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Maritimes Region | Science Advisory Report 2025/047

STOCK ASSESSMENT FOR 4X5Y HADDOCK IN 2024

CONTEXT

The Fisheries Management Branch of Fisheries and Oceans Canada (DFO) requested an assessment of stock status using the new assessment framework developed in 2024 for Haddock (*Melanogrammus aeglefinus*) in the NAFO Divisions 4X5Y management area and catch advice using the chosen management procedure for the 2025/26 fishing year. This Science Advisory Report is from the regional peer review of April 28, 2025, on the Stock Assessment of Haddock in 4X5Y.

SCIENCE ADVICE

Status

- The smoothed 2024 DFO Summer Ecosystem Research Vessel (RV) Survey index, the secondary indicator of stock status, suggests the stock is in the healthy zone.

Trends

- Spawning stock biomass (SSB) has shown a declining trend since 2016, with estimates stabilizing below the USR since 2019.
- No large recruitment events have occurred since 2013; however, both the 2020 and 2021 recruitment estimates were above the time series median.
- Fishing mortality has been below 0.25 (F_{ref}) since 1994.
- Weight-at-age (WAA) and length-at-age (LAA) have declined since the early 1990s, with recent increases.

Ecosystem and Climate Change Considerations

- Bottom water temperatures have been elevated since 2010 in 4X5Y, potentially affecting Haddock behaviour and food availability.
- Haddock adjust their depth distribution with seasonal water temperature changes, typically occupying shallow inshore areas in the summer and moving to deeper waters in winter.

Stock Advice

- Using updated data from the 2024 DFO Summer RV Survey, the selected management procedure generates catch advice of 7,128 mt for 4X5Y Haddock in the 2025/26 fishing year. This is a 15% increase from the 2024/25 fishing year.

Other Management Questions

- In 2024, the fishery catch-at-length peaked at 40.5 cm for the Scotian Shelf and 38.5 cm for the Bay of Fundy, with 18% of the total catch by number below 38 cm.

BASIS FOR ASSESSMENT

Assessment Details

The assessment of stock status for 4X5Y Haddock is based on model-estimated SSB. In interim years when the model is not run, the DFO Summer RV Survey index is used as a secondary indicator of stock status.

Year Assessment Approach was Approved

Barrett et al. (In Press).

Assessment Type

Harvest Decision Rule Update

Most Recent Assessment Date

1. Last Full Assessment: 2017 (DFO 2017)
2. Last Interim-Year Update: 2023 (DFO 2023)

Stock Assessment Approach

3. Full MSE
4. Statistical catch-at-age; State Space

Stock Structure Assumption

Haddock in 4X5Y are comprised of a faster growing stock component in the Bay of Fundy (DFO Ecosystem Research Vessel Survey (Summer RV Survey) strata 482–495) and a slower growing stock component on the western Scotian Shelf (Summer RV Survey strata 470–481). Haddock are known to shift their distribution and home range both seasonally and throughout their life history. Tagging studies have suggested seasonal mixing of Haddock between the Bay of Fundy, Gulf of Maine, Great South Channel, and Georges Bank, with movement varying yearly. When abundance is high, Haddock may move from high density areas to less suitable habitats with lower intraspecific competition (Brodziak et al. 2008, Stone and Hansen 2015). Although some mixing likely exists with adjacent stock units, 4X5Y Haddock are currently assessed as a single unit with the assumption that fish do not move in or out of the area.

Reference Points

- Limit Reference Point (LRP): 23.4 kt, based on three model-weighted estimates of B_{loss}
- Upper Stock Reference (USR): 38.3 kt, based on three model-weighted estimates of B_{PA}
- Fishing Mortality Reference (F_{ref}): 0.25, based on three model-weighted estimates of F_{ref}

Management Procedure

The lower and upper index control points (LCP and UCP) of the management procedure (Fig 2A) are based on the Summer RV Survey index, corresponding with the q-adjusted LRP and USR, respectively. When the index falls below the LCP, the catch advice declines linearly to the origin based on the index. Between the LCP and UCP, the total allowable catch (TAC) follows a non-linear path (leaf pattern, NAFO 2024), dependent on whether the index is decreasing or increasing. Above the UCP, a constant harvest rate (consistent with the F_{ref}) is applied with a 15% limit on annual TAC changes. Catch advice is updated annually based on the 3-year moving geometric mean of the Summer RV Survey index.

Data

- DFO Summer RV Survey index and age-composition data (1970–2024)
- Canadian commercial fishery catch and age-composition data (1970–2024)

Data changes: The Summer RV Survey was completed in 2021 and 2024 with a new vessel and new gear. Length-based conversion factors were developed to make the new vessel comparable to the previous vessels used. Based on the timing of the framework, conversion factors are applied forward to make the new vessel comparable to the old vessels.

ASSESSMENT

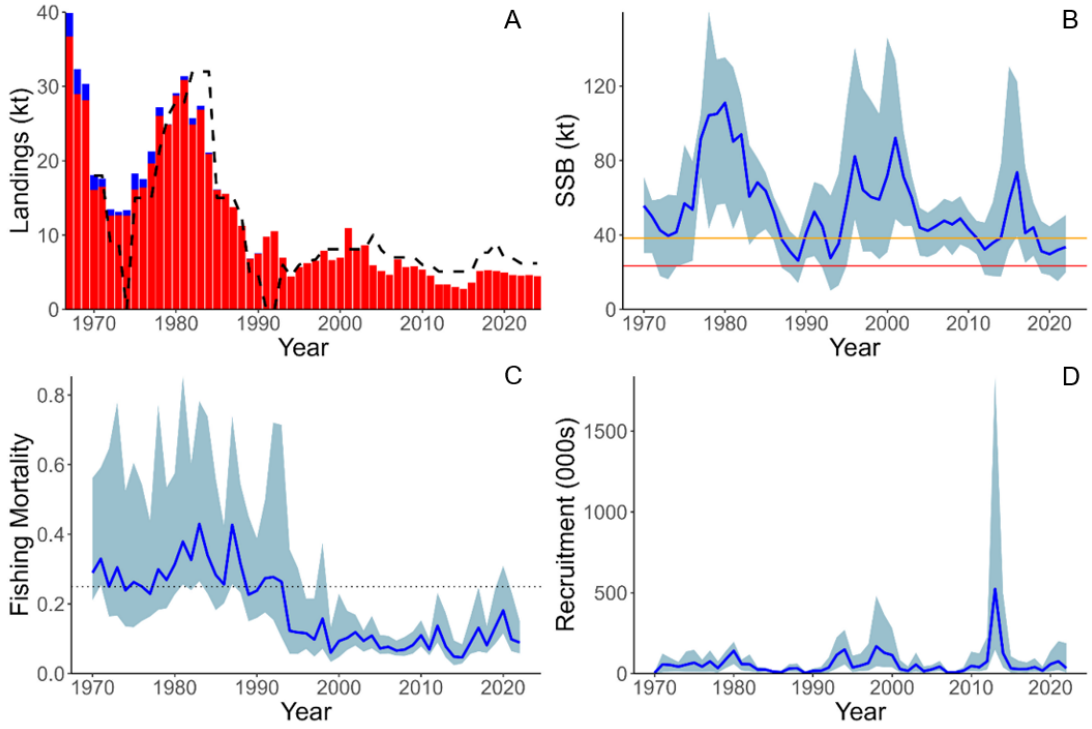

Figure 1. (A) Catch for Canadian (red bars) and foreign (blue bars) fleets and total allowable catch (black dashed line), (B) Spawning stock biomass (SSB) in relation to the limit reference point (red line; 23.4 kt) and upper stock reference (orange line; 38.3 kt), (C) Fishing mortality rate (F) in relation to the removal reference (F_{ref} = 0.25, black dotted line), and (D) Recruitment at Age 0 (numbers). 95% confidence intervals are provided in light blue shading on the figures B–C.

Stock Status and Trends

Spawning Stock Biomass

Following a decrease in the model-estimated SSB since 2016, the stock has remained stable in the last 3 years, with SSB in 2022 estimated as 33,531 mt (Barrett et al. In Press, Fig 1B), which is below the USR, but above the LRP.

Recruitment

Haddock recruitment in 4X5Y has fluctuated annually throughout the time series, with three large recruitment events observed in 1993, 1998, and 2013 (Figure 1D).

To estimate recruitment in update years, the Summer RV Survey numbers-at-age 1 (NAA-1) were compared to model estimated recruitment. Based on a linear regression, the survey NAA1 was a good predictor of model-estimated recruitment (lagged by one year) (R^2=0.824), suggesting the survey NAA-1 could be used an indicator of recruitment. Recent estimates for age-1 recruitment based on the Summer RV Survey were above median recruitment for the time series for 2021 and 2022; however, the 2023 age-1 recruitment estimate was the 3rd lowest in the time series.

Fishing Mortality

Fishing mortality has been below the F_{ref} since 1994 with the most recent model estimates below 0.10 (Figure 1C). In update years, a relative harvest rate is estimated using the ratio of the catch to the survey index, with the current year's relative harvest rate estimated at 0.11 for the Bay of Fundy and 0.19 for the Scotian Shelf (Figure 2D).

Natural Mortality

Models 1 and 2, assume a time-varying natural mortality (M), to account for the hypothesis of density-dependent M. Model 3 assumes a constant M of 0.2 with random effects on NAA.

Current Status

The model-based estimate of SSB from the most recent model run, in 2022, placed the 4X5Y Haddock stock in the cautious zone, with a 0.98 probability it was above the LRP and a 0.34 probability it was above the USR.

In this interim year, the smoothed 2024 DFO Summer RV Survey index suggests the stock is in the healthy zone.

History of Landings, TAC, and Catch Advice

Landings have stabilized since 2017, typically ranging from 4,600 mt to 5,200 mt. Landings from the 2023–24 fishing season were 4,627 mt with approximately 74% of the quota caught (Figure 1A). The fishery catch-at-age for 2023 and 2024 was composed mainly of the 2020 and the 2021 cohorts (37% and 17% by number for 2023; 25% and 49% by number for 2024). The length frequencies of the catch peaked at 42.5 cm for fixed gear and 40.5 cm for mobile gear in 2023 and in 2024, compared to 33.5 cm and 38.5 cm from the Summer RV Survey for 2023 and 2024, respectively.

Table 1. Landings and total allowable catch (TAC) in metric tons for the 4X5Y Haddock fishery by fishing year (April 1–March 31).

Fishing Year	2015/ 16	2016/ 17	2017/ 18	2018/ 19	2019/ 20	2020/ 21	2021/ 22	2022/ 23	2023/ 24	2024/ 25*
TAC (mt)	5,100	5,100	7,650	7,650	9,000	6,877	6,198	6,198	6,198	6,198
Catch (mt)	2,731	3,590	5,182	5,258	5,188	4,979	4,605	4,557	4,627	4,468*

**Catch data for 2024/25 is preliminary, as data was extracted before the end of the fishing season on March 14, 2025.*

Ecosystem and Climate Change Considerations

Potential ecosystem covariates impacting recruitment and growth were evaluated in the development of the assessment framework, but were not directly included in the models, as they did not improve model diagnostics. Higher levels of M were incorporated into the models, which may reflect indirect changes in the environment that impact movement (i.e., temperature; Lapolla and Buckley 2005, Begg 1998, Rogers et al. 2016) or density dependent pressures.

Growth of 4X5Y Haddock differs between the Bay of Fundy and Scotian Shelf, with larger fish associated with the Bay of Fundy (Barrett and Barrett 2025, Hurley et al. 1998) and is likely driven by differences in the ecosystem.

Current ecosystem conditions as described in Hebert et al. (2023) include observations of elevated bottom water temperatures since 2010 in 4X5Y. This could potentially affect Haddock behaviour and food availability. Haddock adjust their depth distribution with seasonal water temperature changes, typically occupying shallow inshore areas in the summer and moving to deeper waters in winter.

Stock Advice

Harvest Decision Rule

The 3-year moving geometric mean of the q-adjusted survey biomass is 26.6 kg/tow. Based on the current index value being above the UCP on the management procedure (MP), the catch advice for 4X5Y Haddock for the 2025–26 fishing year is 7,128 mt. This represents an increase of 15% from the previous fishing year's TAC of 6,198 mt.

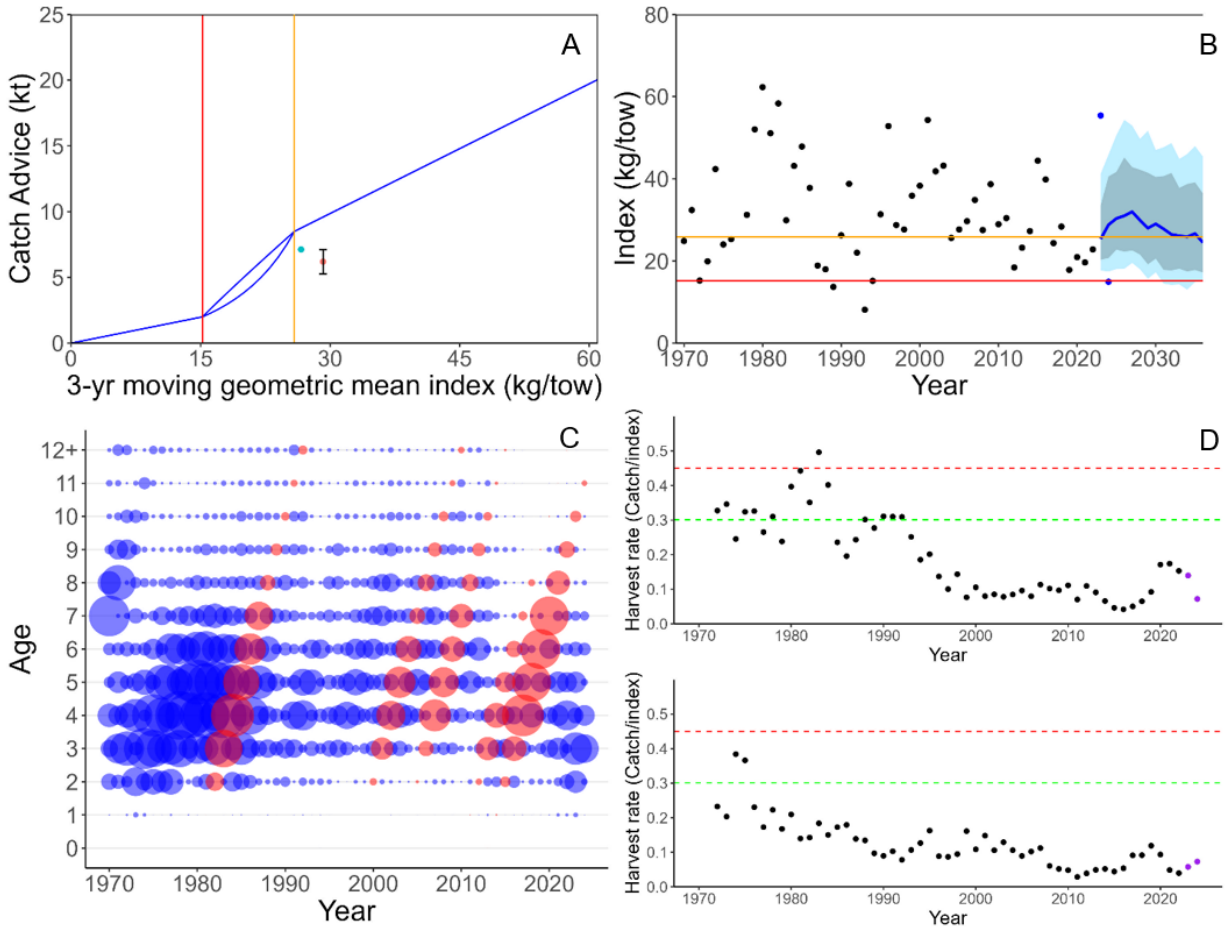

Figure 2. A) Management procedure for 4X5Y Haddock with the 3-yr geometric mean index indicated by a pink circle (2023) and a blue circle (2024). The vertical lines represent the survey q-adjusted limit reference point and the upper stock reference (LRP=red and USR=orange respectively) and the error bars reflect the 15% limit on total allowable catch in the healthy zone. B) Smoothed survey index (black dots for 1970–2022, blue dots for 2023 and 2024) compared to simulations (LRP-red line=23.4 kt; USR-orange line=38.3 kt) with 80% and 90% prediction intervals provided in blue. C) Fishery catch-at-age with the large cohorts tracked in red. D) Relative harvest rate (catch relative to survey index) compared to the relative harvest rate if fishing at Flim (red line) and Fref (green line) for the Scotian Shelf (top) and Bay of Fundy (bottom), 2023 and 2024 are shown in purple dots.

Table 2. Weight-at-age (WAA) from the Summer RV Survey for 2023 and 2024 and the WAAs assumed for the model projections. No data available (–).

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
2023 DFO WAA	0.004	0.077	0.324	0.404	0.457	0.784	0.783	1.039	1.453	0.818	0.981	1.413	–
2024 DFO WAA	0.005	0.068	0.249	0.522	0.686	0.742	0.925	0.910	1.280	1.480	–	1.661	–
Projected WAA	0.000	0.048	0.162	0.344	0.525	0.712	0.844	0.987	1.057	1.096	1.303	1.350	1.380

OTHER MANAGEMENT QUESTIONS

The small fish protocol is a management measure aimed at minimizing undersized fish in the catch. For Haddock, a minimum size of 38 cm was established, and areas are closed when the number of undersized Haddock exceed a percentage of the catch in a trip (25% for 2024/25 fishing season). In 2024/25, the fishery catch-at-length peaked at 40.5 cm for the Scotian Shelf and 38.5 cm for the Bay of Fundy, with 18% of the total catch below 38 cm. The age at 50% maturity for 4X5Y Haddock is estimated to be 2.5 years. The average length-at-age from the DFO summer ecosystem survey is 33 cm and 40 cm for a 2 and 3 year old Haddock, respectively. Currently the fishery catch is mainly comprised of 3 and 4 year old Haddock.

Evaluation of Exceptional Circumstances/Assessment Triggers

Four exceptional circumstances were identified in the most recent framework that would result in additional analyses that could trigger a new framework, revision of operating models or re-evaluation of MPs (See Barrett et al. In Press).

1. The observed DFO survey index is below the LCP in 2 consecutive years (Figure 2B).
2. New data inputs have been identified that suggest the assumptions of the framework data inputs or model assumptions are no longer valid.
3. Fishery selectivity has changed from the assumptions in the operating models (Figure 2C).
4. The Summer RV Survey index is unavailable.

Additional indicators for annual evaluation were also identified at the framework and include:

5. The observed DFO survey index is outside the 80% prediction intervals in the same direction for two consecutive years (Figure 2B).
6. Changes in observed DFO survey WAA to assumed projected WAA (Table 2).
7. Confirm landings do not exceed TAC (Figure 1A).
8. Compare relative harvest rate by region to the proxy for F_{lim} (Figure 2D).

A review of available data determined that no exceptional circumstances have occurred, so a higher-level review has not been triggered for 2025.

PROCEDURE FOR INTERIM YEAR UPDATES

The selected MP was based on annual advice. During MP simulation testing, providing two-year advice was also considered. It resulted in more conservative catch advice to account for high variability in the annual survey index. Since the survey index can vary significantly each year, it was recommended to update the MP annually. Specific actions to be taken when exceptional circumstances are triggered are provided; however, each situation will be evaluated on a case by case basis (Barrett et al. In Press). If no exceptional circumstances are triggered, the MP would be evaluated at the next framework review.

SOURCES OF UNCERTAINTY

The stock origin of catches in the south of 4Xp remains uncertain. Exploration during the data inputs meeting suggested that catches from 4Xp are likely from the eastern Georges Bank stock based on similarities in length frequencies, length-at-age from the survey, and the presence of large cohorts in the fishery not seen in the survey. Haddock movement across stock boundaries remains unknown.

The new models are designed to capture uncertainties in natural mortality and fishery selectivity. Elevated M values linked with density dependence were addressed using a time-varying M in Models 1 and 2 and through incorporating process error on numbers-at-age in Model 3. Changes in fishery selectivity are captured by estimating annual selectivity for Models 1 and 3 and with the addition of process error on fishery selectivity parameters in Model 2.

Uncertainty in future stock dynamics of recruitment was addressed in the projections using two sets of models: one assumed average recruitment and the other mimicked a large recruitment event consistent with 2013. The performance of MPs was evaluated for both recruitment scenarios.

Research Recommendations

Tagging studies suggest that mixing occurs among Haddock stocks in 4X5Y and neighboring stocks on Scotian Shelf, Georges Bank, and the Gulf of Maine. Genetic studies on stock structure are limited for Haddock and could help explain observed differences in growth among populations, and to estimate the amount of movement across stock boundaries.

Higher natural mortality, reduced growth, and poor condition of Haddock in recent years have been attributed to higher densities, but even with the large reduction of the 2013 cohort from the population, these patterns persist. Ecosystem changes, alongside density dependence, could be a contributing factor. Examining shifts in ecosystem indicators, and prey composition and availability, may help explain these patterns. Haddock are known to change their spatial distribution based on temperature; the comparison of tow level survey abundance relative to bottom temperature data may better inform these shifts in distribution.

The small fish protocol management measure was developed in 1994; however, a thorough scientific review of the size of small fish for Haddock and the appropriate proportions allowed by trip has not occurred since its implementation. For the 4X5Y Haddock stock, recent maturity data for the stock area are limited based on the coverage of the DFO Winter Ecosystem Research Vessel Survey, which is the only source of information during the spawning season. A targeted collection of maturity data would assist with both the review of the definition of small fish and the assumed inputs in the model.

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