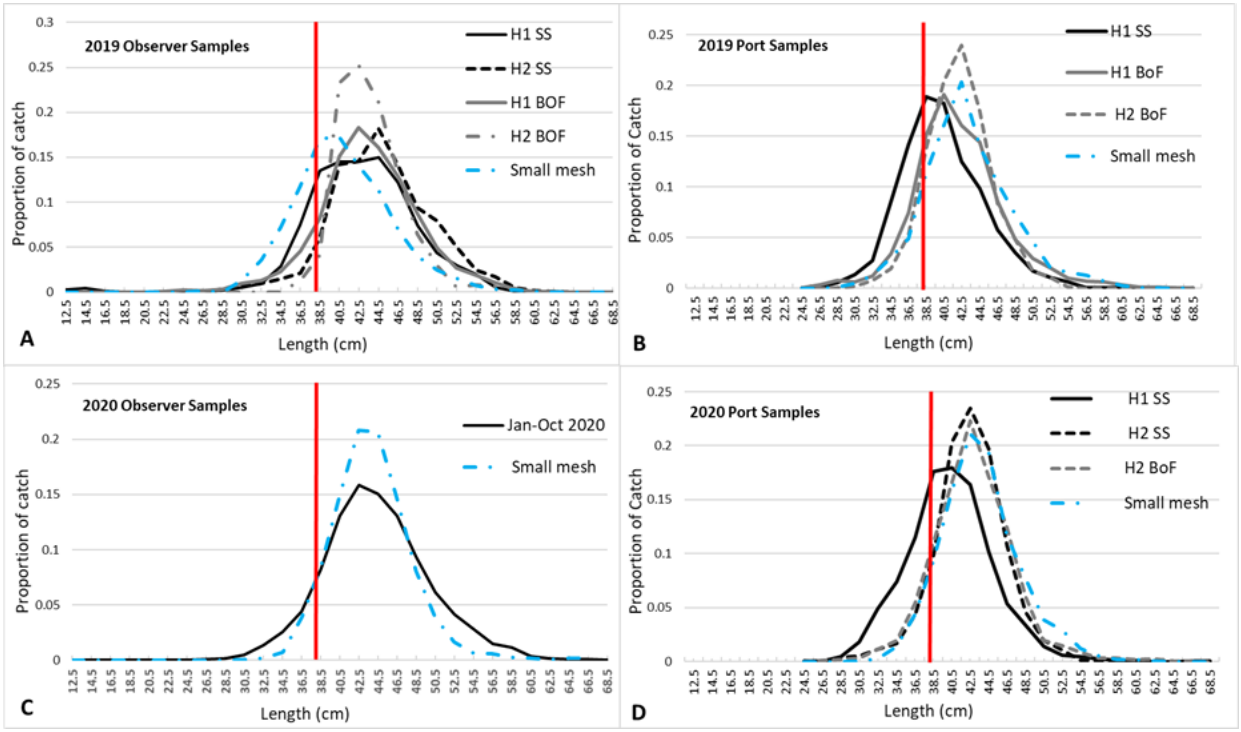

Figure 4. The proportion of catch-at-length from the 4X5Y Haddock observer (A & C) and port (B & D) samples for mobile-gear trips by half year (H1: Jan-Jun and H2: Jul-Dec) from the western Scotian Shelf (SS) or Bay of Fundy (BoF) in 2019. Haddock are caught as bycatch in the redfish fishery; the 'Small mesh' length-frequency data (blue line) are samples from redfish-directed trips. The red reference line indicates small fish as identified in the Conservation Harvesting Plan, which are Haddock < 38 cm. The observer samples for 2020 were grouped to include all 2020 samples in order to meet data sharing guidelines. This figure includes data available as of November 18, 2020. Sample collection and data entry for 2020 are considered incomplete.

Indicators of Stock Status

DFO Summer Research Vessel Survey

The DFO Summer RV Survey (NAFO Divisions 4VWX) biomass indices in 2019 and 2020 were 28,082 t and 32,943 t, respectively (Figure 5). The 2019 and 2020 indices are below the short-term median (5-year: 37,911 t) and long-term median (since 1983: 45,374 t, since 1985: 44,920 t). Haddock were caught in 70 of the 73 tows in 2020; including three tows > 100 kg and one very large tow (> 150 kg).

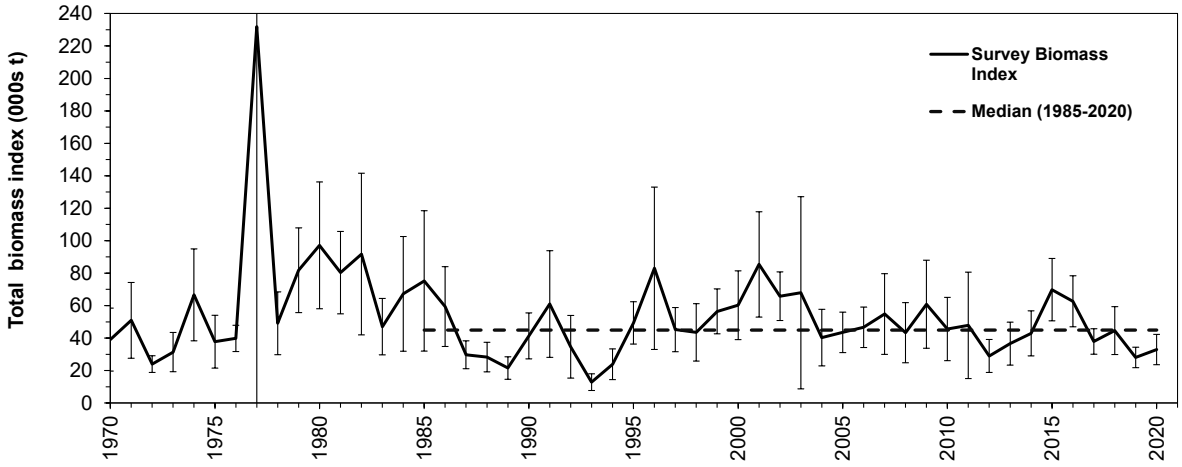

Figure 5. The total biomass index (all ages) ± 2 standard error (000s t) from the DFO Summer RV Survey for 4X5Y Haddock, 1970–2020. The black dashed line represents the long-term median from 1985–2020. A conversion factor of 1.2 has been applied to indices from 1970–1981 to account for vessel and gear changes.

Similar to the trends observed from the commercial fishery, the mean WAA and LAA values for the DFO Summer RV Survey showed a decline from the early 1990s to the mid-2000s, then a levelling off or a modest increase, and then further decline in WAA since 2011. The lowest WAA for most ages occur in the past five years, with a modest increase in 2020. The age composition between the Bay of Fundy and the Scotian Shelf has differed in recent years. Additionally, the lack of older fish increases the uncertainty in the WAA for older fish; only 6 fish aged 9 or greater were found in the 2020 survey catch.

Recruitment is variable throughout the survey time series, with the 2013 yc index at Age 1 being the highest on record with an estimate of 168 million fish (Figure 6). The young-of-the-year index for the 2018 yc was estimated to be the largest in the time series at 137 million (DFO 2019a, DFO 2019b); however, the most recent estimate suggests that the 2018 yc is moderately strong. The young-of-the-year index for 2020 of 36 million is above both the short- and long-term medians (Figure 6). In 2020, the 2013 yc (Age 7) and the 2018 yc (Age 2) each made up 20% of the survey Age 1+ CAA followed by the 2017 yc (Age 3), which made up 18% (Figure 7).

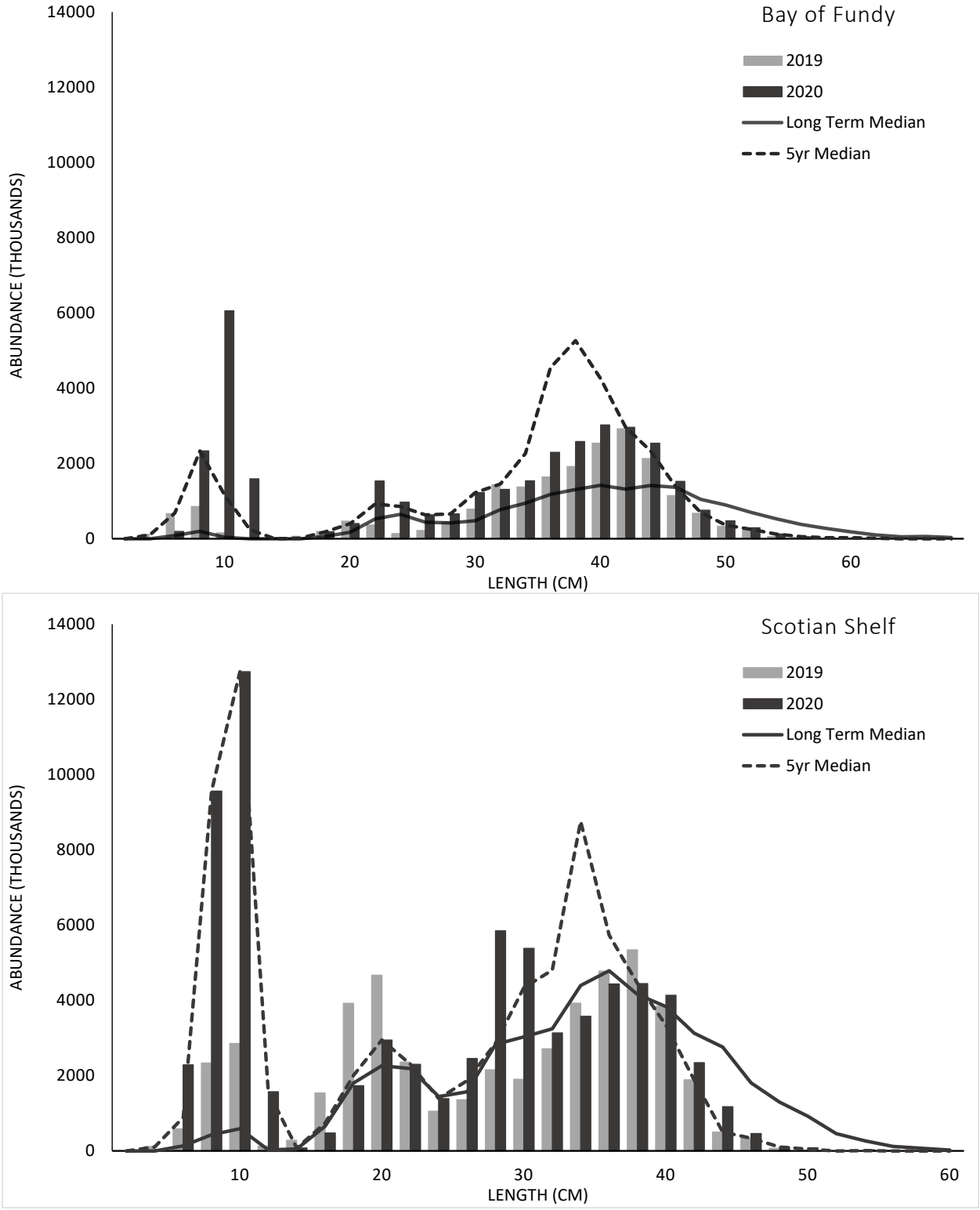

Figure 6. Length frequency of Haddock from the 2019 (grey) and 2020 (black) DFO Summer RV Survey for the Scotian Shelf (top) and the Bay of Fundy (bottom). The dashed line represents the short-term median (2016–2020) and the solid line represents the long-term median (1985–2020).

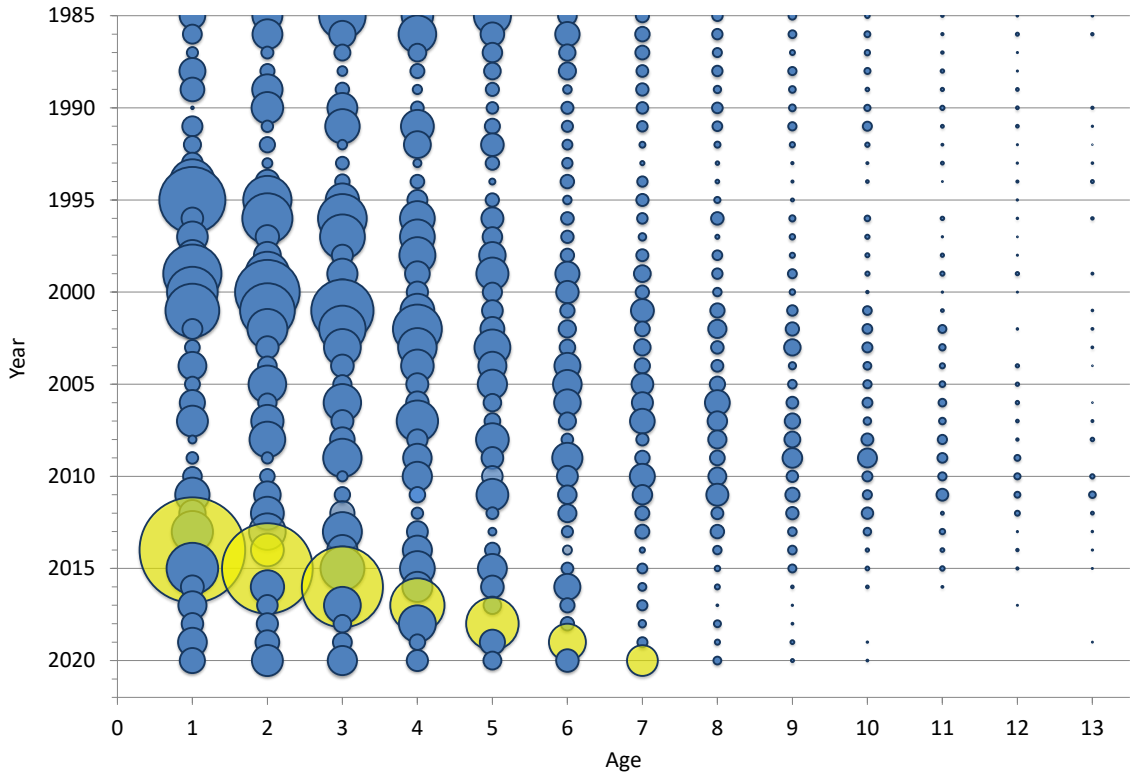

Figure 7. Stratified total number per tow at ages 1–13 for 4X5Y Haddock from the DFO Summer RV Survey, 1985–2020. The yellow circles represent the 2013 year-class at Age 1 in 2014 to Age 7 in 2020. The area of the circle is proportional to the number-at-age for each age and year.

Sources of Uncertainty

The 2018 model retrospective analysis indicated a pattern of overestimating biomass and recruitment (numbers at Age 1), and underestimating F. This pattern has occurred in the past for this stock, particularly when strong year-classes occur (Hurley et al. 2002). The 1998 yc was the largest in the time series during the 2002 assessment of 4X5Y Haddock. The model retrospective analysis indicated that the early estimates of large year-classes may be overestimated by a factor of at least 2 and that the pattern can persist at older ages. It is likely that M is higher than assumed in the model due to density-dependent effects on large year-classes. The 2013 yc number at Age 1 was first estimated at 314 million in 2016; the 2018 model estimate was 164 million.

Three years of survey data have been collected since the 2018 model run, and an assessment was scheduled for this stock in 2020. A model run was completed including the 2018–2020 data; however, model diagnostics were poor. Year effects were apparent in the analysis of model residuals, and the resulting historical biomass estimates were not supported by the data. The 2020 VPA model run was not used to provide 4X5Y Haddock biomass estimates, or catch advice, for the 2021–22 fishing year. Two primary causes for the model misspecification were identified: 1) lack of older ages in the survey and fishery resulted in zeros at Age 10 in 2017 and 2018, as well as zeros in the 11+ plus group category; and 2) the assumed natural mortality of 0.2 for some ages less than Age 10 no longer appears to be true.

State of the Resource Relative to Adopted Reference Points

The adopted LRP of 19,700 t Spawning Stock Biomass (SSB) (Age 4+) and USR point of 40,000 t (Age 4+) were based on model estimates of SSB. The model does not provide reliable biomass estimates; therefore, indicators were examined and compared to proxies for the LRP and USR. The survey biomass indices have declined since 2015 to a level consistent with those seen in 2012–2014. The 2020 survey biomass index is currently below the 80% of the time series (1985–2020) median and above the 40% of the time series (1985–2020) median (Figure 8).

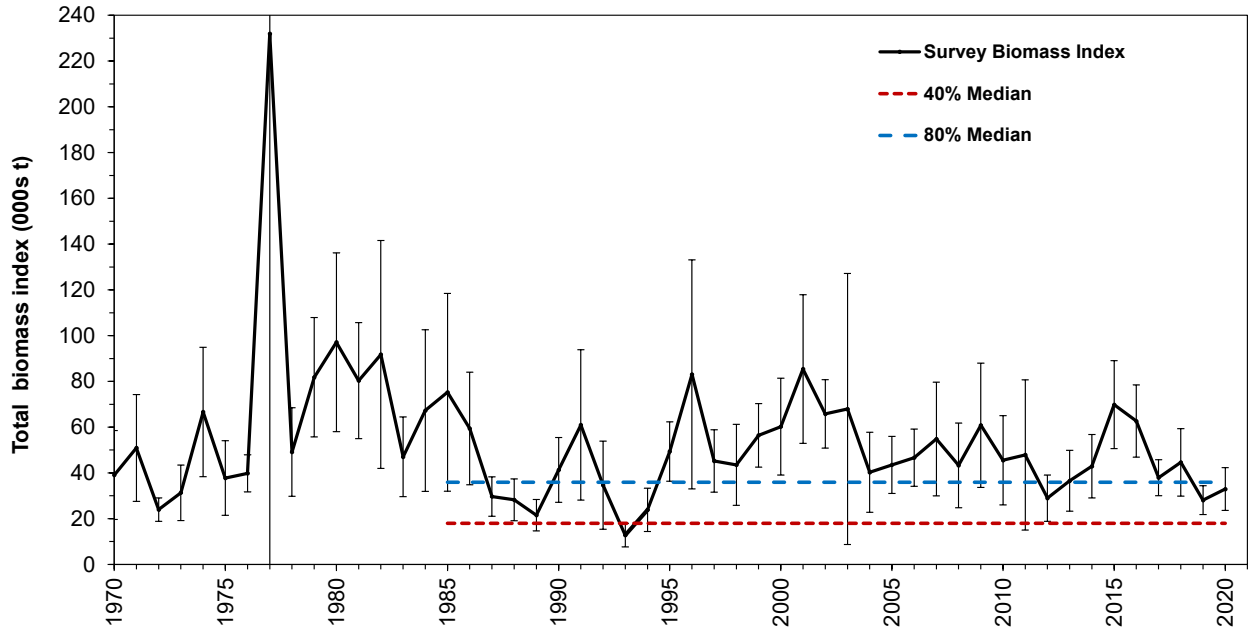

Figure 8. Biomass index for Haddock in 4X5Y from the DFO Summer RV Survey, 1970–2020. The biomass index is represented by the solid black line. The dashed blue and red lines represent 80% and 40% of the 1985–2020 median, respectively. A conversion factor of 1.2 has been applied to indices from 1970–1981 to account for vessel and gear changes.

Relative Fishing Mortality

Due to the lack of an assessment model, an estimate of fishing mortality (F) rate can no longer be calculated. Relative fishing mortality (catch/survey biomass) was examined; however, model estimated F and relative F are not directly comparable. Relative F tended to be above the mean during the earlier years of the time series until 1994 and has remained low since (Figure 9).

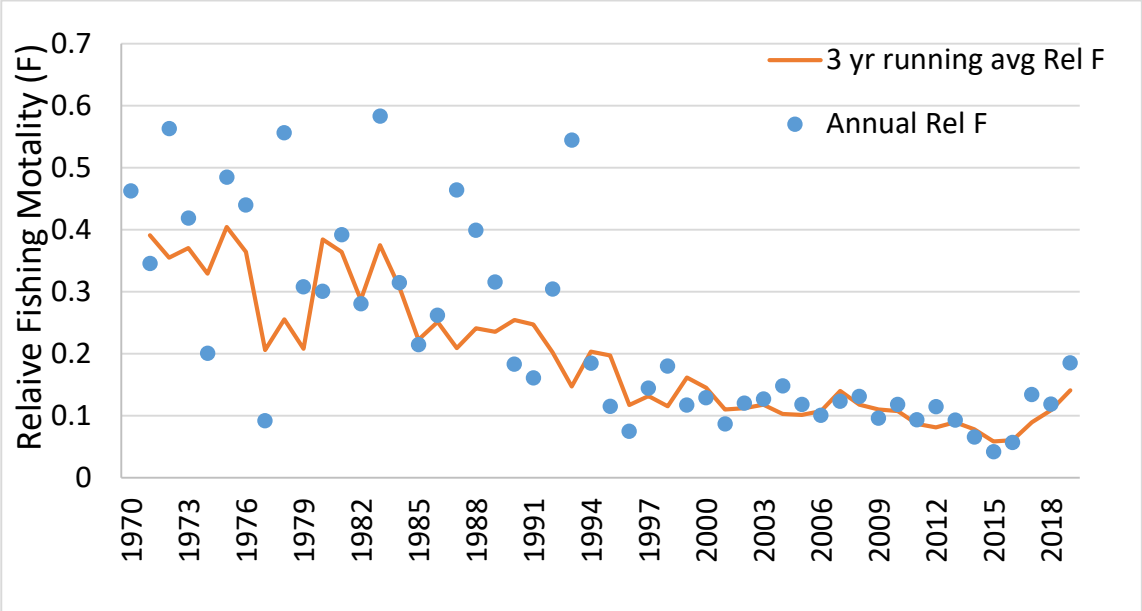

Figure 9. Relative fishing mortality by calendar year for 1985–1999 and by survey biomass/catch by fishing year for 2000–2019 for 4X5Y Haddock, 1970–2019. The average (orange line) is calculated using 3-year running average of the survey biomass index/catch by calendar year for 1985–1999 and the 3-year running average of the survey biomass/catch by fishing year for 2000–2019.

Total Mortality

The total mortality (Z), calculated using a 3-year running average on ages 4+, is variable throughout the time series (Figure 10). Since the mid-1990s, relative fishing mortality has remained low; however, Z has been variable and higher in the years that include the 2010 yc and 2013 yc. There is a general trend of increasing Z on ages 6 and up since 2010 (Figure 11).

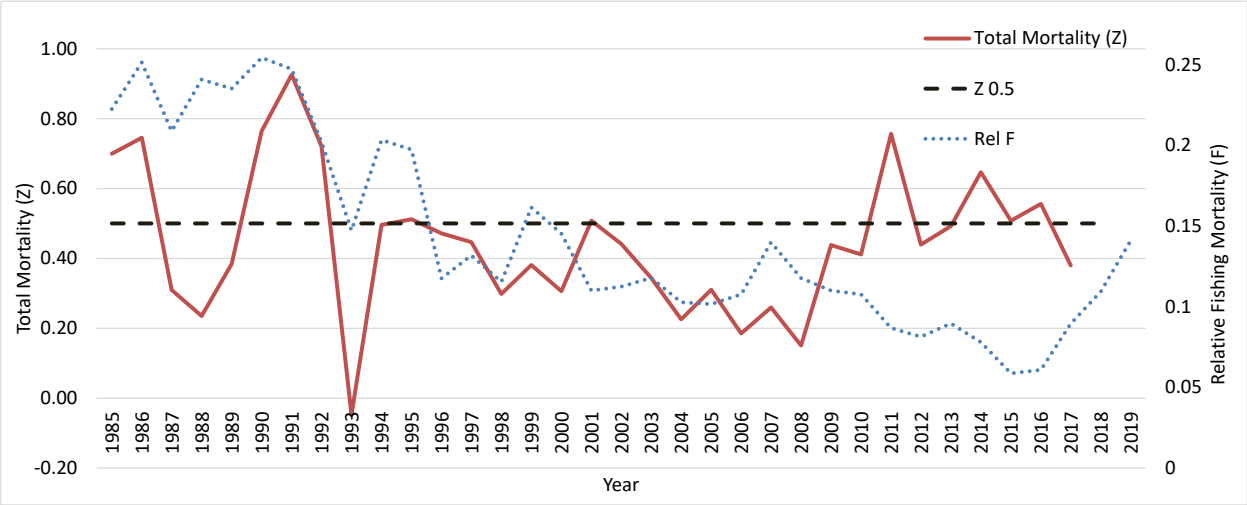

Figure 10. The 3-year running average of total mortality on ages 4+ (red solid line) and the 3-year running average of relative fishing mortality (blue dotted line) for 4X5Y Haddock, 1985–2019. The dashed reference line represents a total mortality of 0.5.

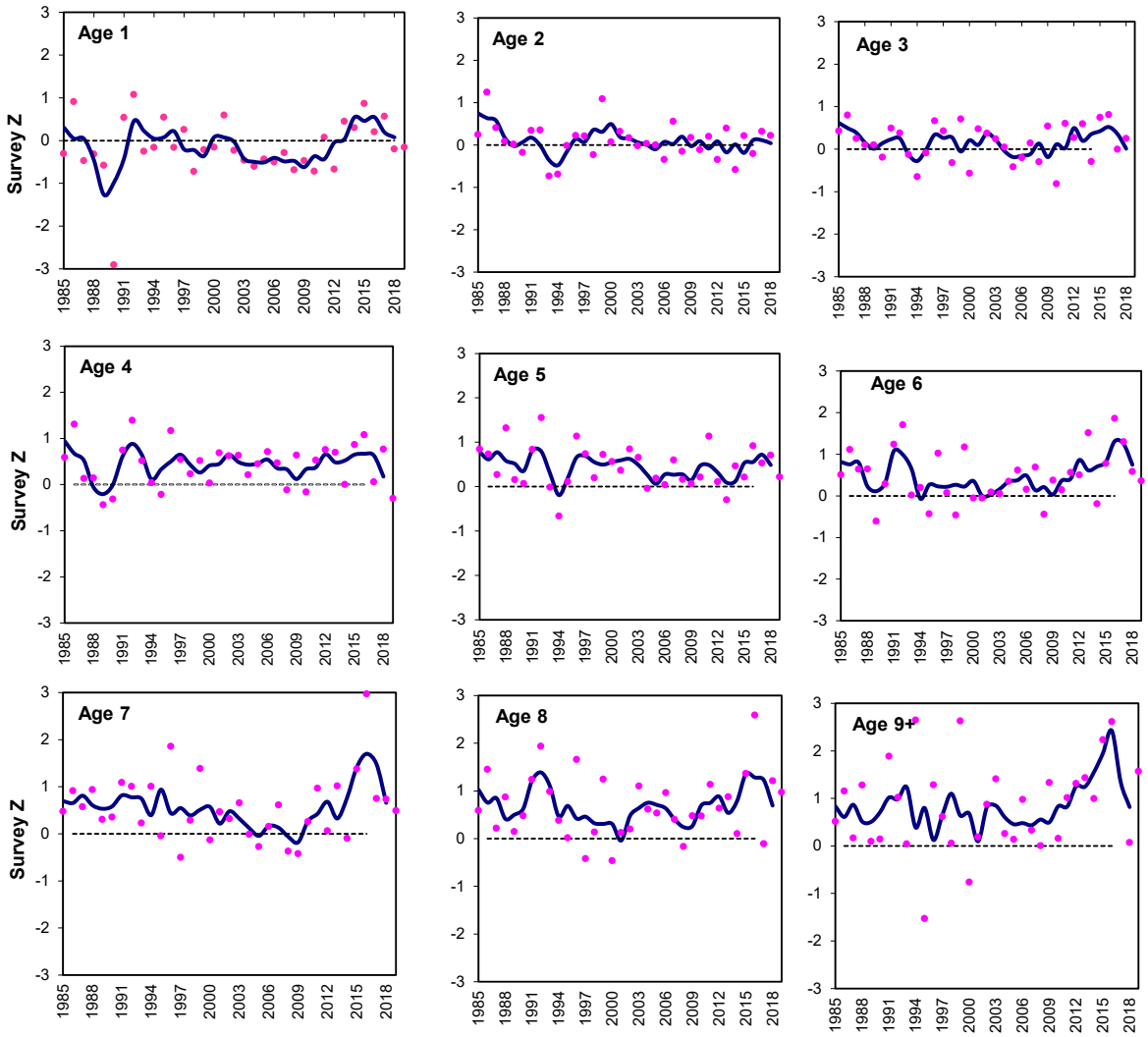

Figure 11. A 3-year smooth (solid blue line) and point estimates (circles) of total mortality (Z) at-age, 1985–2018. The dashed reference line is at zero.

Conclusions

The assessment model was not deemed appropriate, so there are no analytical projections to characterize risk for catches in 2021–22. Instead, total mortality and relative F trends were provided. Since the mid-1990s, relative fishing mortality has remained low; however, Z has been variable and higher in the years that include the 2010 yc and 2013 yc. There is a general trend of increasing Z on ages 6 and up since 2010. The model-free information suggests that 2020 4X5Y Haddock biomass is in the Cautious Zone. Table 3 provides information to support increasing, maintaining, or reducing catch in 2021–22.

Table 3. Information either supporting increasing, maintaining, or reducing existing catch for the 2021–22 fishing year. A dash (-) indicates a blank cell, as the lists are not equal in length.

Increase Existing Catch	Maintain Existing Catch	Reduce Catch
The 2017 year-class is above the time-series median (at Age 3 in 2020) and available to the fishery at Age 4 in 2021.	Survey biomass increased 17% in 2020.	The 2019 and 2020 survey-biomass estimates are below the time-series median.
-	The 2020 DFO Summer RV survey caught Haddock in > 96% of the tows, including one very large tow (> 150 kg).	Total mortality has increased on ages 6+ in the past decade. Older ages (Age 11+) are not being caught in the survey or fishery.
-	The number at Age 2 (2018 yc) in the survey index is above the time-series median.	The lowest survey and fishery weights-at-age for most ages occurred in the past 5 years.
-	In 2020, DFO Summer RV Survey indices of abundance for 2013 yc at Age 7 are at the highest levels observed for the time series and continues to be available to the fishery.	-
-	Relative F has been low since 1994.	-

Contributors

Name	Affiliation
Monica Finley (Lead)	DFO Science, Maritimes Region
Brad Hubley	DFO Science, Maritimes Region
Donald Clark	DFO Science, Maritimes Region
Allan Debertin	DFO Science, Maritimes Region
Daphne Themelis	DFO Science, Maritimes Region
Nell den Heyer	DFO Science, Maritimes Region
Irene Andrushchenko	DFO Science, Maritimes Region
Michelle Greenlaw	DFO Science, Maritimes Region
Alex Dalton	DFO Science, Maritimes Region
Ellen MacEachern	DFO Science, Maritimes Region
Tim Barrett	DFO Science, Maritimes Region
Jamie Emberley	DFO Science, Maritimes Region
Claire Mussels	DFO Science, Maritimes Region
Quinn McCurdy	DFO Science, Maritimes Region
Catriona Regnier-McKellar	DFO Science, Maritimes Region
Ryan Martin	DFO Science, Maritimes Region
Danni Harper	DFO Science, Maritimes Region
Rabindra Singh	DFO Science, Maritimes Region
Yanjun Wang	DFO Science, Maritimes Region
Yihao Yin	DFO Science, Maritimes Region
Jennifer Saunders	DFO Resource Management, Maritimes Region
Penny Doherty	DFO Resource Management, Maritimes Region

Approved by

Alain Vézina
Regional Director of Science, DFO Maritimes Region
Dartmouth, Nova Scotia
Ph. 902-426-3490

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Sources of Information

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Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
Bedford Institute of Oceanography
1 Challenger Drive, PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Canada

Telephone: 902-426-7070
E-Mail: MaritimesRAP.XMAR@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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