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Canadian Science Advisory Secretariat
Newfoundland and Labrador Region | Science Advisory Report 2025/043

NAFO DIVISIONS 2J3KL NORTHERN COD (*GADUS MORHUA*) STOCK ASSESSMENT TO 2025

CONTEXT

The Fisheries Management Branch of Fisheries and Oceans Canada (DFO) has requested that the Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL Atlantic Cod stock (Integrated Fisheries Management Plan; IFMP) be assessed relative to reference points that are consistent with the DFO Precautionary Approach (PA) and that harvest advice be provided for this stock. This Science Advisory Report is from the regional peer review of March 24–27, 2025 Stock Assessment of Northern Cod in 2J3KL. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SCIENCE ADVICE

Status

- The 2025 Spawning Stock Biomass (SSB) is 2.0 (95% Confidence Interval [CI] = 1.2–3.3) times the Limit Reference Point (LRP). The probability that the stock is above the Critical Zone is greater than 99%.
- Retrospective analyses identified that the assessment model underestimates SSB and overestimates the LRP, leading to underestimation of relative stock size (SSB/LRP). While these patterns suggest issues with the accuracy of absolute estimates, they have not affected interpretation of stock trajectory or status.

Trends

- SSB has changed little following a period of growth from 2010 to 2016. SSB in 2025 is estimated at 524 Kt (95% CI = 404–678 Kt).
- Estimated numbers of recruits (age 0) has changed little since 2015, corresponding to about 90% of pre-collapse (1954–90) levels.
- Natural mortality (M, ages 5+) has varied between 0.28 and 0.89 since 1995 (mean = 0.47) and in 2024 was 0.32 (95% CI = 0.17–0.59).
- Fishing mortality (F, ages 5+) has been below 0.05 since 2004 and in 2024 was 0.020 (95% CI = 0.016–0.026).

Ecosystem and Climate Change Considerations

- The ongoing warm phase in ocean climate that started around 2020, along with recent improvements in zooplankton biomass levels, are currently favourable for groundfish productivity. However, long term impacts of increasing warming due to climate change are unknown.

- Total biomass level of the fish community shows improvements from the lows in the mid-late 2010s and is currently at or near post-collapse highs, but remains below pre-collapse levels. These increases are linked primarily to groundfish.
- Northern cod productivity is linked to Capelin availability. Capelin collapsed in 1991 and has yet to recover. Capelin biomass was at near post-collapse highs in 2024, but it is forecast to decline in 2025. Under these conditions, the scope for growth for Northern cod in the near future appears limited.

Stock Advice

- SSB projections to 2028 with zero to two times total authorized removals for 2024 of 21,317 t show the probability of the stock declining into the Critical Zone increases from 15% with zero removals to 27% if removals are doubled.
- With total removal levels examined here (0 to 42,634 t) the risk of stock decline from 2025 to 2028 is moderate to moderately high, ranging from 56% to 71%. There is no level of removals that gives a high (≥75%) probability of stock growth.
- Under current ecosystem conditions and total removals the stock has not grown since 2017 and short-term prospects for stock growth are limited even under zero removals.

BASIS FOR ASSESSMENT

Assessment Details

Year Assessment Approach was Approved

2023 (DFO 2024a)

Assessment Type

Full Assessment

Most Recent Assessment Date

1. Last Full Assessment: 2024 (DFO 2024b)
2. Last Interim-Year Update: 2020 (DFO 2021)

Assessment Approach

1. Broad category: Ecosystem-informed stock assessment model
2. Specific category: State-space age-structured assessment model with Capelin-informed mortality rates

The assessment model estimates stock size back to 1954, a stock-recruit relationship, and time-varying rates of fishing mortality (F) and natural mortality (M). The model also accounts for bias introduced by partial reporting of total removals from all sources. Data for Capelin, a key prey species, are used to improve predictions of M and aid forecasts of cod productivity. The model is used to assess the impact of proposed fisheries catches under recent levels of Capelin availability.

Ecosystem and Climate Change Assessment Approach

Ocean climate conditions and trends were evaluated with indicators including water temperature, ice conditions, and the Newfoundland and Labrador Climate Index (NLCI). Lower

trophic levels were characterized using nutrients, chlorophyll, and zooplankton indicators from Atlantic Zone Monitoring Program (AZMP) surveys and remote sensing. The assessment also reviewed information on Capelin biomass, fish community status and trends including fish diets, consumption, predation mortality, the risk of ecosystem overfishing, and the role of marine mammals in the ecosystem. Cod productivity and biomass dynamics were examined in relation to likely drivers such as ocean climate, predation, and prey availability – specifically Capelin biomass, which is also used within the assessment model to inform estimates of M.

Stock Structure Assumption

Northern cod was first considered to occupy NAFO Div. 2+3KL (Templeman 1962); however, cod in NAFO Div. 2GH are managed separately from the 2J3KL stock complex (DFO 1996). Core areas of productivity and discrete components of the Northern cod stock complex are not well defined in 2J3KL. While there is likely some mixing of cod in adjacent areas, levels of mixing are assumed to be negligible and cod in NAFO Div. 2J3KL is managed collectively with one LRP.

Reference Points

1. Limit Reference Point (LRP): 40% spawning stock biomass at maximum sustainable yield (40% B_{MSY}; DFO 2024a)
2. Upper Stock Reference (USR): N/A; not defined
3. Removal Reference (RR): N/A; not defined
4. Target Reference Point (TRP): N/A; not defined

The LRP was defined in accordance with PA guidelines (DFO 2009). An USR, RR, and TRP have yet to be defined for this stock. These reference points are to be developed by Fisheries Management in consultation with fishery and other interests, with advice and input from DFO Science.

Data

- Multispecies research vessel trawl surveys (1983–2003, 2005–20, 2023–24)*
- Inshore sentinel survey (1995–2024)*
- Acoustic estimates of cod biomass in Smith Sound (1995, 1997–2004, 2006–09)*
- Inshore juvenile indices from the Fleming (1959–64, 1992–97, 2001, 2020–21, 2024) and Newman Sound surveys (1996, 1998–2024)*
- Fishery landings and catch age composition (1954–2024)*
- Tagging information (1954–2024)*
- DFO Capelin acoustic survey and forecast (1985–92, 1996, 1999–2005, 2007–15, 2017–19, 2022–25)*
- DFO-NL Ecosystem Research Program Indicators (1960–2024)
- AZMP Indicators (1950–2024)
- NASA Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua Ocean Color observation (2003–24)

* data used directly in the assessment model.

ASSESSMENT

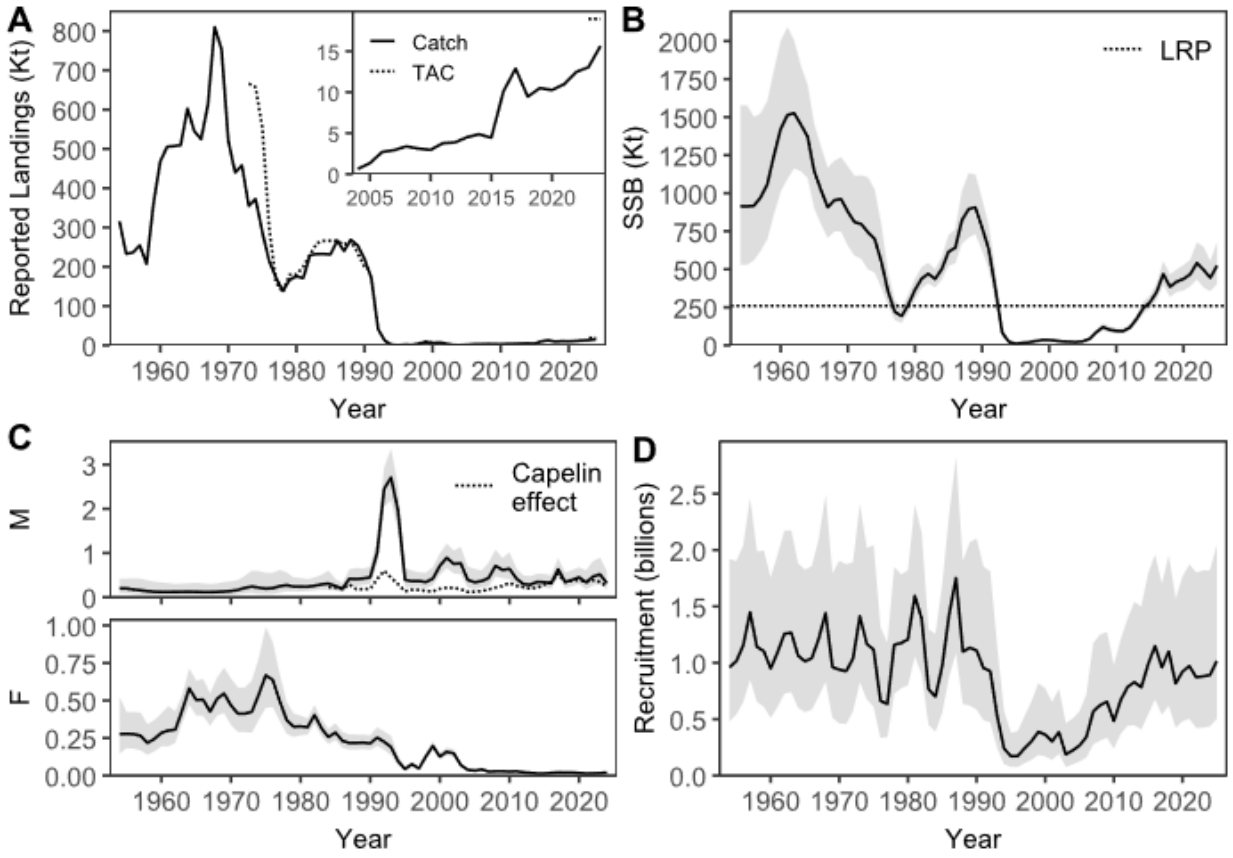

Figure 1. A) Annual reported landings (solid line) and Total Allowable Catch (TAC; dashed line), with inset showing landings and TAC since 2004. B) Estimates of SSB (black line = median estimate; grey area = 95% confidence interval) relative to the LRP (dashed line). C) Average Natural mortality (M; Top) including the effect of Capelin availability (dotted line), and Fishing mortality (F; Bottom) estimates for ages 5+ with 95% confidence intervals (grey area). D) Estimated recruitment (median estimate of age 0 abundance, with 95% confidence interval [grey area]).

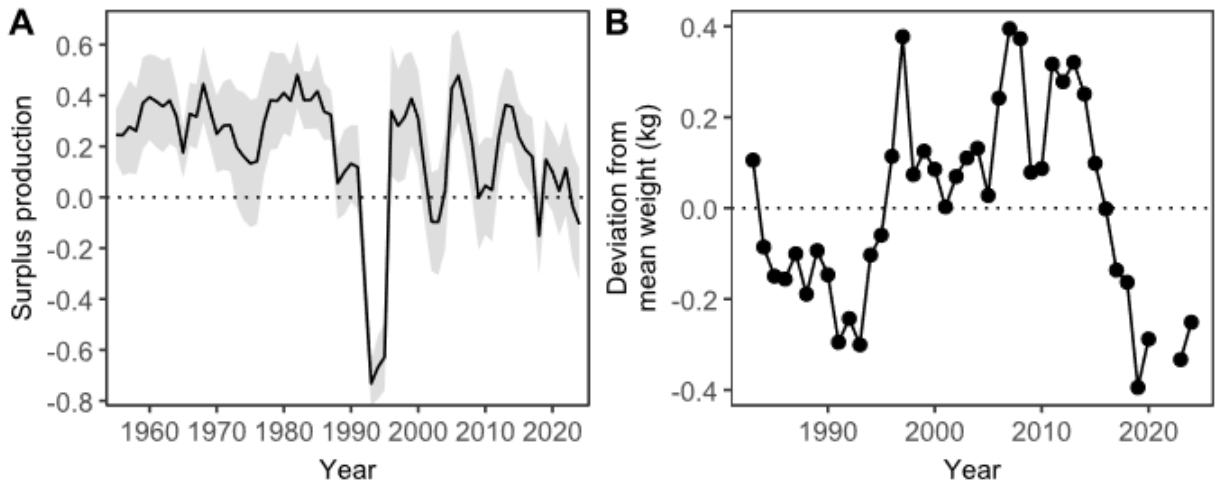

Figure 2. A) Model-estimated annual surplus production – a measure of population growth rate (grey area = 95% confidence interval). B) Average deviation from mean weight-at-age for ages 3–7 from the fall multispecies bottom-trawl survey.

Stock Status and Trends

Table 1. Northern cod SSB, recruitment, and mortality rate estimates over the last five years. Lower and upper 95% confidence intervals indicated in parentheses. Dashes (-) indicate estimate is not yet possible for this year.

Year	SSB (kt)	SSB / LRP	Recruits (age 0; millions)	Average M (ages 5+)	Average F (ages 5+)
2021	467 (388, 561)	1.80 (1.12, 2.89)	971 (504, 1,871)	0.33 (0.18, 0.61)	0.013 (0.010, 0.018)
2022	541 (433, 677)	2.08 (1.29, 3.38)	872 (422, 1,802)	0.47 (0.27, 0.81)	0.014 (0.011, 0.019)
2023	496 (380, 648)	1.91 (1.16, 3.16)	880 (426, 1,819)	0.52 (0.30, 0.90)	0.016 (0.012, 0.020)
2024	444 (356, 553)	1.71 (1.05, 2.78)	891 (436, 1,821)	0.32 (0.17, 0.59)	0.020 (0.016, 0.026)
2025	524 (404, 678)	2.02 (1.23, 3.31)	1,016 (505, 2,043)	-	-

Spawning Stock Biomass

Estimates of SSB increased from the mid-1950s to the early 1960s, after which the stock declined through to the late 1970s. Following a recovery of the stock through the 1980s, SSB rapidly declined in the early 1990s to a time-series low in 1995. SSB remained low through the 1990s, but subsequently increased, especially from 2010–16. SSB has not grown since then, and levels in 2025 [524 Kt (95% Confidence Interval [CI] = 404–678 Kt); Table 1] remain similar to that of 2017 (Figure 1B).

Recruitment

Recruitment (numbers at age 0) declined to its lowest observed level around 1995, but has shown an increasing trend since the mid-2000s. The average number of recruits since 2015 correspond to about 90% of the average numbers of recruits observed prior to 1990 (Figure 1D).

Natural Mortality

Population-weighted average M (ages 5+) increased rapidly in the early 1990s from levels below 0.4 to a peak of 2.5 around 1992–94. Average M declined in 1995 and has since varied between 0.28 and 0.89 (mean = 0.47). In 2024, M was below average [0.32 (95% CI = 0.17–

0.59)]. Periods of elevated M correspond to declines in the relative abundance of Capelin (Figure 1C). There has been insufficient levels of Capelin since 2017 to support growth in the Northern cod population.

Fishing Mortality

Population weighted average F (ages 5+) exceeded M through most of the 1950s to the 1980s; however, M has exceeded F since the collapse. Average F declined when the moratorium was imposed in 1992 and again when an inshore fishery was closed in 2003. While directed inshore fisheries for cod have continued through the moratorium, average F has remained below 0.05. In 2024 average F is estimated at 0.020 (95% CI = 0.016–0.026; Figure 1C).

Surplus Production

Prior to the collapse, surplus production – the surplus biomass generated by the stock (through growth and recruitment) beyond what is necessary to keep the overall stock biomass constant – remained positive. Following a large decline in surplus production between 1991–95, associated with the collapse of this stock, variability has increased and several periods of positive surplus production have contributed to stock growth. Surplus production has been near or below zero since 2018 (Figure 2A), reflecting limited productivity and suggesting that conditions have not been favourable for further stock growth.

Biological Indicators

Mean lengths and weights at age, body condition in spring, and age of maturation all declined during the collapse. Following improvements since 2020, body condition is currently near seasonal averages. However, mean lengths and weights-at-age (Figure 2B) have declined across all divisions since 2015, especially for ages 3+. Since cod are smaller at age recently, a higher number of fish are removed from the system by any given removal weight.

Current Outlook

The 2025 SSB is 2.0 (95% CI = 1.2–3.3) times the LRP. There is less than a 1% chance that the stock is in the Critical Zone.

History of Landings & TAC

Table 2. Reported catch, including bycatch, of Northern cod by NAFO Div. and calendar year (t). Provisional catches for current year.

Division	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
2J	139	214	313	281	444	1,129	1,314	1,836	2,467	3,032
3K	2,256	5,273	6,335	4,430	4,819	3,767	4,387	5,497	5,598	6,196
3L	2,041	4,618	6,232	4,744	5,241	5,364	5,276	5,143	4,980	6,433
Total	4,436	10,105	12,881	9,456	10,503	10,260	10,977	12,475	13,045	15,661

Northern cod once supported one of the largest fisheries in the world, with catches peaking at 810 Kt in 1968 (Figure 1A). The fishery declined through the 1970s, briefly recovered in the 1980s, and collapsed in the 1990s. A moratorium was established in 1992, during which limited inshore fisheries continued to operate in most years. The moratorium was lifted in 2024 following a stock status change from Critical to Cautious, based on a revised assessment framework and LRP. The commercial fishery reopened in 2024 with a Total Allowable Catch (TAC) of 18,947 t. Reported catch, including bycatch, of Northern cod are shown in Table 2.

Northern cod is also the primary species targeted in the recreational groundfish fishery in NL. There is no direct measure of landings from the recreational fishery and these removals are not included in reported catch above. Recreational catch of Northern cod was estimated based on mark-recapture tag returns, averaging 1,864 since 2006, and in 2024 was estimated to be 2,697 t (95% CI = 1,653–4,110 t).

Ecosystem and Climate Change Considerations

The ocean climate in the NL bioregion shows multi-year to decadal scale cold and warm phases. The warm phase that started around 2020 continues, with record high sea surface temperatures in 2024. There has been a shift towards earlier spring phytoplankton blooms since 2020, which favours recruitment of the copepod *Calanus finmarchicus*, a key food item for many fish. Total zooplankton biomass has been improving since the lows in the early-mid 2010s. These conditions are generally favourable for groundfish production, but long term impacts of increased warming due to climate change remain unknown.

NL marine ecosystems collapsed in the late 1980s and early 1990s associated with extreme cold ocean conditions and ecosystem overfishing. Declines in biomass of groundfish and Capelin were not offset by increases in shellfish, with total biomass remaining below pre-collapse levels.

While these ecosystems continue experiencing overall low productivity compared to the pre-collapse period – likely related to bottom-up processes (e.g. food limitation) – increases have been observed since the collapse with those since 2020 linked primarily to groundfish.

Capelin are a major driver of Northern cod biomass dynamics and productivity. Increases in relative availability of Capelin to cod are linked to reductions in M for cod in the assessment model, and subsequent increases in the cod stock. The proportion of M attributed to Capelin is a major component in recent years, suggesting that relative Capelin availability is limiting cod growth. Capelin biomass has increased from late 2010s levels, and was near post-collapse highs in 2024. However, Capelin biomass is forecast to decline to post-collapse average levels in 2025, which is expected to reduce cod productivity. Consumption of cod by fish predators (including cannibalism) appears comparable to pre-collapse levels which could also be limiting cod growth. Under these conditions, the scope for growth in cod biomass in the near future appears limited. While Harp Seal consumption and its effect on cod remains under investigation, current evidence suggests it is not a major driver of cod biomass dynamics.

Projections

Projections assume terminal year selectivity, average mean weight and proportion mature at age over 2022–24 and average levels of Capelin[1] over 2023–25. The stock was projected to 2028 under catch scenarios from 0 (no fishing), 0.5, 1 (status quo), 1.5, and 2 times authorized removals for 2024 (21,317 t), where authorized removals includes cod removals from all sources, including commercial catch (directed and bycatch), the NL recreational groundfish fishery, Sentinel fishery, and Food, Social and Ceremonial fisheries.

These projections indicated moderate to moderately high probabilities of decline (56–71%) over the next three years (Table 3), though remaining near levels observed since 2017. Across all removal scenarios, probabilities of being in the Critical Zone by 2028 are low to moderate,

[1] DFO. In prep. Assessment of Divisions 2J+3KL Capelin to 2025. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.

ranging from 15-27%. Under status quo removals (~21,317 t), spawning stock biomass relative to the LRP is projected to be 1.62 (95% CI = 0.52–5.03) by 2028 (Figure 3).

Table 3. Probability of SSB declining from 2025 levels and SSB being in the Critical Zone at various catch multipliers over a three year projection period.

Catch multiplier	Catch (t)	Prob. decline 2026	Prob. decline 2027	Prob. decline 2028	Prob. SSB<LRP 2026	Prob. SSB<LRP 2027	Prob. SSB<LRP 2028
0	0	56%	57%	59%	2%	8%	15%
0.5	10658	59%	61%	62%	3%	9%	17%
1	21317	63%	64%	65%	3%	11%	20%
1.5	31976	66%	68%	68%	4%	13%	23%
2	42634	70%	71%	71%	4%	15%	27%

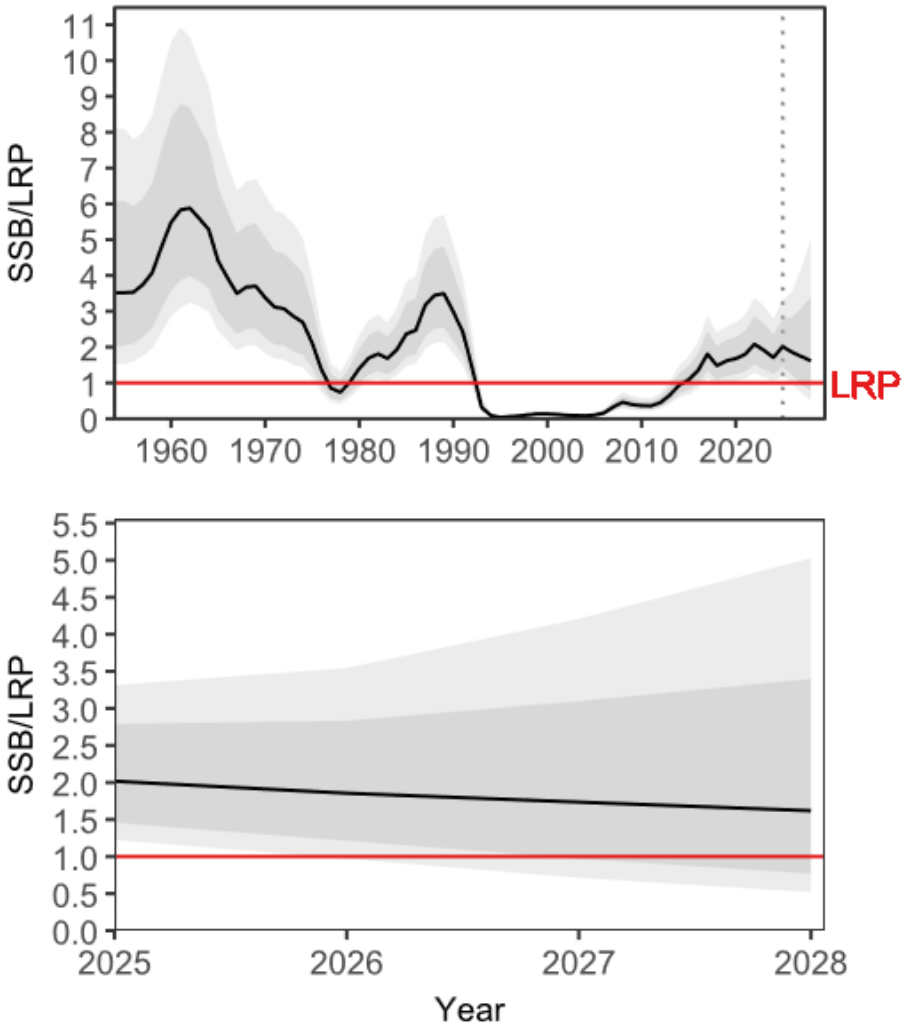

Figure 3. Projected relative SSB (SSB/LRP) assuming status quo levels of Capelin and catch, where LRP (horizontal solid red line) is defined as 40% of BMSY. Solid black line is the model estimate and the grey and dark grey shaded region are 95% and 80% CIs, respectively. The dotted vertical line in the top panel indicates the beginning of the projection period, which is the focal period of the lower panel.

SOURCES OF UNCERTAINTY

M plays an important role in model projections for this stock and the drivers contributing to large changes in M are not fully understood. The inclusion of Capelin in the model addresses one of the major drivers of cod dynamics within the ecosystem, but does not fully resolve the uncertainties around M, nor does it account for uncertainty with regards to future levels of Capelin. Consequently, projections carry considerable uncertainty and may be biased in either direction, reflecting incomplete understanding of the underlying drivers and the unpredictability of future ecosystem conditions.

Estimates of B_{MSY} are highly sensitive to M and the stock-recruitment relationship, both of which tend to shift as more data are added. These changes have contributed to downward revisions of B_{MSY} and, consequently, the LRP. As a result, SSB/LRP tends to increase with each assessment update, further inflated by concurrent upward revisions of SSB. While these retrospective patterns suggest potential issues with the accuracy of absolute estimates, they have not affected interpretation of stock trajectory or status.

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Centre for Science Advice (CSA)
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ISSN 1919-5087
ISBN 978-0-660-78436-6 Cat. No. Fs70-6/2025-043E-PDF

Correct Citation for this Publication:

DFO. 2025. NAFO Divisions 2J3KL Northern Cod (*Gadus morhua*) Stock Assessment to 2025. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2025/043.

Aussi disponible en français:

*MPO. 2025. Évaluation du stock de morue du Nord (*Gadus morhua*) dans les divisions 2J3KL de l'OPANO jusqu'en 2025. Secr. can. des avis sci. du MPO. Avis sci. 2025/043.*