



STOCK STATUS UPDATE OF HADDOCK (*MELANOGRAMMUS AEGLEFINUS*) IN NAFO DIVISIONS 4X5Y FOR 2021

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 mortality 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 DFO Summer Research Vessel Survey (RV survey) biomass (DFO 2020). In 2020, indicators were provided along with information to support increasing, maintaining, or reducing catch in the 2021–22 fishing season. The objectives of this update are to report the commercial fishery landings data and the most recent data on the length captured by the fleet, and to comment on the changes in the available biological indicators.

This Science Response Report results from the regional Science Response Process of December 15, 2021, on the Stock Status Update of Haddock in 4X5Y.

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

Maritimes Region

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 RV 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).

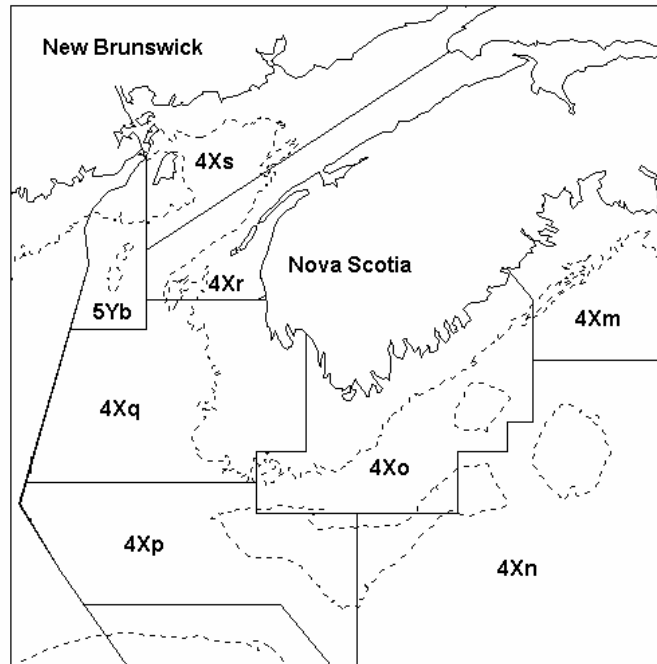


Figure 1. Northwest Atlantic Fisheries Organization Divisions, 4X5Y.

Analysis and Response

The Fishery

Haddock is harvested as part of a mixed groundfish fishery. Reported annual landings of 4X5Y Haddock averaged 18,500 t during the 1970s and 19,800 t during the 1980s, with peaks occurring in the late 1960s and early 1980s (Table 1; Figure 2). Noteworthy is that from 1982–1984, the TAC peaked at 32,000 t, but it was quickly reduced to 4,600 t by 1989. In 1991 and 1992, there was no TAC for Haddock under a Management Plan that called for a bycatch fishery only, although landings exceeded 9,000 t during these years (Hurley et al. 2009). The TAC for Haddock was 5,100 t for the 2012–13 to 2016–17 fishing years, it increased to 7,650 t for the 2017–18 to 2018–19 fishing years, followed by an increase to 9,000 t for the 2019–20 fishing year, and a reduction 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. The TAC remained 6,877 t in 2021–22. The fishing year landings for 2020–21 were 4,866 t (Table 1). The 2021–22 fishing season is ongoing, and landing statistics are incomplete. Catches have been lower than the TAC since 1993 (Figure 2).

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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– 2016/17 Average	2017/18	2018/19	2019/20	2020/21*
TAC	14,650	21,385	5,050	8,030	5,357	7,650	7,650	9,000	6,877
Landings	18,522	19,851	7,219	6,579	3,697	5,087	5,294	5,206	4,866

*Extracted from MARFIS November, 2021.

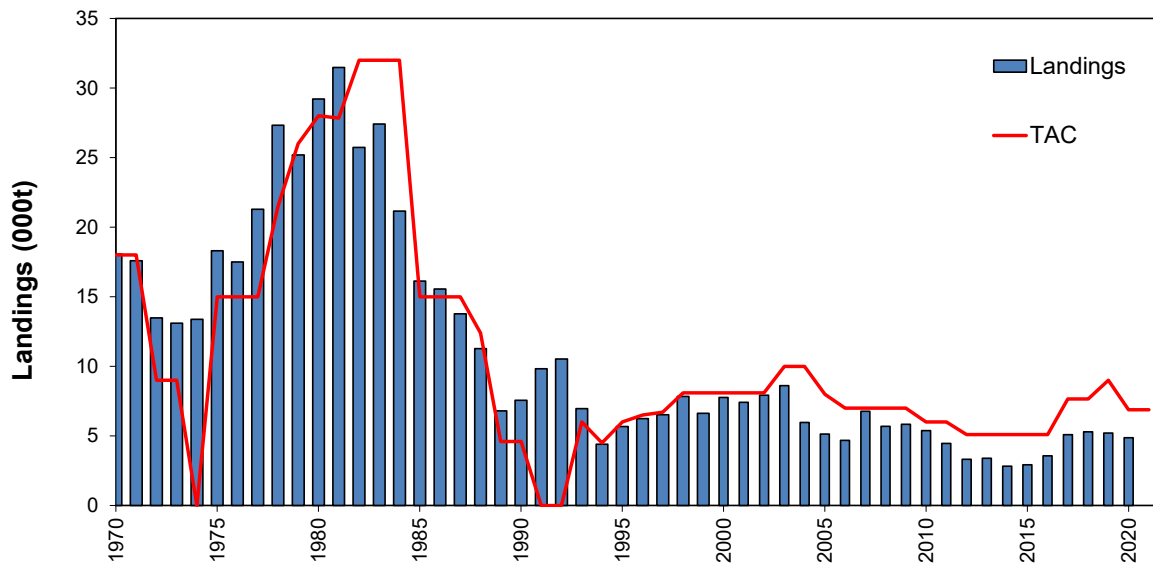


Figure 2. Reported annual and fishing-year landings and Total Allowable Catch (TAC) for the 4X5Y Haddock fishery, 1970–2020. The fishing year changed from Jan 1st–Dec 31st to Apr 1st–Mar 31st in 2000.

The 4X5Y Haddock fishery CAA shows the presence of the strong 2013 year class (yc) (Figure 3). In the 2020 fishery, the 2013 yc (Age 7) was predominant and represented 44% of the Number-At-Age (NAA) in the catch, followed by the 2014 yc (Age 6) at 18%, and the 2016 yc (Age 4) at 13%. Preliminary data for the first half of 2021 suggest the continued availability of the 2013 yc at Age 8, comprising 24% of the CAA in numbers. The 2018, 2017, 2016, and 2014 year classes make up the remainder of the 2021 catch, representing 20%, 17%, 15%, and 9% percent of the NAA, respectively. For the first half of 2021, the 2013 yc comprised 32% of the total weight of the catch, the remainder being made up by the 2017 (Age 4), 2016 (Age 5), 2014 (Age 7), and 2018 (Age 3) year classes making up 13%, 13%, 11%, and 11%, in weight, respectively.

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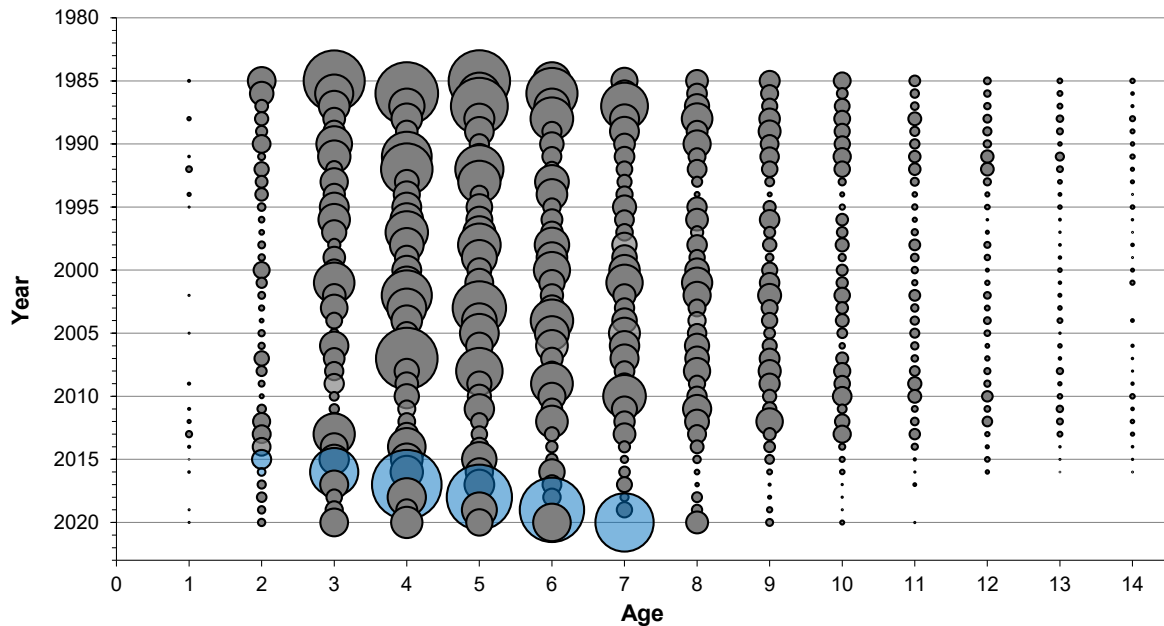


Figure 3. Fishery catch-at-age for 4X5Y Haddock for ages 1–14, 1985–2020. The area of the circle is proportional to the catch in numbers at that age and year. The 2013 year class is highlighted in blue.

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. The RV survey length-weight relationship was used to estimate the fishery weights as no individual weight data were available from the fishery. In 2020, the fishery weighted mean WAA for ages 2, 4, 5, 6, 7, and 9 were 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.

Year	Source	Age Group										
		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*	-
2020	Fishery	0.17	0.29	0.44	0.59	0.65	0.74	0.84	0.96	0.96	1.28	1.48*
1985–2019 Minimum	Fishery	0.11	0.29	0.41	0.59	0.66	0.78	0.94	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	1.40	1.68
2020	Survey	0.09	0.23	0.34	0.46	0.63	0.69	0.78	0.88	1.00	1.13	-
2021	Survey	0.13	0.31	0.43	0.62	0.73	0.79	0.94	0.95	1.40	-	-

*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 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

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in 2020 was 3.4% of trips (19 observed trips). Additionally, in 2020, there was a total of 46 port samples completed from the 4X5Y Haddock mobile gear fishery.

For the small fish protocol, the threshold for the percentage of small fish in the catch was changed from 30% to 40% in 2020–21. In the mobile fleet, 8% (four of 46) port samples had > 40% of small fish (< 38 cm) in the catch, while no observer samples exceeded 40% small fish in the catch. Of the trips that exceeded 40% small fish in 2020, most occurred in 4Xn during the month of February. Of the 12 observer and 5 port bycatch samples in 2020 from small mesh gear, none exceeded 40% small fish in the catch. The bycatch of Haddock from small mesh (< 30 mm) gear made up 7% of the total 2020 Haddock landings (by calendar year).

Haddock catches from the fixed gear fleet are a small proportion of the total Haddock landings in 4X5Y, < 1% in 2020. There were 9 port samples in 2020 from fixed gear; none of these samples have exceeded 30% small fish in the catch.

The preliminary coverage of the 4X5Y Haddock mobile gear fishery in the first half of 2021 consists of 10 observer samples and 18 port samples. Of the January–June data for 2021, 39% (seven of 18) port samples exceeded 40% small fish in the catch and no observer samples exceeded 40%. Two port samples in 2021 had a proportion of small fish between 30% and 40%. All of the trips that exceeded 40% small fish in 2021 occurred March–June with all occurring on the Scotian Shelf.

Observer companies have been struggling to achieve pre-COVID-19 pandemic coverage levels. The COVID-19 pandemic and difficulties in recruiting and retaining observers has led to lower observer coverage levels in 2021–22. Industry has indicated that when a license holder is chosen to take an observer, there is often no observer available. This has resulted in a reduction in observer sampling data for analysis.

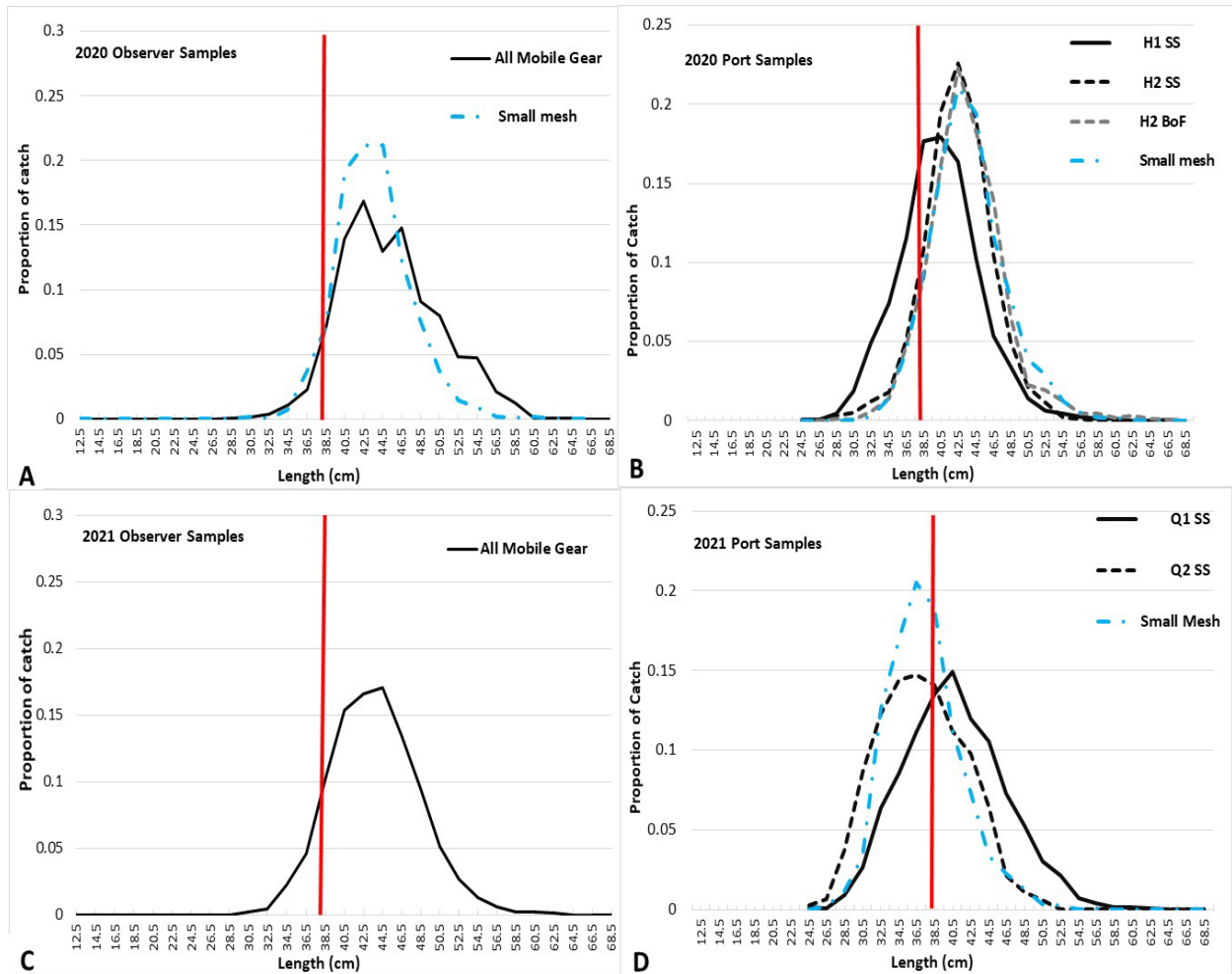


Figure 4. Proportion of catch at length from the 4X5Y Haddock observer (A & C) and port (B & D) samples for mobile gear trips by half year (H1; Jan–Jun and H2; Jul–Dec) from the western Scotian Shelf (SS) or Bay of Fundy (BoF) in 2020 and 2021. Haddock are caught as bycatch in the redfish fishery; the ‘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 2021 were grouped to include all 2021 samples in order to meet data sharing guidelines. This figure includes data available as of November 18, 2021. Sample collection and data entry for 2021 are considered incomplete.

Indicators of Stock Status

The 2021 RV survey was conducted on the *CCGS Capt. Jacques Cartier* using NEST trawl gear. A total of 70 sets were completed in the 4X5Y area, 91% of these sets caught Haddock (Figure 5). Due to vessel mechanical issues, the *CCGS Alfred Needler* was not able to complete comparative fishing in 2021; therefore, no calibration factors are available to provide trends in length frequency or biomass for Haddock. The 2021 data will be included in the time series once comparative fishing data are available and the calibration factors have been approved.

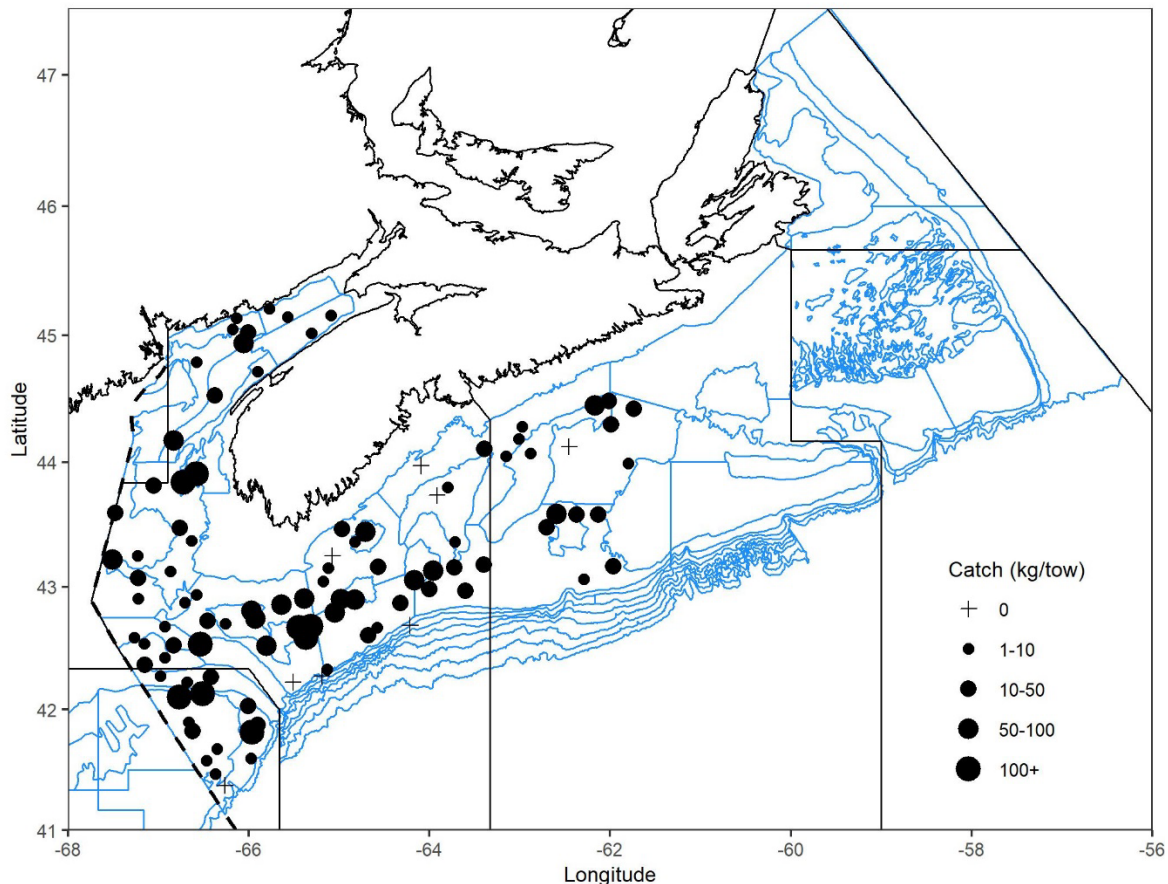


Figure 5. Distribution of Haddock catches during the 2021 DFO Summer RV Survey. Zero catch is represented by the + symbol. Black circles represent catches. The circle area is proportional to the catch size. No vessel or net calibration factor was applied to the DFO Summer RV Survey in 2021.

Similar to the trends observed from the commercial fishery, the mean WAA and LAA values for the RV survey showed a decline from the early 1990s to the mid-2000s, then a levelling off or a modest increase, and a further decline in WAA since 2011. The lowest WAA for most ages occur as the large 2010 and 2013 yc aged, with a modest increase in WAA in 2020 and 2021 (Figure 6). The age composition between the Bay of Fundy and the Scotian Shelf has differed in recent years. The lack of older fish increases the uncertainty in the WAA; only eight fish were identified as Age 9 fish in the 2021 survey catch, and no fish were greater than Age 9.

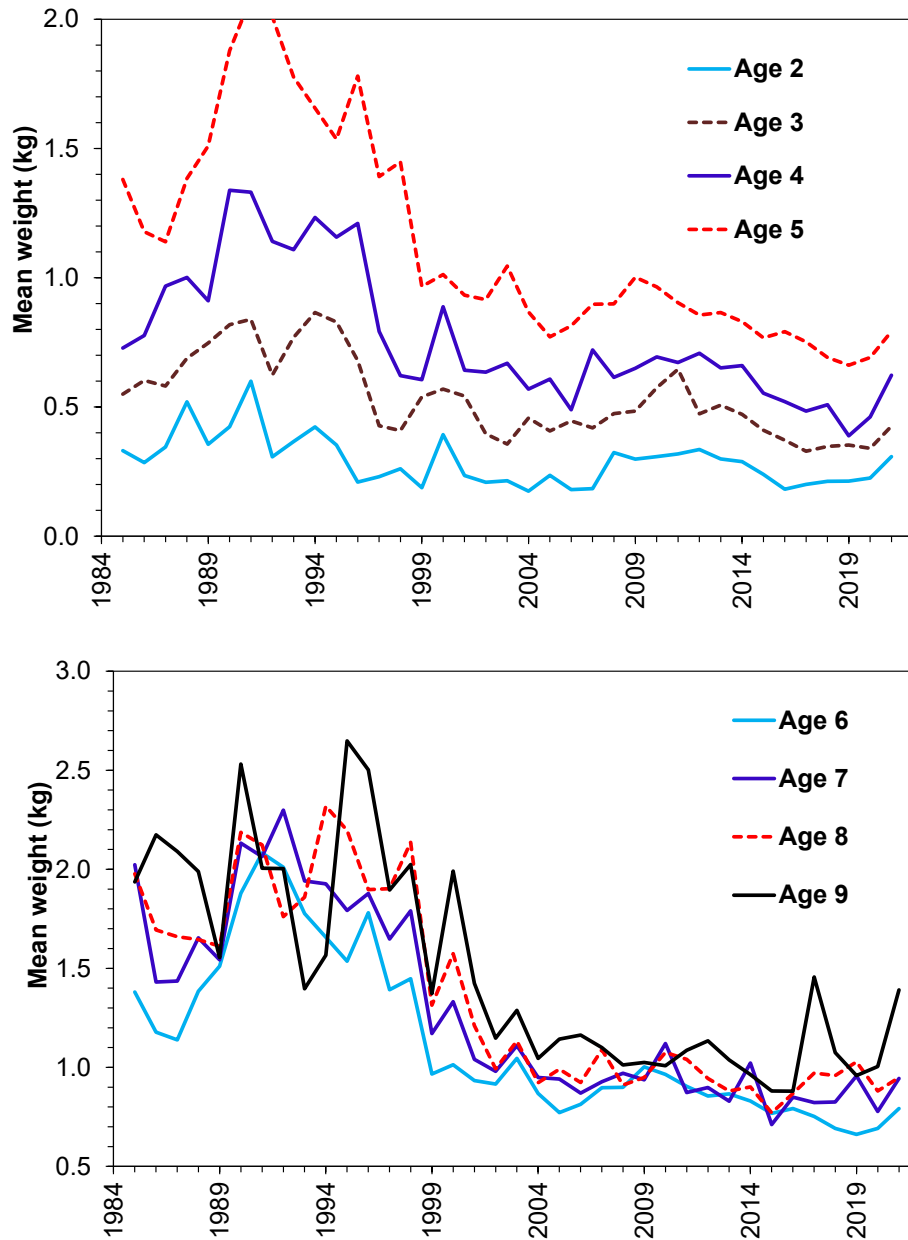


Figure 6. The Summer survey mean weight-at-age (kg) for 4X5Y Haddock ages 2, 3, 4, 5, 6, 7, 8, and 9 for 1985–2021.

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 7). 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 2020 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 7). 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).

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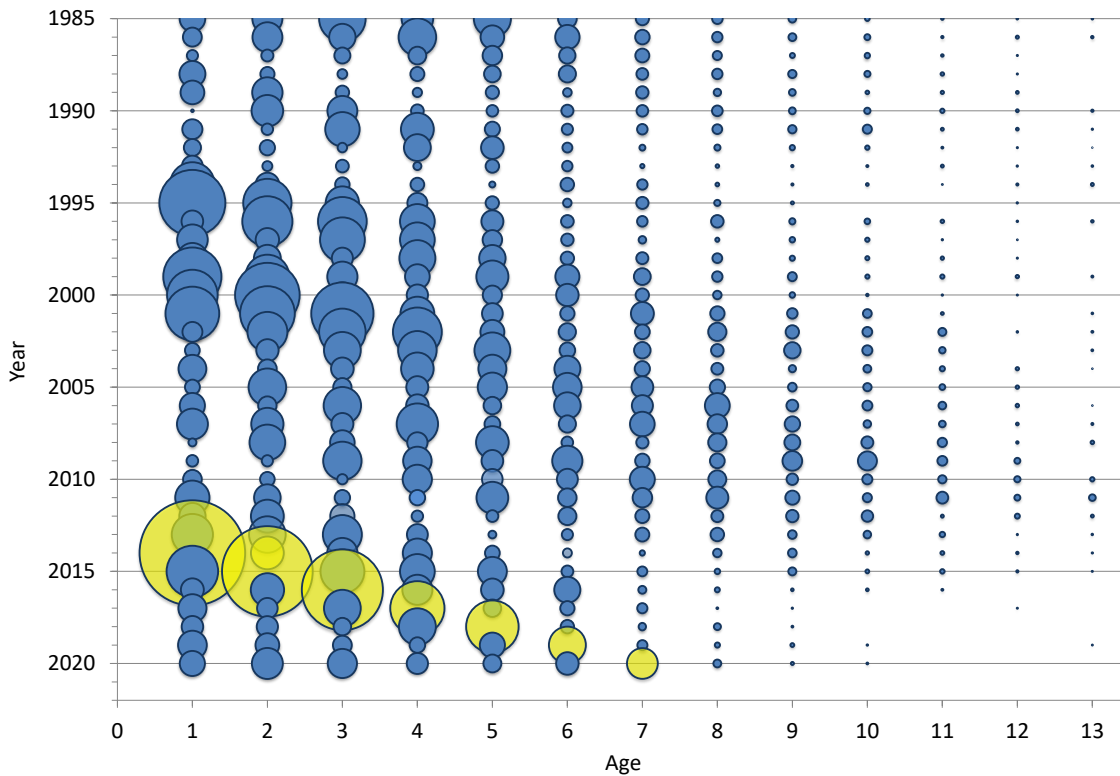


Figure 7. Stratified total number per tow at-age (1–13) for 4X5Y Haddock from the DFO Summer RV Survey, 1985–2020. The yellow circles represent the 2013 year class at Age 1 in 2014 to Age 7 in 2020. The area of the circle is proportional to the number-at-age for each age and year. This figure has not been updated for 2021.

In 2021, the 2020 yc made up 31% of the survey Age 1+ CAA followed by the 2018 (Age 3), 2019 (Age 2), and 2013 (Age 8), which made up 19%, 18%, and 10%, respectively (Figure 8). The 2014, 2015, 2016, and 2017 year classes were caught less frequently and made up only 5%, 2%, 9%, and 6%, respectively (Figure 8). The US Bottom Trawl Surveys made the switch from a Yankee to a NEST trawl in 2009, and the resulting Haddock calibration estimate varied by length, with higher numbers caught at the lower lengths in the NEST trawl (Miller 2013). The length frequency of Haddock caught in the 2021 DFO RV survey, Figure 9, reflects the expected increased number at smaller sizes. Therefore, without the calibration factor, interpretation of the proportion of the catch in 2021 is uncertain.

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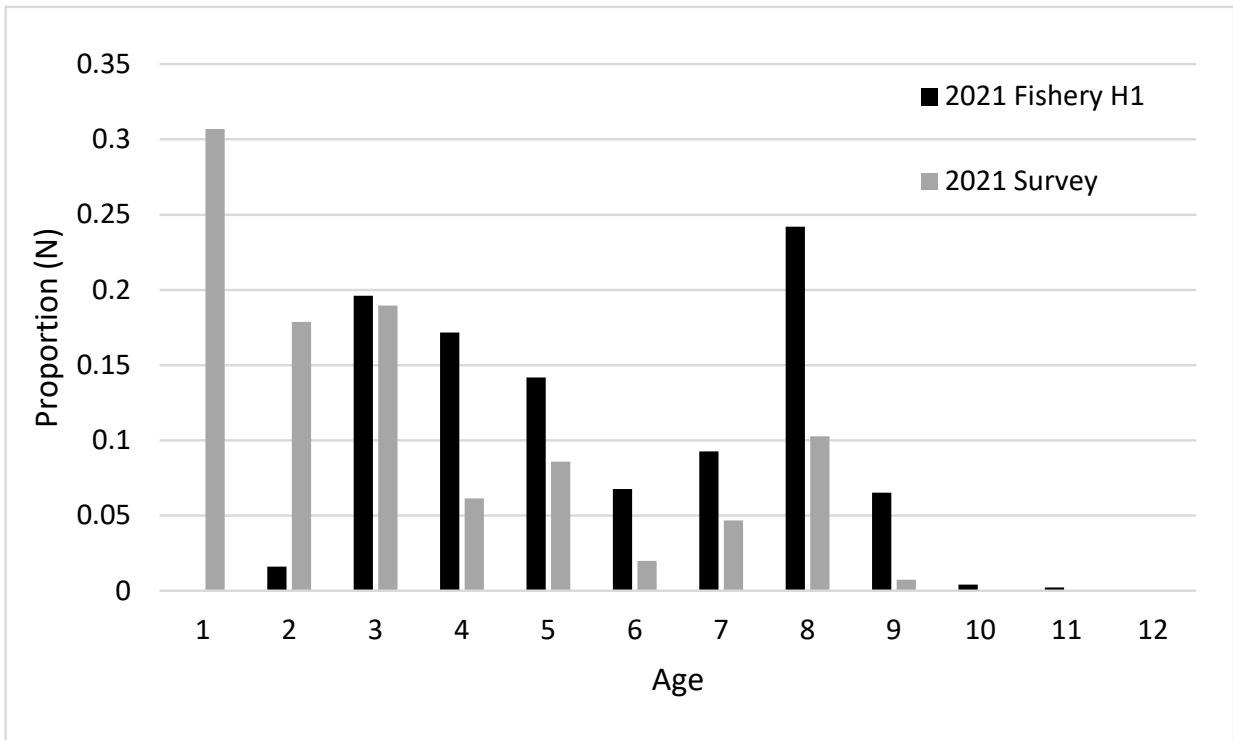


Figure 8. The age 1+ proportion at age, in numbers, of the 4X5Y Haddock caught in the 2021 DFO Summer RV Survey (grey) and the Jan–Jun fishery (black).

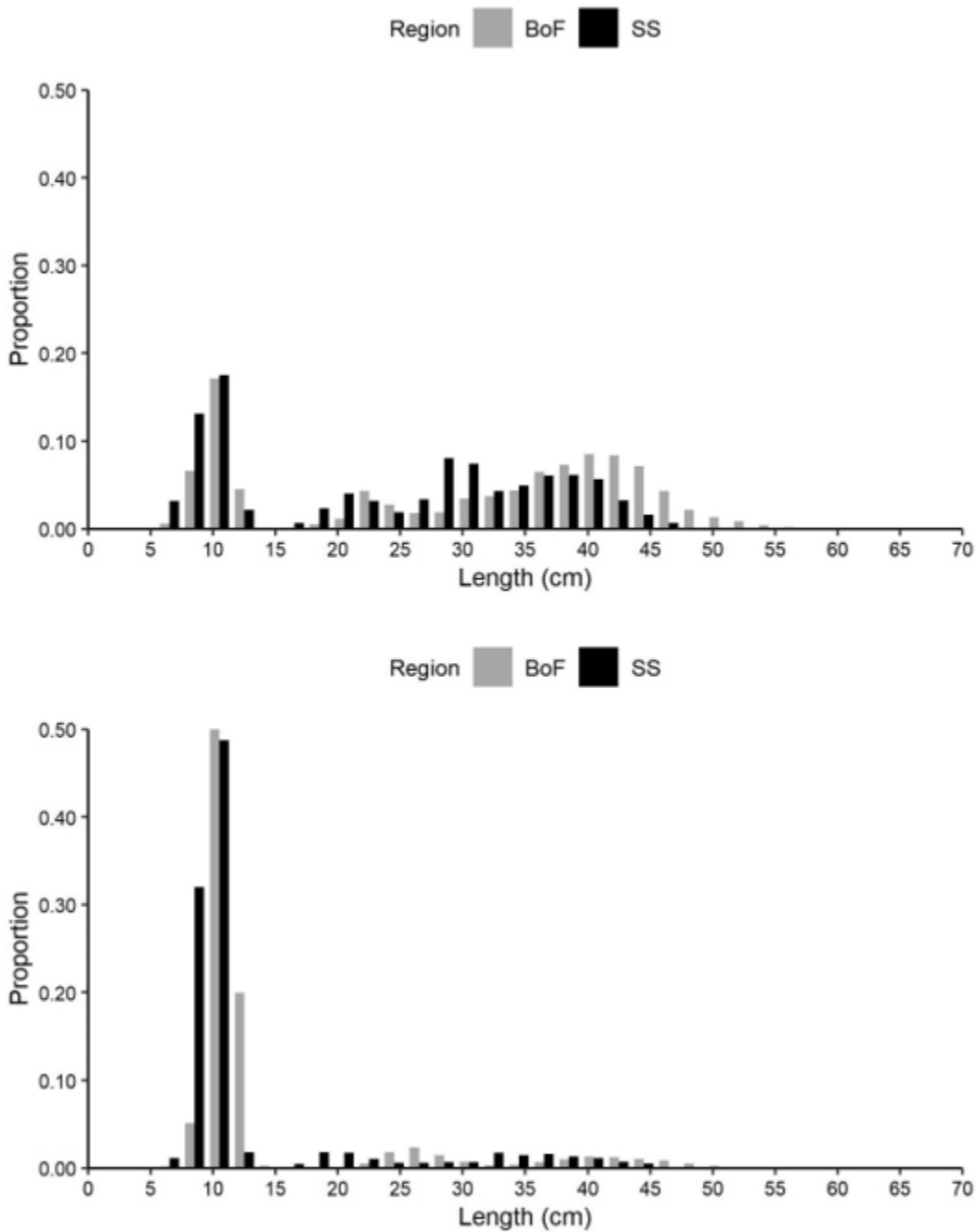


Figure 9. Length frequency of Haddock in 4X5Y in 2020 (top) and 2021 (bottom) from the DFO Summer RV Survey for the Scotian Shelf (black) and the Bay of Fundy (grey).

Sources of Uncertainty

There is high uncertainty due to the lack of a survey calibration factor required to update the RV survey indices of total biomass, relative fishing mortality, and total mortality for 2021. The contribution of the 2013 yc at Age 7 in 2020 is the highest proportion at 44% (in number) for the time series at-age but is expected to continue to decline in importance, and the continued

contributions of the 2013 yc to the fishery is uncertain. Historically, the largest contribution of Age 8 to the fishery was the 2003 yc, which made up 22% at Age 8. The 2014 (Age 6) and 2015 (Age 7) year-classes appear to be weak in both the survey and fishery indicators. Therefore, the 2013 (Age 8), 2018 (Age 3), and 2017 (Age 4) year-classes make up a large proportion of the first half of the 2021 catch.

State of the Resource Relative to Adopted Reference Points

The adopted LRP of 19,700 t 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, in 2020, 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 between 80% and 40% of the time series (1985–2020) median (Figure 9). It was not possible to evaluate the state of the resource in 2021 due to the lack of a calibration factor for the survey index.

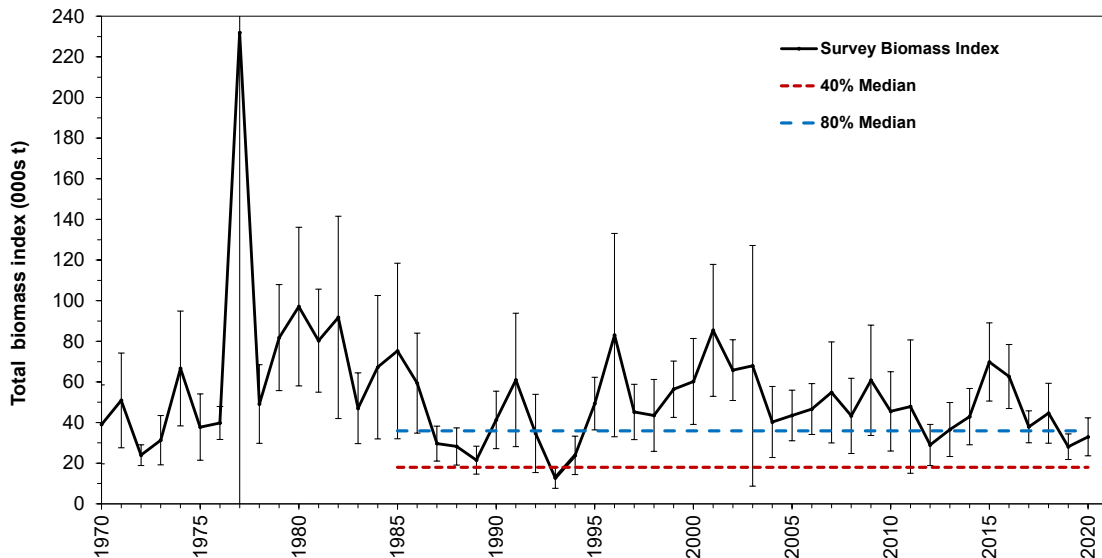


Figure 10. Biomass index for Haddock in 4X5Y from the DFO Summer RV Survey 1970–2020. The biomass index is represented by the solid black line. The dashed blue and red lines represent 80% and 40% of the 1985–2020 median, respectively. A conversion factor of 1.2 has been applied to indices from 1970–1981 to account for vessel and gear changes. This figure was not updated in 2021.

Conclusions

In 2020, the assessment model was not deemed appropriate to provide stock advice, so there are no analytical projections to characterize risk for catches in 2022–23. Without the vessel and net calibration factor, there is limited information available from the DFO Summer RV Survey in 2021. Therefore, this stock does not have an updated index of total biomass, relative fishing mortality, or total mortality for 2021. The available 2021 survey data suggest some recent improved growth, with Haddock continuing to be widely distributed in the survey area and caught in large quantities on the CCGS *Capt. Jacques Cartier* using the NEST trawl. The 2013 yc at Age 8 continues to be captured and made up 10% of the 2021 survey catch and 24% of the January to June 2021 fisheries catch in number (32% in weight). However, the continued contributions of the 2013 yc to the fishery is uncertain.

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