Fisheries and Oceans Canada | Pêches et Océans Canada
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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/056

EASTERN GEORGES BANK HADDOCK (*MELANOGRAMMUS AEGLEFINUS*) ASSESSMENT TO 2023

*Image: Haddock (*Melanogrammus aeglefinus*)*
Credit: Fisheries and Oceans Canada

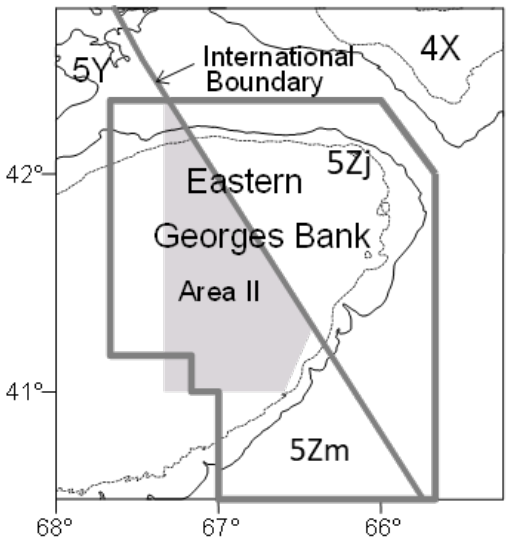

Figure 1. Map of management area for Haddock on eastern Georges Bank (unit areas 5Zj and 5Zm within Northwest Atlantic Fisheries Organization Subdivision 5Ze)

Context:

Fisheries and Oceans Canada (DFO) and the United States of America (USA) National Marine Fisheries Service (NMFS) have previously jointly assessed the Haddock stock on the eastern portion of Georges Bank (EGB; unit areas 5Zj and 5Zm) under the Transboundary Resources Assessment Committee (TRAC) peer review process since 1998. Given that each country has developed their own assessment models, catch advice will be provided through their respective domestic peer review processes in 2024.

The EGB Haddock model was developed as part of the Georges Bank and eastern Georges Bank Haddock Research Track Assessment Peer Review meeting in March 2022 and has been subsequently used to support the provision of advice to the Transboundary Management Guidance Committee (TMGC) in 2022 (TRAC 2022) and 2023 (TRAC 2023). Catch advice for the 2025 fishery will be provided using this assessment model and stock status of Haddock will be evaluated.

This Science Advisory Report is from the July 8–12, 2024, regional peer review on the Framework Review for Atlantic Cod in NAFO Division 5Z: Part 2 - Modelling Review and Interim Advice for Eastern Georges Bank Cod and Stock Assessment of Haddock on Eastern Georges Bank. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The 2023 spawning stock biomass of EGB Haddock is above the USR, placing the stock in the Healthy Zone, based on domestically defined reference points.
- Combined Canada and United States of America (USA) eastern Georges Bank (EGB) Haddock catches in 2023 were 2,840 mt and represented 74% of the combined 3,840 mt quota.
- Model-estimated spawning stock biomass (SSB) for EGB Haddock has declined from a peak of 83,000 mt in 2016 to 31,733 mt in 2023, which is above the median SSB of 24,939 mt for the time series (1969–2023).
- The model estimates of the 2020 and 2021 age-1 fish are 110 million and 86 million, and are above the long-term average (9 million; 1968–2022 year-classes).
- Improvements in Haddock length- and weight-at-age, and fish condition have been observed in the fishery and surveys.
- Fishing mortality (F) was estimated to be 0.60 and 0.11 for 2022 and 2023, respectively.
- Sensitivity analyses suggest there is no evidence to suggest M has decreased in the recent time period.
- Recommended catch advice was 6,160–9,130 mt based on the 25%–75% risk of exceeding the fishing mortality reference.

BACKGROUND

Haddock *(Melanogrammus aeglefinus)* on eastern Georges Bank (management unit areas 5Zj and 5Zm; EGB) is a transboundary stock that was previously jointly assessed by Fisheries and Oceans Canada (DFO) and the National Marine Fisheries Service (NMFS) under the Transboundary Resources Assessment Committee (TRAC) peer review process. In 2024, a Canada-United States working group was formed to develop guidance to improve the TRAC process. The recommendation of the joint working group proposed that the assessment of the EGB Haddock stock be conducted separately by both countries using the modeling approaches that were peer reviewed at the 2022 Georges Bank and eastern Georges Bank Haddock Research Track Assessment Peer Review Meeting (Kronlund et al. 2023). The proposal was supported by the Transboundary Management Guidance Committee (TMGC) and both countries agreed to provide advice from their respective domestic assessments to support the management decision process.

The previous EGB Haddock assessment developed in 1998 was based on a Virtual Population Analysis (VPA) model and was rejected at the 2019 TRAC meeting. This was due in large part to a strong retrospective pattern and poor model fit (TRAC 2019). A new statistical catch-at-age model using a state-space framework (Woods Hole Assessment Model [WHAM], Stock and Miller 2021) was developed and reviewed at the 2022 GB and EGB Haddock Research Track peer review meeting. This model supports the working group analysis that suggested that natural mortality (M) was increasing in the EGB management unit area since 2010. The review panel recommended the EGB Haddock model be used for providing catch advice over the short term (Kronlund et al. 2023).

In this assessment, the EGB Haddock model is updated with the 2023 Canadian and US fisheries data, as well as, the 2023 DFO Winter Ecosystem Research Vessel (RV) survey and

the 2023 NMFS fall survey. Biological indicators from the 2024 DFO Winter Ecosystem RV survey are also incorporated to inform on the state of Haddock.

ASSESSMENT

Fishery

Combined Canada and USA catches for EGB Haddock are presented in Figure 2. The total catch decreased to 5,485 mt and 2,840 mt in 2022 and 2023, respectively, corresponding to a reduction in quota from 14,100 mt to 3,840 mt. In 2023, the total catch represented 74% of the combined quota (Table 1).

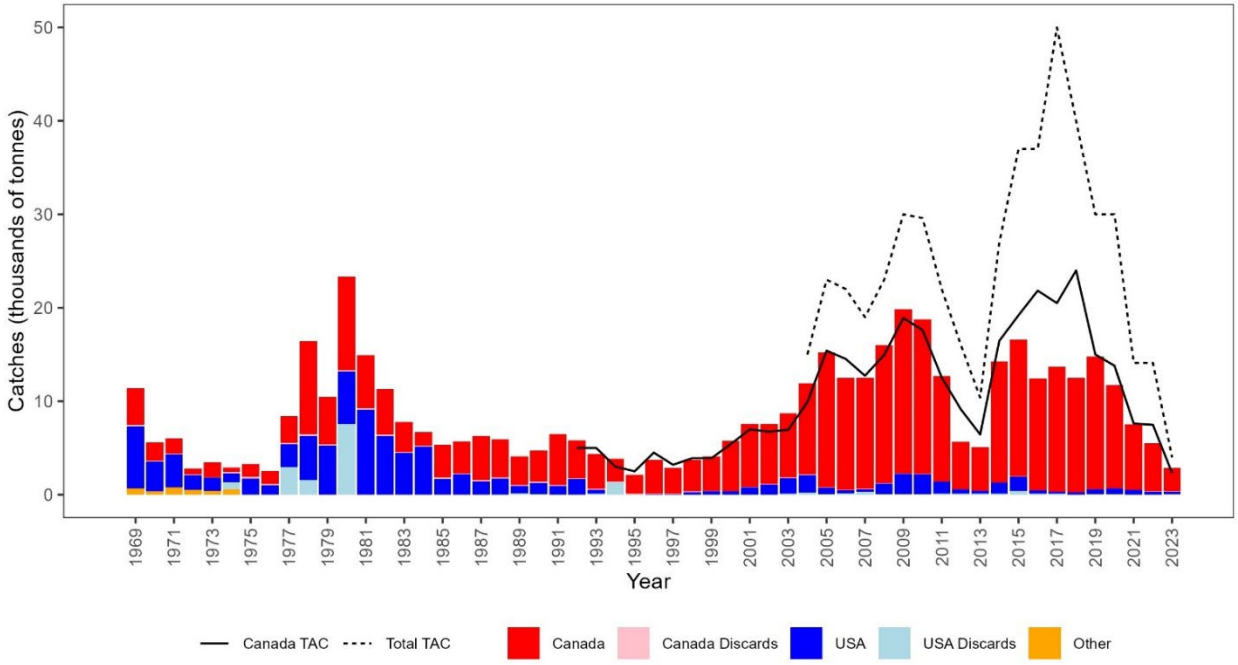

Figure 2. Annual catches of eastern Georges Bank Haddock from 1969–2023.

The Canadian catch decreased from 5,150 mt in 2022 to 2,507 mt in 2023. Discards in the groundfish fishery are considered to be negligible. Discards of Haddock by the Canadian Scallop fishery were 8 mt in 2023, and have ranged between 4 mt and 186 mt over the time series. Canada caught 108% of its 2,320 mt allocation.

USA catches were 334 mt in 2022 and 332 mt in 2023. Landings in 2023 were 299 mt and discards were estimated to be 33 mt. The USA caught 13% of its 1,520 mt allocation.

The 2020 year-class at age 3 was a major contributor to the 2023 Canadian fishery catch (landings and discards, 60% of the fish by number), followed by the 2021 year-class at age 2 (32% by number, Figure 3). In 2023, fish aged 9+ accounted for only 1% of the fish caught in the Canadian fishery. The size compositions of the 2023 Canadian fishery catches were derived from port samples and at-sea samples for the principal gear types. Catches by otter trawl gear in 2023 peaked at 44.5 cm, an increase in size from the 2022 fishing season. Catches by long line gear peaked at 48.5 cm, consistent with the 2022 season, and catches of discards (scallop dredge) peaked at 30.5 cm (Figure 4).

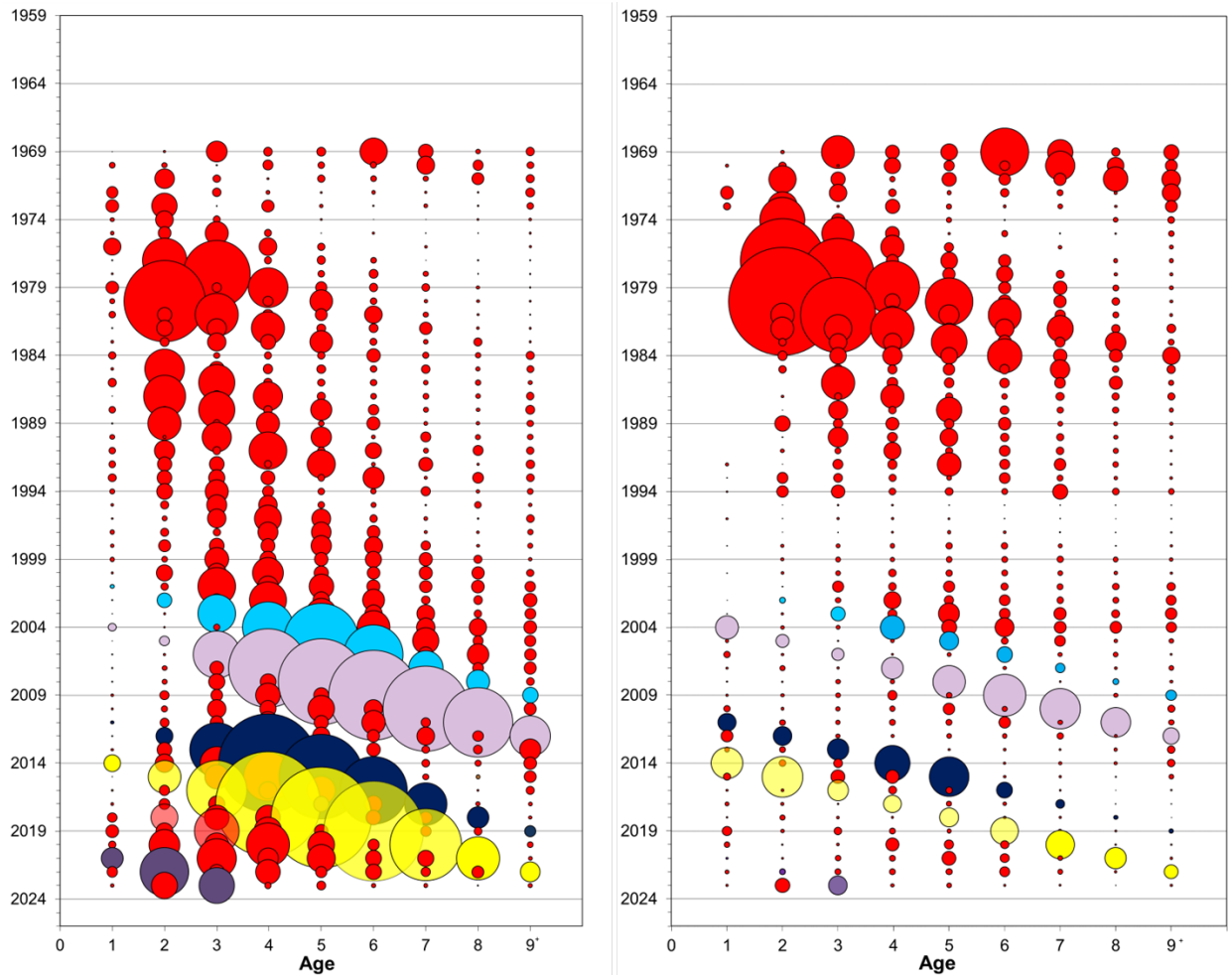

Figure 3. Commercial catch at age (numbers) of eastern Georges Bank Haddock from 1969–2023 for Canada (left) and USA (right). The 2000, 2003, 2010, 2013, and 2020 year-classes are indicated in light blue, light purple, dark blue, yellow, and dark purple respectively. The bubble area is proportional to catch magnitude. This includes both landings and discards.

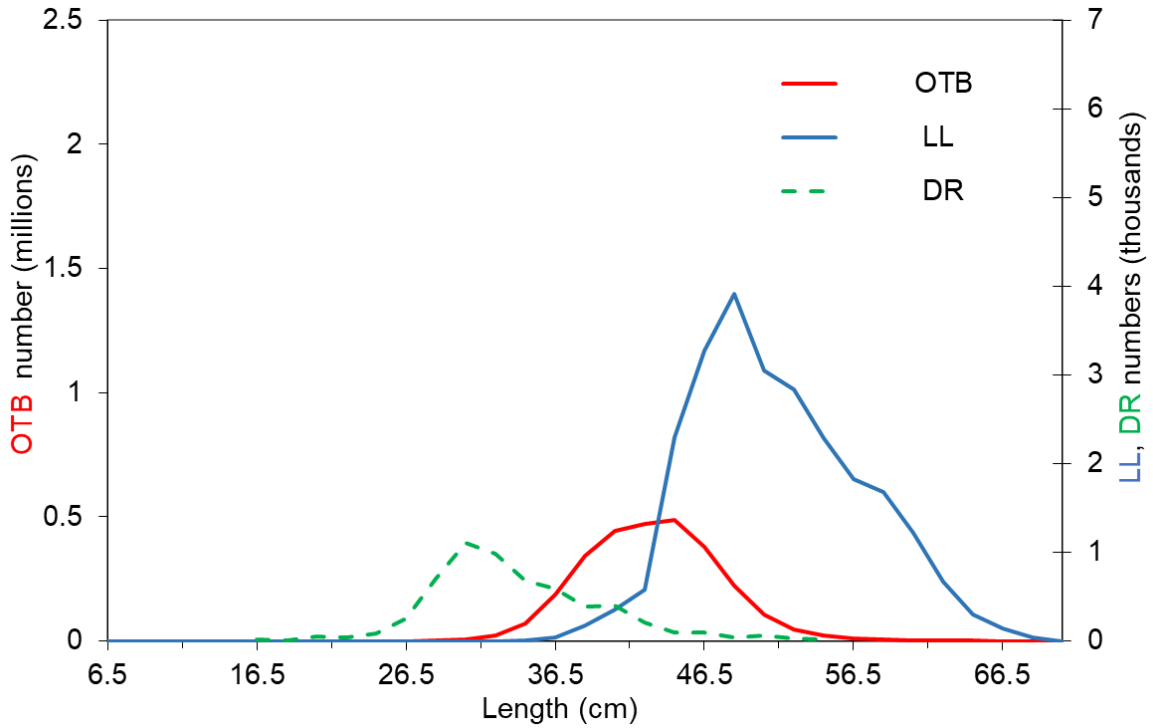

Figure 4. Canadian eastern Georges Bank Haddock fishery catch-at-size in numbers by gear for 2023. OTB=otter trawl bottom, LL=longline, DR=scallop dredge.

The 2023 USA fishery catch-at-age (CAA) and catch-at-length (CAL) were not provided to DFO. The USA CAA for 2023 was estimated using the Canadian fishery proportions-at-age for 2023. Historically, the USA fishery weights-at-age (WAA) differ from the Canadian fishery so the average ratio of USA and Canadian WAA from the last two years was applied to the 2023 Canadian WAA to obtain an estimate of the 2023 USA fishery WAA.

Table 1. Catches (mt) of eastern Georges Bank Haddock. A dash (-) indicates not applicable.

		2020	2021	2022	2023	2024	Avg[1]	Min[1]	Max[1]
Canada[2]	**Quota**	13,800	7,614	7,473	2,320[6]	6,900	-	-	-
	Landed	11,045	6,997	5,143	2,499	-	6,502	462	17,595
	Discard	7	5	7	8	-	84	4	186
USA[2]	**Quota**[3]	16,200	6,486	6,627	1,520[7]	3,100	-	-	-
	Catch[3]	563	417	260	201	-	-	-	-
	Landed	633	518	327	299	-	1,742	15	9,081
	Discard	50	6	8	33	-	428	0	7,561
Total[2]	**Quota[4]**	30,000	14,100	14,100	3,840	10,000	-	-	-
	Catch[4]	11,615	7,418	5,477	2,708	-	-	-	-
	Catch[5]	11,735	7,526	5,485	2,840	-	8,693	2,150	23,344

[1] 1969–2023
[2] unless otherwise noted, all values are reported for the calendar year
[3] for fishing year from May 1st–April 30th
[4] for Canadian calendar year and USA fishing year May 1st–April 30th
[5] sum of Canadian landed, Canadian discards, and USA catch (including discards)
[6] Canadian adopted quota for 2023
[7] USA adopted quota for 2023

Surveys

Indicators from the DFO Winter RV survey, NMFS Spring and NMFS Fall surveys are assessed annually for biomass, age composition, size-at-age, and survey catch distribution. The 2022 DFO Winter RV survey used a new vessel and gear and conversion factors to calibrate catches are in development. The 2023 NMFS Spring survey was conducted using an altered sampling protocol. These surveys were excluded from the indicators. The swept-area biomass indices for the NMFS Fall and DFO Winter RV surveys are consistent and track each other well (Figure 5). There has been a sharp increase and then a decline in haddock catches in the last decade for both the DFO Winter RV and NMFS Fall surveys. Despite some year effects, surveys show a biomass recovery from the mid-1990s followed by a steady increase due to better recruitment since the 2000s. The survey swept-area biomass decreased from 20,770 mt in 2022 to 9,598 mt in 2023 for the NMFS Fall survey, and increased from 27,730 mt in 2021 to 56,922 mt in 2023 for the DFO Winter RV survey. The average swept-area biomass was 33,260 mt for 2023 for both the DFO Winter RV and NMFS Fall surveys, an increase from the 2022 average of 16,906 mt. In 2024, the DFO Winter RV survey swept-area biomass estimate declined to 18,198 mt.

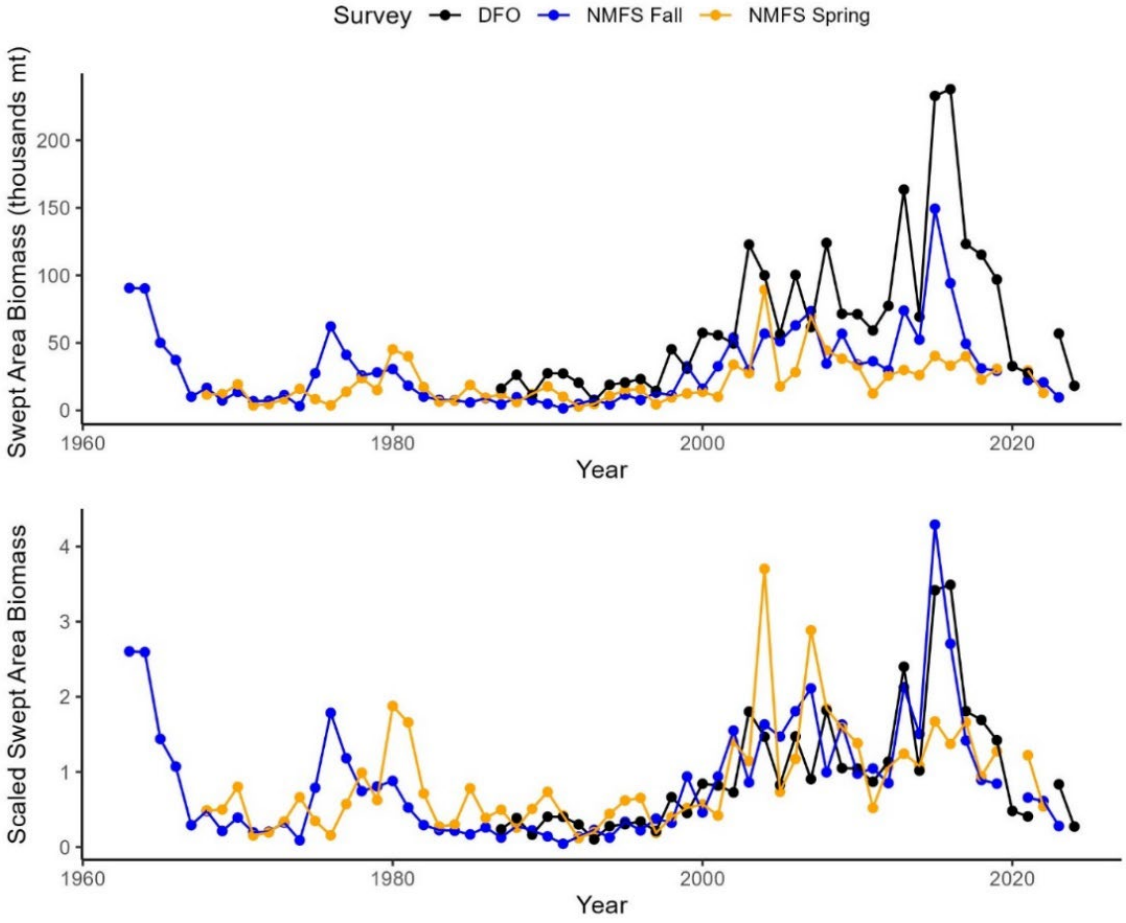

Figure 5. Raw (top panel) and standardized (bottom panel) survey swept-area biomass from National Marine Fisheries Service (NMFS) Fall (1963–2023), NMFS Spring (1968–2022), and Fisheries and Oceans Canada (DFO; 1987–2024) Winter Ecosystem Research Vessel surveys for eastern Georges Bank. Biomass conversion coefficients have been applied to the NMFS surveys to adjust for changes in door type (BMV vs Polyvalent; 1968–1984), vessel (Delaware II vs Albatross IV; 1968–2008), and vessel/net (Albatross IV vs Henry B. Bigelow; Yankee 36 vs 4 seam-3 bridle; 2009–2023). The NMFS spring and fall survey in 2020 were cancelled due to Covid-19 restrictions and the 2022 DFO Winter RV survey was excluded until calibration factors for the new vessel are available. The 2023 NMFS Spring survey was not included because of a change of survey protocol. The model only uses survey data up to 2023 and excludes the 2024 survey.

The 2020 and 2021 year-classes were a major component of the latest 2024 DFO Winter RV survey catches (20% and 58% respectively), followed by the 2022 year-class at age 2 (13%, Figure 6). For the 2023 NMFS Fall survey, the 2021 and 2022 year-classes contributed 56% and 32%, respectively, to the catch. Fish aged 9+ accounted for only 1% of the fish caught in the most recent surveys (Figure 6). The length frequency distribution of the survey catch for the 2023 NMFS Fall survey and the 2024 DFO Winter RV survey catch peaked at 38 cm (Figure 7). The spatial distribution patterns observed during these surveys are generally similar to the average patterns over the previous ten years. For the 2023 NMFS Fall survey, most Haddock aged 1+ were caught in 5Z1, while Haddock of all ages caught on the 2024 DFO Winter RV

survey were dispersed across the bank on the eastern side of the Hague line (Figure 8, Figure 9).

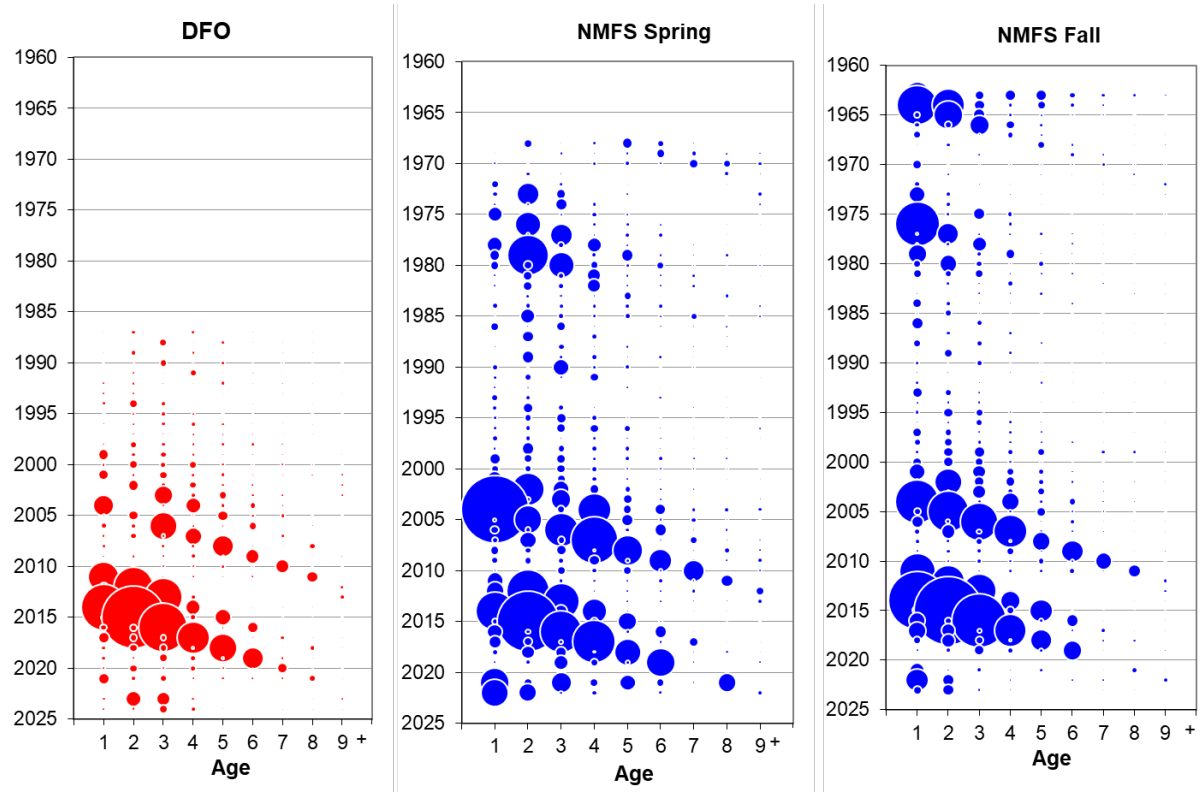

Figure 6. Age-specific mean abundance indices per tow of eastern Georges Bank Haddock for the Fisheries and Oceans Canada (DFO) Winter Ecosystem Research Vessel survey for 1986 to 2024, the National Marine Fisheries Service (NMFS) Spring survey for 1968 to 2022, and the NMFS Fall survey for 1963 to 2023. Bubble area is proportional to magnitude. Conversion factors to adjust for changes in door type and survey vessel were applied to the NMFS surveys. The NMFS Spring and Fall surveys in 2020 were cancelled due to Covid-19 restrictions, the 2022 DFO Winter RV survey was excluded until calibration factors for the new vessel are available, and the 2023 NMFS Spring survey was not included because of a change of survey protocol.

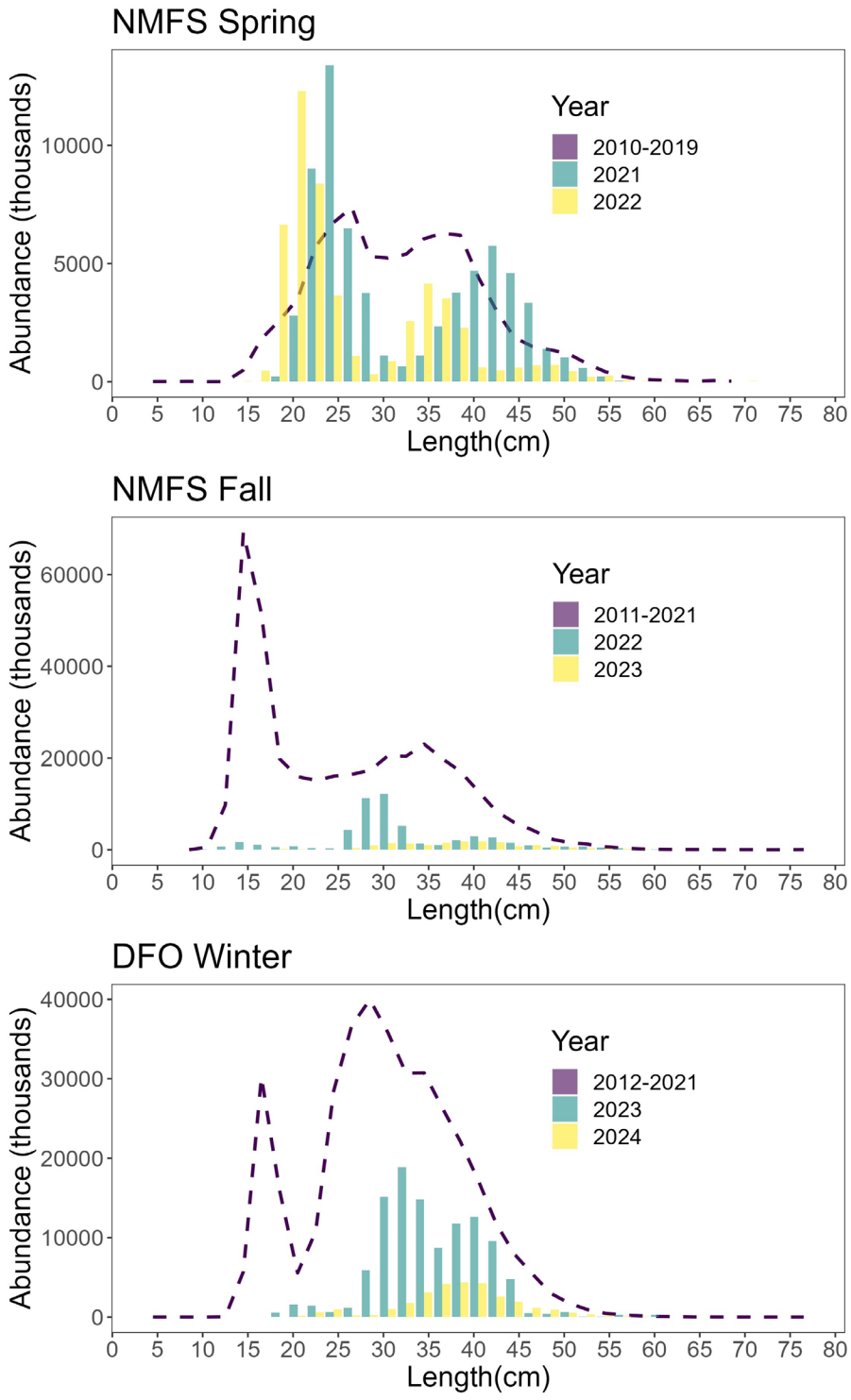

Figure 7. Length-frequency distribution of the National Marine Fisheries Service (NMFS) Spring (2021 and 2022) and NMFS Fall (2022 and 2023) surveys and the Fisheries and Oceans Canada (DFO) Winter Ecosystem Research Vessel survey (2023 and 2024). Bars represent the most recent two years and the dashed line shows the average abundance from the previous ten years with data.

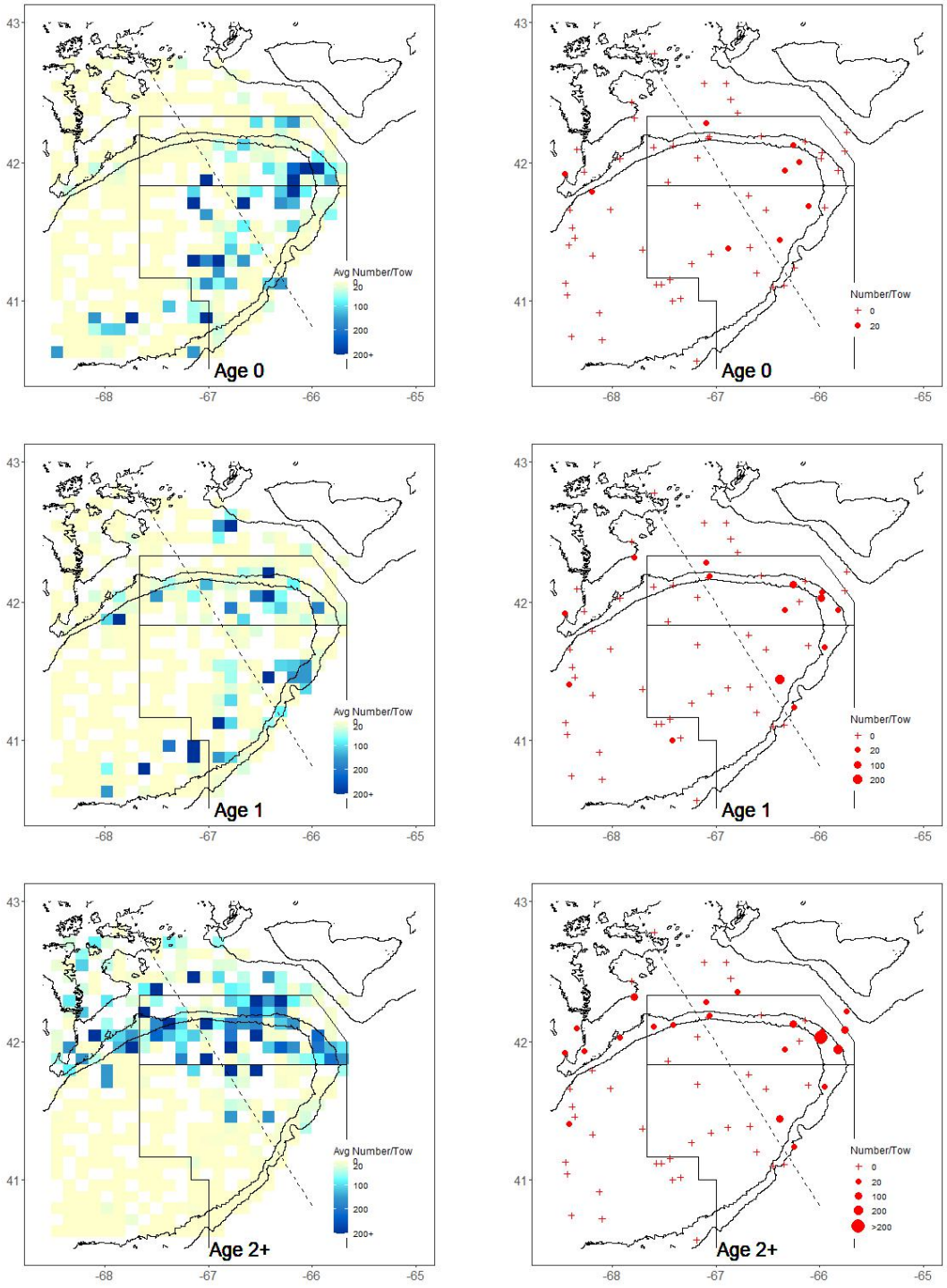

Figure 8. Distribution of eastern Georges Bank Haddock abundance (number/tow) as observed from the National Marine Fisheries Service Fall survey for ages 0, 1, and 2+. The squares (left panels) are shaded relative to the average survey catch for 2012 to 2022 (No survey was conducted in 2020). The expanding symbols (right panels) represent the 2023 survey catches. Length-based conversion coefficients have been applied since the 2009 survey to make them comparable to surveys undertaken by the Albatross IV. The dashed line marks the international boundary, Hague Line.

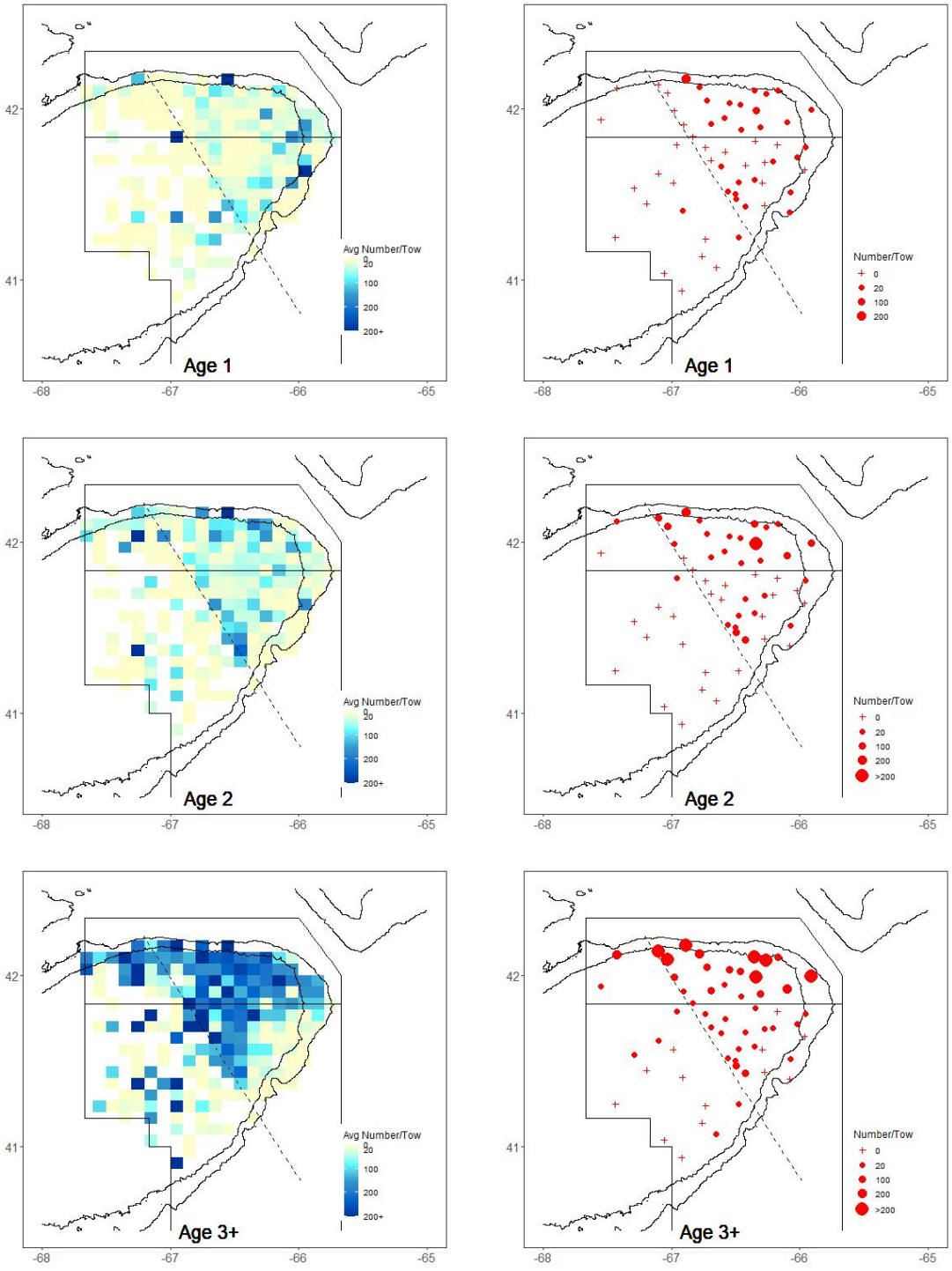

Figure 9. Distribution of eastern Georges Bank Haddock abundance (number/tow) as observed from the Fisheries and Oceans Canada Winter Ecosystem Research Vessel survey. The squares (left panel) are shaded relative to the average survey catch for 2013 to 2023. The expanding symbols (right panel) represent the 2024 survey catches. Conversion factors were not available for the 2022 spring survey to include in the assessment. The dashed line marks the international boundary, Hague Line.

Harvest Strategy

The Transboundary Management Guidance Committee (TMGC) adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality reference (F_{ref}). The results of the EGB Haddock model suggested that the F_{ref} = 0.26, derived from the 2002 VPA model output, and previously adopted by TMGC (TMGC Meeting Summary, Oct. 2, 2003), was no longer appropriate. The new F_{ref} = 0.367 was calculated using $F_{40\%SPR}$ (fishing mortality rate at a spawning potential ratio of 40%) as a proxy for F_{MSY} (fishing mortality rate at maximum sustainable yield, Wang et al. In Prep[1]).

State of Resource

The state of the resource is based on the EGB Haddock model (Table A1, Table A2). In this model, M is fixed at 0.2 from 1969 to 2009 and M is estimated in the model as a single value for the period from 2010 to 2023. Alternative model configurations were examined, but the base model fit continued to have the best diagnostics based on Akaike information criteria (AICs) and retrospective patterns (Mohn's rho; Figure 10, Figure 11).

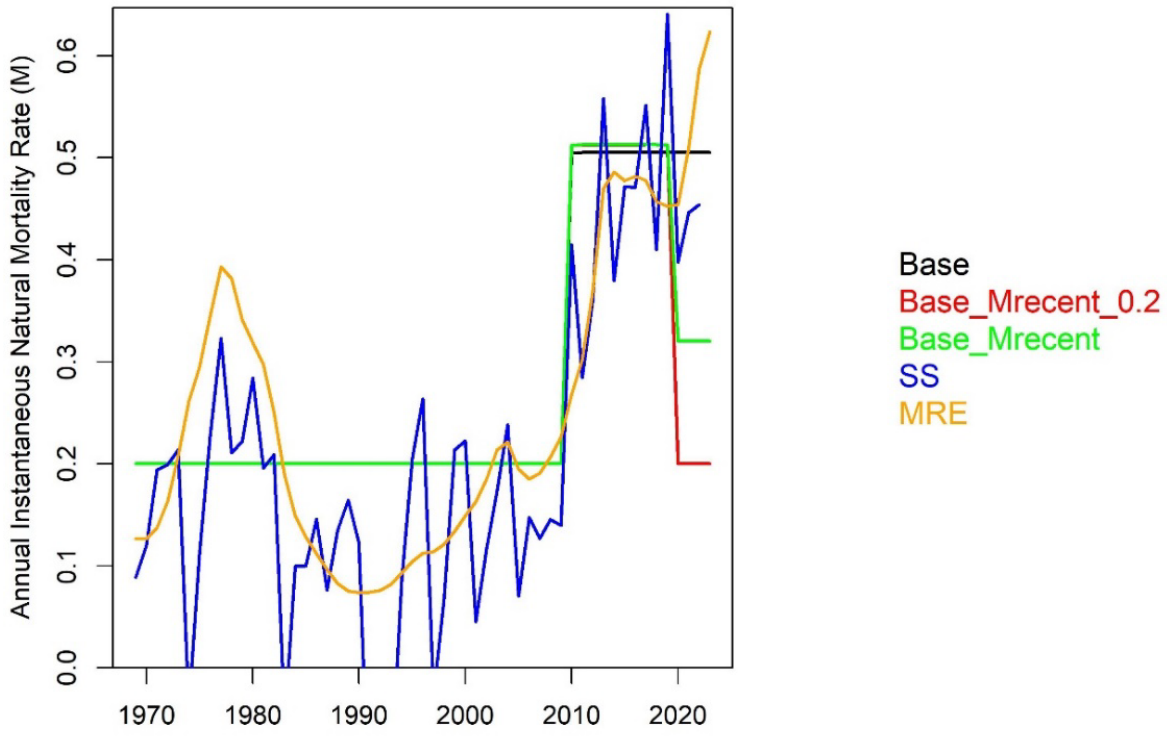

Figure 10. Estimates for natural mortality (M) from different M configuration models and two sensitivity analyses. Base $M_{recent\_0.2}$ assumes M goes back to 0.2 from 2020–present, Base M_{recent} assumes M goes to an intermediate value between 0.2–0.505 from 2020–present) and two sensitivity analyses (SS= Georges Bank model used by USA, MRE= random effects on M).

[1] Wang Y., C. Regnier-McKellar and K. Kraska. In Prep. Assessment of Haddock on Eastern Georges Bank for 2022. TRAC Reference Document.

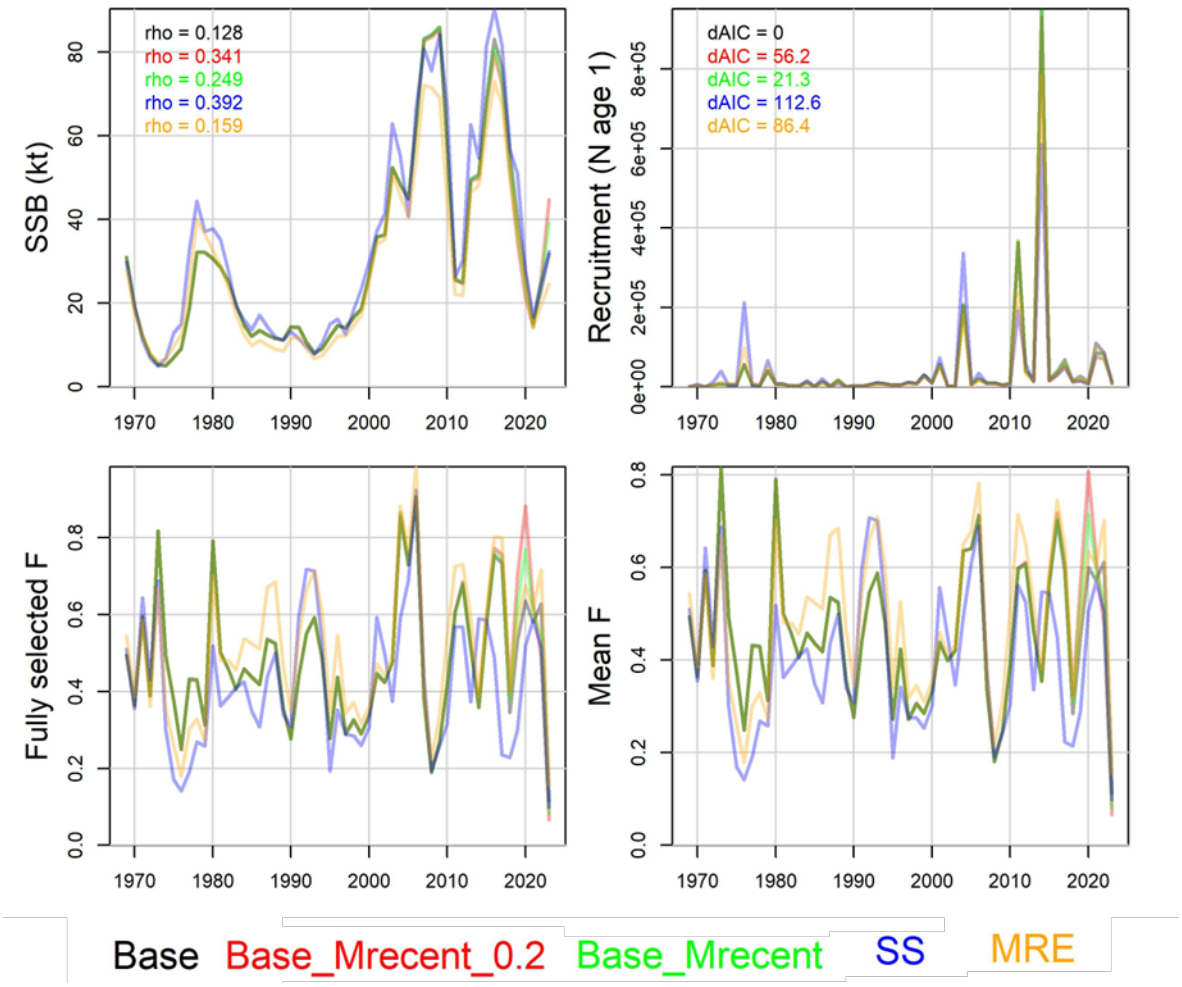

Figure 11. Comparison of diagnostics among different natural mortality (M) configuration models (Base= model used in assessment, Base $M_{recent\_0.2}$ assumes M goes back to 0.2 from 2020–present, Base M_{recent} assumes M goes to an intermediate value between 0.2–0.505 from 2020–present) and two sensitivity analyses (SS= Georges Bank model used by USA, MRE= random effects on M). SSB= Spawning Stock Biomass, F= Fishing mortality, rho=Mohn's rho probability, nll=negative log likelihood, dAIC= delta Akaike information criterion, conv=model converged successfully.

Historically, significant changes in the dynamics of the resource have been a function of year-class strength, with the 2013 year-class sustaining the fishery since it recruited. Subsequent year-classes have been poor at contributing to the fishery. Density-dependent changes in growth have occurred, but presently, the contribution of the large 2013 year-class to the stock is minimal. Preliminary evidence suggested relatively strong 2020 and 2021 year-classes would recruit to the fishery in 2023 (Figure 3); however, survey indices suggest these year-classes are not as comparable to other large cohorts (Figure 6). Since 2020, at least one of the survey indices has been missing from the time series in four of the five years, increasing the uncertainty in the estimates for the 2020 and 2021 year-classes. These estimates should improve with the continued collection of additional years of data.

Improved recruitment since 1990, lower exploitation, and reduced capture of small fish in the fisheries all contributed to the SSB estimate increasing to 52,000 mt in 2003. A subsequent increase to 86,000 mt in 2009 was largely due to the strong 2003 year-class, estimated at 206

million age-1 fish. The biomass decreased after the 2009 high and in 2012 the SSB was estimated at 25,000 mt. When the strong 2010 and 2013 year-classes became sexually mature, the estimated SSB increased to 83,000 mt in 2016, followed by a continued decline in the subsequent years. Despite the recruitment being much higher for the 2010 and 2013 year-classes compared to the 2003 year-class, the SSB did not increase as much, hypothesized to be due to a higher M beginning in 2010. The current SSB estimate for 2023 is 31,733 mt, which is above the median SSB of 24,939 mt for the time series (1969–2023, Figure 12).

Recruitment at age-1 has fluctuated between 1.7 and 67 million since 1990, except for the strong year-classes. The 2003, 2010, and 2013 year-classes were estimated at 206, 362, and 952 million, respectively. The model estimates of the 2020 and 2021 year-classes are 110 and 86 million age-1 fish. The median recruitment for the time series (1968–2022 year-class) is 9.0 million (Figure 12).

The model assumes logistic, fishery-selectivity and a variation in fully-recruited fishing mortality throughout the time series, fluctuating between 0.18 in 2008 to 0.70 during the mid-2010s (Figure 13). Fishing mortality was estimated to be approximately 0.60 over the last few years with a decrease to 0.11 for 2023.

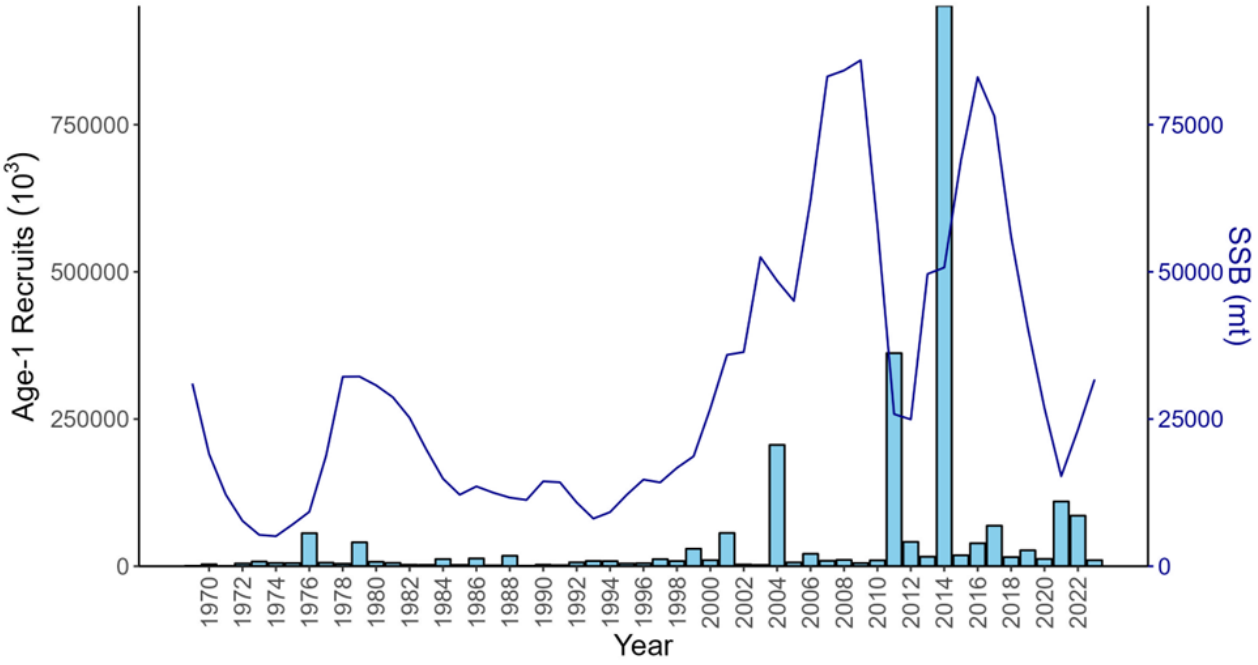

Figure 12. Recruitment at age-1 (bars) and spawning stock biomass (SSB; line) estimated from the Base model for Haddock on eastern Georges Bank.

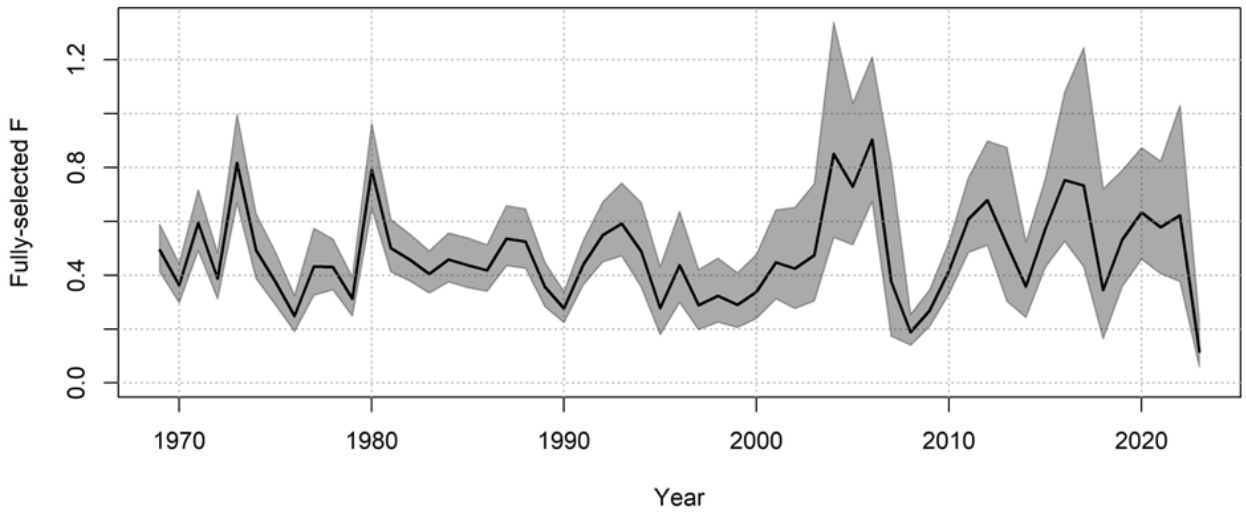

Figure 13. Fully selected fishing mortality (F) estimated from the Base model for Haddock on eastern Georges Bank. The black line is the maximum likelihood estimate, the gray shaded area represents the 95% confidence interval. Note that M=0.2 for 1969–2009; M=0.505 for 2010–2023.

Productivity

Recruitment, natural mortality, growth, and condition reflect changes in the productive potential of the stock. Recruitment has been highly variable. This stock has produced eight strong year-classes in the last two decades. However, the Base model estimates a substantial increase in M from the historical assumed level of 0.2 to a recent time block (2010–2023) where M is estimated at 0.505 (0.46–0.55). Estimated total mortality (Z), and relative fishing mortality (F, catch/survey) varied among years and missing surveys in 2020, 2022, and 2023 made it difficult to interpret any trends in the available data (Figure 14, Figure 15).

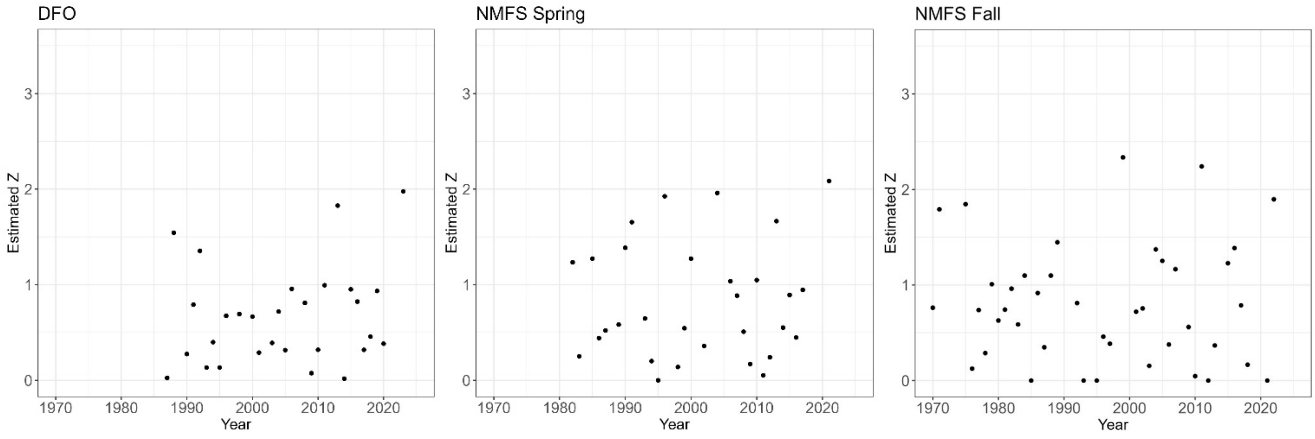

Figure 14. Estimated relative total mortality (Z) (circles) of fish aged 3–6 for Fisheries and Oceans Canada (DFO) Winter Ecosystem Research Vessel survey, and fish aged 4–7 for National Marine Fisheries Service (NMFS) Spring and Fall surveys.

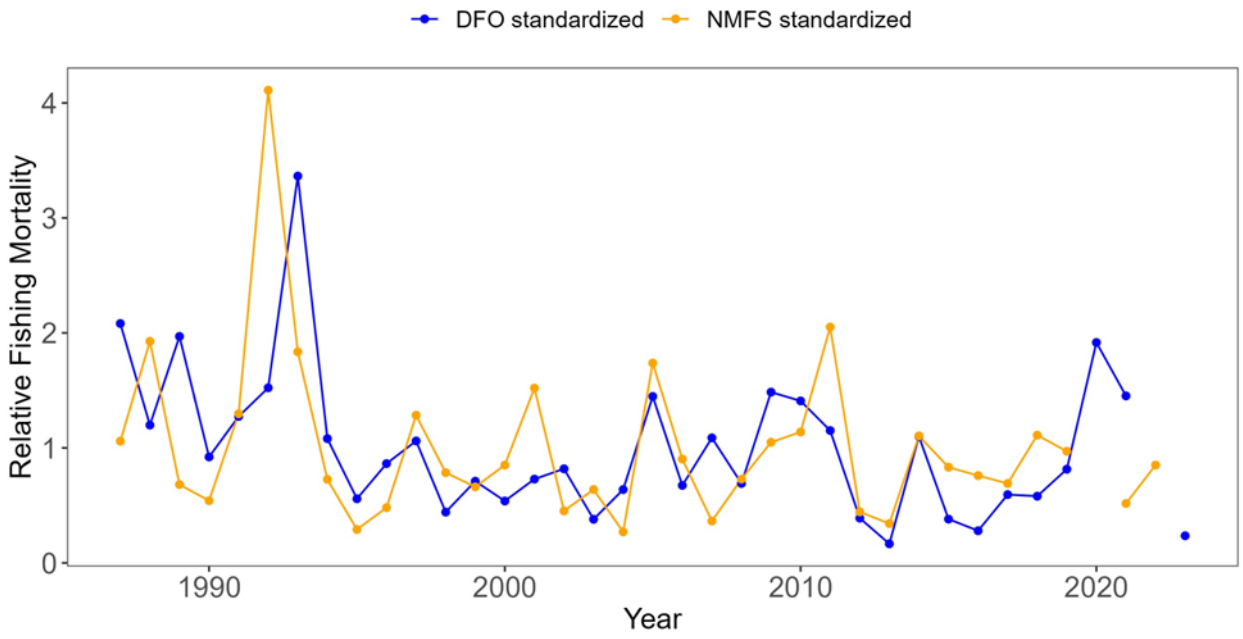

Figure 15. Relative fishing mortality for eastern Georges Bank Haddock derived from the ratio of fishery catch to Fisheries and Oceans Canada (DFO; blue) Winter Ecosystem Research Vessel survey and National Marine Fisheries Service (NMFS) Spring survey (orange) biomass.

Both fishery and survey average lengths- and weights-at-age have declined considerably since 2000, coinciding with an increase in stock biomass. With density-dependent effects, changes in growth in response to changes in stock biomass and episodes of strong recruitments have been observed throughout the history of this stock. With the sharp decrease in biomass in the last few years, Haddock length- and weight-at-age have increased for most ages in both the fishery and survey data (Figure 16, Figure 17). Fish condition has improved in the most recent years, but missing survey values make interpretation of this pattern challenging (Figure 18).

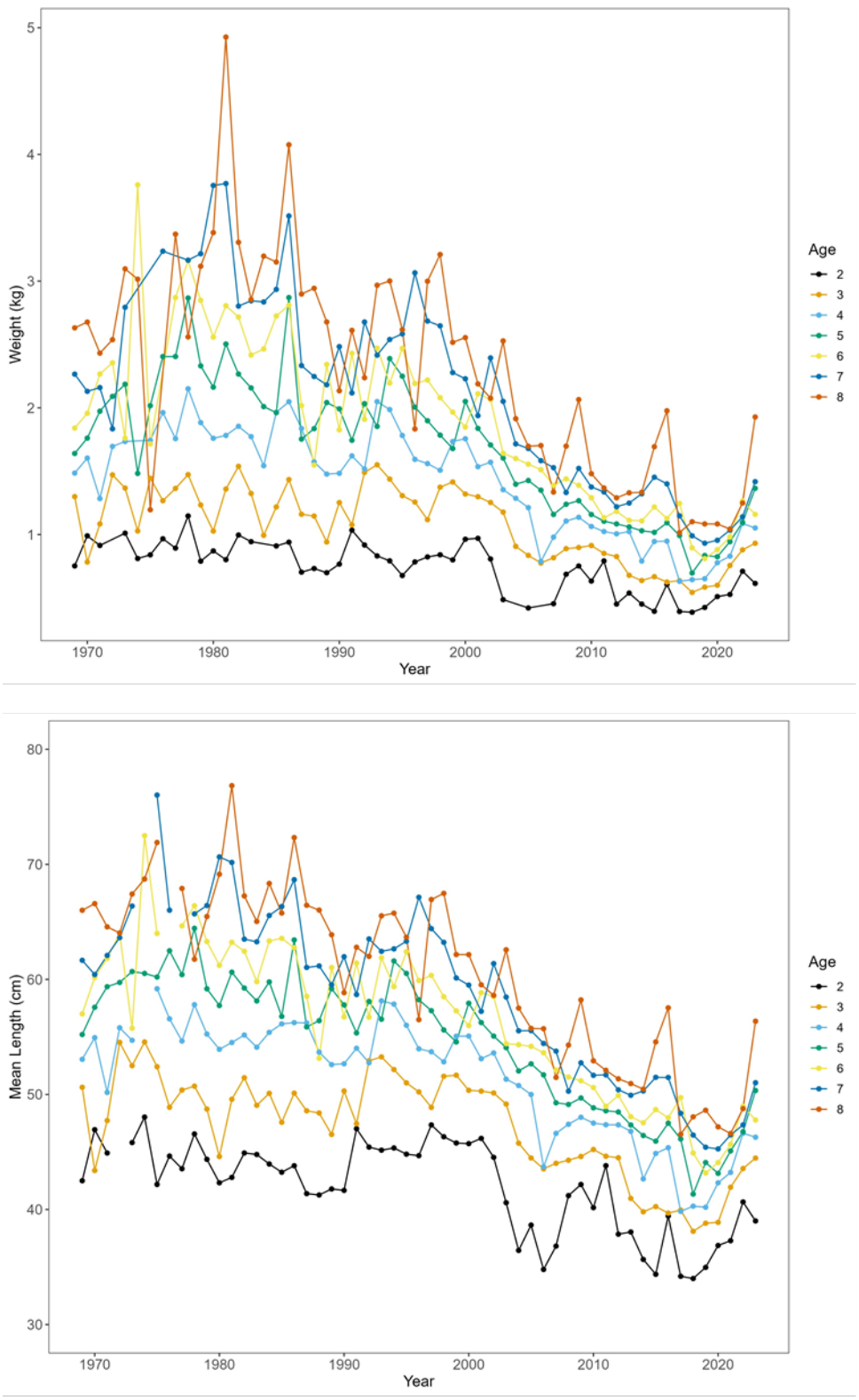

Figure 16. Average weights-at-age (top) and lengths-at-age (bottom) for eastern Georges Bank Haddock from the Canadian commercial groundfish fishery for 1969–2023.

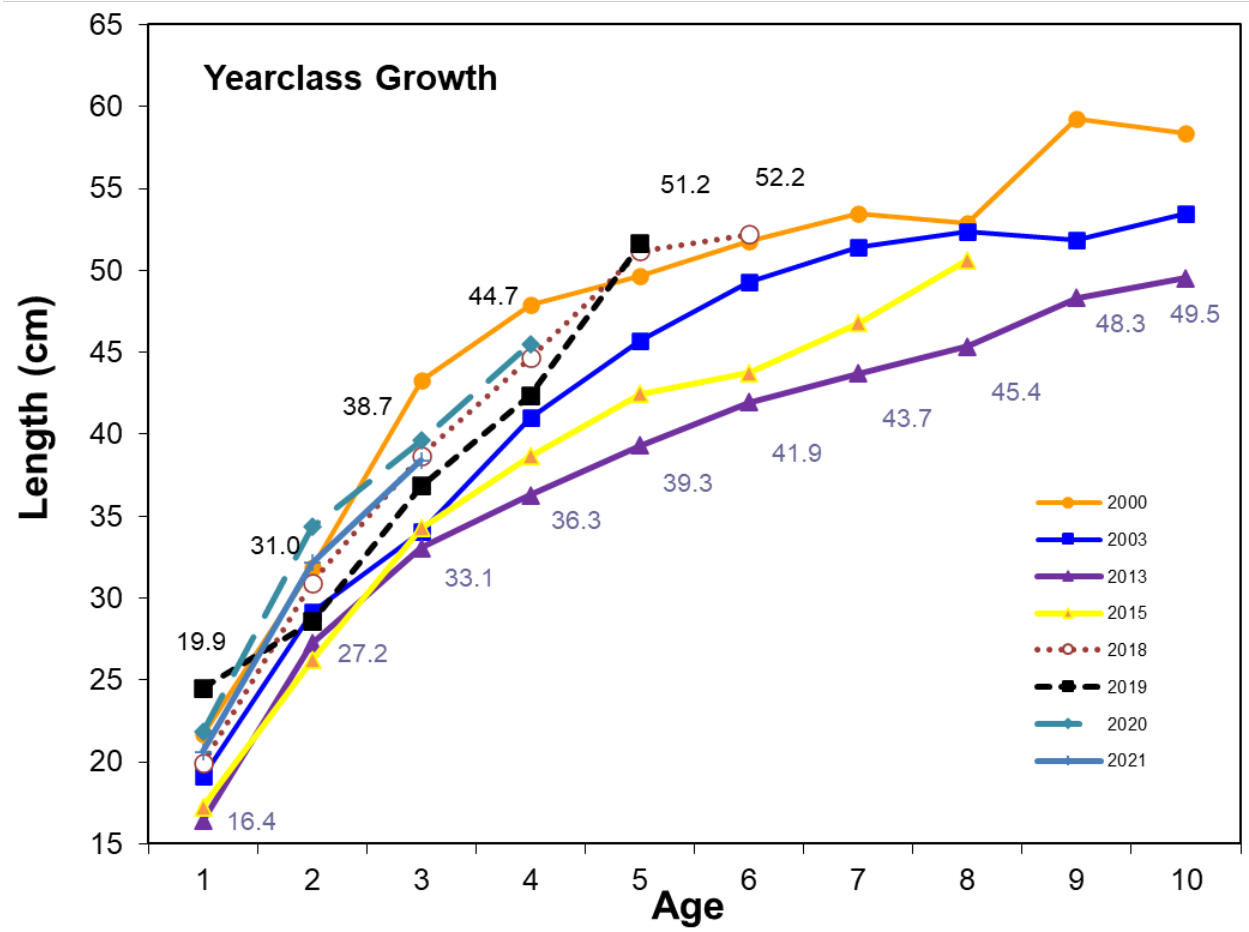

Figure 17. Mean length-at-age for selected year-classes of eastern Georges Bank Haddock sampled from the Fisheries and Oceans Canada Winter Ecosystem Research Vessel survey. The numbers indicate the mean value of the 2013 year-class (purple) for comparison with the 2018 year-class (brown).

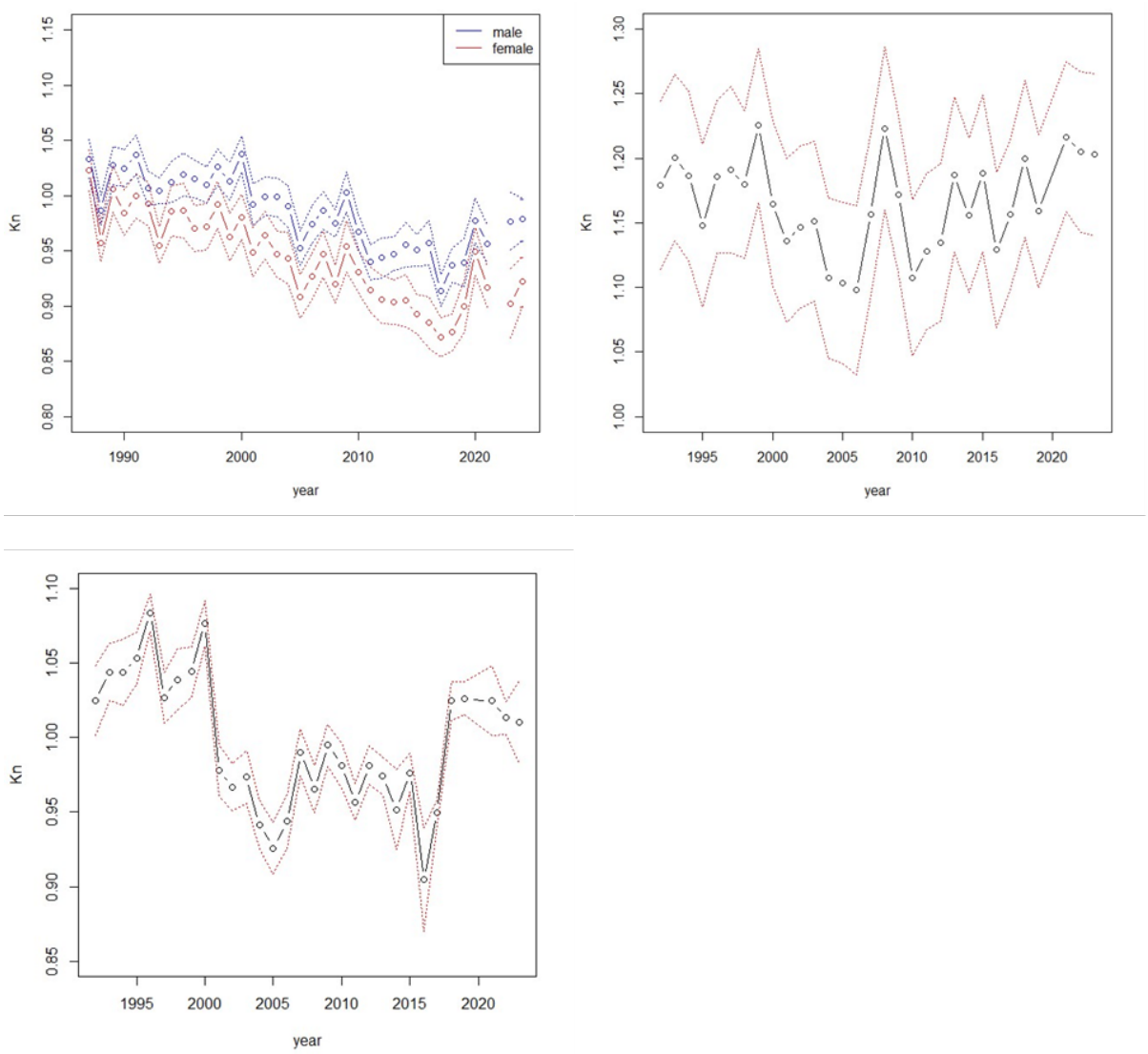

Figure 18. Relative condition factors of National Marine Fisheries Service (NMFS) Spring survey for 1993–2023 (left panel), NMFS Fall survey for 1993–2023 (middle panel) and the Fisheries and Oceans Canada (DFO) Winter Ecosystem Research Vessel survey for 1987–2024 (right panel). The dotted line is +/- 2 standard errors.

Projections

The full quota for EGB Haddock has not been utilized since 2004, when the TMGC began setting the total allowable catch (TAC). In the past 10 years, between 27–74% of the TAC was utilized. This is largely driven by lower USA catches relative to the USA allocation (TRAC 2021) and the Canadian fleet-share arrangements. Based on the recent history of USA catches, 7,400 mt was assumed to be the most appropriate estimate for the 2025 catch in the projections. This value was based on the Canadian fleet catching all of their 6,900 mt quota and a USA catch consistent with the average of the last 5 years (approximately 500 mt).

For projections, the WHAM Base assessment model is converted to an openMSE (Hordyk et al. 2024) operating model. Recruitment is generated from a lognormal distribution with a mean

recruitment and lognormal deviations from the historical simulated recruitment. The average weights-at-age (2021–2023) from the DFO RV Winter survey and fishery data are used to estimate the stock and fishery weights-at-age, respectively. Model derived selectivity, maturity-at-age, and M are used in the projections based on the average of the last 3-years (Table A3).

Assuming the M continues to be 0.505 (as estimated by the model) in 2024–2026, Table 2 shows the median estimates of biomass, SSB, and F in 2024 based on 2,000 realizations of terminal year population sizes and an assumed 2024 catch of 7,400 mt. For 2025, the median biomass, SSB, and catch estimates are obtained by applying an F=0.367 to each realization. The risk analysis in Figure 19 applies a similar logic to estimate the probability of exceeding F=0.367 in 2025 given various catch levels ranging from 0 mt to 30,000 mt in steps of 2,000 mt. The levels of catch associated with 25%, 50%, and 75% risk are estimated by linear interpolation such that the catch associated with the 50% probability of exceeding F_{ref}=0.367 (7,410 mt) in Figure 19 differs slightly from the equivalent median catch for 2025 (7,385 mt) reported in Table 2.

Table 2. Projections from the base model with an assumed 2024 fishery catch of 7,400 mt of eastern Georges Bank Haddock (median value across 2,000 simulations). SSB=spawning stock biomass. A dash (-) indicates not applicable.

Year	Recruitment	Biomass (mt)	SSB (mt)	Catch (mt)	Fishing Mortality (F)
2024	17,200	41,771	35,889	7,400	0.313
2025	19,687	34,853	29,676	7,385	0.367
2026	-	29,073	22,708	-	-

The median SSB is projected to decrease from 35,889 mt in 2024 to 29,676 mt in 2025 and 22,708 mt in 2026. In 2024, F is estimated to be 0.313 assuming a catch of 7,400 mt (Table 2). The median catch at the proposed F_{ref}=0.367 in 2025 is 7,385 mt. The stock biomass is projected to decrease in both 2025 and 2026. The 2020 year-class at age 5 and the 2021 year-class at age 4 are projected to be the dominant contributors to fishery catch in 2025 due to the lack of older fish in the population and low selectivity of younger age groups (Figure 20).

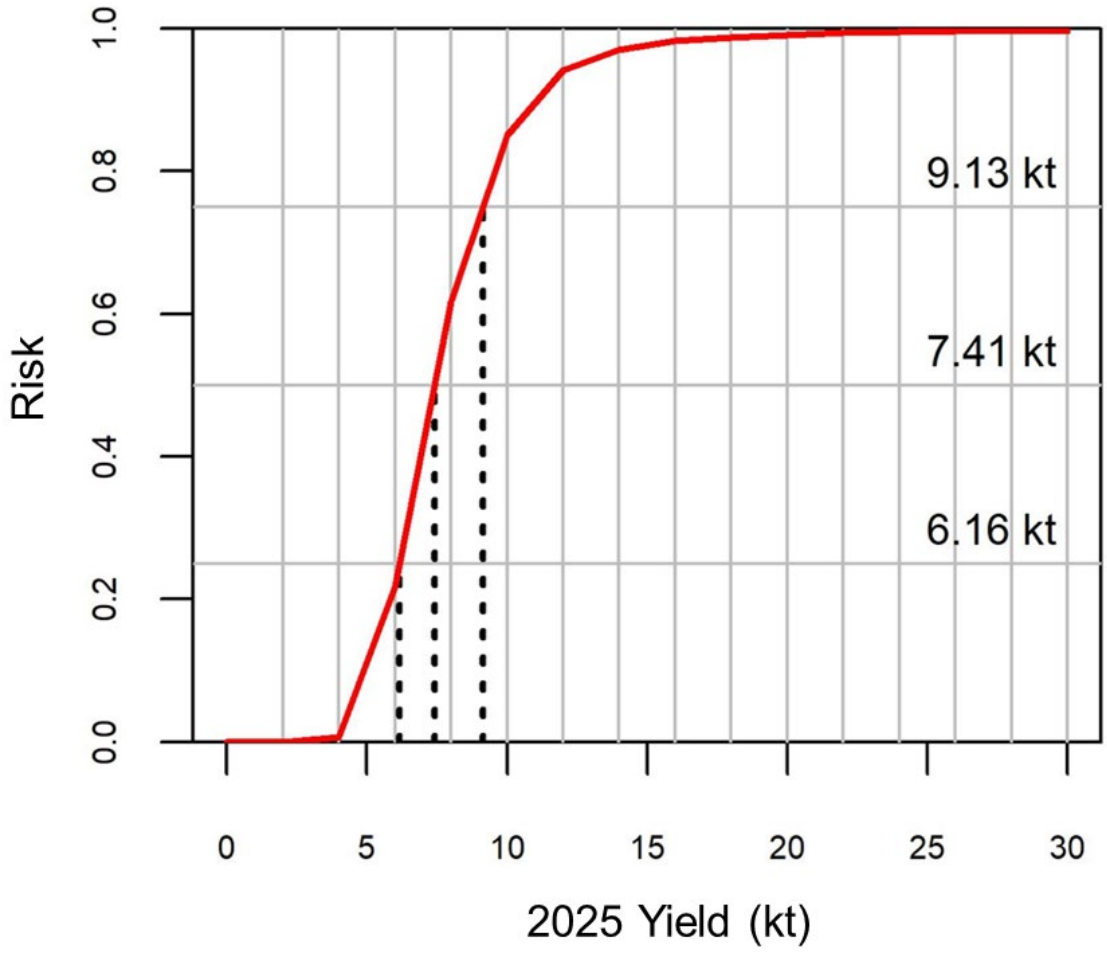

Figure 19. Probability of exceeding the F_{ref} (0.367) in 2025 assuming a 2024 fishery catch of 7,400 mt for Haddock on eastern Georges Bank. Dashed lines denote the 2025 yield (kt) associated with 25% (6.16 kt), 50% (7.41 kt), and 75% (9.13 kt) probability of exceeding F_{ref}.

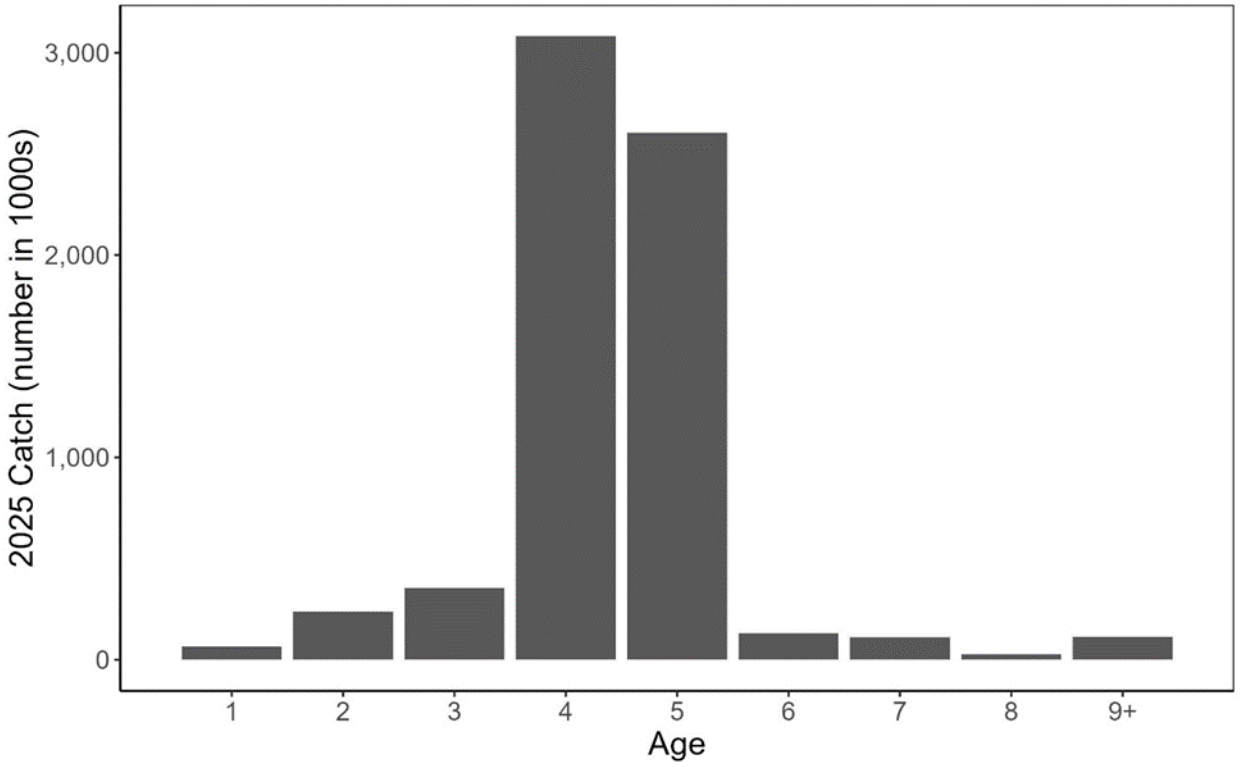

Figure 20. Projected fishery catch-at-age in numbers in 2025 with an assumed 2024 fishery catch of 7,400 mt for Haddock on eastern Georges Bank.

Sources of Uncertainty

- Mohn's rho is used as one of the measures of model performance. It is the relative percent change (relative bias) in a model-estimated parameter from the sequential addition or removal of a full year of data. In general, the model tends to overestimate both SSB and recruitment and underestimate fishing mortality. The mean Mohn's rho over a 7-year peel for SSB, F, and recruitment were larger than 0.2 in some cases; however, fluctuations in the rho for F is similar to last year's assessment and the magnitude of change is small for the numbers-at-age 1 (i.e., recruitment; Figure 21).
- The selection of a change point year (i.e., 2010) for M has important implications. The basis for this selection was described in the Georges Bank and eastern Georges Bank Haddock Research Track Stock Assessment peer review (Kronlund et al. 2023). The good performance of the past VPA model with constant M=0.2 in pre-2010 also supports 2010 as a change point year.
- Inconsistencies in the average weights-at-age in the stock and in the fishery need further investigation. Initial review suggested problems in average weights for fish aged 6 and older due to limited samples and ageing challenges.
- Density dependence is suggested as a basis for an increase in M. The exit of the 2013 year-class has led to rapid reduction in overall stock biomass. Contrary to expectations, there is limited evidence of reductions in M. Our understanding of the factors leading to high M in recent years is incomplete.

- Small changes in timing of surveys may be important in recent years as populations shift distributions in response to seasonal temperature changes. Coincidence of these factors may lead to changes in relative abundance indices independent of actual changes in abundance.
- Available survey indices declined in recent years which could be attributed to changes in spatial distribution of Haddock to deeper water adjacent to the current management area. Haddock distribution has been known to vary throughout the year, although the amount of movement across management areas are unknown.
- Estimates of time-varying M in the model reflect potential changes in multiple factors including migrations, catch reporting errors, ageing error, misspecification of selectivity, and so forth. Therefore, one cannot simply assume that all of the putative changes in estimated M are associated with true changes in natural mortality.
- The F_{ref}=0.367 is estimated by using M=0.2 while using the estimated selectivity patterns from the Base model that assumes M=0.505. It is unknown how the selectivity pattern in the Base model with a freely estimated value of M would have changed under the assumption that M was fixed at 0.2.

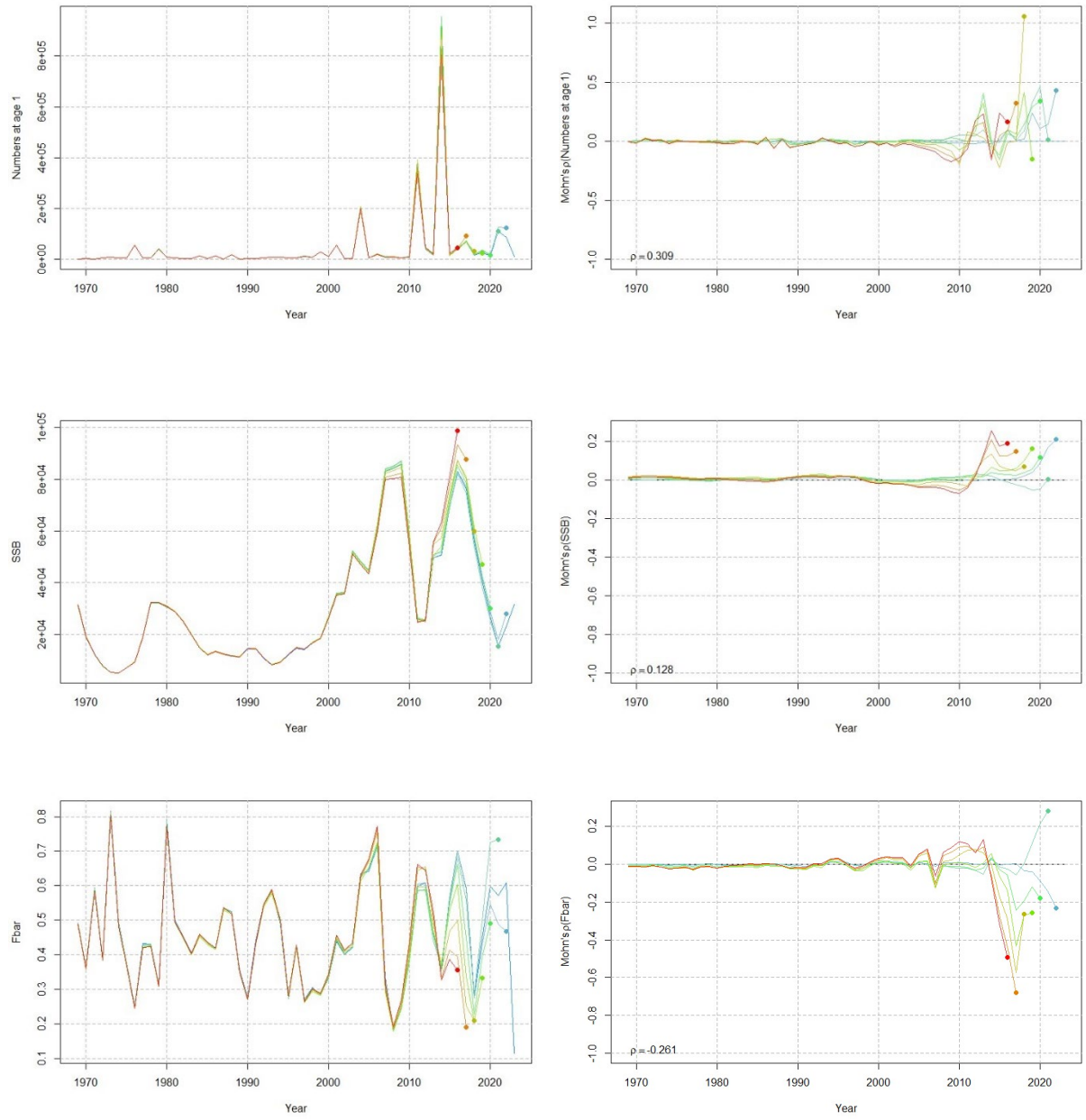

Figure 21. Retrospective analysis of recruitment (Numbers at age-1), spawning stock biomass (SSB), and mean fishing mortality rate (F_{bar}) of the Base model.

CONCLUSIONS AND ADVICE

Catch advice in 2022 (TRAC 2022) and 2023 (TRAC 2023) was provided as a range of projected catch bounded by the model estimated M (0.505) and historical M (0.2) to account for uncertainty in M in the projections. In 2024, a sensitivity analysis was conducted to profile the model AICs over a range of M values for the recent time period (2020–2023), which indicated M remains high. Given the lack of evidence for a return to M=0.2, the catch advice was based on projections using the model derived M. Catch advice for the 2025 fishing year ranged from 6,160–9,130 mt based on the 25–75% risk of exceeding F_{ref} (Table 3).

Table 3. Catch advice for eastern Georges Bank Haddock for 2025 based on the probabilities of exceeding the F_{ref} value.

Probability of exceeding F_{ref} (0.367)	**25%**	**50%**	**75%**
2025 Catch	6,160 mt	7,410 mt	9,130 mt

In May 2023, biomass-based reference points were developed domestically for EGB Haddock (DFO 2024) using the new assessment model. The limit reference point (LRP) was defined using the lowest SSB in the time series that resulted in sustained recovery ($B_{recover}$, 1991–1996) and the upper stock reference (USR) was proposed based on the Rago-Razor method (DFO 2024). Based on the current level for SSB (31,733 mt), the stock status of EGB Haddock is in the healthy zone (Figure 22).

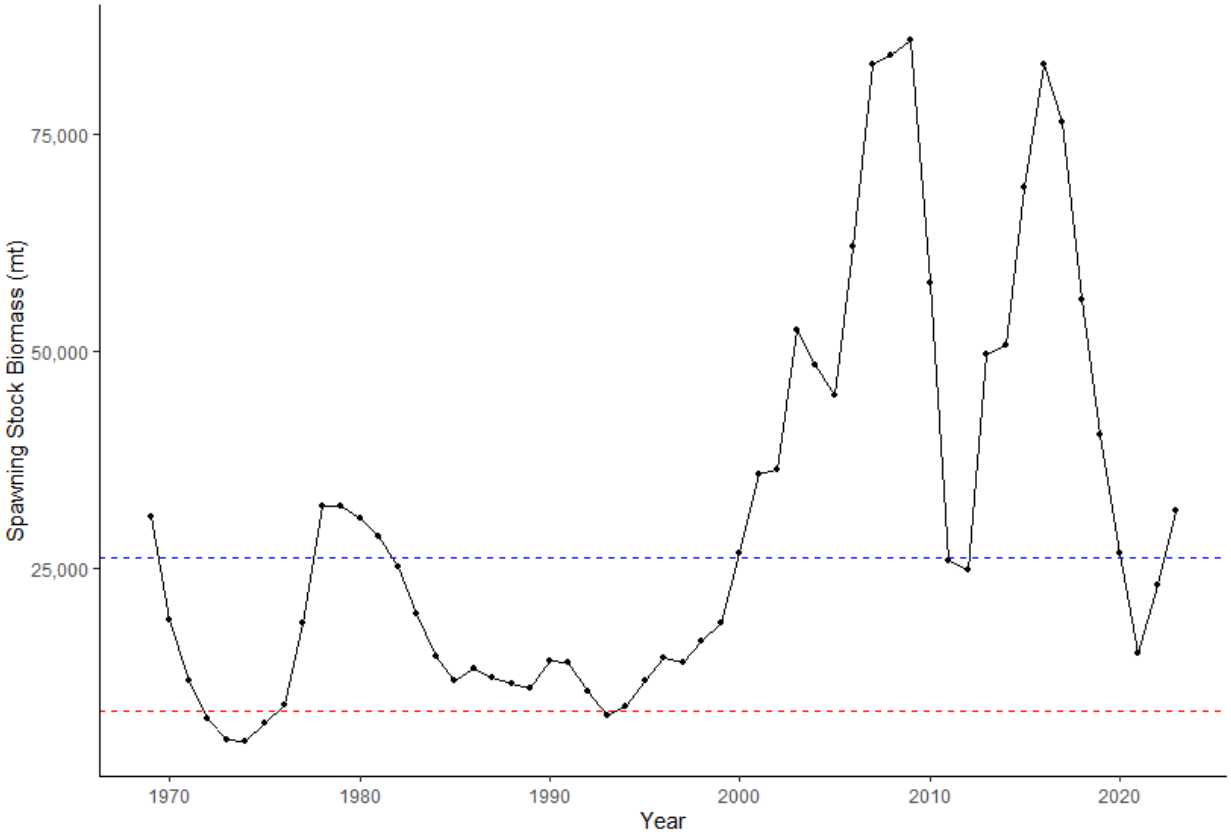

Figure 22. Spawning stock biomass of eastern Georges Bank Haddock relative to developed reference points (DFO 2024).The dashed red line is the limit reference point and the dashed blue line is the upper stock reference.

OTHER CONSIDERATIONS

Due to the exit of the 2013 year-class from the population, density-dependent factors influencing EGB Haddock maturity, growth, and associated changes in fishery selectivity will be reduced.

The Base model has the time period to estimate M (2010+) hard-wired into the model. A number of models with alternative M values were examined for the updated year (2023).

Despite the uncertainties of M in recent years, SSB estimated from all models show a consistent trend over time (Figure 11).

The 2020 and 2021 year-classes appear to be the largest since 2013 based on estimates from the 2023 Base model and the surveys; however, the 2020 year-class numbers-at-age 3 were lower than anticipated from the estimates at age-1 and age-2 (Figure 3, Figure 6).

The 2022 DFO Winter RV survey was conducted using a different research vessel and gear. Calibration factors were not available to include these data in the assessment but are currently being developed for use in future assessments. The 2023 NMFS Spring survey experienced vessel delays and a change in survey protocols by only sampling during daylight hours. Analyses will need to be conducted in the future to determine whether data from this survey are appropriate to use.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Andrushchenko, Irene	DFO Science - Maritimes Region
Barrett, Melanie	DFO Science - Maritimes Region
Barrett, Tim	DFO Science - Maritimes Region
Benoit, Hugues	DFO Science - Quebec Region
Bhardwaj, Anjali	National Marine Fisheries Service
Blackhart, Kristan	National Marine Fisheries Service
Byrne, Vanessa	Atlantic Groundfish Council
Cadigan, Noel	Marine Institute of Memorial University of Newfoundland
Cadrin, Steve	University of Massachusetts
Clancey, Lewis	NS Department of Fisheries and Aquaculture
Clark, Caira	DFO Science - Maritimes Region
Cooper-MacDonald, Kathryn	DFO Resource Management - Maritimes Region
Couture, John	Oceans North
d'Entremont, Alain	Scotia Harvest Fisheries
Dinning, Kristin	New Brunswick Department of Aquaculture and Fisheries
Frede, Robin	New England Fishery Management Council

Name	Affiliation
Greenlaw, Michelle	DFO Science - Maritimes Region
Hart, Amanda	National Marine Fisheries Service
Hebert, Nathan	DFO Science - Maritimes Region
Keith, David	DFO Science - Maritimes Region
Kraska, Kelly	DFO Science - Maritimes Region
Liljestrand, Emily	National Marine Fisheries Service
McIntyre, Tara	DFO Science - Maritimes Region
Mohan, Selvan	DFO Science - National Capital Region
O'Keefe, Cate	New England Fishery Management Council
Paul, Tyson	Unamaki Institute of Natural Resources
Perretti, Charles	National Marine Fisheries Service
Pomerleau, Corinne	DFO Science - Maritimes Region
Regnier-McKellar, Catriona	DFO Science - Maritimes Region
Regular, Paul	DFO Science - Newfoundland and Labrador Region
Robertson, Matthew	Marine Institute of Memorial University of Newfoundland
Salerno, Dan	New England Fishery Management Council
Talmage, Spencer	National Marine Fisheries Service
Thomas, Reide	DFO Resource Management - Maritimes Region
Townsend, Kathryn	Maritime Aboriginal Aquatic Resources Secretariate
Vascotto, Kris	Nova Scotia Seafood Alliance
Wang, Yanjun	DFO Science - Maritimes Region
Way-Nee, Emily	DFO Science - Maritimes Region
Yin, Yihao	DFO Science - Maritimes Region

SOURCES OF INFORMATION

This Science Advisory Report is from the July 8–12, 2024, regional peer review on the Framework Review for Atlantic Cod in NAFO Division 5Z: Part 2 - Modelling Review and Interim Advice for Eastern Georges Bank Cod and Stock Assessment of Haddock on Eastern Georges Bank. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2024. Identification of a Limit Reference Point and Proposal of an Upper Stock Reference for Canadian Fishery Management of Eastern Georges Bank (5Zjm) Haddock (*Melanogrammus aeglefinus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/028.

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APPENDIX

Table A1. Input data for the Base model for EGB Haddock.

Data	List	Description
Fishery data	annual aggregate catch (biomass, 1 fleet)	1969–2023
	annual CVs for aggregate catch observations	0.1
	annual fishery age composition (numbers)	1969–2023, ages 1–9+
	annual effective samples size for age composition	70
	annual fishery weight at age	1969–2023, ages 1-9+
Survey data	annual aggregate catch for each survey index (mean number/tow)	1969–1972,1982–2022, NMFS Spring Survey 1969–2023, NMFS Fall Survey 1987–2023, DFO Spring Survey
	annual CVs for each index's aggregate observations	Calculated for each survey based on survey design
	annual age composition(numbers) for each index	ages 1–9+ for three surveys
	annual effective sample sizes for each index's age composition observations	40 for three surveys
	Survey timing(month)	3 for NMFS spring survey 9 for NMFS fall survey 2 for DFO spring survey
Others	spawning stock weight at age	1969–2023, ages 1–9+
	spawning time	0.25
	maturity at age data	1969–2023, ages 1–9+

Table A2. Configuration of the Base model for EGB Haddock.

Model feature	Base configuration
Modeling / estimation framework	Woods Hole Assessment Model (WHAM, GitHub v1.0.5.9000) (Stock and Miller 2021) using Template Model Builder (TMB v1.7.21) (Kristensen et al. 2016)

Model feature	Base configuration
Model type	Statistical catch-at-age with random effects for fleet selectivity
Model years	1969 – 2023
Modeled age classes	1 – 9+
Fleet structure	Single aggregate fleet
Fleet selectivity	Two blocks: 1969 – 1991, time-invariant logistic; 1992 – 2023, iid random effects in logistic parameters.
Survey selectivity	Single block, time-invariant, age-specific selectivity for each survey. 1969 –1972, 1982 – 2022, NMFS Spring Survey 1969 – 2023, NMFS Fall Survey 1987– 2023, DFO Spring Survey
Stock recruitment model	Mean recruitment with log deviations estimated as fixed effects.
Natural mortality rate	Two blocks: 1969 – 2009, age- and time-invariant $M = 0.2$ 2010 – 2023, age- and time-invariant, M estimated.
Likelihood function for fishery catch and survey index data	Lognormal
Likelihood function for catch age-composition data	Logistic-normal, ignoring zeros (self-weighted)
Likelihood function for survey age-composition data	Logistic-normal, ignoring zeros (self-weighted)
Process errors (survival deviations) for numbers-at-age	None
Approach to characterizing model uncertainty	Multivariate normal sampling of parameters from the inverse Hessian (variance-covariance matrix)

Model feature	Base configuration
Reference point calculation and short-term projections	openMSE (Hordyk et al. 2021)

Table A3. Input data for projections used to provide 2025 catch advice for eastern Georges Bank Haddock.

	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9+
Stock Weight at Age (kg) 2021-2023	0.087	0.311	0.551	0.742	0.960	1.043	0.996	0.951	1.248
Fishery Weight at Age (kg) 2021-2023	0.392	0.621	0.851	0.986	1.112	1.109	1.198	1.404	1.337
Natural Mortality 2023	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
Selectivity 2021-2023	0.029	0.136	0.444	0.793	0.949	0.989	0.998	1.000	1.000
Maturity at Age 2021-2023	0.076	0.64	0.87	1	1	1	1	1	1

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Centre 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

E-Mail: DFO.MaritimesCSA-CASMaritimes.MPO@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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