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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/006

ASSESSMENT OF 4X5Y HADDOCK IN 2016

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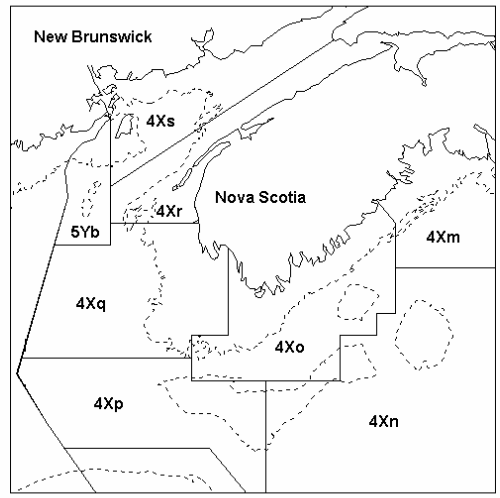

Figure 1. Northwest Atlantic Fisheries Organization Unit Areas.

Context:

Haddock (Melanogrammus aeglefinus) are found on both sides of the North Atlantic. They occur in the northwestern Atlantic from southwest Greenland to Cape Hatteras. The species is a bottom dwelling member of the gadid family that occurs most commonly at depths of 46-228m and at bottom temperatures above 2°C. Their diet consists mainly of small invertebrates. A major stock exists on the western Scotian Shelf and in the Bay of Fundy (Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Y) (Figure 1). 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).

NAFO 4X5Y Haddock are harvested as part of a mixed, multi-species fishery that includes Atlantic Cod, Halibut, redfish, Pollock, White Hake, and flounders. Since the mid-1970s, the mobile gear sector has accounted for most of the total landings from the 4X5Y Haddock fishery, except during the early 1990s when the percentage taken by the fixed gear sector was greater. Quotas for this stock were introduced in 1970 and spawning season and area closures have been in place since that time.

The status of 4X5Y Haddock was last assessed in January 2012 (DFO 2012). Given model uncertainties, a framework review was recommended. An initial science review meeting held in October 2014 reviewed results of updated analyses on stock structure, spatial and temporal patterns in distribution, bycatch, biological attributes, and revisions/updates to data inputs for stock assessment (Stone and Hansen 2015). A second science review meeting held in April 2016 reviewed the methodologies developed for estimating current stock status, fishery reference points, forecasting methodology for providing advice, and guidance on inter-framework review activities.

This Science Advisory Report is from the November 28-29, 2016 regional peer review on the Stock Assessment with Catch Projections for 4X5Y Haddock. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Fishing year landings for 2014/2015 and 2015/2016 were 2,825 tonnes (t) and 2,926 t, respectively, well below the total allowable catch of 5,100 t.
- Over the past 10 years, the mobile gear sector (small otter trawlers) have taken an average of about 80% of the catch and the fixed gear sector (primarily longline) about 20%, with the majority coming from the Scotian Shelf.
- The DFO Summer Research Vessel survey biomass index in 2015 and 2016 was 69,800 t and 62,700 t, respectively. The 2015 and 2016 index was above the short (5 year: 48,193 t), and long-term (since 1970: 55,470 t) averages.
- For both the commercial fishery and the summer survey, values for the mean weights-at-age and lengths-at-age show a decline from the early 1990s to the mid-2000s and then a levelling off or a modest increase, followed by the lowest weights-at-age for many ages occurring in 2015.
- The estimated spawning stock biomass at the beginning of 2016 was 33,770 t, above the established biomass limit reference point (B_{lim}) of 19,700 t and the long-term average of 32,258 t. The stock is not in the critical zone.
- 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=0.25) and cautious zone (F=0.15).
- A deterministic projection was conducted with a catch of 5,100 t in 2016 under fishing at F_{ref}=0.25 in the healthy zone scenario for 2017 and 2018, and a second deterministic projection was conducted under fishing at F=0.15 in the cautious zone scenario for 2017 and 2018. In both scenarios, spawning stock biomass estimates for 2017-2019 remained above the time series average and B_{lim}.
- A stochastic projection was conducted with a catch of 5,100 t in 2016 under fishing at F_{ref}=0.25 in the healthy zone scenario in 2017 and 2018, and a second stochastic projection was conducted under fishing at F=0.15 in the cautious zone scenario in 2017 and 2018. Catch estimates for 2017-2019 ranged from 11,000 t to 27,100 t.
- The 2013 year class appears to be much stronger than anything previously witnessed, but there is uncertainty around this estimate given the retrospective, the small number of observations in both the survey and fishery, and the apparent mismatch between survey abundance estimates and the virtual population analysis in recent years.
- The status of the stock cannot be attributed specifically to the cautious or the healthy zone due to an absence of a defined upper stock reference. Under the various harvest scenarios examined, the spawning stock biomass is projected to increase to around 100,000 t, double the previous peak observed from 1985 to 2015.

INTRODUCTION

This assessment uses the Virtual Population Analysis (VPA) model and data framework presented in Wang et al. (2017) with one exception; the most recent weight-at-age was used rather than the 5-year average.

ASSESSMENT

The Fishery

Haddock is harvested as a multi-species fishery. The Total Allowable Catch (TAC) for Haddock was 6,000 tonnes (t) from 2009-2010, and was lowered to 5,100 t for the 2012–2016 fishing years (Table 1, Figure 2). However, catches have been lower than the TAC, averaging approximately 4,500 t since 2006. Fishing year landings for 2014/2015 and 2015/2016 were 2,825 t and 2,926 t, respectively, well below the TAC of 5,100 t.

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

Year	1970-1979 Average	1980-1989 Average	2000-2009 Average	2010-2015 Average	2012	2013	2014	2015
TAC	14,650	21,385	8,030	5,400	5,100	5,100	5,100	5,100
Catch	18,522.4	19,851.3	6,579	3,719	3,323	3,393	2,825	2,926

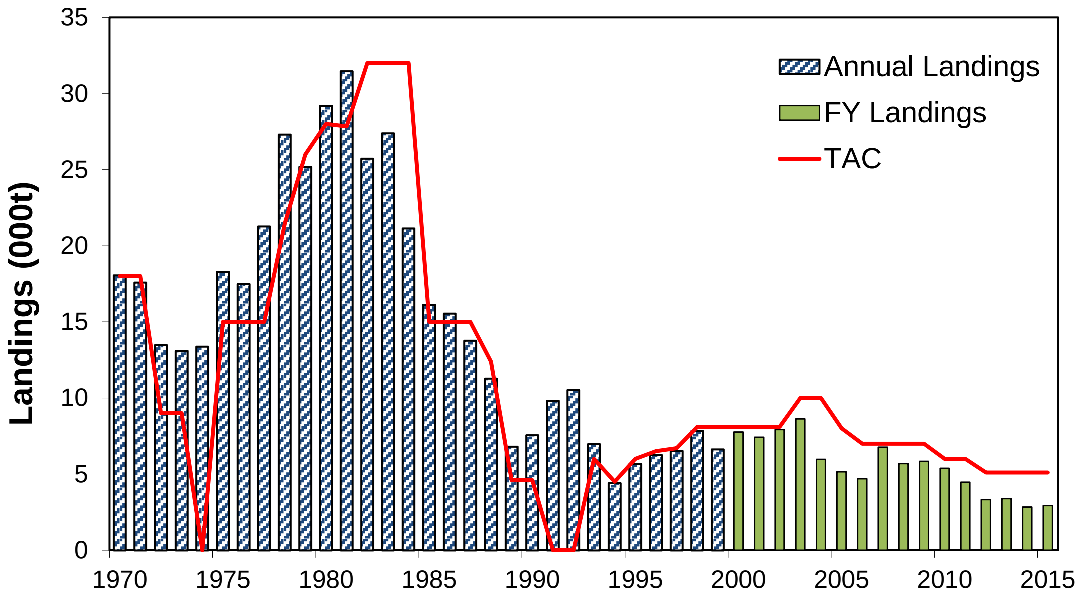

Figure 2. Reported annual landings (t), fishing year landings (FY; April 1st – March 31st) and Total Allowable Catch for the 4X5Y Haddock fishery, 1970-2015.

There have been changes in the fishing distribution and gear type used by the fishery throughout the time series. Over the past 10 years, the mobile gear sector (small otter trawlers) have taken an average of about 80% of the catch and the fixed gear sector (primarily longline) about 20%, with the majority coming from the Scotian Shelf. Fixed gear catches from the both the Bay of Fundy and Scotian Shelf regions remain low, contributing only 4% and <1%, respectively, in 2015. Since 2010, most landings have occurred during the 1st quarter (42%), followed by the 3rd (25%), 4th (19%) and 2nd (14%) quarters.

The 4X5Y Haddock fishery catch-at-age (CAA) data for assessment modelling includes ages 1-14 for 1985-2015 (Figure 3). This series shows the presence of some recent strong year classes; 2003, 2010, and the incoming 2013 year class. In the 2015 fishery, the 2010 year class at Age 5 was predominant and represented 32% of the CAA followed by the 2011 year class at 27%.

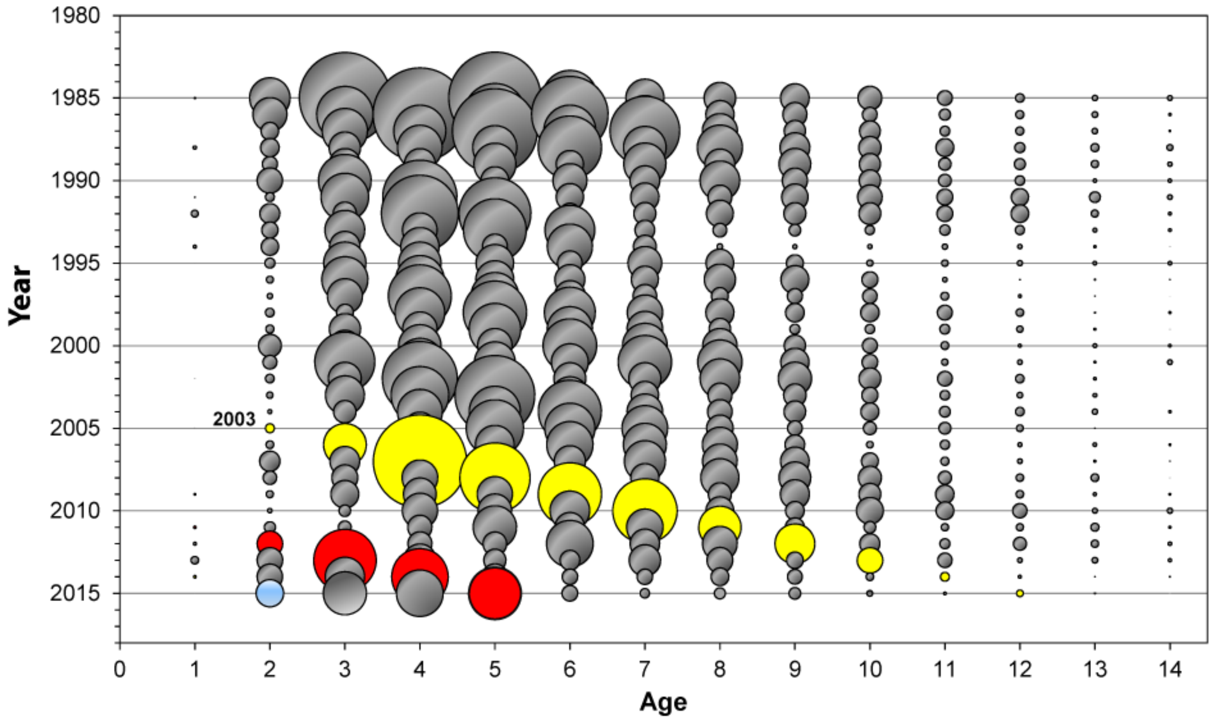

Figure 3. Catch-at-age for 4X5Y Haddock for ages 1-14, 1985-2015. The area of the circle is proportional to the catch at that age and year. Three examples of recent strong cohorts are highlighted: 2003 (yellow), 2010 (red), and 2013 (blue).

Separate age length keys are used for Scotian Shelf and Bay of Fundy samples to generate numbers-at-age, which are then used for weighting the calculations of the overall fishery weight-at-age (WAA). Both series indicate a declining trend in WAA and length-at-age (LAA) from the early 1990s to mid-2000s and then show a modest increase or level off in the recent period, followed by a decrease in 2015. 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). In 2015, the weighted mean WAA for ages 1, 2, 3, 4, 5, 8, and 9 are the lowest in the time series (Figure 4).

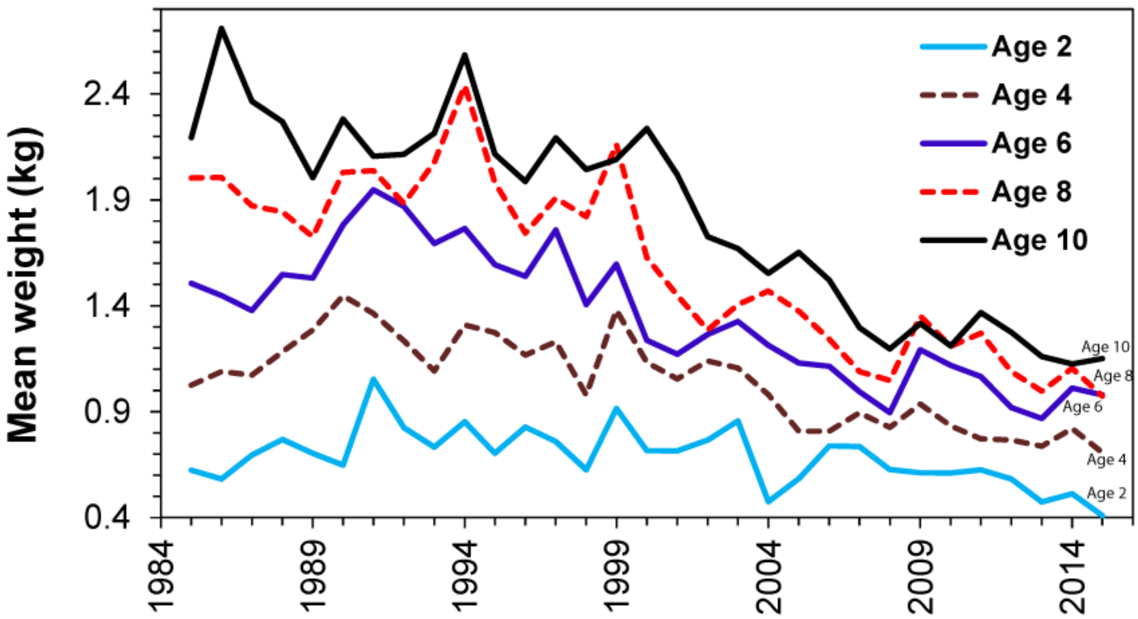

Figure 4. Commercial fishery mean weighted weight-at-age (kg) for 4X5Y Haddock ages 2, 4, 6, 8, and 10 for 1985-2015.

DFO Summer Research Vessel (RV) Survey

The DFO Summer RV survey biomass index in 2015 and 2016 was 69,800 t and 62,700 t, respectively (Figure 5). The 2015 and 2016 index was above the short (5 year: 48,193t), and long-term (since 1970: 55,470 t) averages.

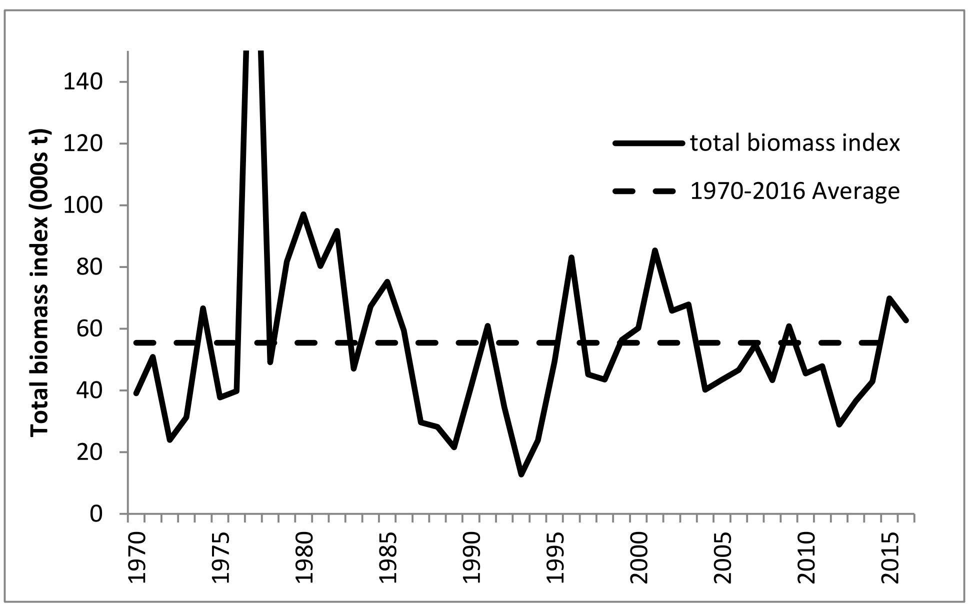

Figure 5. Trends in the total biomass index (000 t), including all ages, from the DFO Summer Research Vessel survey compared to the long-term average, 1970-2016. A conversion factor of 1.2 has been applied to total biomass estimated for 1970-1981 to account for vessel and gear changes.

Recruitment (Age 1) is variable throughout the time series. All the year classes at Age 1 since 2010 are above the geometric mean for 1985 to 2015 (9,381,000 in numbers) with the 2013 year class being the highest on record. The estimate of the 2013 year class at Age 1 from the survey was 168,470,000 in numbers. In 2015, the 2013 year class (Age 2) made up 54% of the survey CAA, the 2014 year class (Age 1) made up 17%, followed by the 2012 year class (Age 3), which made up 13% (Figure 6).

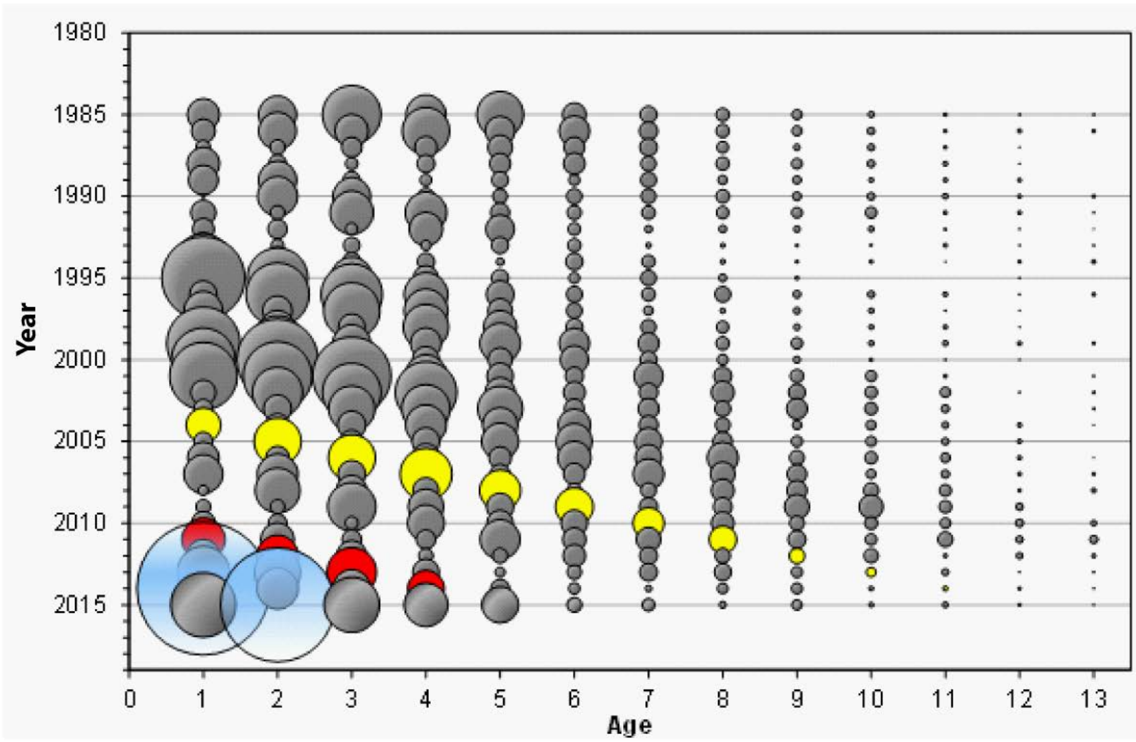

Figure 6. Stratified total number per tow at age (1-13) for 4X5Y Haddock from the DFO Summer Research Vessel survey, strata 470-495, 1985-2015. The 2003 year class is shown in yellow and the 2010 in red. The blue semi-transparent circle represents the 2013 year class at Age 1 in 2014 and Age 2 in 2015. The area of the circle is proportional to the catch at that age and year.

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 occurring in 2015. 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 are derived primarily from fish caught on the Scotian Shelf (Figure 4).

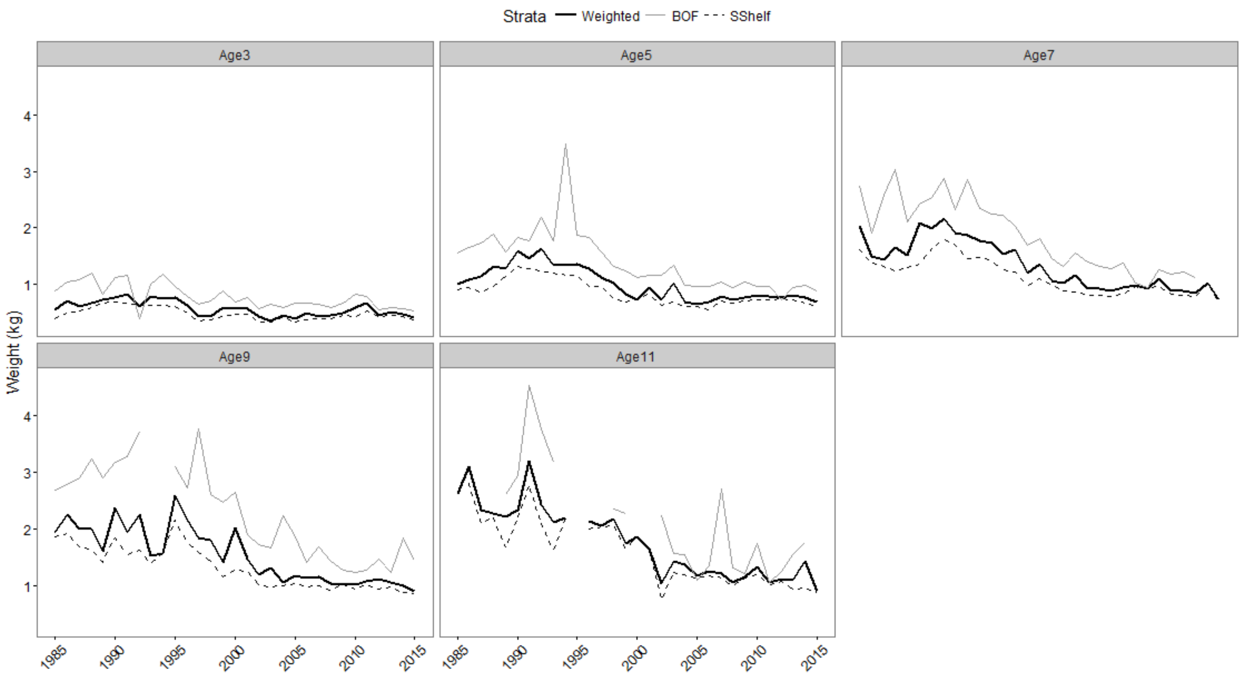

Figure 7. DFO Summer Research Vessel survey mean weight-at-age (kg) for the Scotian Shelf and Bay of Fundy; as well as the mean weighted weight-at-age (combined) for 4X5Y Haddock ages 3, 5, 7, 9, and 11 for 1985-2015. Mean weighted weights-at-age were calculated separately for Bay of Fundy and western Scotian Shelf strata and then combined after weighting using total abundance-at-age from each area.

Estimation of Stock Parameters and Comparison to Reference Points

The adaptive framework, ADAPT (Gavaris 1988), was used for calibrating the VPA with the trends in abundance from the DFO Summer Research Vessel survey. The retrospective analysis showed some minor retrospective patterns. For the most recent years, the model tended to overestimate the biomass and underestimate fishing mortality (F) (Figure 8).

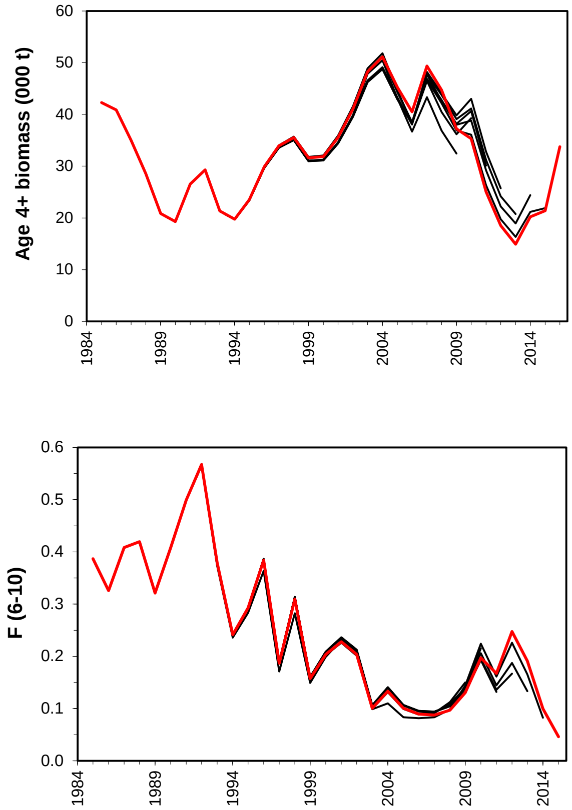

Figure 8. Retrospective analysis for the ADAPT virtual population analysis model formulation of natural mortality fixed at 0.2, except 0.3, 0.6, and 0.9, for ages 10-11+ for the three time blocks (2000-2004, 2005-2009, and 2010-2015; respectively) for 4X5Y Haddock.

Spawning Stock Biomass (SSB, Age 4+) decreased from 42,000 t in 1985 to 20,000 t in 1990 and started to increase in 1996 due to the contribution of the stronger year classes. A period of lower recruitment followed resulting in an SSB of 15,000 t in 2013, but the SSB started to increase due to the strong incoming year classes. The estimated SSB at the beginning of 2016 was 33,770 t, above the established biomass limit reference point (B_{lim}) of 19,700 t and the long-term average of 32,258 t (Figure 9). The stock is not in the critical zone, but as there is no identified upper stock reference, it is not possible to distinguish whether the stock is in the cautious or healthy zones.

Preliminary estimates for the 2013 year class at Age 1 remain extraordinarily high for this stock at 264 million recruits. The estimate for the 2014 year class (Age 1 in 2015) is 74 million, above the long-term geometric mean for Age 1 of 20 million recruits (Figure 9).

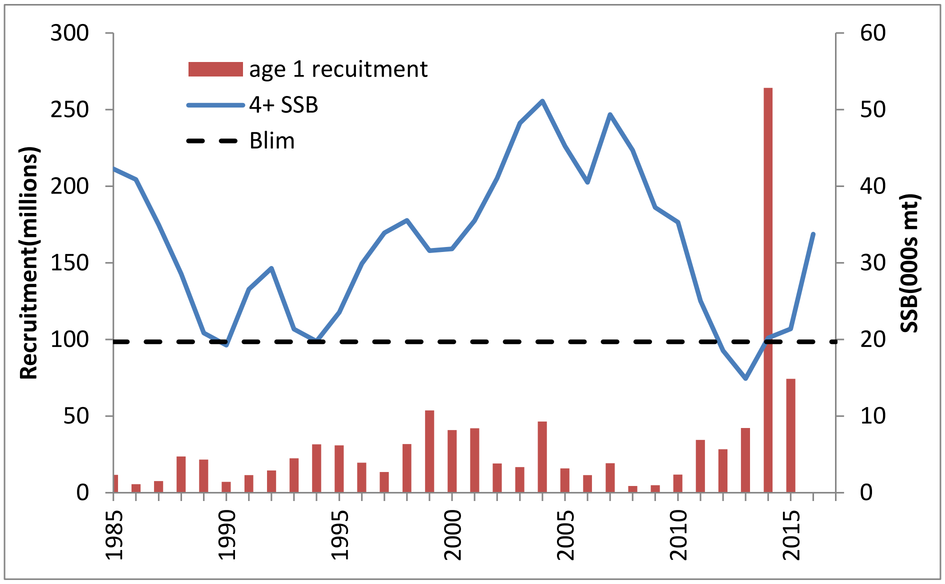

Figure 9. The model estimated Age 4+ biomass and Age 1 recruits, 1985-2016, for 4X5Y Haddock. The established B_{lim} (dashed reference line) for the Spawning Stock Biomass (SSB) is 19,700 t.

Despite the uncertainties in estimating fishing mortality at maximum sustainable yield (F_{msy}), it was agreed at the April 2016 framework meeting that a fishing mortality (ages 6 to 10) of 0.25 would be the fishing mortality removal reference (F_{ref}) when the stock is in the healthy zone, and a F_{ref} (ages 6 to 10) of 0.15 would be an appropriate target when the stock is in the cautious zone (Wang et al. 2017). The estimated F for ages 6 to 10 in 2015 was 0.05 for 4X5Y Haddock, therefore below the F_{ref} in both the healthy zone (F=0.25) and cautious zone (F=0.15) (Figure 10).

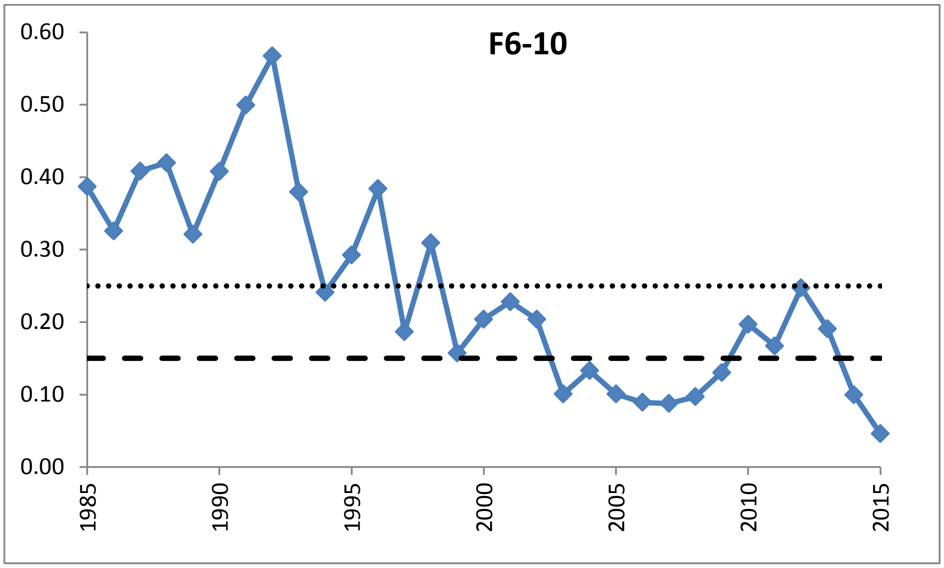

Figure 10. Estimated fishing mortality (F) on ages 6 to 10. The dotted line indicates the F_{ref} of 0.25 when the stock is in the healthy zone and the dashed line indicates the F_{ref} when the stock is in the cautious zone.

Projection and Risk Analysis

Since it cannot be distinguished whether the stock is in the cautious or healthy zone, projections were conducted using both scenarios with F=0.15 and F=0.25. A deterministic projection was conducted with a catch of 5,100 t in 2016 under fishing at F_{ref} =0.25 in the healthy zone scenario for 2017 and 2018, and a second deterministic projection was conducted under fishing at F=0.15 in the cautious zone scenario for 2017 and 2018 (Table 2, Figure 11). In both scenarios, SSB estimates for 2017-2019 remained above the time series average and B_{lim}.

Due to the uncertainties around the estimate of the 2013 year class and the significant impact of that estimate on projections, sensitivity deterministic projections were conducted assuming the 2013 year class recruitment was equal to the largest recruitment in the time series prior to 2013 (54 million). Given that the 2013 year class appears to be much stronger than anything previously witnessed and that 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 is a conservative approach to assessing this uncertainty.

Table 2. The model estimated (2016, using the weight-at-age in 2015) and projected (2017-2019) Age 4+ biomass under different fishing mortality scenarios, for 4X5Y Haddock. The 2013 year class (yc) columns (assigned to 53,755 for Age 1 in 2014) were completed as a sensitivity analysis.

Year	F=0.15	F=0.25	2013 yc F=0.15	2013 yc F=0.25
2016	29,115	29,115	27,807	27,807
2017	91,998	91,998	35,829	35,829
2018	103,128	97,208	48,213	45,516
2019	92,645	81,381	45,791	40,660

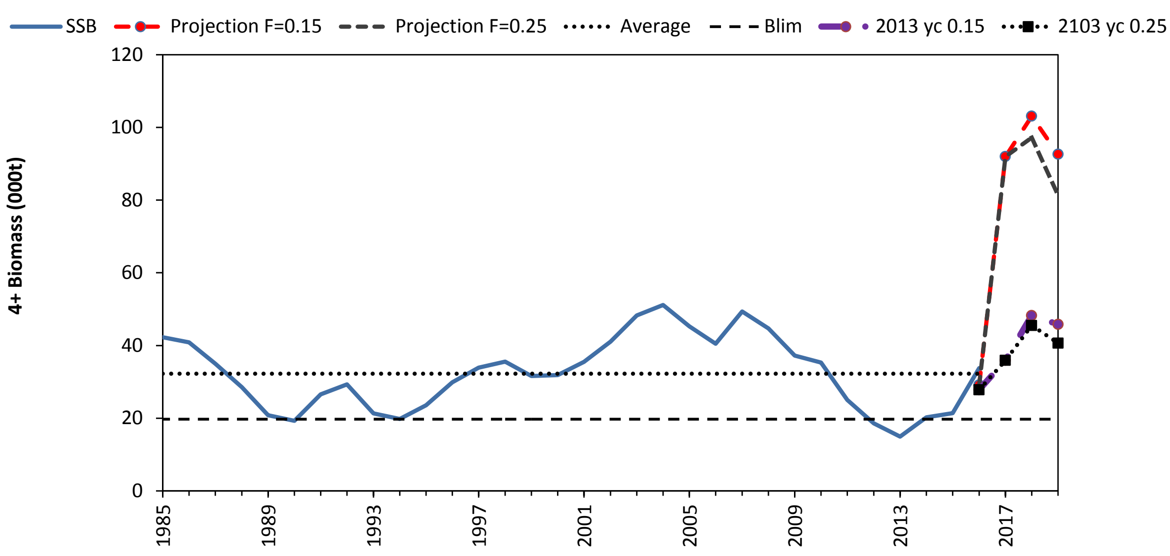

Figure 11. The model estimated (1985-2016) and projected (2017-2019) Age 4+ biomass for 4X5Y Haddock.

A stochastic projection was conducted with a catch of 5,100 t in 2016 under fishing at F_{ref}=0.25 in the healthy zone scenario in 2017 and 2018, and a second stochastic projection was conducted under fishing at F=0.15 in the cautious zone scenario in 2017 and 2018. Catch estimates for 2017-2019 ranged from 11,000 t to 27,100 t (Table 3). Risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. Table 3 provides the risk of F in 2017 and 2018 exceeding F_{ref}=0.25 and F=0.15 under a range of catch values.

Table 3. The levels of catch (t) projected in 2016 for which there is a 25%, 50%, and 75% risk of the fishing mortality in 2017 and 2018 exceeding F=0.25 and F=0.15.

Probability of Exceeding	Catch Year	25%	50%	75%
F=0.15	2017	11,000	12,980	15,240
F=0.25	2017	17,780	21,040	24,660
F=0.15 if F=0.15 in 2017	2018	12,600	15,100	17,600
F=0.25 if F=0.25 in 2017	2018	19,100	23,100	27,100

The deterministic projections for the sensitivity analyses conducted with a value of 54 million for the 2013 year class produced catch advice for ages 1+ of 9,666 t in 2017 and 10,379 t in 2018 with F=0.25, and for F=0.15 produced catch advice of 5,989 t in 2017 and 6,831 t in 2018.

Sources of Uncertainty

Differences in the growth between the Bay of Fundy and the Scotian Shelf regions have been documented for this resource, and a recent analysis confirmed it is still appropriate to use separate age length keys (Stone and Hansen 2015). However, the defined survey strata used to evaluate growth differences between the Bay of Fundy and the Scotian Shelf are different from the statistical areas used to match length-weight and age length key relationships with catch data. The impact of this mismatch should be evaluated. Given that the location of future harvesting cannot be predicted, this growth mismatch could have effects on the accuracy of projections.

The high M used in the assessment model could be aliasing fish moving to adjacent areas or deeper waters where the fishery or survey cannot catch them. Noteworthy is that the adjacent Haddock stock on Eastern Georges Bank also shows high total mortality (Z) on older (Age 8+) fish (Stone and Hansen 2015). Research on a possible mechanism for high M on older ages would aid in the understanding of the population dynamics of 4X5Y Haddock.

The 2013 year class appears to be much stronger than anything previously witnessed, but there is uncertainty around this estimate given the retrospective, the small number of observations in both the survey and fishery, and the apparent mismatch between survey abundance estimates and the VPA in recent years. The Coefficient of Variation (CV) is high for the VPA estimate of the 2013 year class (0.4 at Age 3 in 2016).

CONCLUSIONS

The 4X5Y Haddock stock has experienced strong recruitments since 2010. Although the status of the stock cannot be attributed specifically to the cautious or the healthy zone due to an absence of a defined upper stock reference, the SSB is expected to increase. Based on the VPA model, the estimated spawning stock biomass at the beginning of 2016 was 33,770 t, above the established B_{lim} and the long-term average. Under the various harvest scenarios examined, the SSB is projected to increase to around 100,000 t, double the previous peak observed from 1985 to 2015. The model estimate for the 2013 year class is the highest in the time series and the model estimate for the 2014 year class is the second highest; their future performance will impact stock dynamics.

SOURCES OF INFORMATION

This Science Advisory Report is from the November 28-29, 2016 regional peer review on the Stock Assessment with Catch Projections for 4X5Y Haddock. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

DFO. 2012. Assessment of the Status of 4X5Y Haddock in 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/023.

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