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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/004

ASSESSMENT OF DIVISIONS 2J+3KL CAPELIN IN 2022 AND EVALUATION OF PROPOSED LIMIT REFERENCE POINTS

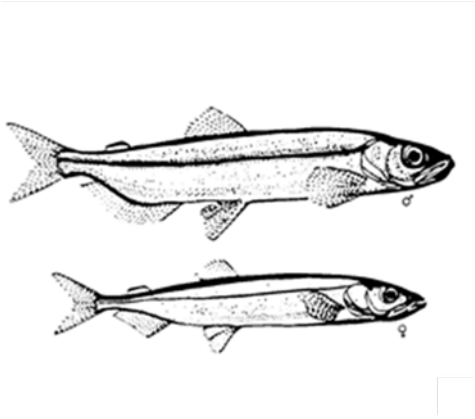

Image: Capelin (Mallotus villosus)*, adapted from a drawing in C.E. Hollingsworth (2002).*

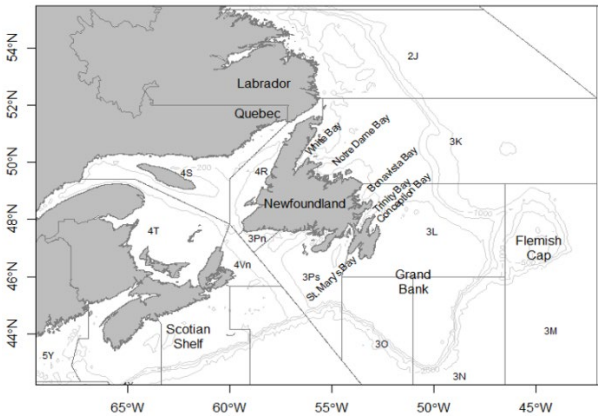

Figure 1. 2J3KL Capelin stock area with 100 m and 500 m contours.

Context:

This Science Advisory Report (SAR) is from the March 6-10, 2023 Regional Peer Review for the Assessment of Divisions 2J+3KL Capelin and Evaluation of Proposed Limit Reference Points. 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 2021 (DFO 2022) and included research and commercial fishery data up to 2020. There was a stock update report in winter 2022 that included research and commercial fishery data up to 2021 (DFO 2023a). 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 ocean climate on the Newfoundland and Labrador (NL) shelf fluctuates at decadal time scales, with potential impacts on ecosystem productivity. The warmer and potentially more productive period emerging since 2018 has continued in 2022.
- Overall conditions of the past three years are indicative of improved productivity at lower trophic levels in the NL bioregion (Northwest Atlantic Fisheries Organization [NAFO] Divisions [Divs.] 2J3KL). This includes earlier phytoplankton blooms, higher chlorophyll concentrations, and increased zooplankton biomass with a higher abundance of larger, more energy-rich Calanus copepods.
- Fish communities in NL marine ecosystems continue to experience overall low productivity, with total biomass well below pre-collapse levels. While the fish community has returned to a finfish-dominated structure, groundfish rebuilding stalled in the mid-2010s. Ecosystem indicators in recent years appeared to show improvements, but the lack of surveys in 2022 prevented an update of these trends.
- The 2J3KL Capelin stock has been depleted since 1991. The Capelin acoustic biomass index in 2022 was 262 kt (90% confidence interval 177–448 kt), a level generally higher than the post-collapse period (1991–2022), but well below the 1985–90 period. Capelin indicators derived from predator diets also suggest similar biomass levels in 2019 and 2022.
- There was no commercial Capelin fishery in 2022 due to market reasons.
- In 2022, peak timing of beach spawning was typical of the post-collapse period. The larval index was the highest observed in nearly a decade, but average compared to the post-collapse time series and low relative to the productive pre-collapse period. These two indices suggest 2022 was a weak year-class.
- Fall Capelin condition has been high since 2019; however, while there is confidence that condition was high in 2022, the estimate may not be directly comparable with prior estimates due to an earlier than usual sampling time in 2022.
- Since the Capelin forecast model is sensitive to fall condition, the results can only be described qualitatively due to uncertainty in the 2022 condition value. The Capelin acoustic biomass index in 2023 is expected to be at or above the level of 2022.
- A Limit Reference Point (LRP) was chosen for 2J3KL Capelin from a suite of LRP options based on the history of the stock trajectory and biology, and its importance to the ecosystem as a whole.
- Using Northern cod as an ecosystem indicator, a 640 kt Capelin acoustic biomass index was selected as the current LRP below which the Capelin stock and ecosystem are likely at risk of serious harm. This level is expected to support the growth of the Northern cod stock to levels last observed in the 1980s.
- Since 1991, with the exception of 2013 and 2014, the Capelin stock has been in the Critical Zone. The upper confidence limit (95th percentile) from the 2022 acoustic survey biomass index was 449 kt, indicating a very low (less than 5%) probability of being above the LRP.
- Consistent with the DFO decision-making framework, incorporating the precautionary approach requires that removals from all sources must be kept at the lowest possible level until the stock clears the Critical Zone.

BACKGROUND

Species Biology, Stock Structure, and Management

Since 1992, as a result of accumulated biological evidence (Nakashima 1992), it was recommended that Capelin in Northwest Atlantic Fisheries Organization (NAFO) Subarea (SA) 2 + Division (Div.) 3K and Div. 3L be 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 but 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 with minimal recovery in the subsequent 30 years (reviewed in Buren et al. 2019). Historically, Capelin matured and spawned at ages-3–4. Following the collapse of the stock, immature Capelin experienced fast growth and matured 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, the spawning population is age-truncated compared to the 1980s. Year-class strength is set early in the life history of Capelin (Murphy et al. 2018), and delayed spawning is predicted to produce weak year-classes (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 continued in 2022. 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), and 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 three years are indicative of improved productivity at the lower trophic levels in the NL bioregion (NAFO Divs. 2HJ3KLNOPs) observed since the mid-2010s. This includes earlier phytoplankton blooms, higher chlorophyll concentrations, and increased zooplankton biomass with a higher abundance of larger, more energy-rich Calanus 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 indicators in recent years appeared to show improvements in total biomass, but the lack of surveys in 2022 prevented an update of these trends. In 2021, Capelin biomass and abundance in the multi-species survey were the highest since 2014 (Div. 2J3K only; there was no coverage in Div. 3L in 2021). Finfish predators' diets and consumption in the fall are considered an indicator of Capelin biomass the following spring (DFO 2023a). The proportion of Capelin in the diet of its main predators, Northern cod (*Gadus morhua*) and Greenland Halibut (*Reinhardtius hippoglossoides*; Turbot), increased to almost one quarter and one half, respectively, in Div. 2J in 2021, but diet changes were relatively minor in Div. 3K. Capelin consumption by its finfish predators in Divs. 2J3K increased in 2020–21 compared to 2019,

suggesting that there would be an increase in Capelin biomass in the spring acoustic survey in 2022 (see “Spring Acoustic Survey” section below).

Fishery

Capelin fishery 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 2022, the Total Allowable Catch (TAC) for Capelin was 14,533 t, but there were no landings due to market reasons. This is the third time in the post-collapse period where there was no fishery due to market reasons (Fig. 2).

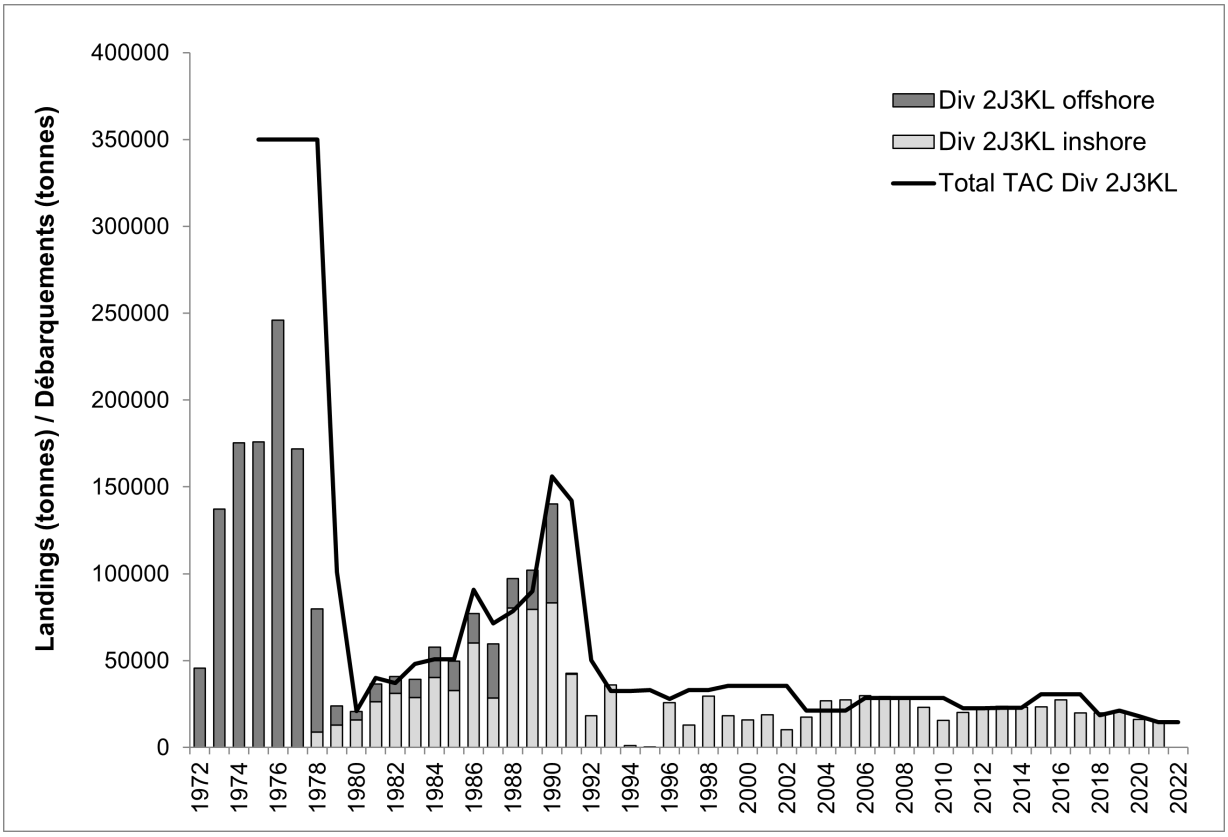

Figure 2. Inshore landings (light grey bars), offshore landings (dark grey bars) and TAC (line) for Capelin in Divs. 2J3KL from 1972 to 2022. Note that annual inshore landings were likely greater than 0 t between 1972 and 1977, but they were not recorded prior to 1978. There were no commercial fisheries 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 2022, these data were collected by 16 citizen scientists. Median peak spawning day was July 8 (Day of year [DOY]: 189), which was approximately two weeks later

than median peak spawning day in 2021 (June 22) but similar to the 1991–2020 median (July 9) (Fig. 3). Two waves of spawning were documented in 2022. Typical post-collapse peak beach spawning timing in 2022 predicts production of a weak year-class (Murphy et al. 2021).

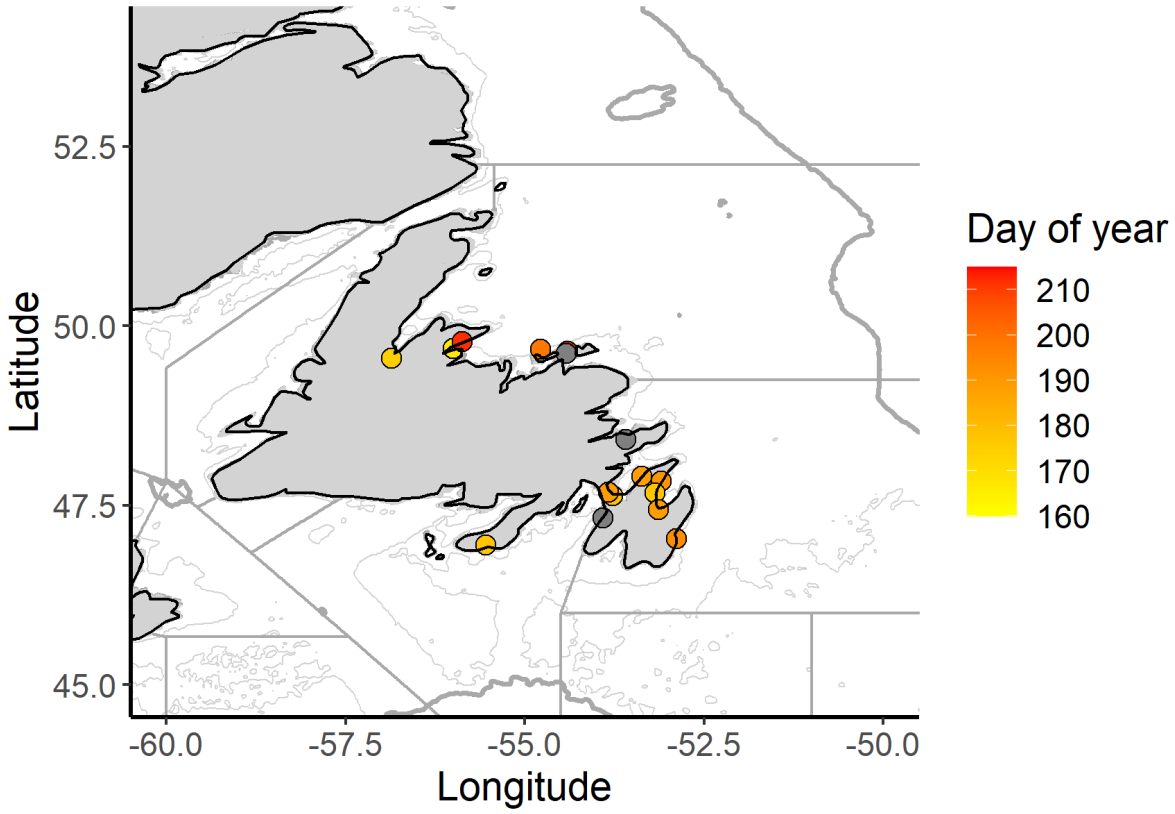

Figure 3. Capelin spawning timing in 2022 at the 16 beaches monitored in the Capelin citizen science spawning diary program. Grey dots indicate monitored beaches with no spawning recorded in 2022. Bathymetry: 100 m light grey and 500 m dark grey contour lines.

Larval Index

The 2022 Bellevue Beach (BB) larval index (1,322 ± 387.7 ind. m^{-3}) was at its highest level since 2013 and was similar to the post-collapse time series mean (1,439.5 ind. m^{-3}; 2001–21) (Fig. 4). There have been nine consecutive low larval abundance years (2014–22) including all year-classes available to the fishery in 2023.

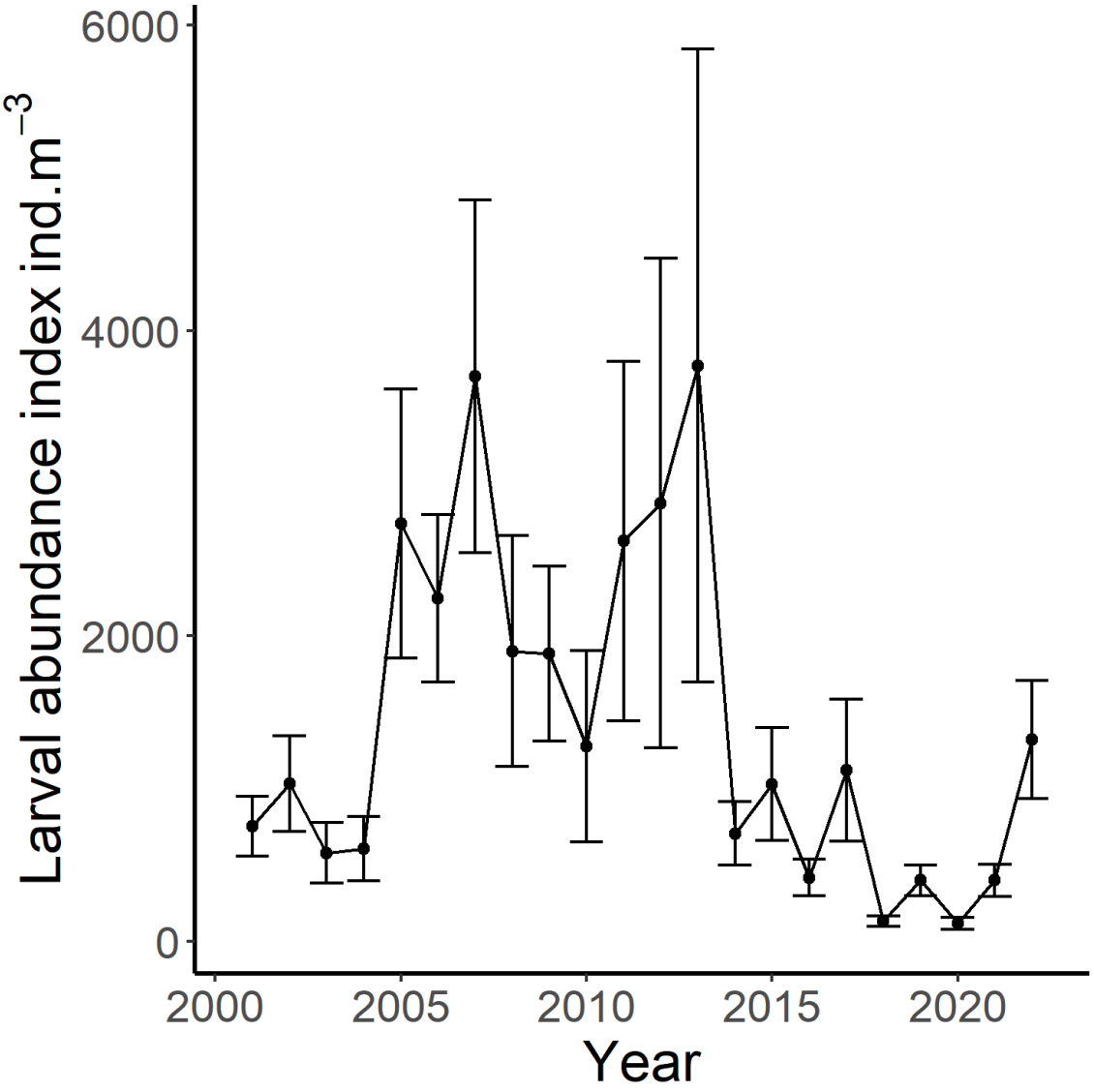

Figure 4. Bellevue Beach larval abundance index. Points show the total annual larval abundance (ind. m^{-3}) ± standard error for the years 2001–22.

Spring Acoustic Survey

The Capelin spring acoustic surveys have been conducted in their current form in most years since 1982 in Div. 3L with an extension into southern Div. 3K in 1996 (Fig. 5). The acoustic survey produces a biomass index rather than a Spawning Stock Biomass (SSB) estimate since it is focused on Div. 3L and does not cover the entire stock area. In 2022, the biomass index was 262 kt (90% confidence interval: 177–448 kt), which was similar to 2018 and 2019 (288.9 kt and 282.4 kt, respectively). Since the collapse of the stock in 1991, the median annual Capelin acoustic biomass index was 156 kt, which was well below the 1985–90 median (3,704 kt)

(Fig. 5). The spring acoustic abundance index in 2022 was 26.6 billion fish, which was higher than the 1991–2019 median (18.4 billion fish) (Murphy et al. in press[1]).

All abundance and biomass data from the acoustic surveys from 1999 onwards have been re-calculated using a standard set of data subsets and groupings (see Table 1 in Murphy et al. in press[1]). This time period corresponds to the years for which at-sea measurements of Capelin weights were collected. Prior to 1999, Capelin weights were estimated using samples collected from other sources (i.e., spring multi-species bottom trawl survey, and bycatch from other fishery-independent surveys and commercial fisheries). This recalculation made little difference in most years. During this process, we found two errors in how biomass estimates were calculated for 2014 and 2015, which resulted in a revision downwards of the biomass index for those two years. The corrected biomasses were used in all figures and models for this assessment.

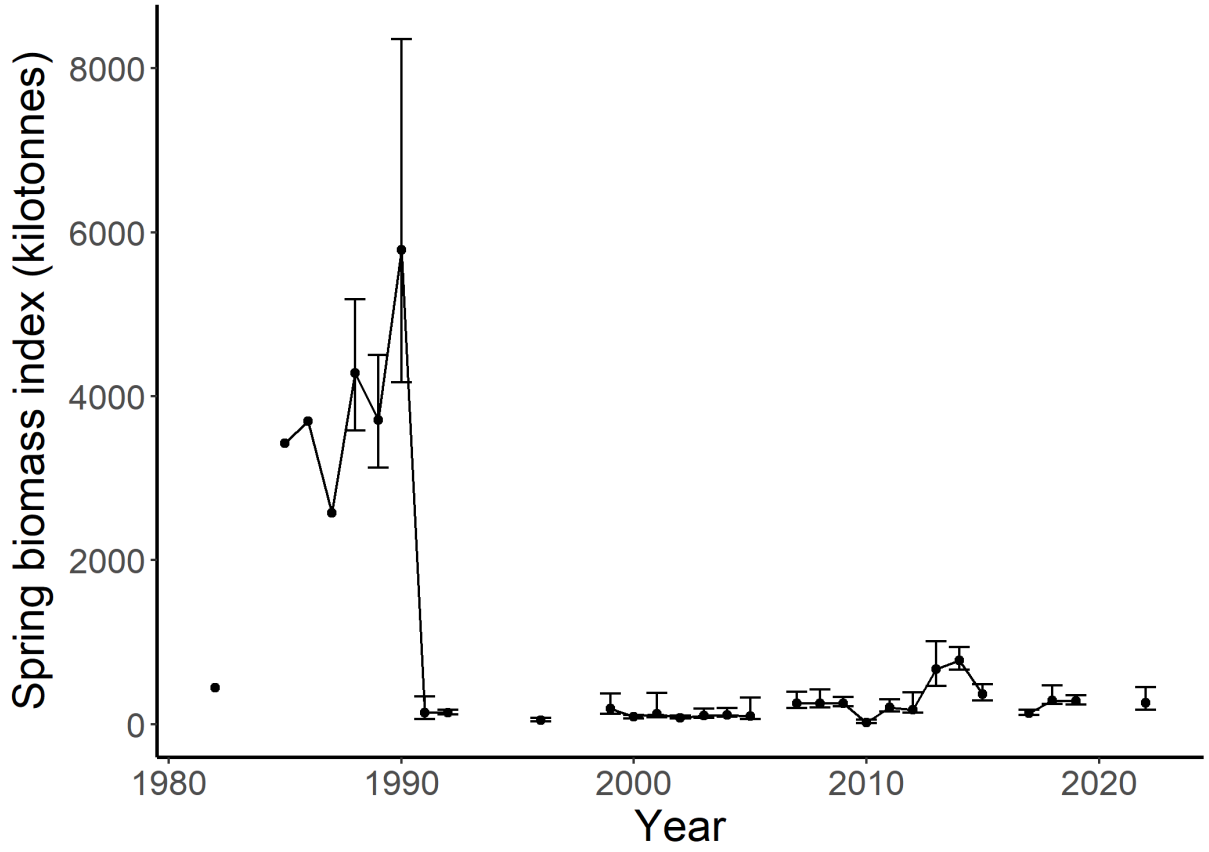

Figure 5. Spring acoustic survey biomass index from 1982–2022. Points show the median estimate and error bars are 90% confidence intervals, ranging from the 5th to the 95th percentiles of the estimate. Confidence intervals could not be calculated for 1982–87 due to data availability limitations.

[1] Murphy, H.M., Adamack, A.T., Mowbray, F.K., Lewis, K.P., and Bourne, C.M. In press. An Assessment of Capelin (*Mallotus villosus*) in 2J3KL to 2022. DFO Can. Sci. Advis. Sec. Res. Doc.

Biological (Age, Length, Condition, Diet) Characteristics of Capelin

When the Capelin stock collapsed in 1991, there was a change in population dynamics. Immature growth rates increased which resulted in increased lengths and weights of age-1 and -2 fish (Fig. 6a, b), and an increased proportion of age-2 and -3 fish matured and spawned since maturation in Capelin is based on length not age (Fig. 7). In 2022, 67% of age-2 fish collected during the spring acoustic survey were maturing and would have spawned in 2022. This high proportion of maturing age-2s is a phenotypic response (driven by environment) which is typical of lower biomass years. In comparison, recent higher biomass years (2013–14) resulted in slower Capelin growth and a lower proportion (22–35%) of maturing age-2 fish (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).

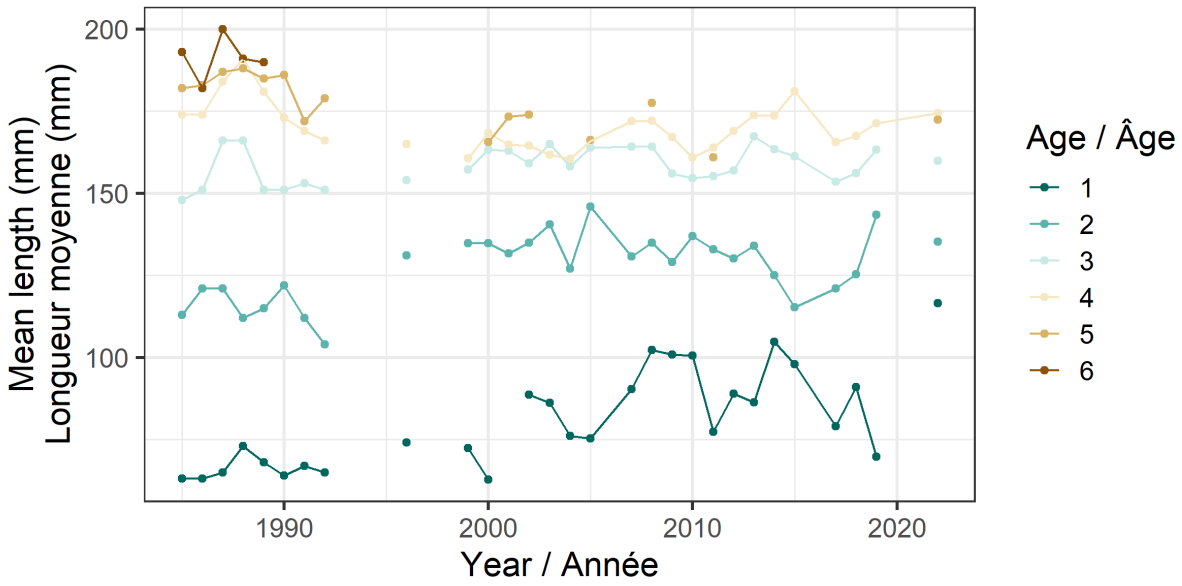

Figure 6a. Mean lengths of 2J3KL Capelin sampled in the spring acoustic survey (ages-1–6) from 1985–2022.

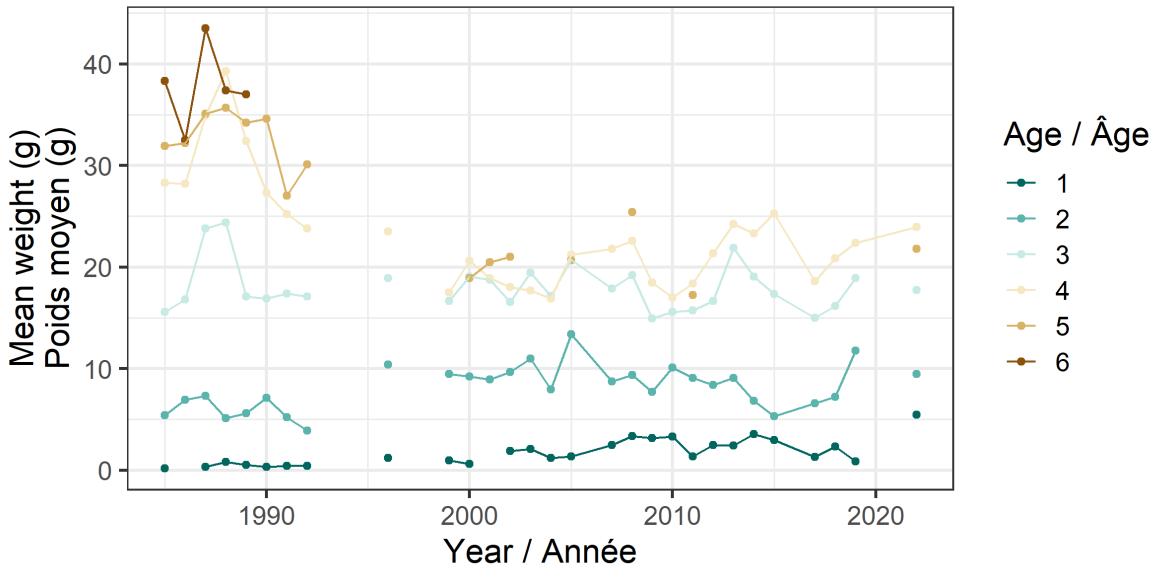

Figure 6b. Mean weights of 2J3KL Capelin sampled in the spring acoustic survey (ages-1–6) from 1985–2022.

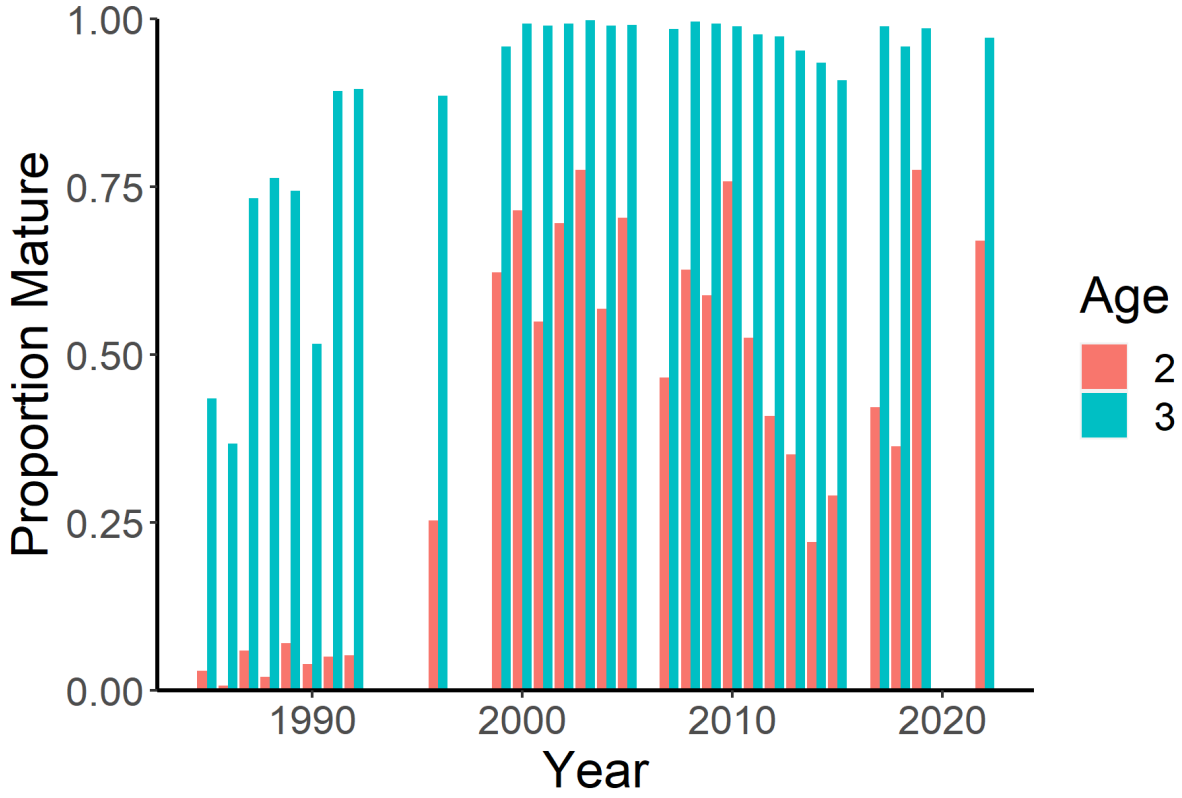

Figure 7. Proportion mature of Capelin (pooled by sex) in the spring acoustic survey at age-2 and age-3 since 1985.

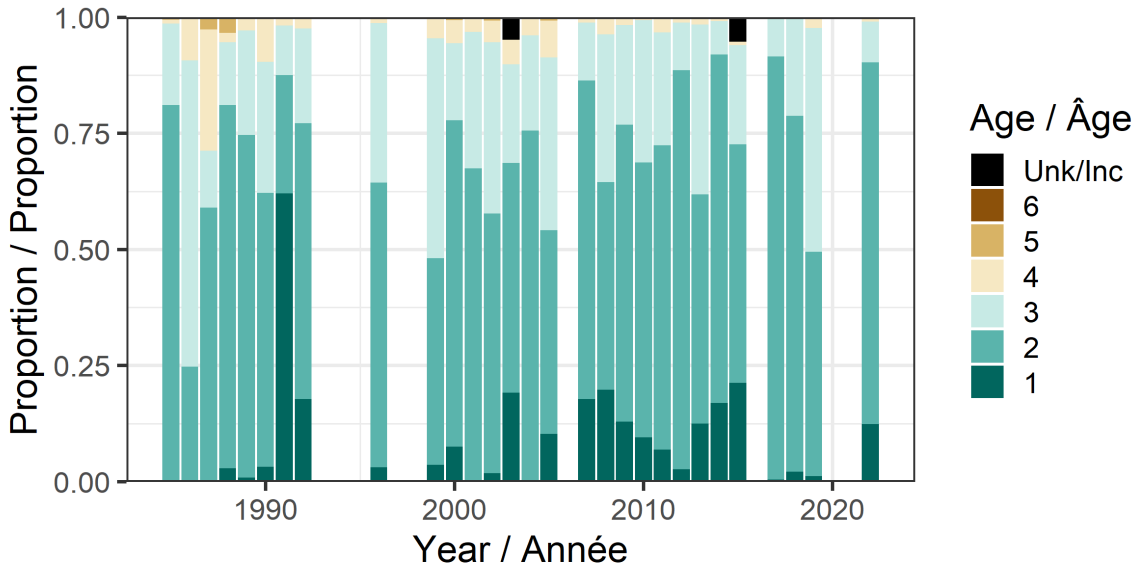

Figure 8. Age composition of 2J3KL Capelin in the spring acoustic survey since 1985.

The calculation of fall relative condition (Le Cren 1951) changed in 2022 due to an incomplete fall bottom trawl survey in 2021 and the replacement of the fall bottom trawl survey with the Comparative Fishing Program in 2022 (Murphy et al. in press[1]). In 2022, fall condition was the highest value in the time series, which could be due to unusually good feeding conditions in fall 2022 and/or by changes in the survey design (e.g., changes in timing of the survey in Div. 3K due to comparative fishing) (Fig. 9). While there is confidence that condition was high in 2022, the condition estimate may not be directly comparable with prior estimates due to survey timing. Fall Capelin condition has been high since 2020, which suggests increased overwintering survival potential (Buren et al. 2014).

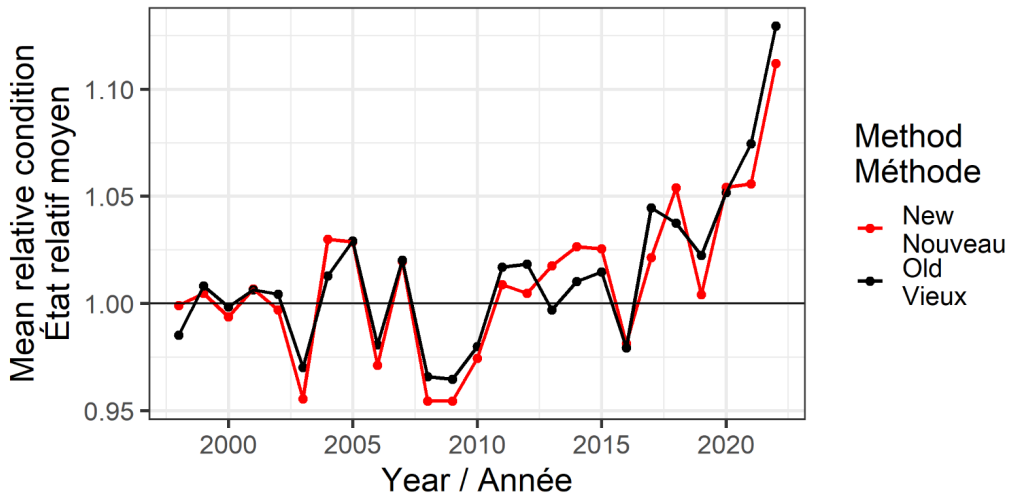

Figure 9. Comparison of previous (old) and new methods for calculating mean relative condition of male and female age-1 and -2 Capelin sampled in the fall multi-species bottom trawl survey by year (1995–2022) for NAFO Divisions 2J3KL. The change in methods for calculating mean relative condition was required due to the lack of survey coverage in Div. 3L in 2021 and the change in survey protocols required for the Comparative Fishing Program in 2022. In 2021, 3L was not surveyed so the condition value used average 3L condition from 2011–20.

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 sea ice retreat). Since the Capelin forecast model is sensitive to fall condition, the results for 2023 can only be described qualitatively due to uncertainty in the 2022 condition value. A range of plausible condition values were used to predict the general trend of the 2023 spring acoustic survey, and based on this prediction, the Capelin acoustic biomass index in 2023 is expected to be at or above the level of 2022 (262 kt; 90% confidence interval: 177–448 kt).

Limit Reference Point

The LRP is the point between the cautious and critical zone in the DFO Precautionary Approach (PA) Framework (DFO 2023b). A LRP was established for 2J3KL Capelin during this meeting, which is the first step in applying the PA Framework to this stock. After exploring a number of different approaches for setting a LRP for Capelin, a LRP was established based on the history of the stock's trajectory, biology, and its importance to the ecosystem as a whole. The Northern cod stock was used as an ecosystem indicator for the Capelin LRP as the state of the finfish community has positive relationships with the status of the Northern cod and Capelin stocks. Therefore, setting a LRP for Capelin that considers Northern cod's dependence on Capelin is expected to benefit the entire finfish community. Consequently, the Capelin-Cod model, i.e., Capcod model (Koen-Alonso et al. 2021), was used to calculate a LRP of 640 kt of Capelin in the acoustic biomass index, below which the Capelin stock and the finfish community as a whole are likely at risk of serious harm. This Capelin LRP is the level necessary to support the growth of the Northern cod stock to levels last seen in the 1980s, i.e., the Northern cod LRP (Koen-Alonso et al. 2021). In addition, several Capelin biological characteristics (i.e., age-truncation of the stock, faster immature growth, and maturity at younger ages) are consistent with other Capelin stocks when in depleted states indicating the 2J3KL Capelin stock is likely at risk of serious harm. Based on this LRP, the Capelin stock has been in the Critical Zone since 1991, with the exception of 2014 (Fig. 10). In 2013, the probability of the stock being in the Critical Zone was ~45%.

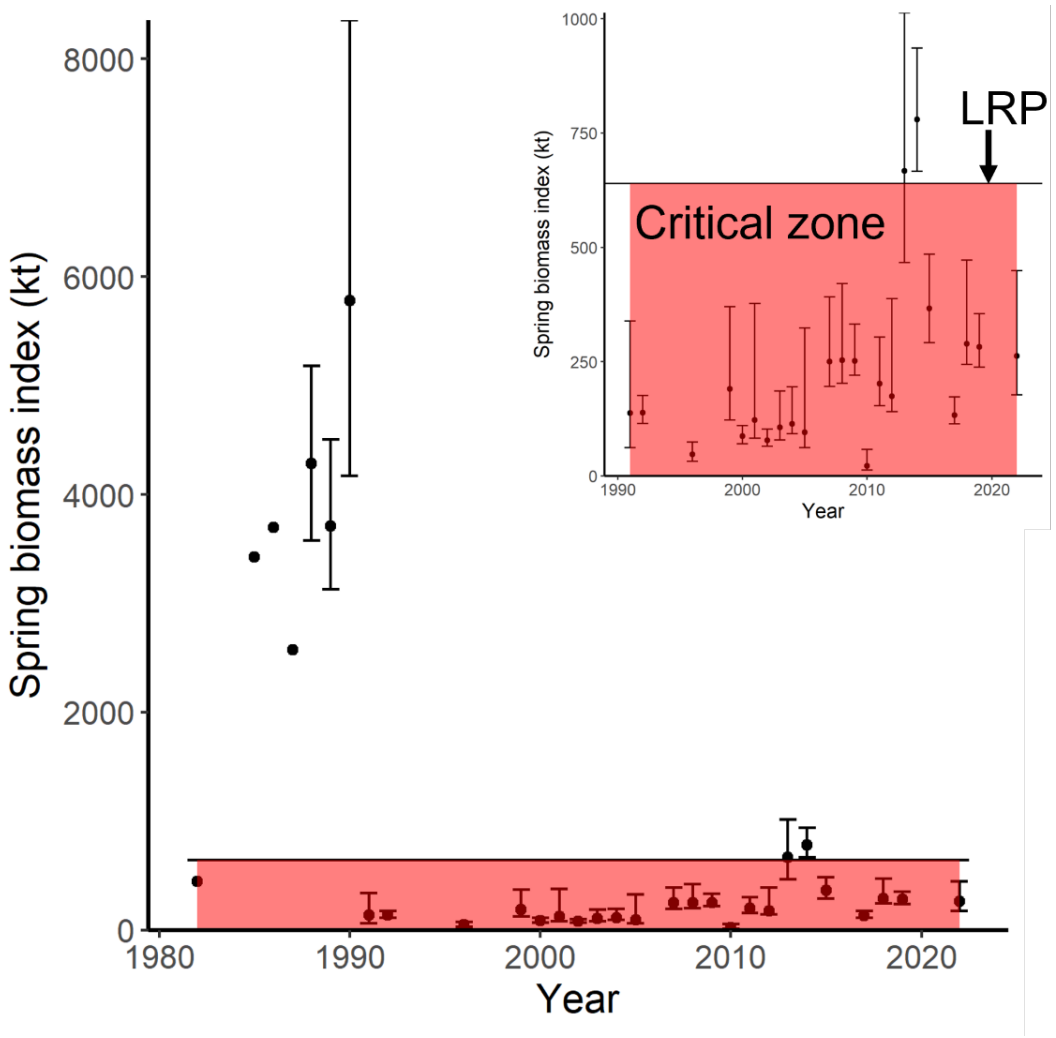

Figure 10. A Capelin LRP was established based on its importance to the ecosystem. A 640 kt Spring acoustic biomass index was selected as the LRP, below which the Capelin stock and the finfish community are likely at risk of serious harm. The inset figure shows the post-collapse years only (1991–2022).

Sources of Uncertainty

There is no estimate of SSB for this stock.

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 its targeted impact on pre-spawning, egg-bearing females that have already survived predation and other sources of natural mortality.

CONCLUSIONS AND ADVICE

The 2J3KL Capelin stock has not recovered from its collapse in 1991, even though there was a brief recovery in stock size in 2013–14. 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 2022 with a high proportion of Capelin maturing at age-2. Due to semelparity, the stock is age-truncated compared to the 1980s. The collapsed stock is also characterized by delayed spawning and low recruitment. Spawning timing in 2022 was typical of the post-collapse period; and while the BB larval index improved, it was similar to the post-collapse time series mean. Capelin fall relative condition has been high since 2020 and was the highest in the time series in 2022; however, the 2022 fall condition value may not be directly comparable with prior estimates due to an earlier than usual survey timing in Div. 3K. In 2022, the 2J3KL Capelin acoustic biomass index was above the post-collapse median and similar to 2018 and 2019, 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 2023 would be at or above the level of 2022.

A 640 kt Capelin acoustic biomass index was selected as the LRP below which the Capelin stock and the finfish community are likely at risk of serious harm. This is the level necessary to support the growth of the Northern cod stock to levels seen in the 1980s, i.e., the Northern cod LRP. Since 1991, with the exception of 2013 and 2014, the Capelin stock has been in the Critical Zone. Consistency with the DFO decision-making framework, incorporating the PA requires that removals from all sources must be kept at the lowest possible level until the stock clears the Critical Zone.

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SOURCES OF INFORMATION

This Science Advisory Report is from the March 6-10, 2023 Regional Peer Review for the Assessment of Divisions 2J+3KL Capelin and Evaluation of Proposed Limit Reference Points. 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): e87589.

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