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Canadian Science Advisory Secretariat
Maritimes Region **Science Response 2018/028**

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

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) and Resource Management to determine a Total Allowable Catch (TAC) that is consistent with the Integrated Fisheries Management Plan (IFMP). The most recent framework was completed in 2016 (Stone and Hansen 2015, Wang et al. 2017). A Virtual Population Analysis (VPA) model with M (natural mortality) 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 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 used 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 recruit relationship precludes the calculation of an appropriate biomass at Maximum Sustainable Yield (B_{MSY}), a more conservative biomass level from which the stock has recovered ($B_{recover}$; Age 4+ biomass; 19,700 metric tonnes (t)) was recommended as Limit Reference Point (LRP) for 4X5Y Haddock. In the spring of 2017, Resource Management agreed upon twice the limit reference point (LRP), or 40,000 t, as the Upper Stock Reference (USR; Age 4+ biomass).

The most recent assessment of 4X5Y Haddock was conducted in 2016 (DFO 2017). The 2016 assessment provided a two year projection of biomass and catch. The objective of this interim update is to report new information from the DFO Summer Research Vessel (RV) Survey (NAFO Divisions 4VWX) and commercial fishery landings data and compare this information to the 2016 assessment results and projection input parameters. The recent biomass trend is evaluated against reference point values.

This Science Response Report results from the Science Response Process of December 5, 2017, on the Stock Status Update of 4X5Y Haddock.

Background

Biology

Haddock are found on both sides of the North Atlantic and occur in the northwestern Atlantic from southwest Greenland to Cape Hatteras, US. A major stock 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 (NAFO Divisions 4Xqrs5Y) are higher than those of Haddock on the western Scotian Shelf (NAFO Division 4Xmnop) (Hurley et al. 1998); therefore, separate age length keys are used for calculating the fishery catch-at-age (CAA) and survey indices of abundance. Major

spawning grounds are found on Browns Bank, and peak spawning occurs 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) from the early 1990s to mid-2000s with a modest increase or level off in the recent period, followed by a decrease in 2015 and 2016. While it is not clear what caused the declining trend over this time period, the effect on stock productivity is significant and has been discussed in previous assessments (Hurley et al. 2009, Mohn et al. 2010).

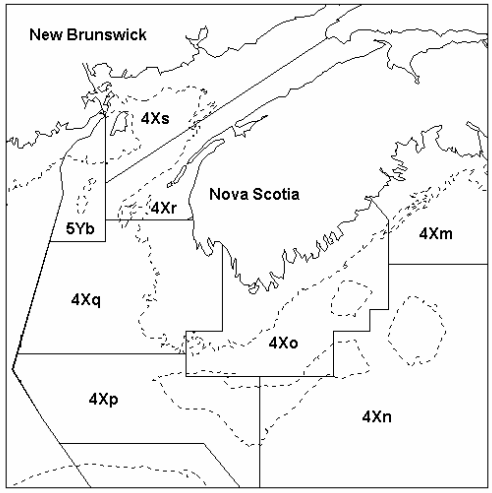

Figure 1. Northwest Atlantic Fisheries Organization Subdivisions, 4Xmnopqrs5Yb.

Analysis and Response

The Fishery

Haddock is harvested as part of a mixed groundfish fishery. The TAC for Haddock was 5,100 t for the 2012/13–2016/17 fishing years, and increased to 7,650 t for 2017/18. However, catches have been lower than the TAC since 2002 (Figure 2). The fishing year landings for 2015/16 and 2016/17 were 2,926 t and 3,567 t, well below the TAC of 5,100 t (Table 1). The 2017/18 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	1970-1979 Average	1980-1989 Average	1990-1999 Average	2000-2009 Average	2010-2015 Average	2015/16	2016/17*
TAC	14,650	21,385	5,050	8,030	5,400	5,100	5,100
Landings	18,522	19,851	7,219	6,579	3,719	2,926	3,567

*Extracted October 2017

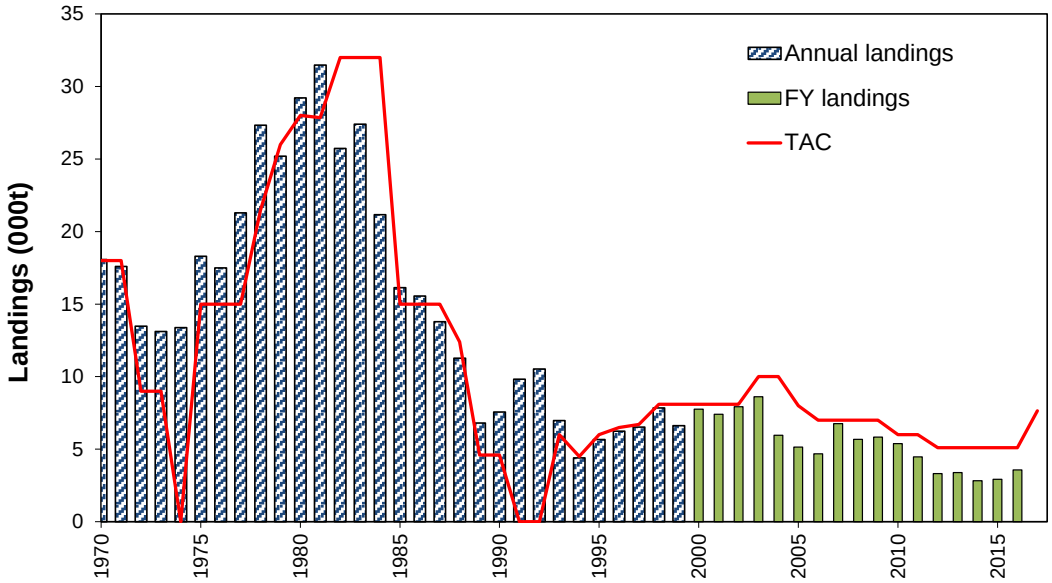

Figure 2. Reported annual landings (t), fishing year landings (FY; April 1st - March 31st) and total allowable catch (TAC) for the 4X5Y Haddock fishery, 1970-2017.

The 4X5Y Haddock fishery catch-at-age (CAA) shows the presence of recent strong year classes, including 2010 and the incoming 2013 year class (Figure 3). In the 2016/17 fishery, the 2013 year class at Age 3 was predominant and represented 46% of the CAA followed by the 2012 year class at 21% and the 2011 year class at 15%. The 2016 fishery CAA is similar to the projected CAA (2016 assessment; DFO 2017); the 2013 year class at Age 3 was projected to represent 50% of the CAA followed by the 2012 year class at 15% and the 2011 year class at 12%.

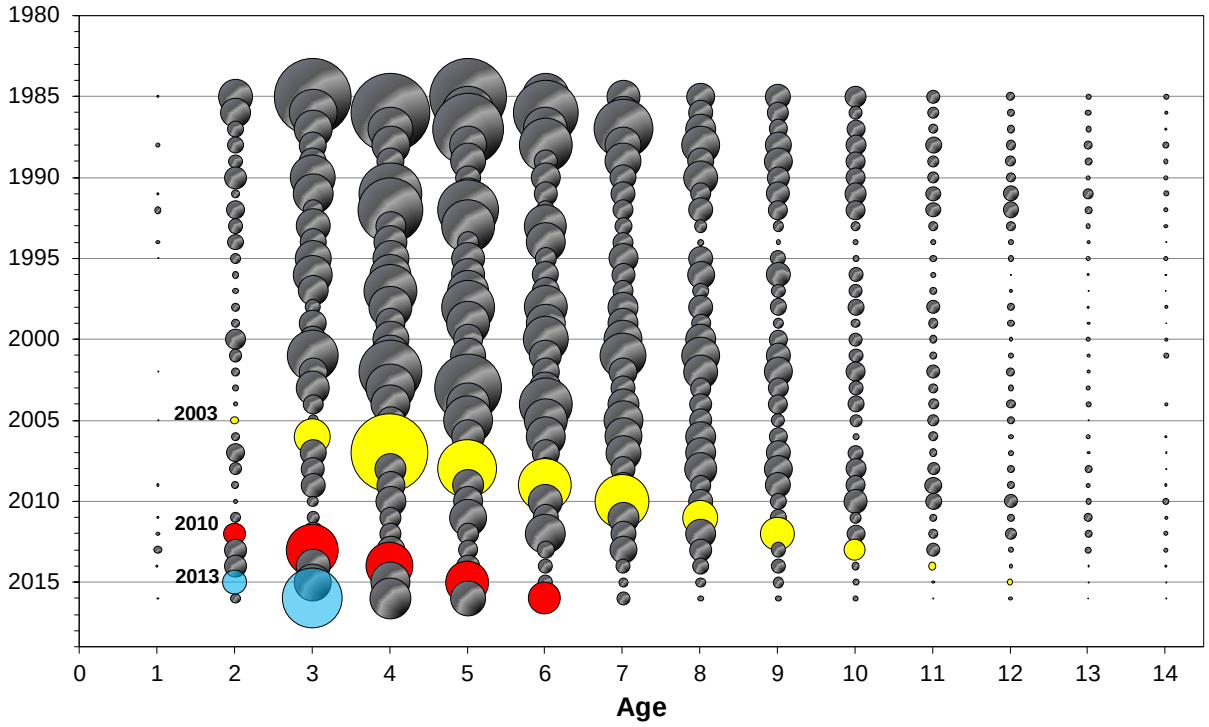

Figure 3. Catch-at-age for 4X5Y Haddock for ages 1-14, 1985-2016. The area of the circle is proportional to the catch in numbers at that age and year. Three examples of recent strong cohorts are highlighted: 2003 (yellow), 2010 (red), and 2013 (blue).

Separate age length keys are used for Scotian Shelf and Bay of Fundy samples to generate numbers-at-age (NAA), which are then used for weighting the calculations of the overall fishery WAA. In 2016, the weighted mean WAA for ages 2, 3, 4, 5, and 8 are the lowest in the time series. The time series (1985-2015) minimum WAA was used for projection in the 2016 assessment; therefore, the assumed WAA for ages 2, 3, 4, 5, and 8 in the projection were higher than the observed values (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+**
2015 Projection	Fishery	0.11	0.41	0.57	0.71	0.86	0.98	1.01	0.97	1.02	1.15	1.39
2016 Observed	Fishery	0.17	0.39	0.52	0.66	0.80	1.02	1.19	0.90	1.28	1.21	1.92
2015	Survey	0.08	0.24	0.41	0.55	0.70	0.77	0.71	0.77	0.88	1.08	1.48
2016	Survey	0.07	0.18	0.37	0.52	0.61	0.79	0.85	0.87	--	1.16	1.33

DFO Summer Research Vessel (RV) Survey

The DFO Summer RV Survey (NAFO Divs. 4VWX) biomass index in 2016 and 2017 was 62,700 t and 37,850 t, respectively (Figure 4). The 2017 index is below the short (5 year: 49,967 t), and long-term (since 1970: 52,161 t) averages. Haddock were caught in >95% of the tows in 2016 and 2017; however, no large tows (>150 kg) were caught in 2017.

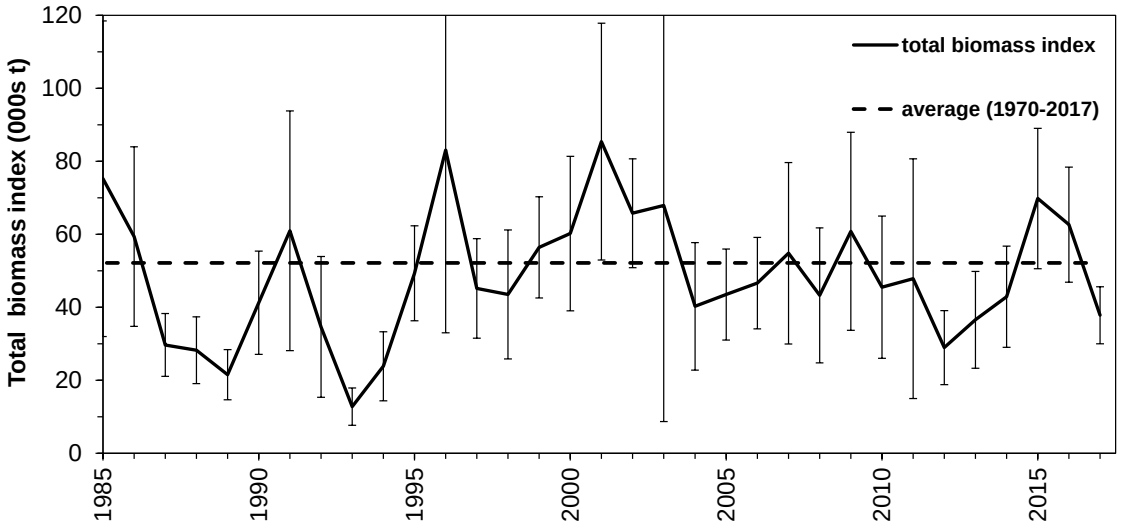

Figure 4. The total biomass index (all ages) ± 2 standard error (000s t) from the DFO Summer RV Survey for 4X5Y Haddock, 1985-2017. The black dashed line represent the long term average from 1970-2017.

Similar to the trends observed for the commercial fishery, the summer survey values for the mean WAA and LAA show a decline from the early 1990s to the mid-2000s and then a levelling off or a modest increase, followed by the lowest WAA for many ages (1-5) occurring in 2016 (Table 2). The age composition between the Bay of Fundy and the Scotian Shelf has differed in recent years. The lack of older fish (Age 7+) in the Bay of Fundy means that the WAA calculations for older fish are derived primarily from those caught on the Scotian Shelf.

Recruitment (Age 1) is variable throughout the survey time series, the 2013 year class being the highest on record with the estimate of 168 million (Figure 5). In 2016, the 2013 year class (Age 3) made up 63% of the survey CAA, the 2014 year class (Age 2) made up 11%, followed by the 2012 year class (Age 4), which made up 9%.

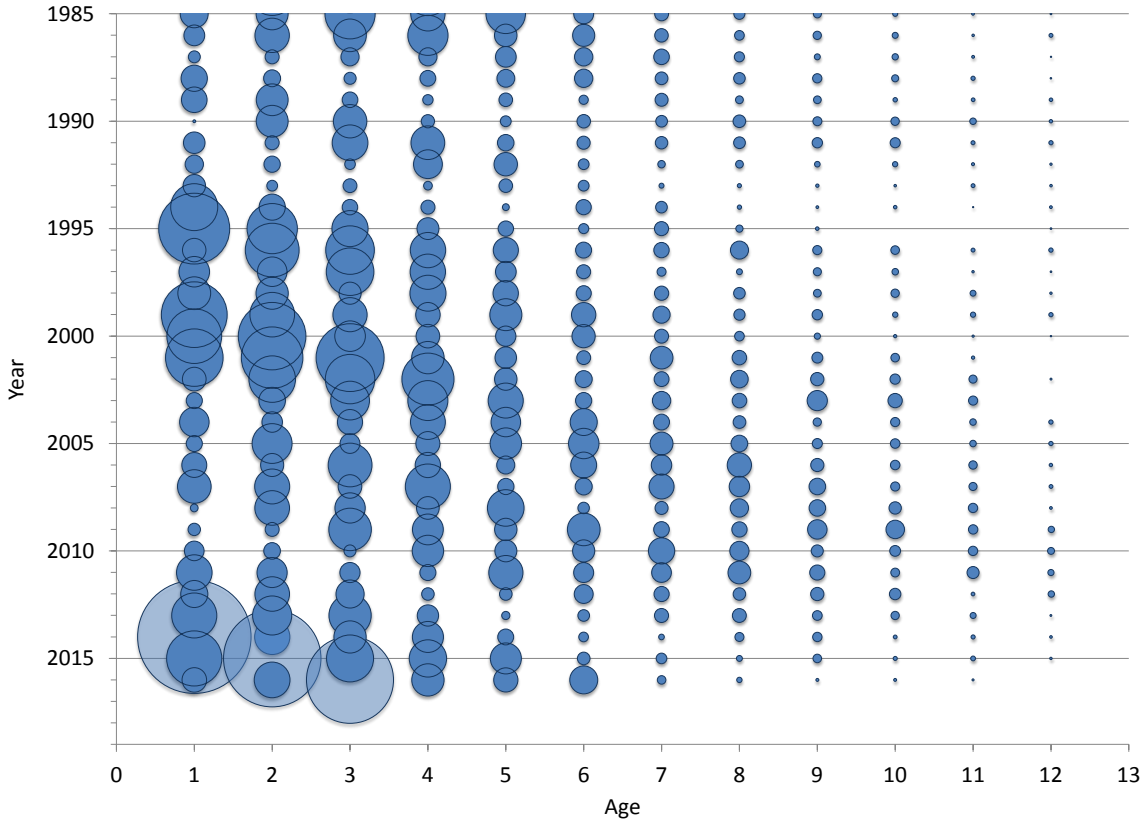

Figure 5. Stratified total number per tow at age (1-13) for 4X5Y Haddock from the DFO Summer RV Survey, 1985-2017. The semi-transparent circles represents the 2013 year class at age 1 in 2014 to age 3 in 2016. The area of the circle is proportional to the number at age for each age and year.

Sources of Uncertainty

Two years of survey data were collected since the 2016 assessment model run and a mismatch between survey biomass index and the VPA is apparent for 2016 and 2017 (Figure 6). The decrease in survey abundance in 2016 and 2017 when compared to previous years (2015 and 2016, respectively) cannot be explained by current estimates of natural mortality and fisheries mortality. The model and projection performance are impacted by the substantial fluctuations in the survey biomass index and the decreasing WAA (survey and fishery).

The 2013 year class appears to be much stronger than anything previously observed, but there is uncertainty around this estimate; the Coefficient of Variation (CV) is high for the VPA estimate of the 2013 year class (0.4 at Age 3 in 2016). The model retrospective analysis shows some minor retrospective patterns. For the most recent years, the model tends to overestimate the biomass and underestimate F when each year of data is removed.

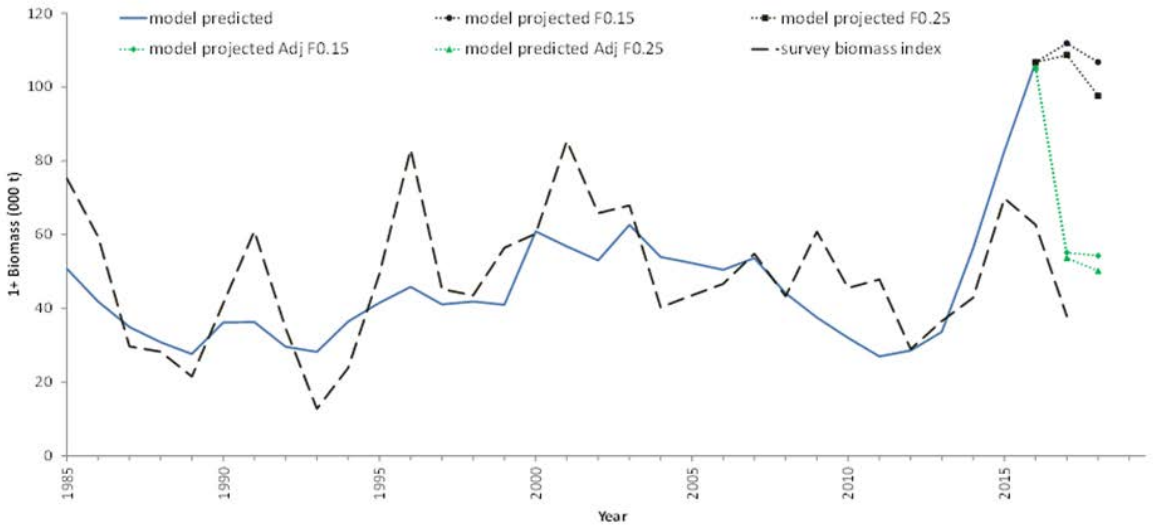

Figure 6. The model estimated 1985-2016 (solid blue line), projected 2017-2018 (shaped markers), and survey 1+ (black dashed line; t) biomass index for 4X5Y Haddock.

State of the Resource Relative to the Adopted Reference Points

Due to the uncertainties around the model estimate of the 2013 year class and the significant impact of that estimate on projections, sensitivity deterministic projections were conducted in 2016 assuming the 2013 year class recruitment was equal to the largest recruitment in the time series prior to 2013 (54 million in numbers). Given that the 2013 year class appeared to be much stronger than previous observations and the 54 million falls outside of the 90% confidence interval for the estimate of the 2013 year class (104 million to 348 million in numbers), this was a conservative approach to assess this uncertainty. In both scenarios (F_{lim}=0.25 and F_{ref}=0.15), the sensitivity projection SSB estimates for 2018 remained above the USR (Figure 7).

Indicators that would trigger an earlier than scheduled assessment based on the established recommendations in DFO 2017 include:

1. A difference in strong year class projected versus realised. In this case, if the perception of 2013 year class strength goes below the second highest observed year class, (i.e. below the value used for sensitivity analysis (1999 year class) and outside the range of sensitivity projections), then a more complete review will be conducted.
2. Low survey biomass trigger (Suggested a 3 year running q adjusted average below B_{lim}) using the previous year's q values.

There was insufficient information to evaluate the triggers at the time of the update, and they will be evaluated once the model is run in 2018.

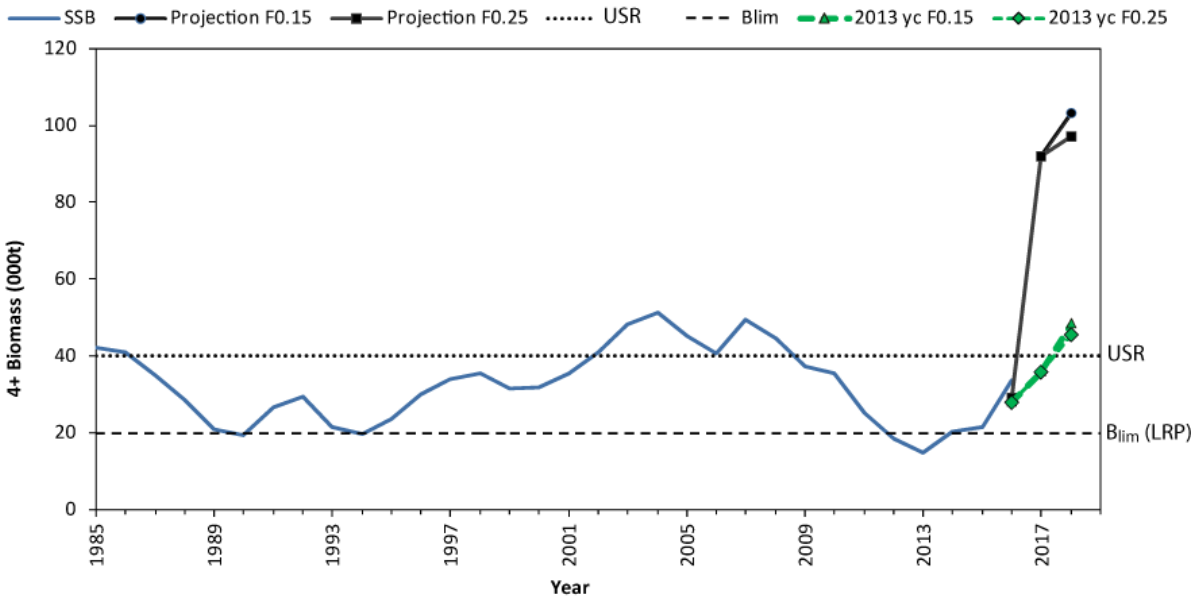

Figure 7. The model estimated spawning stock biomass 1985-2016 (SSB; solid blue line) projections under F_{ref} (F=0.15; black circle markers) and F_{lim} (F=0.25; black square markers) scenarios for 2017 and 2018, as well as the 2013 year class sensitivity projections under F_{ref} (green triangle markers) and F_{lim} (green diamond markers) scenarios for 2017 and 2018. The established B_{lim} (black dashed reference line) is 19,700 t and the upper stock reference point (black dotted reference line) is 40,000 t.

Conclusions

At the 2016 framework and assessment, it was concluded that 2016 4X5Y Haddock biomass, 33,770 t, was above the established B_{lim} reference point (19,700 t) and marginally below the USR (40,000 t). The estimated fishing mortality (F) for ages 6 to 10 in 2015 was 0.05 for 4X5Y Haddock, therefore below the fishing mortality reference point (F_{ref}) in both the Healthy Zone (F_{lim}=0.25) and Cautious Zone (F_{ref}=0.15). Since that assessment of the resource, new information is available from two sources: commercial landings data and DFO Summer RV Survey. The current document provides updated data and compares this information to the 2016 assessment results and projection input parameters.

The 2016 assessment projection of Age 4+ biomass in 2017 and 2018 (91,998 t and 103,128 t, respectively) for 4X5Y Haddock (Figure 7) is above both the established B_{lim} reference point (19,700 t) and the USR (40,000 t). The projections for the sensitivity analyses conducted with a value of 54 million in numbers for the 2013 year class produced Age 4+ biomass estimates marginally below the USR in 2017 and marginally above the USR in 2018 (35,892 t and 48,213 t, respectively).

The decreases in the 2016 WAA and survey biomass index suggest an overly optimistic outlook for the stock from the 2016 assessment. However, the 2013 year-class from the DFO Summer RV Survey is the strongest observed for the time series. The 2017 Age 4+ biomass is expected to have been close to the upper stock reference point, although there is uncertainty whether it was above or below.

Considering the summary information to inform catch advice (Table 3), the standard projection from the 2016 assessment is not supported for providing catch advice. For the 2016/17 fishing year, the TAC was set at 7,650 t due to the uncertainty around the projections. It is

recommended a similar approach to be taken for the 2017/18 fishing year. Since the sensitivity analysis was considered a conservative approach to assessing the uncertainty of the 2013 year class the sensitivity, deterministic projections could be useful as a lower bound for catch advice (Table 4).

Table 3. Information either supporting the catch advice from the 2016 assessment or supporting a reduction in the advice.

Maintain Existing Catch Advice	Reduction of Catch Advice
The projected adult biomass in 2017 is the highest in the time series.	The 2017 DFO Summer RV Survey biomass index is below the time series average.
Only 70% of the 2016 TAC was caught.	A mismatch between survey biomass index and the VPA is apparent for 2016 and 2017.
In 2016, DFO Summer RV Survey indices of abundance for 2013 year class are at the highest levels observed for the time series.	A retrospective pattern was observed in the 2016 Haddock assessment. The pattern leads to overestimated biomass and underestimated F.
The DFO Summer RV Survey caught Haddock in >95% of the tows.	The DFO Summer RV Survey did not catch any large tows (>150 kg) in 2017.
	The lowest weight-at-age for many ages occurred in 2016 for both fishery and survey.

Table 4. The levels of catch (t) projected in 2016 for which there is a 25%, 50%, and 75% risk of the fishing mortality in 2018 exceeding F=0.25 and F=0.15. Dash (-) indicates data not available.

Model	Risk of Exceeding	Catch Year	25%	50%	75%
Framework accepted	F= 0.15 if F=0.15 in 2017	2018	12,600	15,100	17,600
Framework accepted	F= 0.25 if F=0.25 in 2017	2018	19,100	23,100	27,100
Sensitivity analysis	F= 0.15 if F=0.15 in 2017	2018	-	6,831	-
Sensitivity analysis	F= 0.25 if F=0.25 in 2017	2018	-	10,379	-

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Sources of Information

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