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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/046

NORTHERN (2J3KL) ATLANTIC COD ASSESSMENT FRAMEWORK

*Image: Atlantic Cod (*Gadus morhua*).*

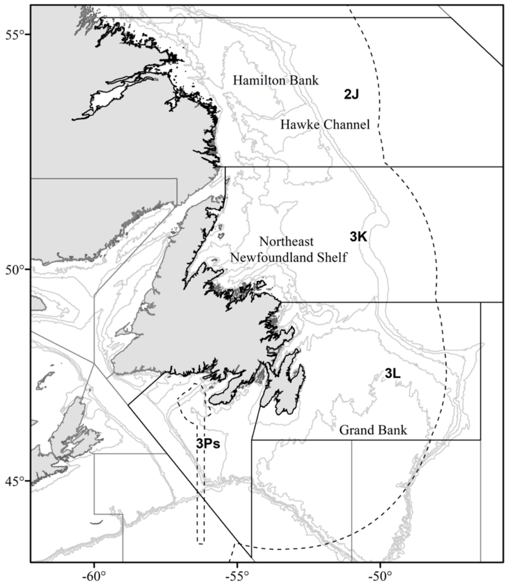

Figure 1. Stock area of Northern (2J3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ).

Context:

*The Atlantic Cod (*Gadus morhua*) stock inhabiting Northwest Atlantic Fisheries Organization (NAFO) Divisions (Div.) 2J3KL (Figure 1), commonly known as "Northern cod", once supported one of the largest fisheries in the world. However, this stock experienced a precipitous decline, dropping by over 90% in the early 1990s (COSEWIC 2003). Its historical significance has attracted substantial interest, prompting the establishment of multiple long-term monitoring programs. These initiatives have made Northern cod one of the most comprehensively studied and data-rich stock assessments globally.*

Since 2016, this stock has been assessed with an integrated state-space population model called the Northern cod assessment model (NCAM; Cadigan 2015; DFO 2016). This model utilizes information from offshore trawl surveys, inshore acoustic surveys, fishery catch-at-age compositions, partial fishery landings, and tagging projects. While these inputs constitute the majority of the available data for this stock, considerable historic data were not directly incorporated. Moreover, information from juvenile monitoring programs and the impacts of ecosystem effects such as prey availability have yet to be integrated. To bridge some of these gaps, a new framework process was carried out to review and implement revisions to the assessment approach for this stock.

This Science Advisory Report is from the October 16–20, 2023 regional peer review on Northern (2J3KL) Atlantic Cod Assessment Framework. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

August 2024

SUMMARY

- The assessment model for Atlantic Cod in Northwest Atlantic Fisheries Organization (NAFO) Divisions (Div.) 2J3KL was extended back to 1954 (previously starting in 1983) through the inclusion of additional tagging and landings data. This extended model has refined our understanding of past trends in the stock.
- Juvenile survey data from inshore monitoring programs were incorporated into the model which allowed for the implementation of a stock-recruitment relationship.
- New and prior research demonstrated that Capelin affect the dynamics of this cod stock. A Capelin index was included in the updated assessment model.
- The effects of Harp Seals on cod in Div. 2J3KL were investigated. However, a Harp Seal index could not be included in the current assessment model due to difficulty quantifying size-specific impacts and separating seal impacts from environmental effects.
- The Limit Reference Point (LRP) was updated following the significant model revisions and extension of the time series, and was set at 40% B_{MSY} (biomass at maximum sustainable yield) in accordance with Precautionary Approach (PA) guidelines. Under this new framework, the spawning stock biomass was estimated at 1.16 times the LRP in 2021, with a 29% probability of being below the LRP. Current stock status was not updated in this meeting.

INTRODUCTION

Since 2016, Atlantic Cod (*Gadus morhua*) in NAFO Div. 2J3KL has been assessed with an integrated state-space population model, called the Northern cod assessment model (NCAM; Cadigan 2015; DFO 2016). As of the last assessment (DFO 2022a), NCAM included data from the offshore research vessel (RV) fall multispecies trawl survey (1983–2020), sentinel fishery survey (1995–2020), Smith Sound acoustic survey (1995–2009), tagging program (1983–2020), and commercial fisheries (reported landings and catch-at-age; 1983–2020). By utilizing diverse data, NCAM addresses complex challenges, notably the estimation of annual natural and fishing mortality (M and F, respectively) and the correction of biases introduced by partial reporting of fisheries landings. The primary objective of NCAM was to enhance stock projections and assess the impacts of proposed fishery catches.

What was missing from the NCAM-based assessment was a longer-term perspective on the history and dynamics of the stock, since data prior to 1983 were not included. This limitation not only hindered our understanding of changes in stock productivity but also complicated the examination of reference points, prompting efforts to extend the model back to 1954. Key data sources enabling this extension included existing time-series data on reported landings and catch-at-age, as well as data from the tagging program spanning various years (1954–55, 1962–66, and 1978–96).

Further changes to the assessment approach were driven by results from ongoing research programs. First, continued work on two juvenile cod monitoring programs, the Fleming and Newman Sound surveys, suggests that these data may prove useful for informing trends in recruitment (Lunzmann-Cooke et al. 2021; Lewis et al. 2022). Second, recent studies on the impact of Capelin (*Mallotus villosus*) on the productivity of Northern cod support repeated calls to integrate the effects of this key prey species into the assessment (Koen-Alonso et al. 2021; Regular et al. 2022). Finally, uncertainties surrounding the specific impact of Harp Seals (*Pagophilus groenlandicus*), hereafter referred to as seals, on cod underscore the need for considering these impacts in an assessment context. Therefore, the assessment model was extended to incorporate the juvenile survey data and attempt to estimate the effects of Capelin and seals on the stock.

These extensions facilitated a more comprehensive exploration of the historic dynamics and productivity of Northern cod, and enhanced our understanding of the relationship between stock size and recruitment. Attempts to integrate the impact of Capelin and seals on cod represented a step towards an ecosystem approach to fisheries management for this stock (Pepin et al. 2023). Finally, the extended modeling framework provided an opportunity to revisit the LRP for Northern cod. The overarching goal of the new framework was to improve our understanding of historical trends, enhance our projections of future trends, and ultimately, produce more robust scientific advice.

ANALYSIS

Extensions of the Assessment Model

A series of stepwise changes were implemented to augment the base case NCAM (formulation accepted at the last framework; DFO 2016), which served as the foundation of the extended assessment model, xteNCAM. The core structure of NCAM was described in Cadigan (2015, 2016), and the details of its extensions will be presented in Regular et al. (in prep[1,2]). Broadly, the objective of each step was to:

1. improve the fit of the model to catch composition data,
2. minimize conflicts between survey indices,
3. extend the time series back to 1954,
4. integrate data from juvenile cod coastal monitoring programs,
5. implement a stock-recruitment relationship and calculate per-recruit reference points,
6. estimate baseline levels of natural mortality (M), and
7. quantify the effects of Capelin and seals on the cod stock.

Most of these objectives were listed as research recommendations from preceding Canadian Science Advisory Secretariat (CSAS) processes for Northern cod (e.g., DFO 2019, 2023a).

Changes made for steps 1 and 2 represent an attempt to improve the fit of the model to catch-at-age data, and, the RV and sentinel survey data, respectively. With regards to step 1, base case NCAM utilized an *ad hoc* adjustment of the standard deviations of the catch composition. We replaced the *ad hoc* adjustment with independent estimation of standard deviation for ages ≤2, 3–4, and ≥5. This change resulted in minor improvements to the diagnostics, prompting its retention in step 2.

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[1] Regular, P.M., Robertson, G.J., Kumar, R., Varkey, D.A., Gregory, R.S., Lewis, R.S., Skanes, K., Gullage, N., Koen-Alonso, M., and Dwyer, K.S. In Prep. Extending the Northern Cod (*Gadus morhua*) Assessment Model. Part I: Bridging Gaps with Additional Data and Model Variations. DFO Can. Sci. Advis. Sec. Res. Doc.

[2] Regular, P.M., Kumar, R., Varkey, D.A., Koen-Alonso, M., and Stenson, G.B. In Prep. Extending the Northern Cod (*Gadus morhua*) Assessment Model. Part II: Quantifying the Impact of Capelin and Seals. DFO Can. Sci. Advis. Sec. Res. Doc.

In step 2, we aimed to resolve conflicting trends between the inshore sentinel and offshore RV surveys. The application of a more flexible 2D autoregressive process for catchability resolved the conflicting patterns, as did the exclusion of the sentinel index from the model. Though the more flexible catchability formulation resolves the conflicting patterns by effectively reducing the influence of the sentinel index in the model, this formulation was kept through subsequent steps to retain information from the inshore in the model. Its retention may prove useful, especially if the trends in the sentinel index complements information from the offshore.

Step 3 involved the integration of previously unused data into the model. Two key data sources enabled the extension of the time series from 1983 back to 1954: the existing time series of reported landings and catch-at-age, and data from the tagging program. Reported landings and catch-at-age data back to 1962 have been used in previous assessments of Northern cod, but were excluded when the assessment transitioned to a survey-based model and then to NCAM (Brattey et al. 2018). Reported landings back to 1954 and catch-at-age data back to 1962 were integrated into the model in step 3 and these data were paired with tagging data from the 1954–55, 1962–66, and 1978–96 campaigns (Taggart et al. 1995). Changes made in this step enabled the first age-structured reconstruction of the stock back to 1954. The addition of data from the spring survey of 3L was considered as it extends back to 1971 but it was not adopted since partial coverage of the whole stock area complicated the addition of these data.

Step 4 also involved the integration of previously unused data into the model. Data from two juvenile cod monitoring programs, the Fleming (1959–1964, 1992–97, 2020; Lewis et al. 2022) and Newman Sound (1996, 1998–2020; Gregory et al. 2019) surveys, were integrated into the extended model. These programs contributed data covering age 0 and 1 cod, providing critical information on juvenile cod dynamics. Catchability was assumed to be constant across surveys and time since similar methods are used in both programs. The integration of juvenile survey data, in addition to the time series extension from step 3, enabled explorations of stock-recruitment relationships in step 4.

All versions of the model prior to step 4 assume that recruitment follows a random walk with a break point at 1992 (i.e., the approach used in base case NCAM; Cadigan 2016). This assumption was considered a provisional measure until additional data became available to reliably estimate a stock-recruitment relationship (N. Cadigan, personal communication). The abovementioned extensions allowed the internal estimation of three stock-recruitment relationships in step 5: linear, Beverton-Holt (Beverton and Holt 1957), and sigmoidal Beverton-Holt (Myers et al. 1995). Despite indications from previous research that the relationship between stock size and recruitment is linear (Rose and Rowe 2022), the Beverton-Holt curves were more supported by data, both of which assume an asymptotic relationship. There was also limited evidence for depensatory effects in the sigmoidal Beverton-Holt relationship (i.e., there was no clear point below which rates of recruitment were impaired), which contrasts with the neighboring stock of cod in NAFO Subdivision 3Ps (Perälä et al. 2022; Varkey et al. 2022). The standard formulation of the Beverton-Holt curve was therefore accepted as a plausible description of the relationship between stock size and recruitment. This change also enabled the internal estimation of reference points such as Spawning Stock Biomass (SSB) at maximum sustainable yield, B_{MSY} (Albertsen and Trijoulet 2020), which served as a basis for an updated LRP for Northern cod in step 5 (see the Limit Reference Point section for details).

In step 6, alternative approaches to estimating baseline rates of M were considered. Prior to this step, the default approach was to assume the “M-shift” values utilized in base case NCAM. This M-shift formulation was built to capture large shifts in M using the available knowledge on the stock and its dynamics, and establishes fixed values of M with a range of 0.36–0.43 through pre-collapse (pre-1991) and post-collapse (post-1994) periods, and a large spike through the collapse years (1991–94) with values exceeding 2.0 for most ages (Brattey et al. 2018). In step 6, rather than using *a priori* fixed values, three approaches to estimating baseline M were considered: constant across ages and years, allometric (i.e., decrease as size increases; Lorenzen 2022), or “M-shift 2” which assumes constant M for the same time periods as the M-shift base case NCAM formulation, but instead of using fixed values, the Ms for these periods were estimated. These three approaches were utilized in step 7.

The final step 7 represented attempts to explain changes in M by estimating the impacts of Capelin and seals on the stock within the general xteNCAM framework. Capelin availability was expected to have a bottom-up effect on cod by affecting rates of starvation mortality (Regular et al. 2022). Acoustic estimates of Capelin (DFO 2022b) were therefore used to predict changes in M of cod across ages 2–14 (age-invariant) or across age blocks (2–3, 4–8, 9+), as dependence on Capelin may vary by size/age. In contrast, seals were expected to have a top-down effect on cod, affecting rates of predation mortality. Two model formulations were used to estimate the effect of seals; one using estimates of consumption of cod by seals, as well as age composition of cod consumed derived from otoliths in seal diet samples, and another using estimates of seal abundance (Tinker et al. 2023) to predict changes in M of cod across age blocks (0–3, 4–8).

Capelin availability proved useful for explaining variations in M (see the Impact of Capelin section for details). Among the various formulations including Capelin, the model that utilized constant baseline M from step 6 and an age-invariant Capelin effect was selected as the preferred formulation. This selection was based on its relative simplicity and equivalent capacity to explain the changes in the stock. The more simplistic constant baseline M assumption was chosen over the allometric effect as there was insufficient data to capture decreases in M across ages, while the “M-shift 2” formulation was discarded due to the inability to predict when or if a next shift in the series may occur.

In the case of seals, data uncertainties and the potential for confounding effects with environmental factors not included in the models prevented any clear conclusions on the effect of seals on cod (see the Impact of Seals section for details).

As a result of this entire process, the model that utilized constant baseline M from step 6 and an age-invariant Capelin effect was selected as the new assessment model, which is hereafter referred to as xteNCAM.

Historical Stock Dynamics

In line with previous assessments (Lilly 2008; Brattey et al. 2018), xteNCAM indicates that the stock declined through the 1960s and 1970s, partially recovered in the 1980s, severely declined in the early 1990s, and slowly increased over the last three decades (Figure 2). While stock size in the 1950s was previously thought to be on the same scale or larger than the 1960s (Rose 2004; Schijns et al. 2021), xteNCAM indicates that the stock increased from the mid-1950s to the 1960s, revealing historic dynamics that have previously gone unobserved. Comparing xteNCAM results to those from the last NCAM-based assessment (DFO 2022a), estimates of metrics such as recruitment to age 2, SSB, and average F and M for ages 5+ from 1980 onward were effectively the same (Figure 2). The key advantage of xteNCAM is that it provides a more comprehensive perspective on the history of the stock and its productivity. Specifically, the use of data back to 1954 as well as the integration of juvenile survey data proved to be useful for implementing a stock-recruitment relationship and re-evaluating the LRP for Northern cod (see the Limit Reference Point section). Additionally, the incorporation of Capelin into xteNCAM is expected to enhance stock projections by leveraging its predictive capacity for changes in M (see the Impact of Capelin section for details).

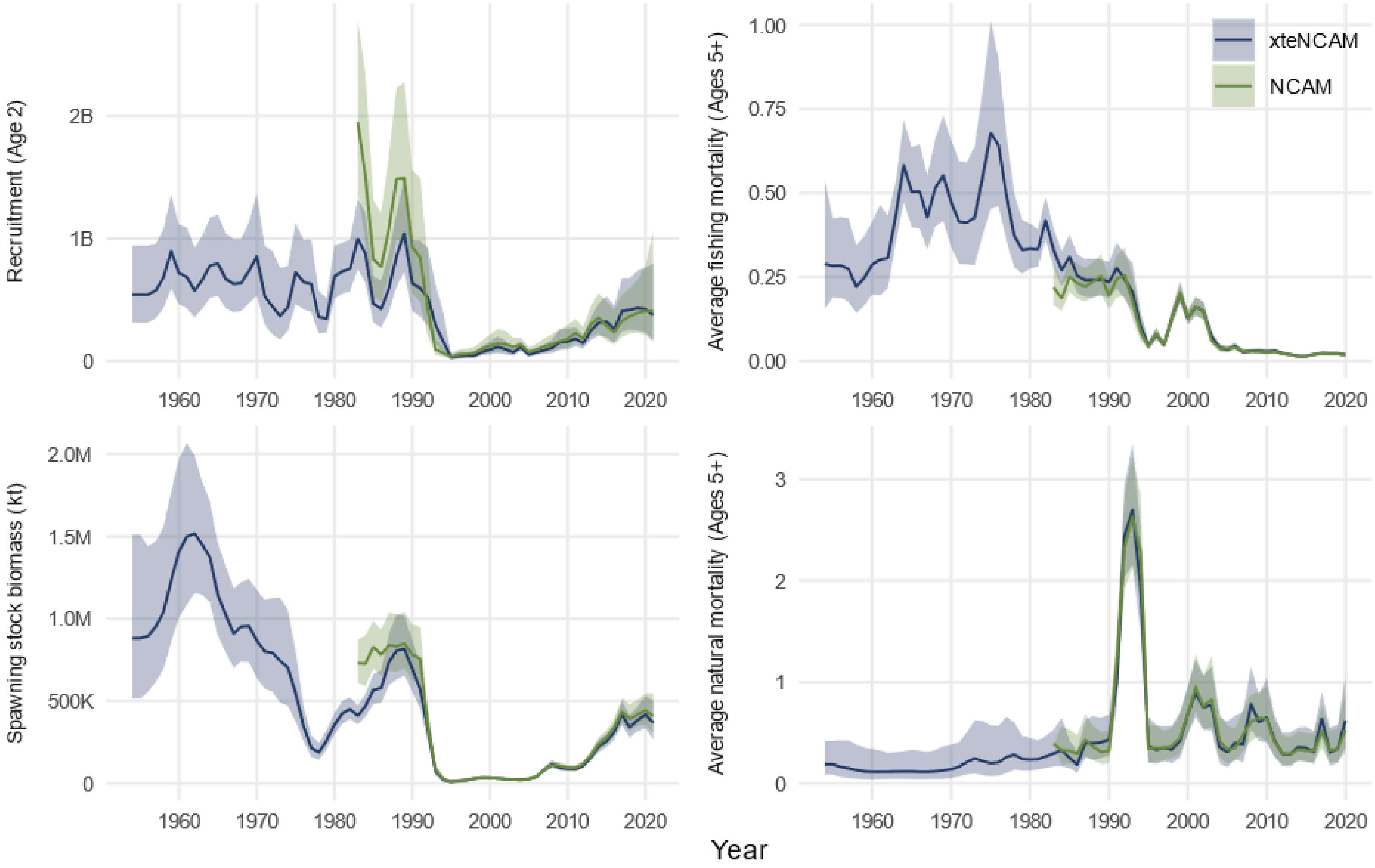

Figure 2. Trends in Northern cod recruitment to age 2 (top left), spawning stock biomass (bottom left), population weighted average fishing mortality (top right), and natural mortality (bottom right) for ages 5+ from the extended assessment model, xteNCAM (blue lines), and the previous assessment model, NCAM (green lines). Shaded regions represent 95% confidence intervals.

Impact of Capelin

Capelin have long been known to be an important prey species for Northern cod (Templeman 1965) and multiple studies have linked Capelin availability to changes in cod productivity (e.g., Rose and O'Driscoll 2002; Buren et al. 2014; Koen-Alonso et al. 2021; Regular et al. 2022). In short, the stock is expected to stagnate or decline when there are insufficient prey, particularly Capelin, available to cod, and starvation-induced mortality is thought to be a key mechanism affecting changes in productivity. These expectations were supported by an update of the capcod model, a bioenergetic-allometric model used to describe the biomass dynamics of cod (Koen-Alonso et al., in prep[3]), and by the accepted version of xteNCAM which includes Capelin availability as a predictor of M.

While Capelin-based predictions of M fail to capture the full extent of the changes in M estimated by xteNCAM, which is not surprising as one prey species is not expected to explain all changes in productivity, they do capture some of the increases and decreases in M that have been observed since 1984 – the year after which survey data were available for use as an explanatory variable (Figure 3). Since M is a key driver of Northern cod productivity, this represents an important advancement as it enhances our ability to explain past trends and forecast future trajectories.

One of the most challenging aspects of the assessment of Northern cod has been explaining the 1990s collapse and subsequent slow recovery. NCAM indicated that M was a key driver (Cadigan 2015); however, factors contributing to large changes in M remain elusive. Independent analyses have suggested that a large portion of what is estimated to be M by NCAM could actually be F stemming from unreported landings (Rose and Walters 2019), while another study indicated that a large portion could stem from starvation-induced mortality (Regular et al. 2022). Results from xteNCAM cannot be used to dismiss the possibility that a portion of M should actually be attributed to F, but it does indicate that Capelin availability contributed to changes in M. Indeed, the largest spike in Capelin-based predictions of M occurred in 1992, following the collapse of Capelin. Subsequent increases in M were also associated with changes in the availability of Capelin (Figure 3). These results are also consistent with those from the capcod model (Koen-Alonso et al. 2021, in prep[3]). That said, considerable unexplained variations in M remain and, as such, further research is needed to identify whether these changes are related to factors such as the availability of other prey species, ocean climate conditions, predation, and/or unreported landings.

An important improvement emerging from explaining changes in M using Capelin is that it provides an avenue to enhance projections of Northern cod. Previous NCAM-based assessments effectively used terminal estimates of M to forecast M. While this was a reasonable approach, forecasts may have been biased if key drivers of M increased or decreased over the projection window of one to two years. Given the explanatory power of Capelin, forecasts of future cod mortality and, consequently, stock size should be improved by utilizing short-term forecasts of Capelin (Lewis et al. 2019; DFO 2022b). These forecasts were not developed for the framework meeting, but they are in development for the March 2024 assessment of Northern cod.

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[3] Koen-Alonso, M., Munro, H., Deering, R., and Regular, P.M. In Prep. Revisiting the Role of Capelin and Harp Seals as Drivers of the Northern Cod Dynamics. DFO Can. Sci. Advis. Sec. Res. Doc.

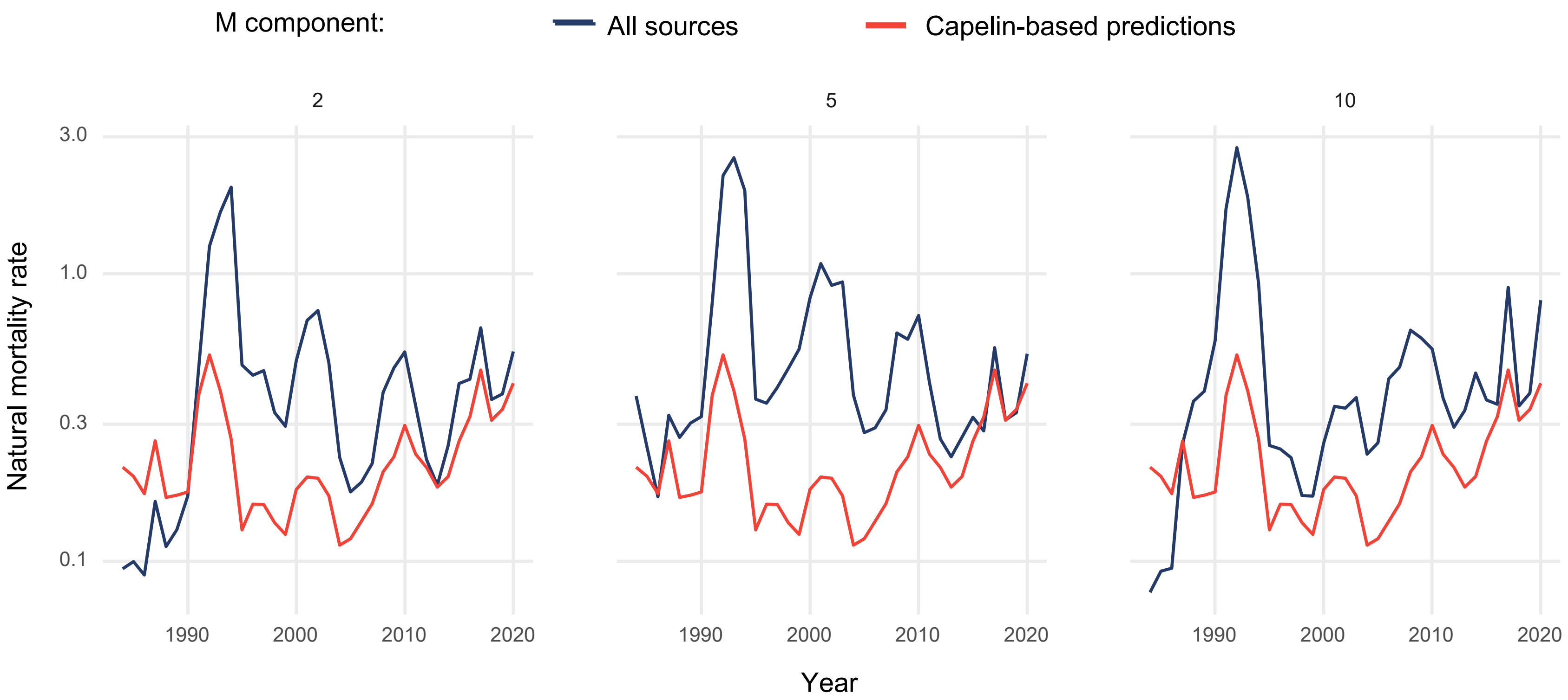

Figure 3. Natural mortality rates of Northern cod estimated by xteNCAM, displayed across key age groups (2, 5, and 10) from all available sources (blue lines), alongside the rates predicted using Capelin availability as the sole explanatory variable (red lines). The x-axis starts in 1984, the year after which survey data were available for use as an explanatory variable, while the y-axis is presented in log scale.

Impact of Seals

Previous research by Buren et al. (2014) concluded that harp seals are not a major driver of Northern cod biomass. This conclusion was re-examined at the Northern Cod Framework using the capcod model (Koen-Alonso et al. 2021; an update of the model used in Buren et al. 2014), alongside analyses of the fish community structure and consumption of cod by both seals and fishes, and the conclusions were consistent with previous results.

However, it was noted that the capcod model is focused on total biomass dynamics and may not detect an effect of seal consumption on juvenile cod which represent a relatively small fraction of the overall cod biomass. In an effort to quantify the impact of seal consumption by cod age group, two new approaches were presented for how seal data could be integrated into xteNCAM (Regular et al. in prep[2]). The first approach incorporates several data sources, including cod consumption by seals and age composition of consumed cod derived from otoliths in seal diet samples. The second approach used seal abundance from Tinker et al. (2023). Both indicated that seals may be an important driver for juvenile Northern cod. However, concerns were raised that the detected seal effect may be confounded with environmental drivers that were not explored in the model. For example, the predicted seal effect is correlated with the NL climate index (Cyr and Galbraith 2021). Additionally, uncertainties associated with the seal data inputs (e.g., age-composition data for cod in seal diets) could not be resolved in the meeting.

The framework concluded that a Harp Seal index could not be included in the current assessment model due to difficulty quantifying size-specific impacts and separating seal impacts from environmental effects. Research recommendations were made to facilitate progress on this question.

Limit Reference Point

Under the DFO Fishery Decision-Making Framework Incorporating the PA, a LRP is defined as the stock status below which serious harm is occurring to the stock (DFO 2009). Since 2010, the LRP for Northern cod has been defined as the average SSB from the 1980s as this was the last time medium levels of recruitment were observed (DFO 2011, 2023a). This definition was formally revisited using the Beverton-Holt stock-recruitment relationship by calculating the level of SSB that produces 50% of maximum predicted recruitment. A MSY based proxy, 40% B_{MSY}, was also considered, as were two empirical proxies (average SSB from the 1980s and the 1970s).

While the empirical proxies were considered useful for comparative purposes, the theoretical recruitment or MSY-based options were deemed more appropriate for this data-rich stock. Though conceptually consistent with the previous LRP, the level of SSB that produced 50% of maximum predicted recruitment was considered less comprehensive than the MSY-based option as it only accounts for one source of productivity, recruits-per-spawner. In contrast, the estimation of MSY requires an accounting of both recruits-per-spawner and spawners-per-recruit. However, a challenge arises in determining the timeframe over which to average time-varying metrics like fisheries selectivity and M. DFO PA suggests the use of the longest time series possible for the definition of reference points (DFO 2009), therefore, whole time-series averages were used. The 40% B_{MSY} proxy was then selected as the new LRP for Northern cod given its more inclusive accounting of productivity and its consistency with policy and guidance (DFO 2009, 2023b).

The revised assessment model and LRP placed the Northern cod stock within the PA Framework's Cautious Zone between 2016–21 (Figure 4). For 2021, SSB was evaluated to be 1.16 times the LRP and, accounting for statistical uncertainties, there was an estimated 29%

probability that the stock was in the Critical Zone. This contrasts with the last assessment of Northern cod which indicated that SSB was well within the Critical Zone, at 0.52 times the previous LRP (DFO 2022a). Notably, SSB estimates in 2021 from both the previous model (411 kt [95% CI = 307–549 kt]) and the revised model (368 kt [95% CI = 269–503 kt]) align closely. The change in relative stock status results from a downward revision of the LRP, not an increase in the quantity of cod estimated by the revised model. The upcoming assessment in March 2024 will evaluate whether Northern cod remains within the Cautious Zone. It is important to note that an Upper Stock Reference (USR), delineating the boundary between the Cautious and Healthy Zones, has yet to be established for this stock.

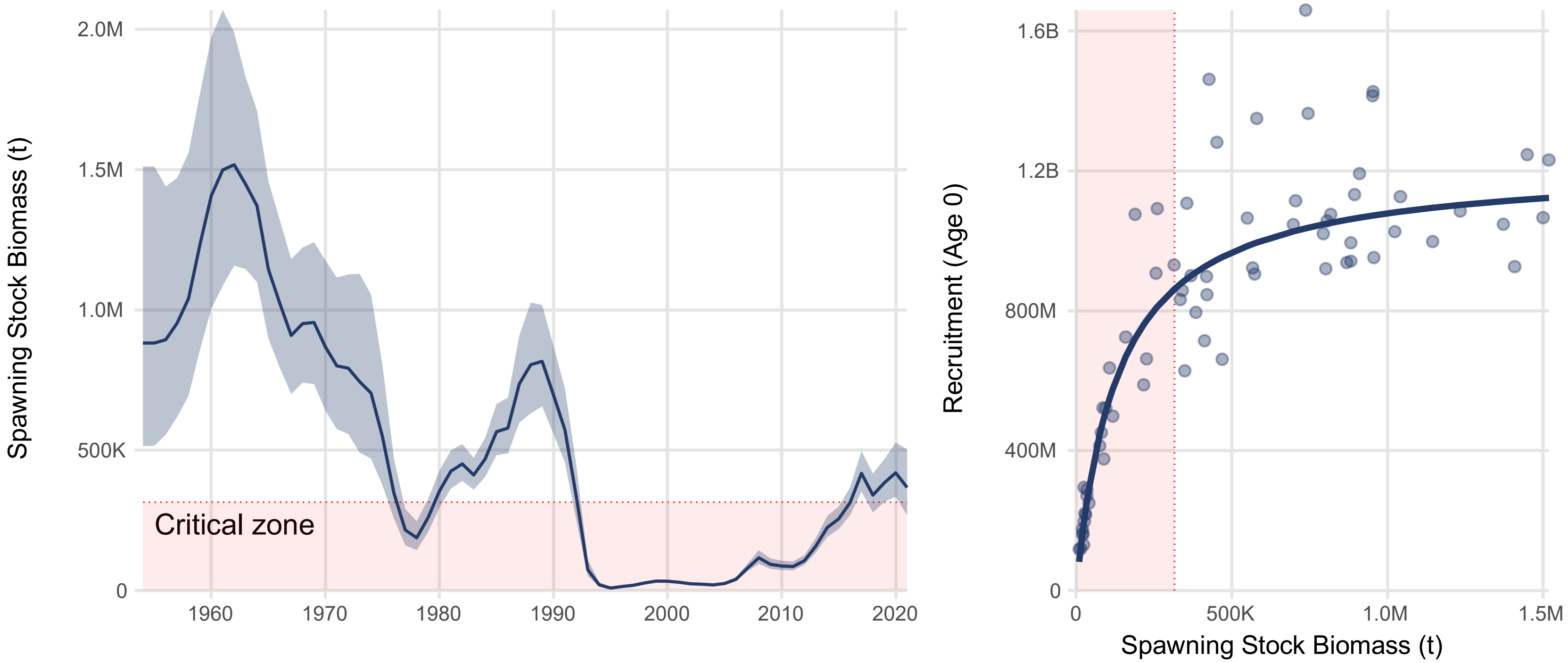

Figure 4. The left panel shows trends in spawning stock biomass from xteNCAM, where the blue shaded region represents 95% confidence intervals. The right panel shows the relationship between spawning stock biomass and recruitment to age 0 from xteNCAM, where the solid line indicates predicted levels of recruitment from a Beverton-Holt curve. The dotted red line in both panels represents the revised LRP.

Sources of Uncertainty

As noted during the March 2021 assessment, the sentinel and RV surveys showed different trends in recent years. Conflicting patterns were potentially related to differences in the frequency, catchability, or distribution of sentinel survey effort. While data from the sentinel survey remain within xteNCAM, they are treated differently than they were in NCAM to account for shifting catchability. Continued investigation was recommended into the sensitivity of the sentinel index to its design and implementation. Further investigations considering the application of acoustic telemetry and other data sources to estimation of cod availability to the sentinel index and other surveys may be beneficial.

The accuracy of the catch bounds used in the assessment model is uncertain. The likely range of catch (lower and upper bounds) incorporated in NCAM was determined during discussions that included stakeholders present at past assessment meetings. However, these previous discussions were in the context of an estimated range of catch for the post-1983 period and did not consider what an appropriate estimate of a range of catch might be for the pre-1983 period. The xteNCAM model used reported landings back to 1954 and the bounds were widened for years preceding 1977, when the 200-mile limit was introduced. While reported catches are likely more uncertain through this early period, the meeting noted that it may be useful to refine the catch bounds by reviewing past records and/or conducting interviews with fish harvesters and historians.

M plays an important role in projections for this stock and some factors contributing to large changes in M remain unexplained. The inclusion of Capelin in xteNCAM helps address some of this concern. The provisional inclusion of seals also improved the explanation of M; however, appropriate modeling of the impact of seals on cod remains unclear. Further, it is unknown how levels of nutrients and zooplankton impact higher trophic levels on the Newfoundland and Labrador Shelf and there is limited knowledge on long-term productivity trends.

The inclusion of juvenile cod survey data in xteNCAM provides valuable information on ages 0 to 1 cod, although there are some lingering questions on recruitment processes, linkages between inshore and offshore surveys, and catchability of cod during early life stages.

CONCLUSION

The assessment model for Northern cod underwent a substantive extension, now reaching back to 1954 compared to its previous starting point in 1983. This extension was achieved by integrating additional tagging and landings data, which bridged gaps in previous assessments of this stock. Additionally, the integration of juvenile survey data from two inshore monitoring programs enabled the implementation of a stock-recruitment relationship, providing valuable insights into the relationship between juvenile and adult cod.

The integration of Capelin data into the model represented another advancement. A novel approach was applied to use the Capelin survey index to predict changes in the rates of M, an important driver of changes in the stock. Simultaneously, investigations were carried out on the effects of seals on cod. However, due to challenges in accurately quantifying size-specific impacts and isolating seal predation effects from broader environmental factors, the inclusion of an explicit seal index in the current assessment model was unfeasible.

The abovementioned revisions provided an opportunity to revisit the LRP for Northern cod. In alignment with PA guidelines, the new LRP was established at 40% B_{MSY}. Under this revised framework, the spawning stock biomass in 2021 was estimated to be in the Cautious Zone at 1.16 times the LRP, with a 29% probability of being in the Critical Zone. However, it is important to note that the current stock status was not updated during this meeting. The upcoming assessment in March 2024 will evaluate whether Northern cod remains within the Cautious Zone.

LIST OF MEETING PARTICIPANTS

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SOURCES OF INFORMATION

This Science Advisory Report is from the October 16–20, 2023 regional peer review on Northern (2J3KL) Atlantic Cod Assessment Framework. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Brattey, J., Cadigan, N., Dwyer, K. S., Healey, B. P., Ings, D. W., Lee, E. M., Maddock Parsons, D., Morgan, M. J., Regular, P., Rideout, R. M. 2018. Assessment of the Northern Cod (*Gadus morhua*) stock in NAFO Divisions 2J3KL in 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/018. v + 107p.

Buren, A.D., Koen-Alonso, M., and Stenson, G.B. 2014. The role of harp seals, fisheries and food availability in driving the dynamics of northern cod. Mar. Ecol. Prog. Ser. 511(10): 265–284.

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E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-73037-0 N° cat. Fs70-6/2024-046E-PDF

Correct Citation for this Publication:

DFO. 2024. Northern (2J3KL) Atlantic Cod Assessment Framework. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/046.

Aussi disponible en français :

MPO. 2024. Cadre d’évaluation de la morue franche du Nord (2J3KL). Secr. can. des avis. sci. du MPO. Avis sci. 2024/046.