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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/050

ASSESSMENT OF DIVISIONS 2J+3KL CAPELIN TO 2023

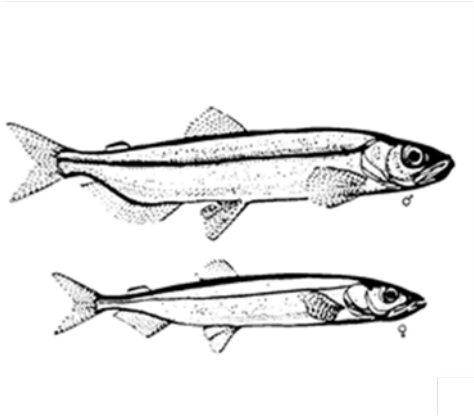

Image: Capelin (Mallotus villosus)*, adapted from a drawing in C. E. Hollingsworth (2002).*

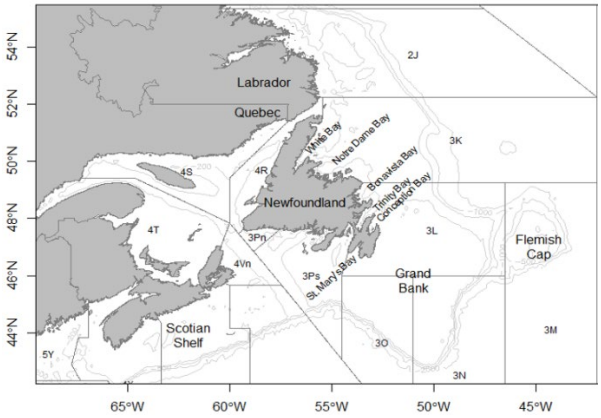

Figure 1. 2J3KL Capelin stock area with 100 m and 500 m contours.

Context:

This Science Advisory Report (SAR) is from the March 5–8, 2024 Regional Peer Review for the Stock Assessment of Capelin in Divisions 2J+3KL. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

The previous full assessment for this stock was in the winter of 2023 (DFO 2024) and included fishery-independent data up to 2022. The 2J3KL Capelin stock has been assessed on both an annual (1992–2001, 2017 onwards) and bi-annual (2008–15) basis, with no stock assessments occurring from 2002–07. The fishery for 2J3KL Capelin was managed with three-year Capelin management plans from 1999–2008 and with single year plans from 2009–11. The current (evergreen) Integrated Fisheries Management Plan (IFMP) commenced in April 2011 and has no fixed end-date.

SUMMARY

- The Newfoundland and Labrador (NL) ocean climate fluctuates on decadal timescales with known impacts on ecosystem productivity. The poor productivity of lower trophic levels in the mid-2010s has been associated with a cooler climate phase. Since 2018, a warmer and potentially more productive ocean phase has been emerging. The current phase is characterized by earlier phytoplankton blooms and higher abundance of *Calanus finmarchicus*, a key zooplankton species for the ecosystem.
- The NL bioregion continues to experience overall low productivity conditions, with total biomass measured in the DFO research vessel survey well below pre-collapse levels. The marine community has returned to a finfish dominated structure. Ecosystem indicators in 2019–23 (e.g., biomass trends, stomach content weights) show improvements from the lows in the late-2010s, but overall biomass has not returned to the early-2010s level.
- This stock continues to have a truncated age structure due to the high proportion of fish that are maturing at younger ages relative to the pre-collapse period, which reduces the reproductive potential of the stock.
- The 2023 larval abundance index suggests an average year-class relative to the post-collapse period.
- The Capelin forecast model predicts that the 2024 Capelin acoustic biomass index will be similar to or slightly lower than 2023.
- The 2J3KL Atlantic Cod Limit Reference Point (LRP) was changed in 2023, which required an update of the Capelin LRP. The revised value of the Capelin LRP is 155 kt for the spring acoustic biomass index.
- The 2023 acoustic biomass index (333 kt, 90% confidence interval (CI): 235–568 kt) was above the LRP. The stock has been mostly above this updated LRP since 2007, except for 2010 and 2017, and is projected to remain so in 2024, with a 10–17% probability of being in the critical zone. The cautious and healthy zones have not been defined for this stock.
- This stock is currently facing challenges related to delayed spawning, early maturation, and an age-truncated population structure. Furthermore, the acoustic biomass index remains well below the 1985–90 period. These factors indicate reduced stock productivity. A cautious management approach is recommended.

INTRODUCTION

Stock Structure and Species Biology

Since 1992, as a result of accumulated biological evidence (Nakashima 1992), Capelin in Northwest Atlantic Fisheries Organization (NAFO) Subarea (SA) 2 + Division (Div.) 3K and Div. 3L have been considered one stock complex (hereafter referred to as 2J3KL Capelin; Fig. 1).

Capelin is the keystone forage fish species in the Newfoundland and Labrador (NL) ecosystem. It spends the majority of its life offshore on the NL shelf and undergoes spring/summer spawning migrations to coastal areas in southern and northeastern NL where it spawns on beaches and at coastal deep-water habitats. The 2J3KL Capelin stock collapsed in the early-1990s and has shown limited signs of recovery in the subsequent 30 years (reviewed in Buren et al. 2019). While Capelin biomass has increased since 2007, other stock indicators show little sign of improvement. Immature Capelin are still experiencing fast growth and maturing at a

younger age, suggesting a compensatory growth response due to a relaxation of resource competition (Engelhard and Heino 2004). Due to earlier age at maturation and semelparity (i.e. high rates of post-spawning mortality), the spawning population is age-truncated compared to the 1980s. Capelin spawning timing has remained delayed since the stock collapsed which has had a negative impact on year-class strength (Murphy et al. 2021).

Ecosystem Context

The NL climate experiences fluctuations at decadal time scales, which may impact ecosystem productivity. The warmer and potentially more productive period emerging since 2018 has continued into 2023. While the impact of large-scale variations in ocean climate on Capelin is largely unknown, the summer North Atlantic Oscillation and NL climate indices predict Capelin spawning timing (Murphy et al. 2021). Inter-annual variability in prey availability associated with changes in the timing of the spring sea ice retreat was hypothesized to influence adult Capelin and, by extension, biomass (Buren et al. 2014).

Overall conditions of the past four years are indicative of improved productivity at the lower trophic levels in the NL bioregion (NAFO Divs. 2HJ3KLNOPs). This includes earlier phytoplankton blooms, higher nutrient inventories, and above-normal zooplankton biomass with high abundances of both small copepods and large, energy-rich *Calanus* spp. copepods. These zooplankton community changes suggest improved foraging conditions for larval (Murphy et al. 2018) and adult (Buren et al. 2014) Capelin.

Biomass data from the fall multi-species bottom-trawl surveys show that the fish community in NAFO Divs. 2J3KL was dominated by finfishes in the 1980s until these populations collapsed in the early-1990s and shellfish increased (Koen-Alonso and Cuff 2018, Buren et al. 2019). Even with the increases in shellfish, total biomass on the NL shelf remains far below pre-collapse levels. Ecosystem trends in recent years (e.g., biomass trends, stomach content weights) indicate improvements from the lows in the late 2010s, but overall biomass has yet to reach the highs of the early 2010s.

Fishery

Capelin fishing effort and landings can be negatively impacted by market factors including low prices, limited processing capacity, international markets (i.e., quota decisions for Iceland-East Greenland-Jan Mayen and Barents Sea Capelin stocks; war in Ukraine), and/or the relative profitability of competing fisheries such as Snow Crab (*Chionoecetes opilio*). For these reasons, the Capelin catch rate is hyper-stable and may not reflect the status of the stock, thus catch rate is not used for the assessment of the 2J3KL Capelin stock. In 2023, the Total Allowable Catch (TAC) for Capelin was 14,533 t, and total landings were 11,355 t (78% percent of the TAC) (Fig. 2). There were no landings in Div. 2J (58 t TAC) or Div. 3Ps (968 t TAC).

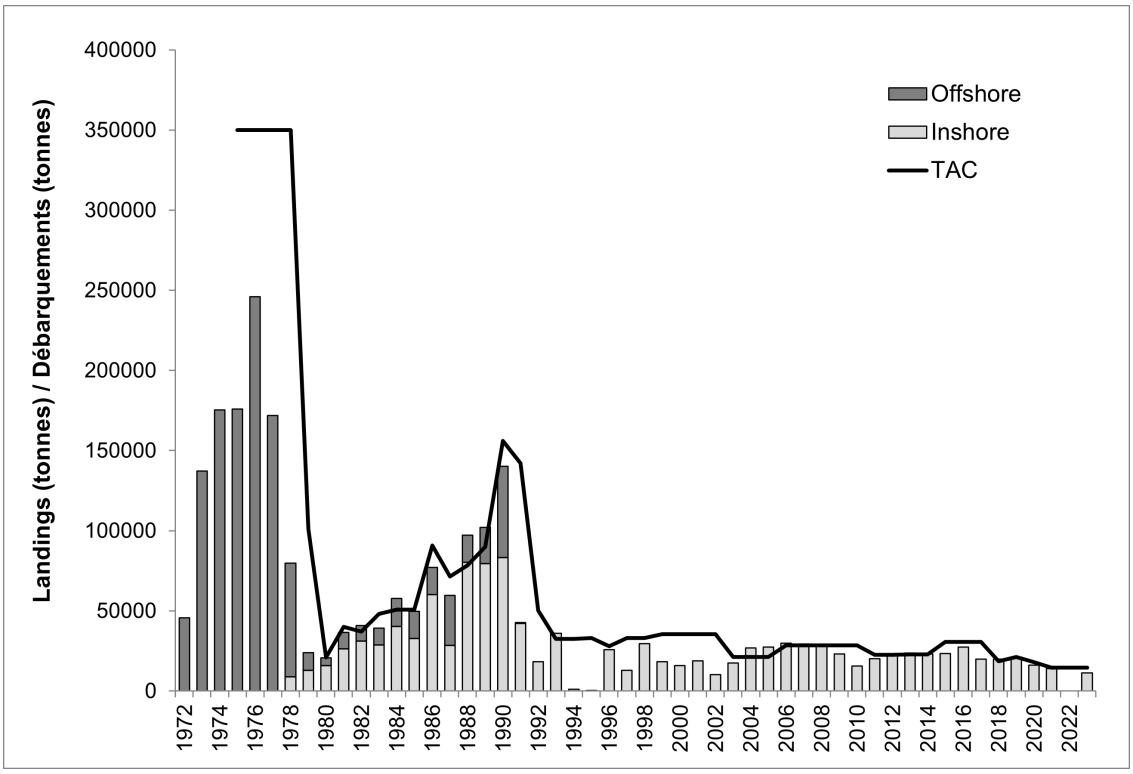

Figure 2. Inshore landings (light grey bars), offshore landings (dark grey bars), and TAC (line) for Capelin in Divs. 2J3KL from 1972 to 2023. Note that annual inshore landings were likely greater than 0 t between 1972 and 1977, but they were not recorded prior to 1978. There was no commercial fishery in 1994, 1995, and 2022.

ASSESSMENT

Beach Spawning Timing

Data on the timing of beach spawning have been collected from 1991 to present by a network of citizen scientists. In 2023, data on the timings of beach spawning were collected by 16 citizen scientists. Median peak spawning day was July 21 (Day of year [DOY]: 202), which was approximately two weeks later than the 1991–2022 median (July 9) (Fig. 3). Delayed peak beach spawning timing in 2023 predicts production of a weak year-class (Murphy et al. 2021).

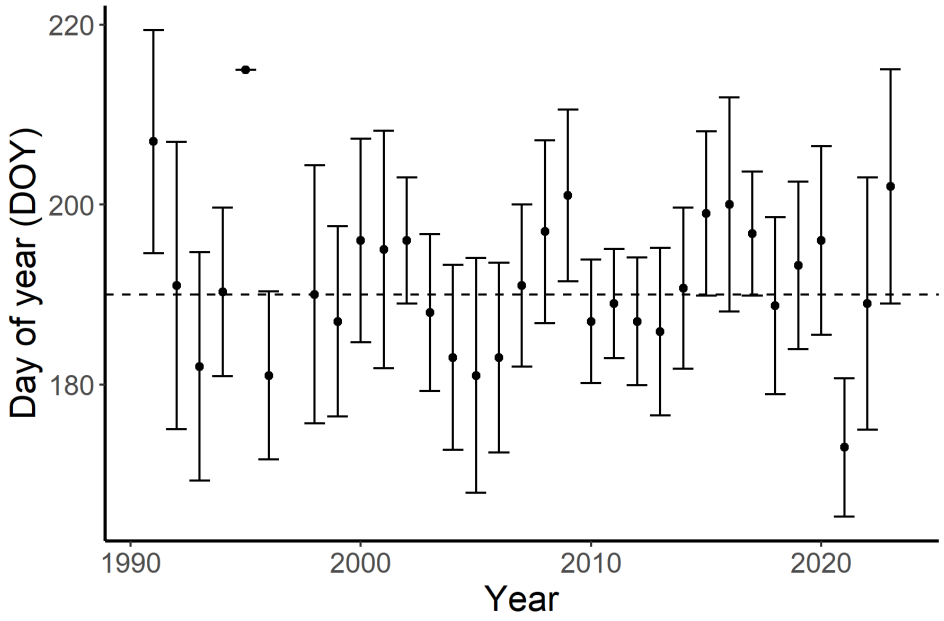

Figure 3. Median peak beach spawning timing for 2J3KL Capelin in 2023 was Day of Year (DOY) 202 (July 21) based on 16 beaches monitored in the Capelin citizen science spawning diary program. The dashed line is the median of the time series (1991–2022; DOY 190). Points show median spawning day ± standard deviation.

Larval Index

The 2023 Bellevue Beach (BB) larval index was 1,391.6 ± 316.9 individuals (ind.) m^{-3} which was similar to the post-collapse time series mean (1,436.1 ind. m^{-3}; 2001–22) (Fig. 4). The BB larval index is used in the most parsimonious Capelin forecast model.

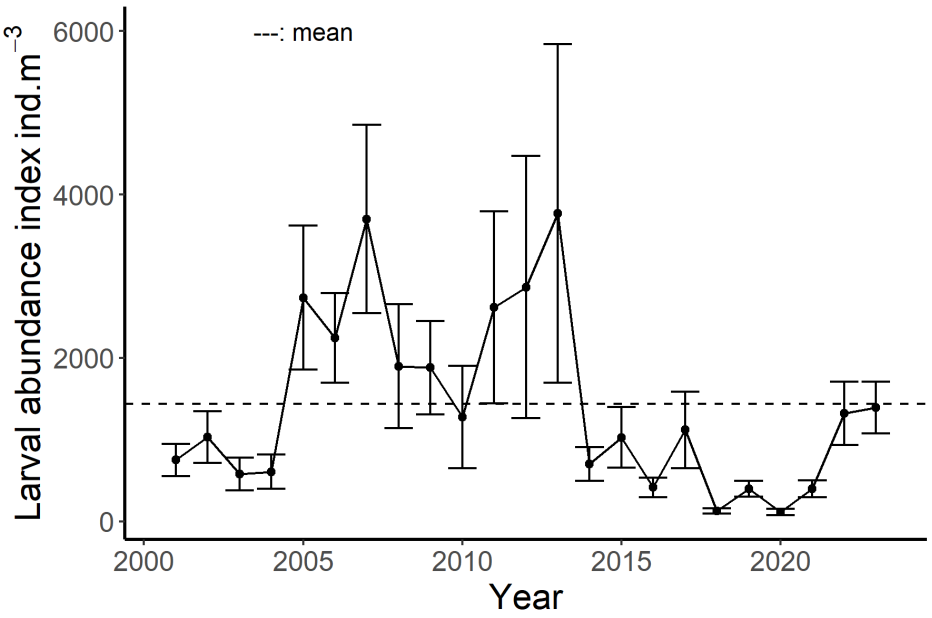

Figure 4. Bellevue Beach larval abundance index. Points show the total annual larval abundance (ind.m^{-3}) ± standard error for the years 2001–23. Dashed line is the mean (2001–22; 1,431.1 ind. m^{-3})

Spring Acoustic Survey

The Capelin spring acoustic survey has been conducted in its current form in most years since 1982 in Div. 3L with an extension into southern Div. 3K (<50°N) starting in 1996 (Fig. 5). The acoustic survey produces a biomass index rather than a spawning stock biomass estimate since it is focused on Div. 3L and does not cover the entire stock area. In 2023, the biomass index was 333 kt (90% CI: 235–568 kt), which was similar to the 2018–22 time period (median: 282 kt). Since the collapse of the stock in 1991, the median annual Capelin acoustic biomass index was 174 kt, which was well below the 1985–90 median (3,704 kt) (Fig. 5). The spring acoustic abundance index in 2023 was 34.4 billion fish, which was higher than the 1991–2022 median (18.5 billion fish) (Murphy et al. 2024).

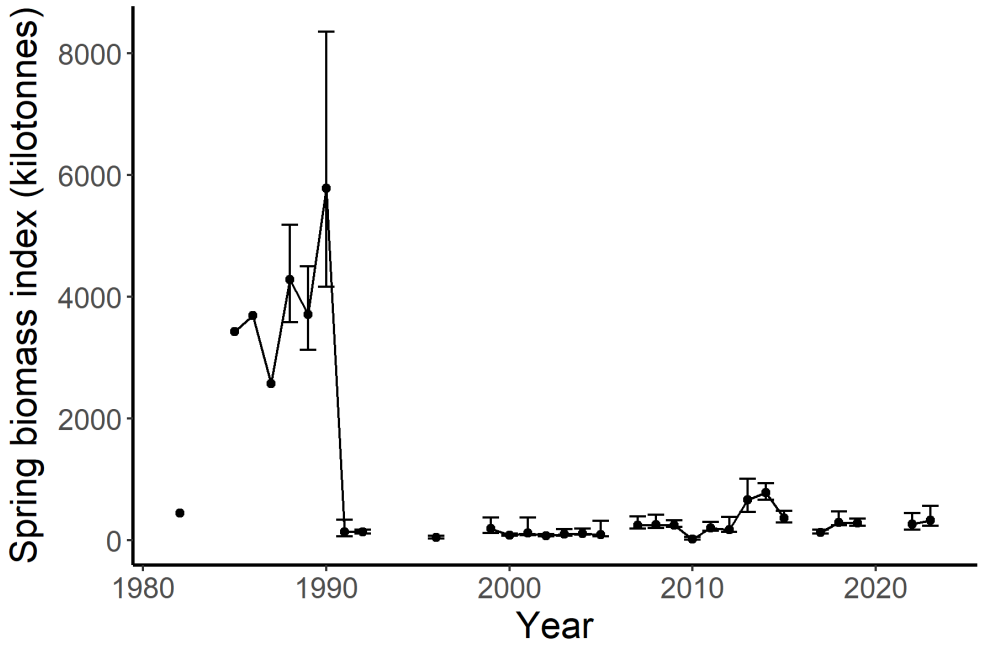

Figure 5. Spring acoustic survey biomass index from 1982–2023. Points show the median estimate and error bars are 90% confidence intervals, ranging from the 5th to the 95th percentiles of the estimate. Confidence intervals could not be calculated for 1982–87 due to data availability limitations.

Biological Characteristics of Capelin

When the Capelin stock collapsed in 1991, there was a change in their population dynamics. Immature growth rates increased which resulted in increased lengths and weights of age-1 and -2 fish (Fig. 6 a, b), and an increased proportion of fish maturing at age-2 since maturation in fish is based on length not age. In 2023, 55.7% of female age-2 fish collected during the spring acoustic survey were maturing and would have spawned in 2023, compared to an average of 3.7% female age-2 fish in 1985–90 (Fig. 7).

Since Capelin experience a very high rate of post-spawning mortality (semelparity), fast immature growth and earlier maturation have resulted in an age-truncated population with few age-4+ fish sampled in the spring acoustic survey since the collapse in the stock (Fig. 8). Of the older ages sampled in the spring acoustic survey, mean weights and lengths of ages-3 and -4 fish have remained the same or decreased since the 1980s and age-5+ fish are generally absent from the survey post-1991 (Fig. 6a, b).

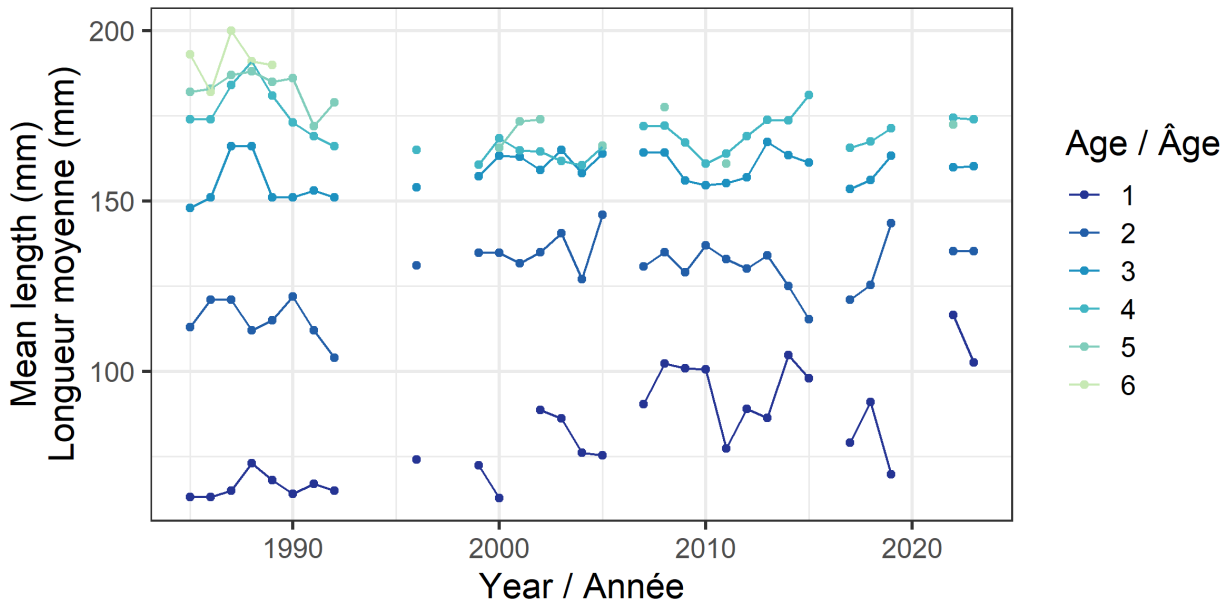

Figure 6a. Mean lengths of 2J3KL Capelin sampled in the spring acoustic survey (ages 1–6) from 1985–2023.

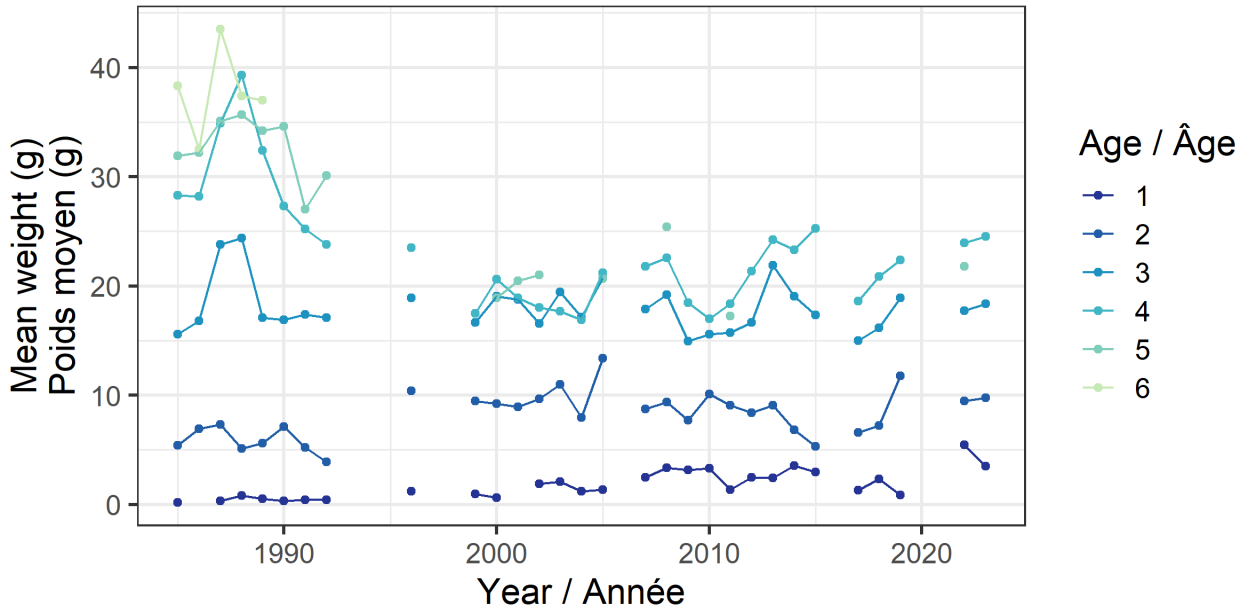

Figure 6b. Mean weights of 2J3KL Capelin sampled in the spring acoustic survey (ages 1–6) from 1985–2023.

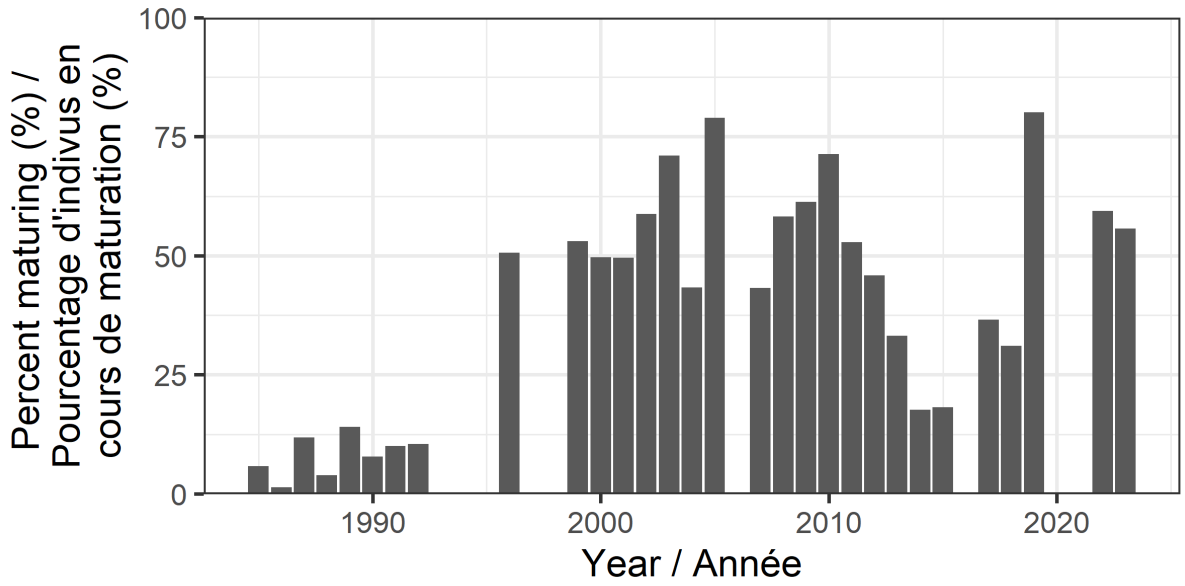

Figure 7. Percent maturing of female age-2 fish in the spring acoustic survey since 1985.

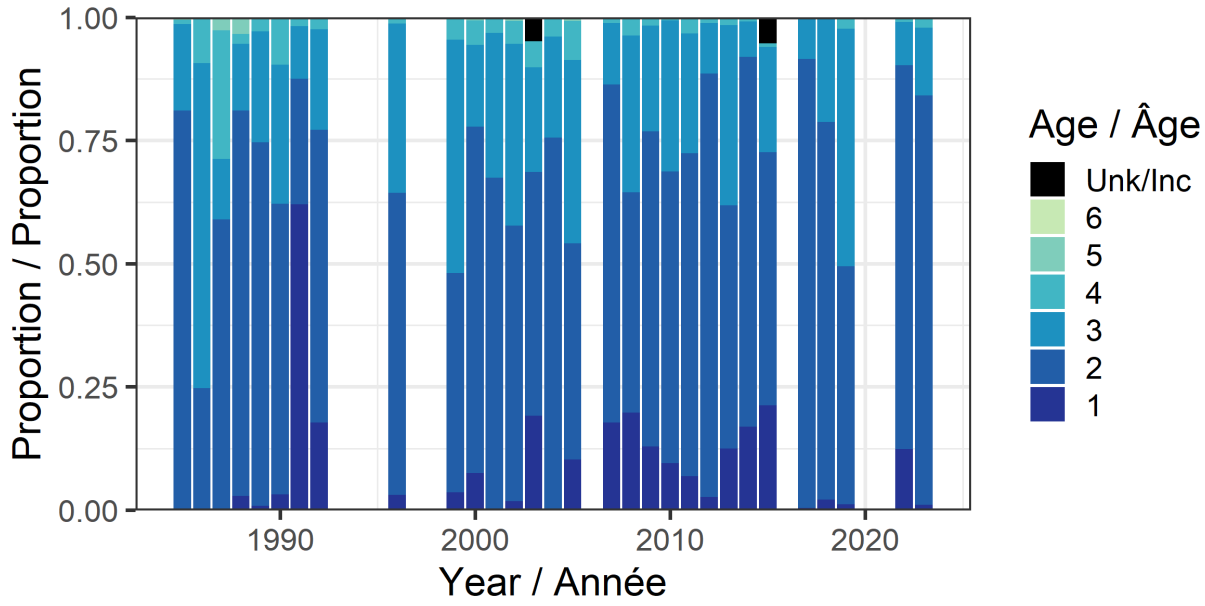

Figure 8. Age composition of 2J3KL Capelin in the spring acoustic survey since 1985.

Capelin fall relative condition in 2023 was calculated using data from multispecies bottom-trawl survey fishing sets where detailed sampling was available as well as four bottom-trawl survey fishing sets from an acoustic research cruise in December 2023 in Div. 2J3K. These additional sets were used to augment the samples from northern divisions. Data were first pooled by NAFO Division. A condition index (LeCren 1951) was then calculated by sex and age class (ages-1 and 2) and the resultant values averaged. Capelin fall relative condition in 2023 was lower than in 2022 and similar to 2020, remaining above the time series mean (Fig. 9).

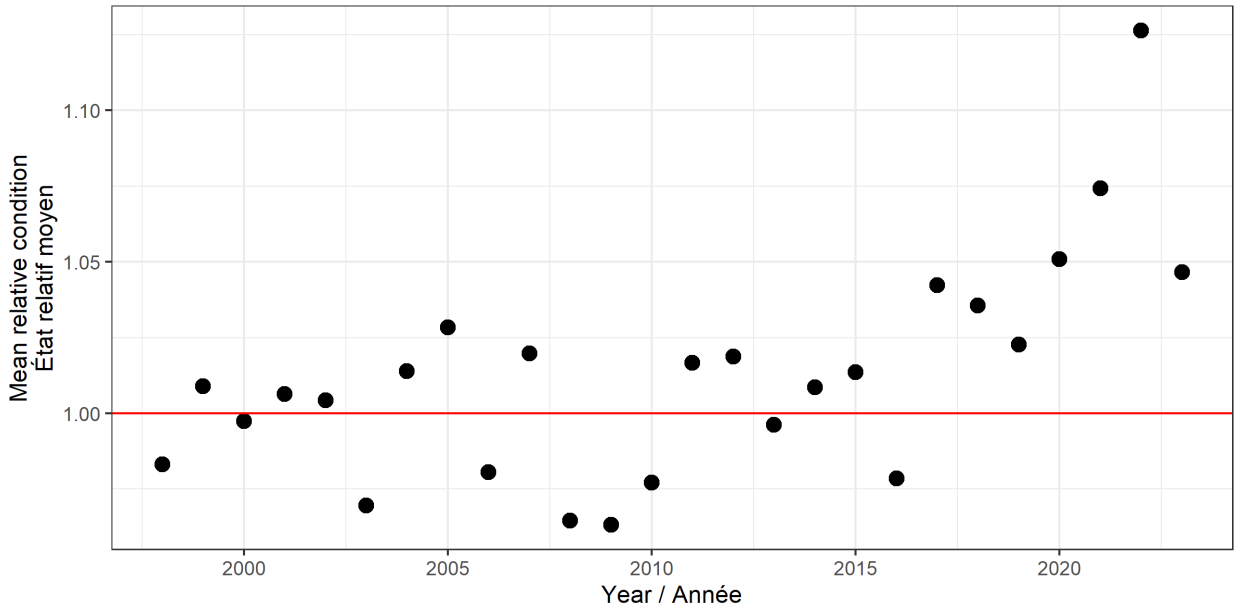

Figure 9. Fall relative condition of ages-1 and -2 Capelin pooled by sex in Div. 2J3KL from 1999–2023. Red horizontal line is the mean relative condition.

Capelin Forecast Model

The Capelin forecast model has been used since 2019 to produce an estimate of the Capelin acoustic biomass index for the current year's spring acoustic survey based on a number of parameters: zooplankton index, BB larval index, fall relative condition, and timing of the sea ice retreat (t_{ice}) (Lewis et al. 2019). The Capelin forecast model was refit with 2023 data and up-to-date t_{ice} data (February 28, 2024). The most parsimonious model included the BB larval index, fall condition, and t_{ice} parameters. The model forecast suggests that the Capelin acoustic biomass index in 2024 will be similar to or slightly lower than the 2023 biomass index (Fig. 10).

In the 2023 Capelin assessment, there was some uncertainty about the validity of the estimated 2022 fall relative condition value as it was substantially higher than any other year and there was a change in the timing of when sampling occurred in NAFO Division 3K, which could potentially be driving this high value for condition (DFO 2024). Given that the model is refit each year using the updated values, there was concern that the 2022 condition value might unduly influence the prediction for 2024 and 2025. To investigate the impact of the 2022 condition value on the model, the forecast model was fit with three different values for condition: the observed value of relative condition for 2022 (1.13); the second highest condition value from the condition time series (1.074); and the midpoint value (1.1) between the highest and second highest condition values. The value used for condition in 2022 had little effect on the predicted biomass indices for 2024 and 2025, so the final forecast model run included the observed value of relative condition for 2022 (Fig. 10).

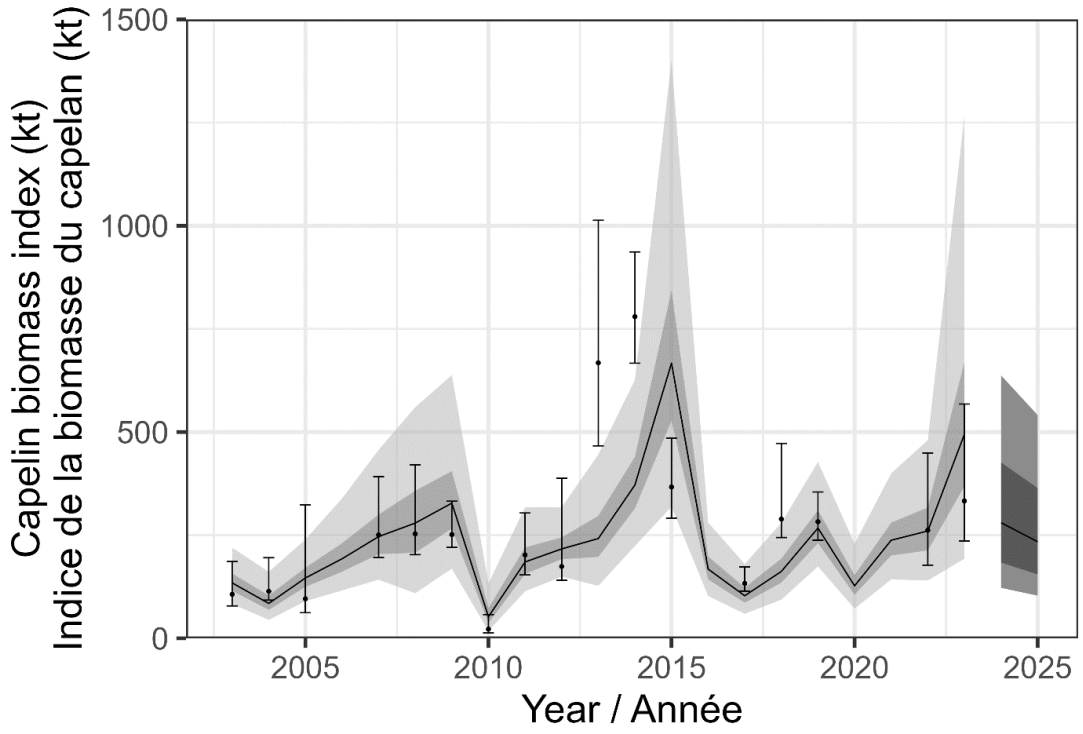

Figure 10. Forecast model credible intervals (2.5th to 97.5th percentiles) from 2003–23, and prediction intervals (10th to 90th percentiles) from 2024 to 2025. Solid lines show the median of the credible or prediction intervals. Observed biomass index values (black circles) with 90% confidence intervals (black lines with whiskers) are also shown.

Limit Reference Point

The LRP is the point between the cautious and critical zones in the DFO Precautionary Approach (PA) Framework (DFO 2023)**.** A LRP of 640 kt in the spring acoustic survey was established for 2J3KL Capelin in March 2023, and the stock was determined to be in the critical zone since 1991 with the exception of 2013 and 2014 (DFO 2024, Lewis et al. in press[1]). In the fall of 2023, the 2J3KL Atlantic Cod (Northern Cod; *Gadus morhua*) LRP underwent a framework assessment and, as a result, the Northern Cod LRP is now based on 40% B_{msy}. Since the Capelin LRP is linked to that of Northern Cod using the capcod model (Koen-Alonso et al. 2021), this resulted in Capelin's LRP changing as well. Using the same model configuration and data for capcod as the 2023 Capelin assessment (i.e. Northern Cod biomass up to 2020) (DFO 2024) and 40% B_{msy} for the Northern Cod LRP (internally estimated by the capcod model), the capcod model estimated a Capelin LRP of 155 kt based on the spring acoustic biomass index (Fig. 11). The Capelin stock in 2023 is above its LRP and has been since 2007 with the exception of 2010 and 2017; however, this does not mean that there are more Capelin in the ecosystem, rather it means that fewer Capelin are needed to maintain

[1] Lewis, K.P., Regular, P.M., Koen-Alonso, M., Mowbray, F., Murphy, H.M., Adamack, A.T., and Bourne, C. In press. A Review and Evaluation of Potential Limit Reference Points for 2J3KL Capelin (Mallotus villosus). DFO Can. Sci. Advis. Sec. Res. Doc.

Northern Cod at its new LRP. The boundary between the cautious and healthy zones has yet to be determined for the 2J3KL Capelin stock.

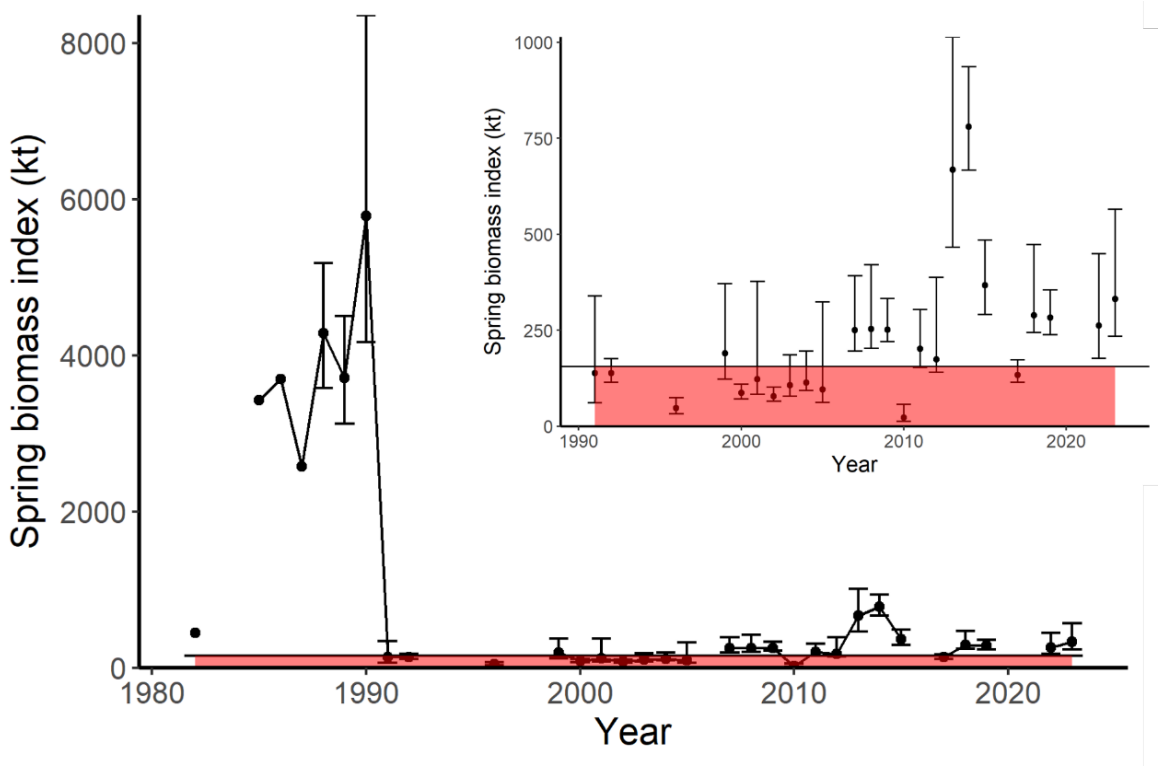

Figure 11. A Capelin LRP was established based on its importance to the ecosystem. A 155 kt Spring acoustic biomass index was selected as the LRP, below which the Capelin stock and the Northern Cod stock are likely at risk of serious harm. The inset figure shows the post-collapse years only (1991–2023). The red area indicates the critical zone (0–155 kt).

Sources of Uncertainty

There is no estimate of spawning stock biomass for this stock.

There are currently limited abundance and biomass data for age-1 Capelin from the spring acoustic survey. Using a smaller meshed pelagic trawl on the spring acoustic survey may increase data on this life stage and potentially fine-tune the recruitment forecast from the larval stage to age-2.

The BB larval index may not be representative of larval densities from areas with a high proportion of demersal (coastal deep-water) spawning habitats. However, trends in larval indices were similar between a site in Notre Dame Bay, which has a high proportion of deep-water spawning, and the BB larval index (Tripp et al. 2023). The BB larval index is included in the most parsimonious Capelin forecast model.

The estimated envelope of Capelin consumption by fishes remains large and is highly dependent on how well these species represent overall predation. While order of magnitude analyses indicated that fishes are the main consumers of Capelin, consumption of Capelin by marine mammals and seabirds remains an important source of uncertainty.

The impact of fishing mortality on the Capelin stock is not quantified and is generally poorly understood, particularly as the fishery is targeted on pre-spawning, egg-bearing females that have already survived predation and other sources of natural mortality.

In response to a changing climate, Capelin may change their distribution northward. This potential change in geographic distribution should be investigated through a combination of qualitative and quantitative studies (i.e., incorporation of Indigenous knowledge, local knowledge, and ongoing research).

In response to a changing climate, there may be potential changes in availability of Capelin to the spring acoustic survey which warrants further exploration.

The impact of ice extent and ice breakup and its associated impact on lower trophic levels is currently unknown, and there is currently no statistical link between zooplankton, especially *Calanus* spp., and Capelin biomass. Further research is required in order to understand the trophic interactions of the NL ecosystem.

Research recommendations for the Capelin forecast model include testing of additional parameters in the model (i.e. timing of the spring bloom); investigation of model residuals; and use of an autoregressive (AR) 1 model or a harmonic model to look at the effect of survey timing on fall condition values and how survey timing may affect the overall condition value used in the Capelin forecast model.

Given the broad confidence intervals of the acoustic estimates, a research recommendation is to investigate how to introduce a probabilistic determination of being above/below the LRP.

CONCLUSIONS AND ADVICE

The 2J3KL Capelin stock has shown limited signs of recovery from its collapse in 1991. Persistent changes in Capelin population dynamics post-collapse are likely due to density-dependent factors, resulting in fast immature growth and maturation at a younger age. This trend continued in 2023 with a high proportion of Capelin maturing at age-2. Due to semelparity and early age at maturation, the stock is age-truncated compared to the 1980s. The collapsed stock is also characterized by delayed spawning and low recruitment. Spawning timing in 2023 was delayed; and while the BB larval index was similar to 2022, it was only average compared to the post-collapse time series mean. Capelin fall relative condition was above average in 2023. In 2023, the 2J3KL Capelin acoustic biomass index was similar to the 2018–22 median, but well below the recent stock high of 2013–14 and a fraction of the 1980s median. The Capelin forecast model predicted that the Capelin acoustic biomass index in 2024 would be similar to or a slight decrease compared to 2023. The Northern Cod LRP changed in 2023 and is now based on 40% B_{msy}. As a result, the Capelin LRP was also revised. Using the capcod model, the Capelin LRP was 155 kt based on the acoustic biomass index. In 2023, the Capelin stock is above its LRP; however, due to the stagnation in stock size since 2018, Science advises management actions that encourage stock growth in the short term. The boundary between the cautious and healthy zones has not been determined for this stock.

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Chelsea Boaler	WWF Canada

SOURCES OF INFORMATION

This Science Advisory Report (SAR) is from the March 5–8, 2024 Regional Peer Review for the Stock Assessment of Capelin in Divisions 2J+3KL. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Buren, A.D., Koen-Alonso, M., Pepin, P., Mowbray, F., Nakashima, B., Stenson, G., Ollerhead, N., and Montevecchi, W.A. 2014. Bottom-up regulation of capelin, a keystone forage species. PLoS One. 9(2): 1–11.

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