Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Newfoundland and Labrador Region | **Science Advisory Report 2021/045**

ASSESSMENT OF 2J3KL CAPELIN IN 2019[1]

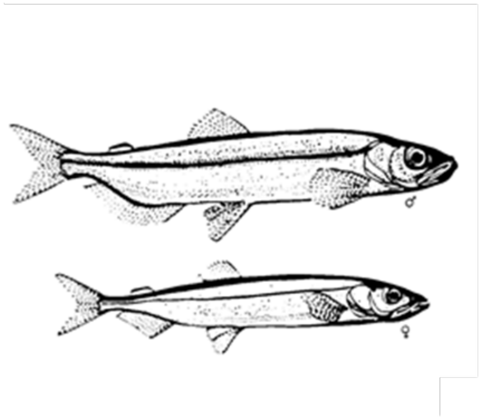

Image: Capelin, adapted from a drawing in C. E. Hollingsworth. 2002. Preface. ICES J. Mar. Sci. 59, p. 861

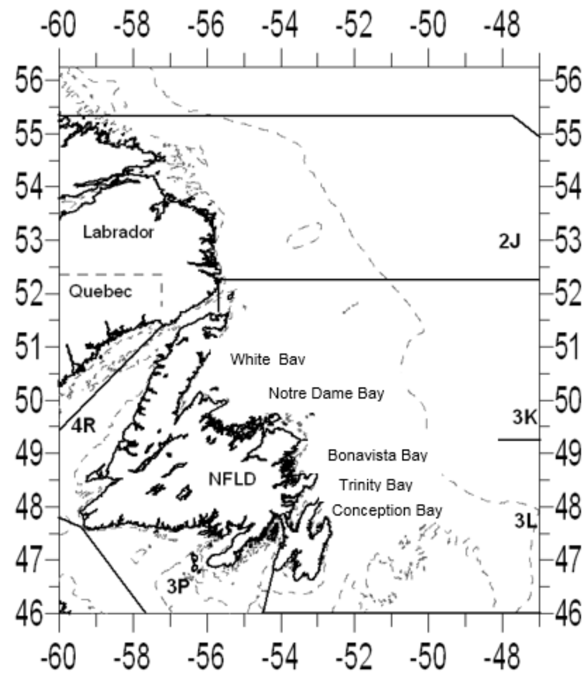

Figure 1. Capelin stock area with 100 m and 500 m contours.

Context:

This Science Advisory Report is from the March 11-13, 2020 Regional Peer Review for the Assessment of Divisions 2J and 3KL Capelin. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

The previous assessment for this stock was in the winter of 2019 (DFO 2019a) and included research and commercial fishery data up to 2018. 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 to 2007. The fishery for 2J3KL Capelin was managed with three-year Capelin management plans from 1999 to 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 recent NL climate has experienced cold conditions between the mid-1980s and the mid-1990s, and from about 2012 to 2017. These cold conditions are associated with positive phases of the North Atlantic Oscillation (NAO) and changes in large-scale ocean circulation (e.g., increased Labrador Current transport along the NL shelf edge).

- Primary (chlorophyll) and secondary (zooplankton biomass) production indices have improved over the past 3-4 years. However, changes in zooplankton community structure up to 2018 have resulted in fewer large copepods which are an important energy source for adult Capelin, and increased abundance of small copepods which indicate improved foraging conditions for larval Capelin.
- Ecosystem conditions in the Newfoundland Shelf and Northern Grand Bank (NAFO Divs. 2J3KL) are indicative of limited productivity of the fish community. Total RV Biomass index remains much lower than prior to the early-1990s. After some recovery since this collapse, current levels of Total RV Biomass index are reduced from those observed in the early-2010s.
- The increases in groundfish observed in the late-2000s and early-2010s appear associated with bottom-up processes, including an improved prey field, with modest increases in Capelin availability in comparison with the 1990s. Capelin and shrimp are key forage species in the ecosystem. More recent declines in total finfish biomass may be associated with simultaneous reductions in Capelin and shrimp availability.
- Predation mortality and consumption of Capelin by fishes declined in 2017-19, suggesting reduced availability of Capelin in the system.
- The commercial fishery in 2019 landed 20,405 t, which is consistent with average landings for the past 10 years (22,000 t). Overall, current removals from predation are large compared to the fishery. However, with declining predation and declining stock size, the proportional impact of fishing has increased.
- There have been six consecutive low larval abundance years (2014-19) including all of the year-classes available to the fishery in 2020.
- The index of Capelin biomass in the 2019 spring acoustic survey was 283 kt (239-356 kt, 95% confidence intervals), near the average biomass index observed from 1999 to 2019 (272 kt), though remaining well below the average observed in the late1980s (1988-1990; 4,593 kt).
- The acoustic abundance index in the 2019 spring survey was 18.5 billion (15.5-23.5 billion, 95% confidence intervals), which is below the average levels observed from 1999 to 2019 (26.6 billion), and the late-1980s (1988-1990, 413.3 billion). Observations of prey consumption by fish predators, Capelin distribution, growth rates, and maturation at age in 2019 are consistent with historical patterns of low abundance.
- In 2019, there was a lower than average proportion of age 2 Capelin in the spring acoustic survey, 80% of which were maturing. Due to the high rate of post-spawning mortality, a decrease in the availability of these Capelin, at age 3, is expected in 2020.
- The forecast model projects that the spring acoustic biomass index in 2020 will be lower than 2019 with a high probability (90%), returning to levels similar to those observed in 2017. The probability of an increase is low (10%).

BACKGROUND

Stock Structure, Management and Species Biology

Capelin (*Mallotus villosus*) is a small pelagic schooling species with a circumpolar distribution with major populations occurring in the Northwest Atlantic Ocean, the waters around Iceland, the Barents Sea and the northern Pacific Ocean. Since 1992, Capelin in Northwest Atlantic

Fisheries Organization (NAFO) Divisions (Divs.) 2J, 3K and 3L (Fig. 1) have been considered a single stock complex and are assessed as such. There are four other recognized Capelin stocks in Canadian waters: the Southeast Shoal (Divs. 3NO), St. Pierre Bank (Subdiv. 3Ps), Gulf of St. Lawrence (Divs. 4RST), and the Scotian Shelf (Divs. 4W).

The 2J3KL Capelin stock experienced a collapse in the early-1990s (Buren et al 2019), with the annual spring acoustic survey index of largely immature (age 2) Capelin declining by an order of magnitude from 6 million t in the late-1980s to less than 150,000 t in 1991. Since then the index has remained low, averaging 250,000 t over the past three decades.

Capelin are a key forage species in the Newfoundland and Labrador (NL) ecosystem. Adults range in size from 12 to 23 cm with males being larger at age than females. Capelin feed on zooplankton and provide energy to higher trophic level predators including marine mammals, seabirds, and larger fish species.

During the fall, both immature and maturing Capelin are distributed offshore in NAFO Divs. 2J3KL where they feed and overwinter. In the spring, maturing Capelin begin to migrate south and move inshore to spawn during the summer. Capelin spawn on beaches and on demersal (deep-water; <40 m) spawning sites. Historically, Capelin matured and spawned at age 3 or 4. Following the collapse of Capelin stocks in the early-1990s, there was a subsequent decline in the proportion of fish in older year classes (Capelin may live up to six years) and increased size at age of younger fish (age 1 and 2). This shift in turn lead to a decrease in age at maturity. Most Capelin now mature at age 2 or 3, with very few surviving to age 4 (or older). Post-spawning mortality is believed to be extremely high for both sexes (Shackell et al. 1994). Since 1991, anecdotal reports have indicated changes in the relative use of beach versus demersal spawning habitat in some locations.

Historically, the timing of peak Capelin spawning was between late-June and mid-July. Since 1991 peak spawning times have been delayed by up to four weeks, shifting to between mid-July and mid-August. Strong year classes are more likely to occur when spawning is earlier in the summer (Hannah Murphy, DFO, unpublished data). Capelin recruitment is highly variable and year class strength is set early during the larval stage (Frank and Leggett 1981; Leggett et al. 1984; Dalley et al. 2002; Murphy et al. 2018). Larval survival in the first two weeks was previously related to the occurrence of onshore winds for the years 1966-90 (Leggett et al. 1984; Carscadden et al. 2000). Onshore wind events both act as a mechanism to release larvae from coarse beach sediment into coastal bays and trigger rapid inshore water mass replacement where cold, high-salinity waters are replaced with warmer, less-saline waters (Frank and Leggett 1982). This water mass replacement was correlated with increased availability of small zooplankton prey (<250 µm) and a decrease in abundance of invertebrate predators (Frank and Leggett 1982). Post-1990, there was no longer a correlation between larval survival and onshore wind events (Murphy et al. 2018). This lack of relationship may be due to the delay in spawning that has persisted since 1991. With predominately south-westerly wind events later in the summer, the number of onshore wind events has decreased during the Capelin spawning period (Murphy et al. 2018). This suggests that Capelin larvae are trapped on the beaches for longer and may not be released into ideal environmental conditions. Post-1990, a match between larval occurrence and prey availability was shown to be important for larval survival (Murphy et al. 2018). Increased availability of preferred prey in autumn, due to a shift in zooplankton phenology seen around 2006, may have improved larval survival from 2011-14. Another important driver of Capelin survival is the timing of ice-mediated spring plankton blooms, which is associated with adult Capelin survival, prey availability and Capelin condition (Buren et al. 2014).

Ecosystem Context

The NL climate experienced cold conditions between the mid-1980s and the mid-1990s, and again from about 2012 to 2017. These cold conditions were associated with positive phases of the North Atlantic Oscillation (NAO) and changes in large-scale ocean circulation (e.g., increased Labrador Current transport along the NL shelf edge) (Cyr et al. 2020). At this point in time, the impact of large scale variations in ocean climate on Capelin is unknown, but it has been shown that mismatches in prey availability associated with changes in the timing of spring sea ice retreat impacts the biomass of adult Capelin (Buren et al. 2014).

Primary (chlorophyll) and secondary (zooplankton biomass) production indices have improved over the past 3-4 years. Recent changes in zooplankton community structure have resulted in fewer large, lipid-rich copepods, which are an important energy source for adult Capelin, and increased abundance of small copepods (DFO 2019b), which indicate poor foraging conditions for adults (Buren et al. 2014), but improved foraging conditions for larval Capelin (Murphy et al. 2018).

Information on the 2J3KL fish community is available from the fall multispecies (bottom trawl) survey (1981-2019). The fish community on the Newfoundland Shelf and Northern Grand Bank (NAFO Divs. 2J3KL) was dominated by finfishes in the 1980s. The ecosystem changes observed in the 1990s involved the collapse of the groundfish community and an increase in shellfish (Koen-Alonso and Cuff 2018, Fig. 2). Capelin also collapsed during this period (Buren et al. 2019). Even with the increases in shellfish, Total biomass from the bottom trawl surveys (Research Vessel [RV] biomass) has not rebuilt to pre-collapse levels.

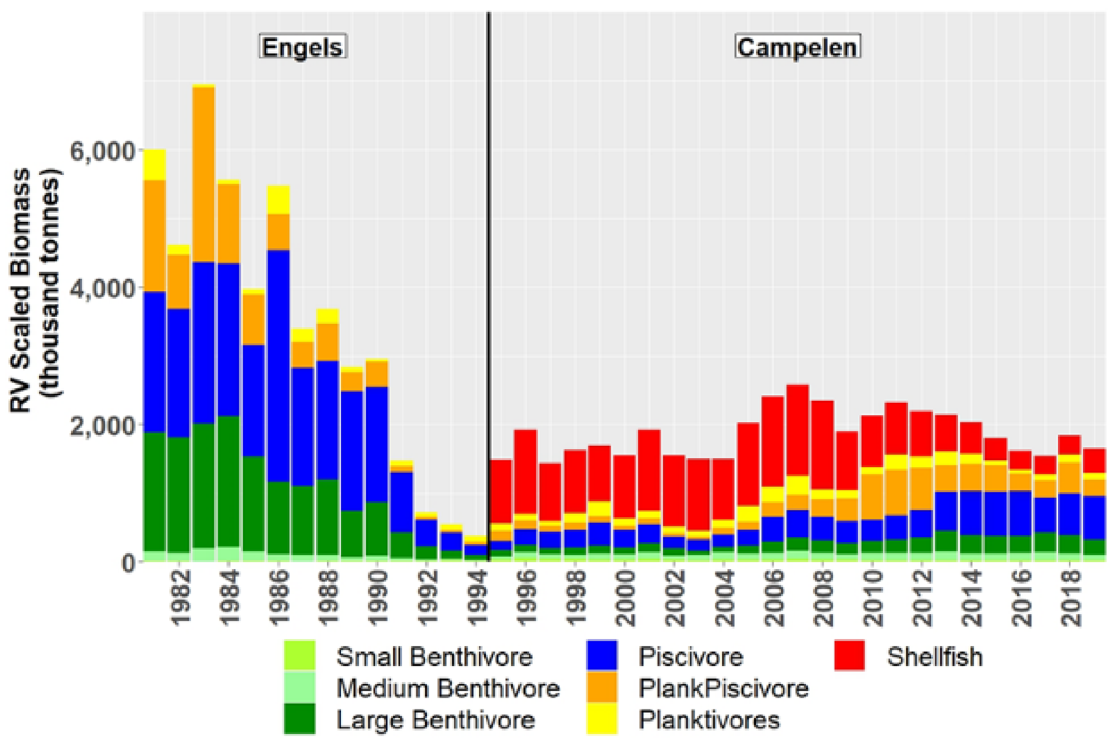

Figure 2. Total RV Biomass index trend of the fish community in the Newfoundland Shelf and northern Grand Bank (Divs. 2J3KL) discriminated by fish functional groups. Indices for the Engel period have been scaled to be comparable to the Campelen series (Koen-Alonso and Cuff 2018). Shellfish data were not consistently collected during the Engel period; the index for this functional group is not available prior to 1995.

Ecosystem conditions continue to be indicative of limited productivity of the fish community. Total RV biomass levels remain much lower than prior to the 1990s collapse. The increases in groundfish observed in the late-2000s and early-2010s appear associated with bottom-up processes, including an improved prey field, with modest increases in Capelin availability in comparison with the 1990s (Buren et al. 2019).

Capelin and shrimp are key forage species in the NL shelf ecosystem. More recent declines in total finfish biomass may be associated with simultaneous reductions in Capelin and Shrimp availability. Consumption of Capelin and Shrimp by fish functional groups that are considered predators of these forage species (i.e. medium and large benthivores, plankpiscivores, and piscivores) was estimated as the median of the consumption envelope derived from a suite of consumption models and diet composition data of key predator species (i.e. a procedure similar to NAFO 2013 and Mullowney et al. 2017).

Both consumption of Capelin by fishes (Fig. 3), and the predation mortality index (estimated consumption of Capelin as a proportion of the an index of Capelin availability) declined from 2017 to 2019 (suggesting reduced availability of Capelin in the system.

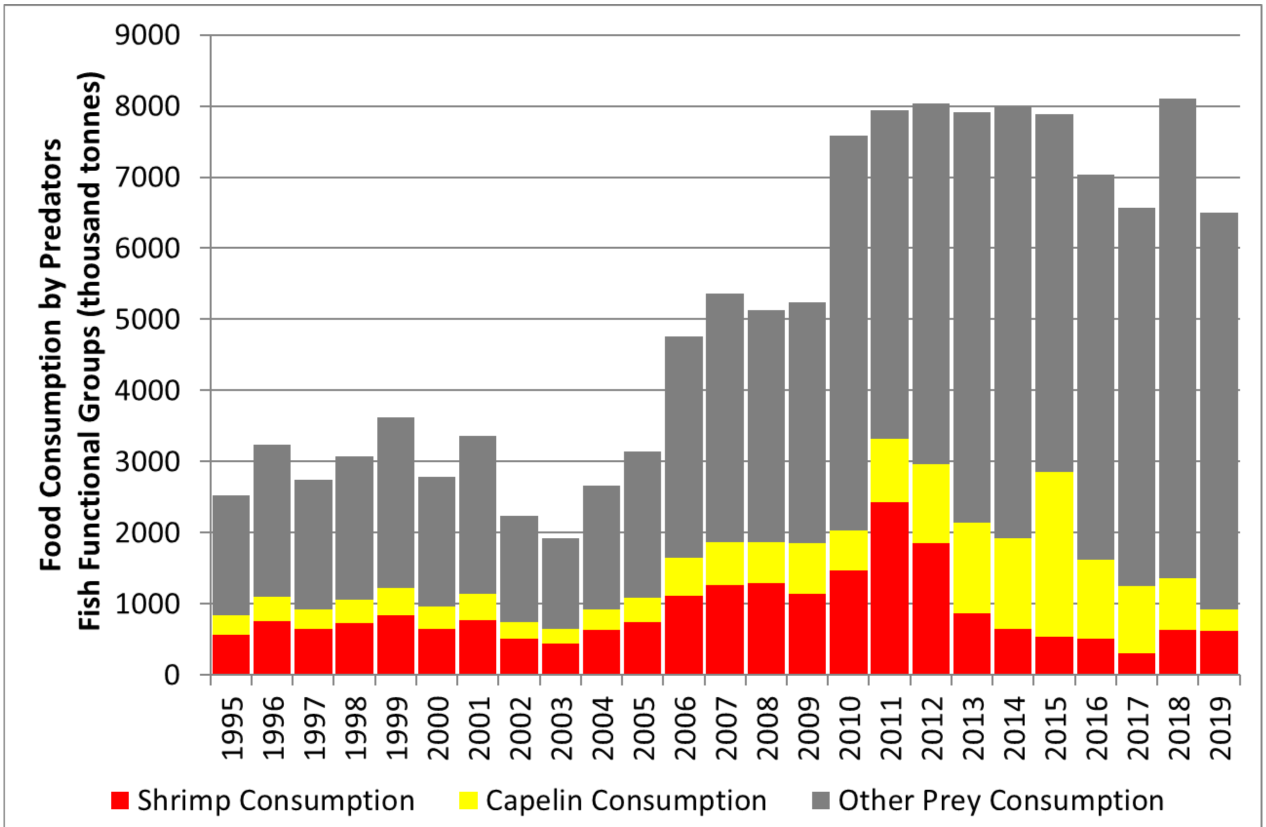

Figure 3. Estimated magnitude of consumption of Capelin, Shrimp, and other prey by the fish functional groups considered predators of these key forage species (i.e. medium and large benthivores, plankpiscivores, and piscivores) from 1995-2019. The estimated magnitudes of consumption are based on a suite of model estimates of total food consumption/requirements and stomach contents data of key groundfish species sampled during the fall RV survey.

Fishery

Historically, Capelin were harvested inshore on spawning beaches for food, bait and fertilizer. A directed foreign offshore fishery began in the early-1970s and was closed in Div. 3L in 1979 and in Divs. 2J3K in 1992. The peak offshore catch of 250,000 t occurred in 1976 (Fig. 4). During the late-1970s, an inshore fishery for roe-bearing female Capelin began. The inshore fishery has been prosecuted using Capelin traps, purse seines, and to a lesser extent, beach seines. Since 1998, modified beach seines called “tuck seines” have been deployed to target Capelin in deeper waters. Peak inshore landings of approximately 80,000 t occurred from 1988 to 1990. Since then annual landings have averaged ~25,000 t (Fig. 4). In some years Capelin fishery effort and landings are negatively impacted by poor price, limited processing capacity and the relative profitability of competing fisheries such as Snow Crab. These factors may result in reduced participation in the fishery within particular years or areas, resulting in Total Allowable Catches (TACs) not being attained.

There are a number of different markets for Capelin, with the highest demand being for frozen roe-bearing females in Japan, where the standard for quality is high. During the 1980s and early-1990s this demand for large females led to high levels of discarding at sea and dumping of (predominantly male) Capelin. To address these issues, several management measures were implemented from the early-1990s onward. These included monitoring of Capelin prior to opening the fishery, with relatively short (two to three days) openings within individual bays; and since 2006 license conditions requiring harvesters to land all Capelin captured (both male and female). Improved markets for male Capelin, including use as animal feed for zoos and aquaculture, have also contributed to full utilization of the landed catch in most areas. Also since 2013, a new sharing arrangement designed to improve equitable access to the TAC within a gear sector was introduced. This arrangement has effectively eliminated discarding when an individual fisher’s catch exceeds trip limits (DFO 2019a).

The commercial fishery in 2J3KL in 2019 landed 20,405 t (96% of the TAC), which is consistent with average landings for the past 10 years (22,000 t) (Fig. 4). In 2019, a higher proportion of age 3 fish were present in landings compared to the two prior years, which resulted in an increase in the average size of Capelin landed. Size and age structure of landed Capelin in 2019 was comparable to the catches observed from the mid-1990s to mid-2000s but were smaller and younger than those in taken the mid-2010s.

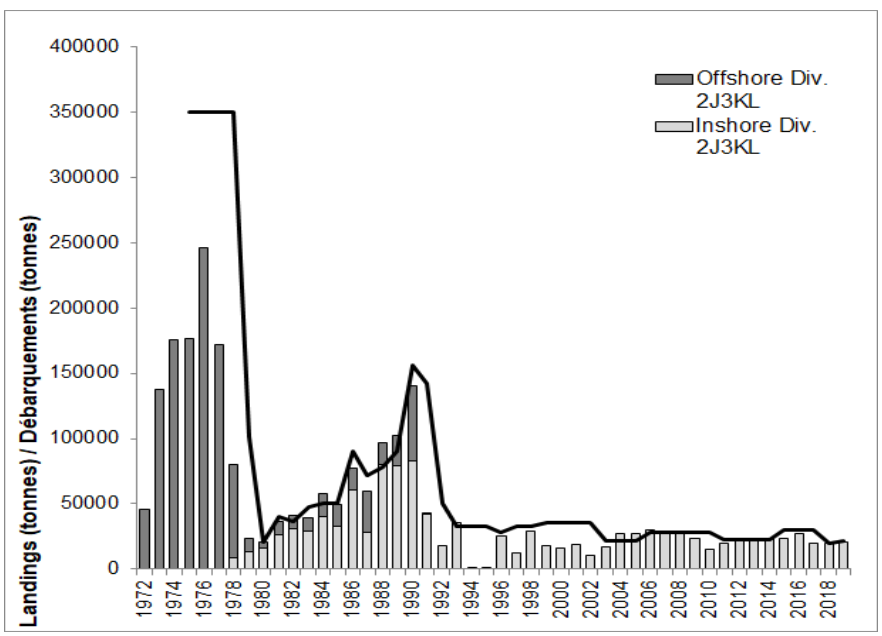

Figure 4. Inshore landings (light grey bars), offshore landings (dark grey bars) and TAC (line) for Capelin in Divs. 2J3KL from 1972 to 2019. Note that annual inshore landings were likely greater than 0 t between 1972 and 1977, but they were not recorded prior to 1978.

ASSESSMENT

The Capelin assessment is based primarily on two main data sources. An index of abundance of younger ages (primarily age 2) Capelin from the spring acoustic survey of NAFO Divs. 3L, and an index of larval Capelin abundance from sampling conducted near Bellevue Beach, in the bottom of Trinity Bay. Additional data used in the assessment include Capelin distribution and biological characteristics from the fall multispecies survey (Divs. 2J3KL), information on the timing of spawning and size of spawners from a number of beach spawning locations, and environmental parameters. A statistical model uses a number of these data sources to forecast Capelin biomass available to the spring acoustic survey in the upcoming year. The Capelin fishery targets spawning fish, but no estimate of the total spawning stock biomass is available.

Spawning

For Capelin, earlier beach spawning is generally associated with a stronger year class (Hannah Murphy, DFO, unpublished data). Data on peak beach spawning timing has been collected at two reference beaches on the Avalon Peninsula: Bryants Cove, Conception Bay (1978-present) and Bellevue Beach, Trinity Bay (1990-present). Timing of peak beach spawning continues to occur later than during the 1980s with peak spawning in 2019 similar to the average for the 1991-2019 period (Fig 5).

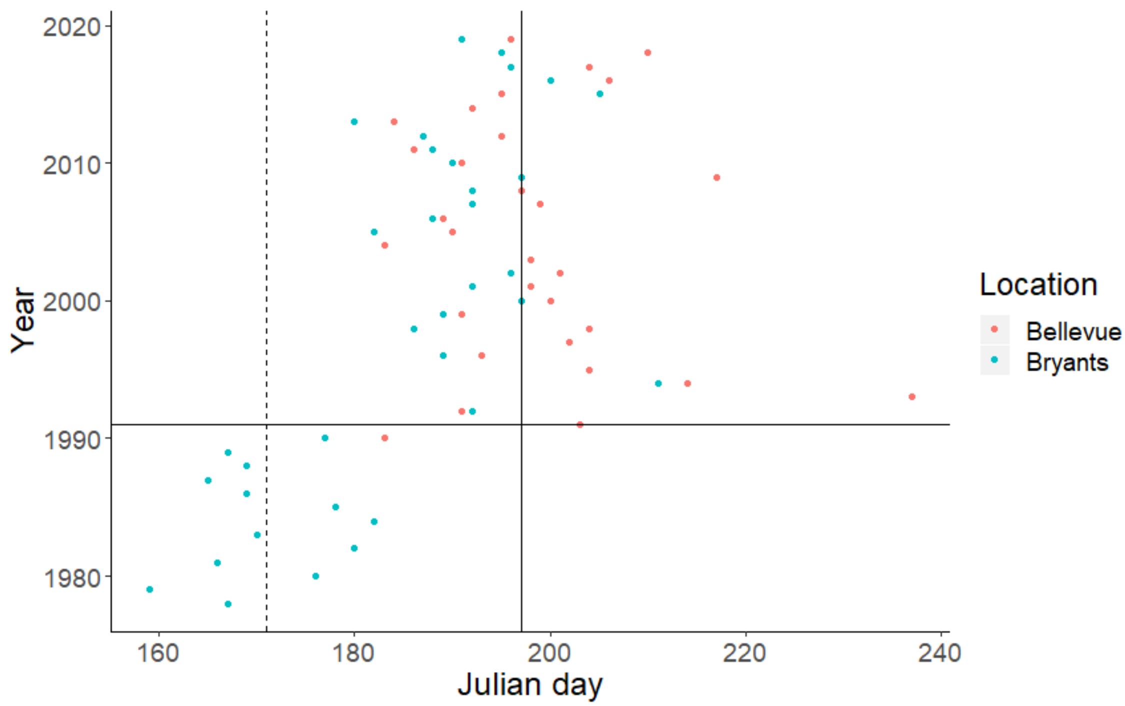

Figure 5. Peak spawning times at Bryants Cove, Conception Bay (1978-2019, and Bellevue Beach, Trinity Bay (1990-2019,). Vertical lines indicate the average day of spawning pre and post collapse (dashed line-1978-90, solid 1991-2019).

Larval Index

Recruitment in Capelin is related to larval survival (e.g., Murphy et al. 2018). The Capelin larval index is the main fishery-independent inshore index used in the assessment. From 2001-19, the nearshore area adjacent to Bellevue Beach, Trinity Bay was surveyed for larval Capelin emerging from one large and four small spawning beaches, and two nearshore deep-water spawning sites (Nakashima and Mowbray 2014). The Capelin larval index has been below average since 2014 and reached a time-series low in 2018 (Fig.6). There have been six consecutive low larval abundance years (2014-19) including all year-classes available to the fishery in 2020.

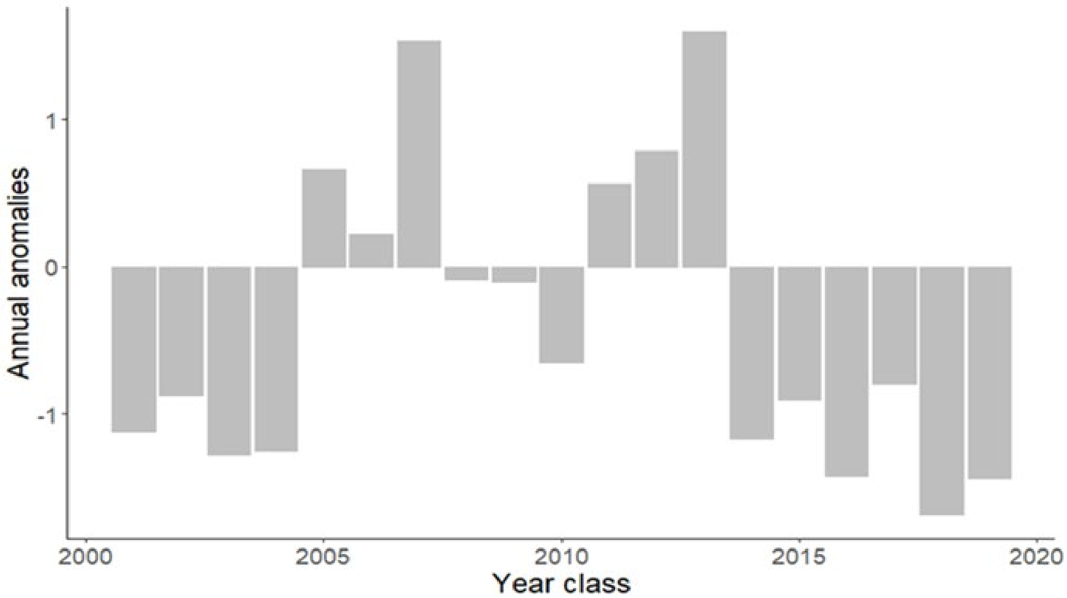

Figure 6. Standardized recruitment index of Capelin larvae from Bellevue Beach, Trinity Bay for the 2001 to 2019 year classes. The mean of the years 2001-13 was used to standardize the data.

Spring Acoustic Survey Indices

Data from spring acoustic surveys were presented for 1988-92, 1996, 1999-2005, 2007-15 and 2017-19. Details on how the abundance and biomass indices and their confidence limits were calculated can be found in Mowbray (2014). The acoustic survey abundance index remains below the levels observed in the late-1980s (Fig. 7). Following a period of very low abundance in the 1990s and early-2000s, the index increased slightly from 2007-12, with the exception of a record low value recorded in 2010. From 2013-15, the abundance index was at the highest levels observed since 1990, ranging from 53-122 billion individuals. Since 2015, the index has ranged from 18.5 to 32.1 billion individuals, comparable to levels observed in the 2000s. The offshore Capelin biomass index for the 2019 spring acoustic survey was 283 kt (95% confidence intervals 239-356 kt), which is similar to the average biomass index observed from 1999 to 2019 (272 kt), though remaining well below the average observed in the late 1980s (1988-90; 4,593 kt). The biomass index from the spring acoustic survey generally tracks the abundance index trend with occasional differences due to variability in the size of Capelin between years, and due to changes in the relative year class strengths of ages 2 and 3.

An abundance index for Capelin in the surveyed inshore area (Trinity Bay) is available for most years. This index is less dynamic than the offshore index and has at times shown contrasting trends (Buren et al. 2019). The Capelin abundance index in Trinity Bay in 2019 (1.7 billion individuals) decreased from 2018 returning to levels observed in the early-2000s (Fig.7).

The relative cohort strength at ages 2 and 3 from the spring offshore acoustic survey has tracked well for most cohorts; consequently, it is considered to be a robust indicator of trends in Capelin biomass and abundance. However, because the spring survey covers only a portion of the stock area, the abundance index is considered to be a minimum abundance estimate and may be subject to unquantified inter-annual variations due to changes in the distribution of the stock within the surveyed area. However the portion of Capelin found inshore in May is a small proportion of the overall stock and therefore trends in the offshore index are thought to reflect those in the population (Buren et al. 2019).

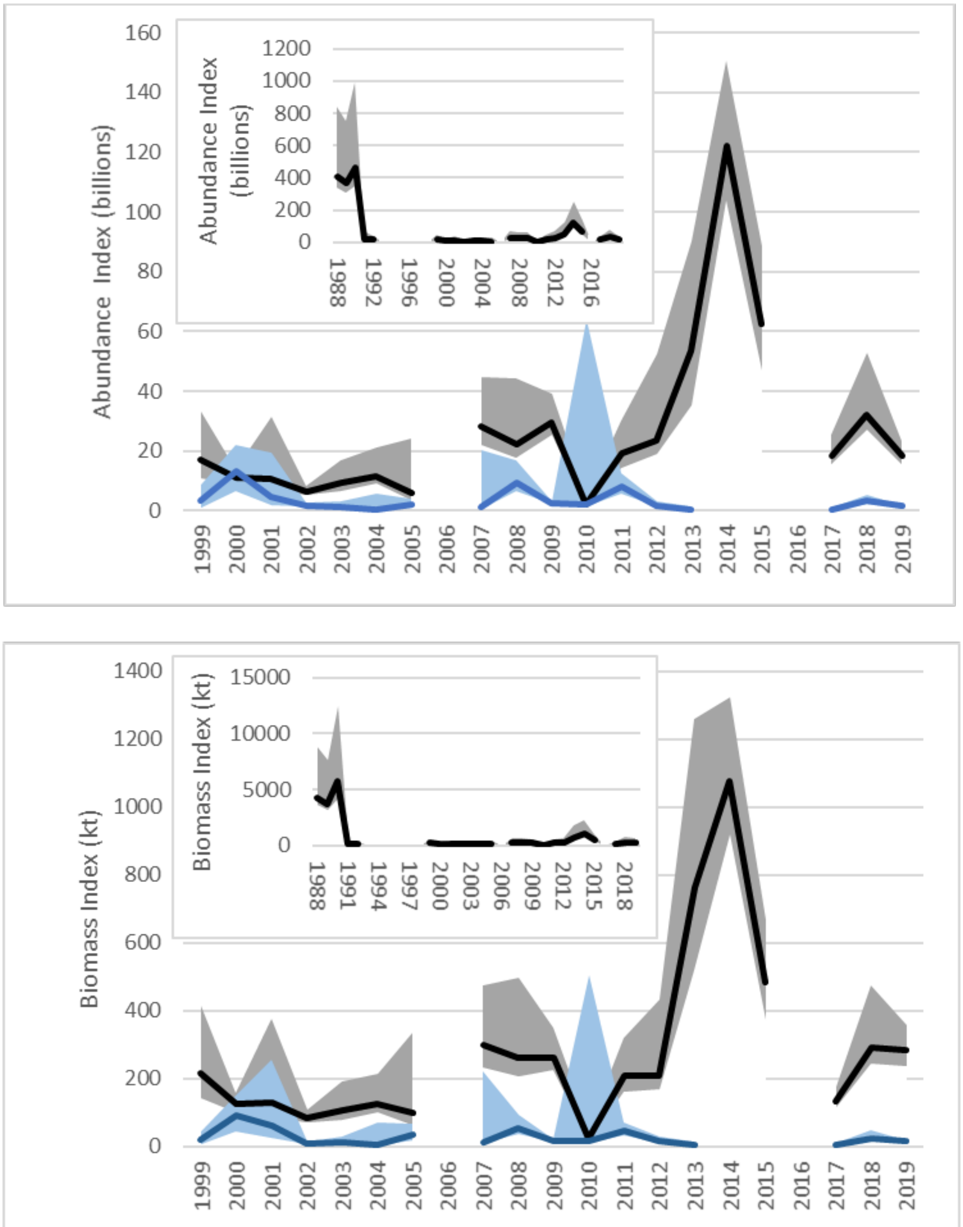

Figure 7. Spring (May) offshore acoustic indices of Capelin abundance (upper panel) and biomass (lower panel) in NAFO Divs. 3L and southern Divs. 3K (solid line) with 95% confidence intervals (shaded area) (1988-92, 1996, 1999-2005, 2007-15, 2017-19) The offshore index is presented in black/grey and Trinity Bay in blue.

Biological Characteristics, Distribution and Consumption of Capelin

By design, the spring acoustic survey primarily intercepts age 2 Capelin, but some age 1 and older age classes are also represented (Fig. 8). Age 1 Capelin have been poorly represented in the survey in the past three years, although poor representation at age one is not always linked with poor cohort strength at age 3. Age 3 Capelin formed a slightly larger proportion of the surveyed abundance in 2019. In 2019, there was a lower than average proportion of age 2 Capelin in the spring acoustic survey, 80% of which were maturing (Fig. 9). Due to the high rate of post-spawning mortality, a decrease in the availability of these Capelin, at age 3, is expected in 2020. Fewer older fish in the population is associated with later spawning, a smaller, more southerly area of distribution in the fall, and may be associated with poorer larval survival.

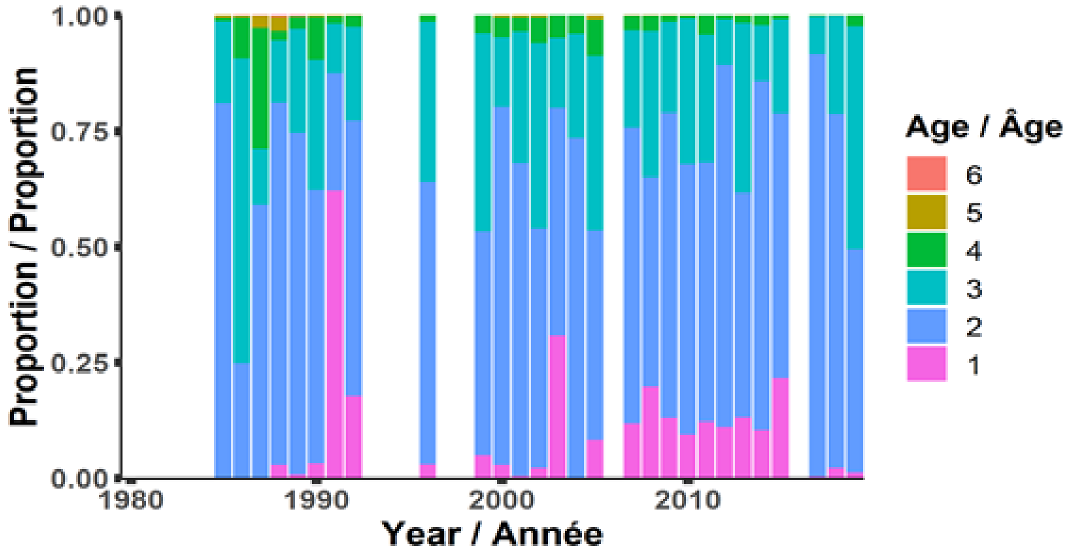

Figure 8. Age composition of Capelin surveyed during the spring (May) Divs. 3L acoustic survey (1985-92, 1996, 1999-2005, 2007-15, 2017-19).

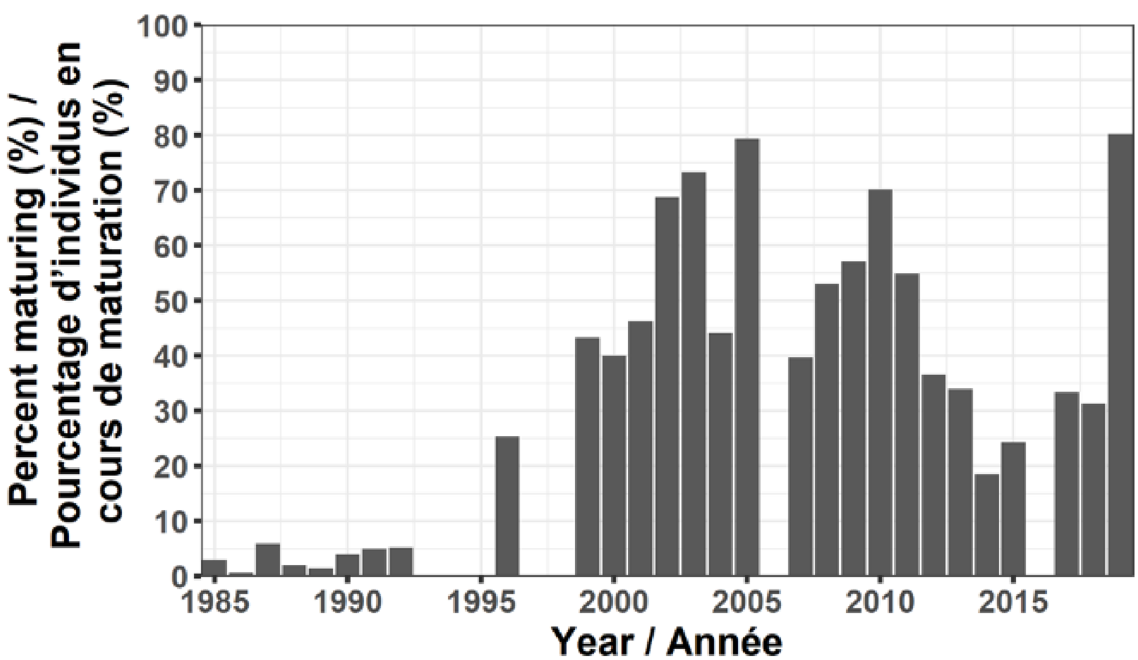

Figure 9. Proportion of maturing Age 2 Capelin which were mature as determined from spring (May) Div. 3L acoustic surveys (1985-92, 1996, 1999-2005, 2007-15, 2017-19).

The mean length at age of age 2-4 Capelin sampled during the spring acoustic survey increased slightly from 2018 to 2019 and is currently at or near the time series high. Age 1 Capelin were smaller in 2019 than in 2018 (Fig. 10), with lengths near the time series mean.

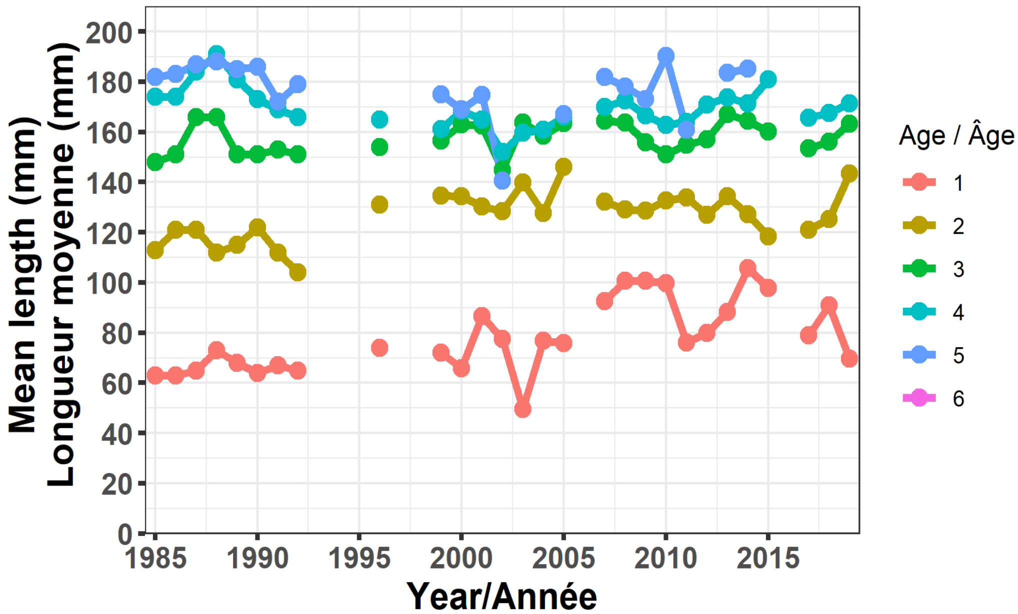

Figure 10. Mean length at age of Capelin sampled during spring acoustic surveys (1985-92, 1996, 1999-2005, 2007-15, 2017-19).

Condition of Capelin in the fall may impact overwintering survival. Relative condition of male Capelin collected during the fall multi-species survey is calculated by NAFO division and age. Female condition is not calculated in the fall due to mixed spawning history (i.e. a variable proportion of females survive spawning) which impacts energy reallocation to gonads. No Capelin samples were available from 2J in 2019. Fall condition of age 1 male Capelin in Divs. 3KL varied without trend, while the fall condition of age 2 male Capelin, which was at a time series high in Divs. 3K (their main distribution area) in 2017, was average or below average in 2019 (Fig. 11).

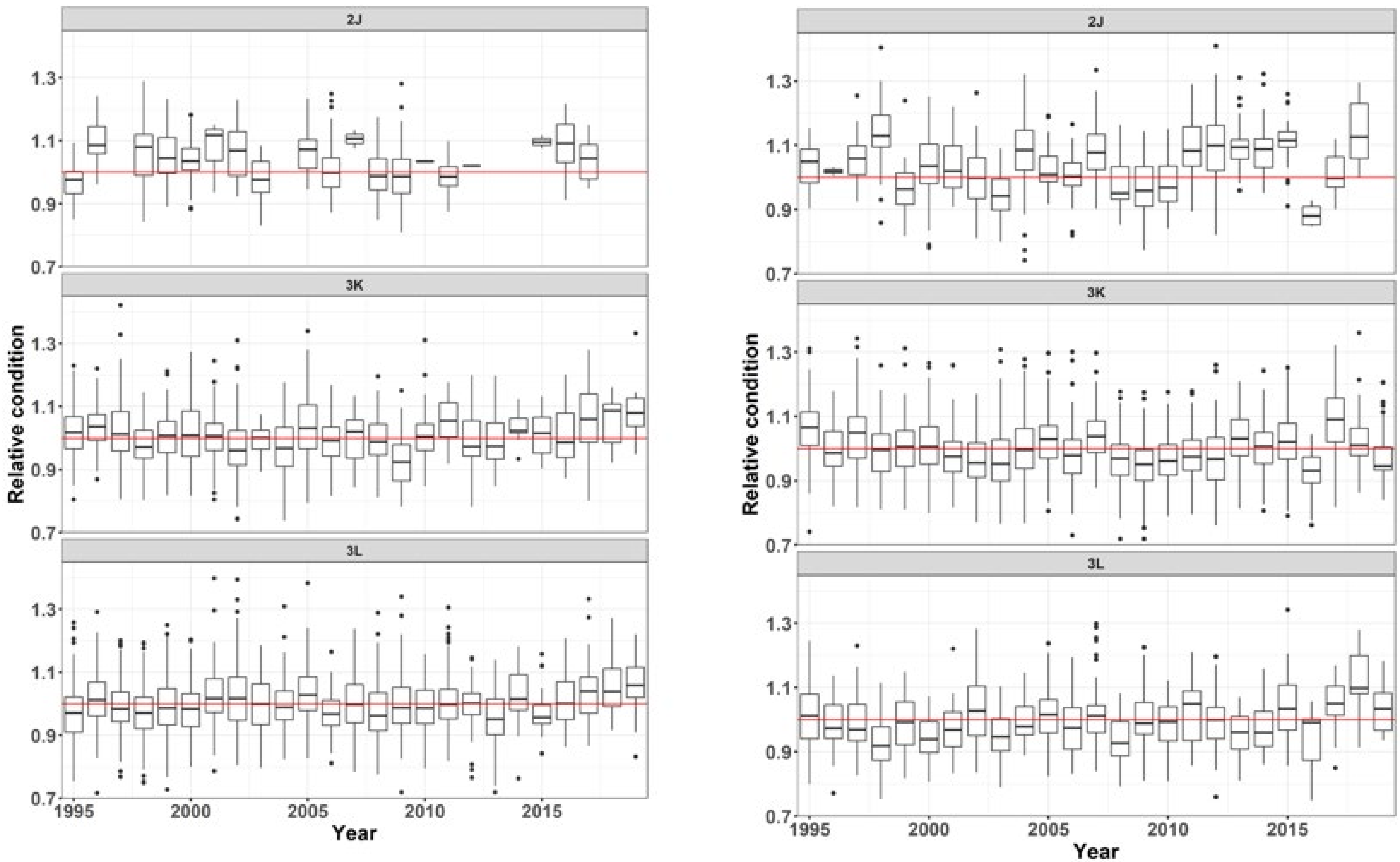

Figure 11. Relative condition of age 1 (left panel) and age 2 (right panel) male Capelin sampled in the fall multi-species bottom trawl survey by year (1995-2019) and NAFO division (2J, 3K, and 3L).

In 2019, the spatial distribution of Capelin observed during the spring acoustic survey was typical of patterns observed during the 2000s with most Capelin offshore in deeper water (200 m) and along the shelf break. This contrasted with the unusual spring distribution observed in 2018 when Capelin were largely concentrated in the northwest portion of Div. 3L and inshore.

Information on fall Capelin distribution comes from multi-species bottom trawl surveys from 1983-2019. When the gear changed from the Engels otter trawl to the Campelen 1800 shrimp trawl in 1995, catchability increased for smaller fish (Warren 1997) resulting in a general increase in the amount and frequency of Capelin being caught in survey fishing sets. However, bottom trawl surveys cannot provide abundance estimates for pelagic species (McQuinn 2009). A center of gravity analysis of the fall bottom trawl data (1983-2019) found that Capelin tended to be distributed farther north when the stock was strong with a larger range of age classes (Fig. 12). In the past decade, the center gravity of Capelin shifted northwards (2011-14), then southwards again (2015-19).

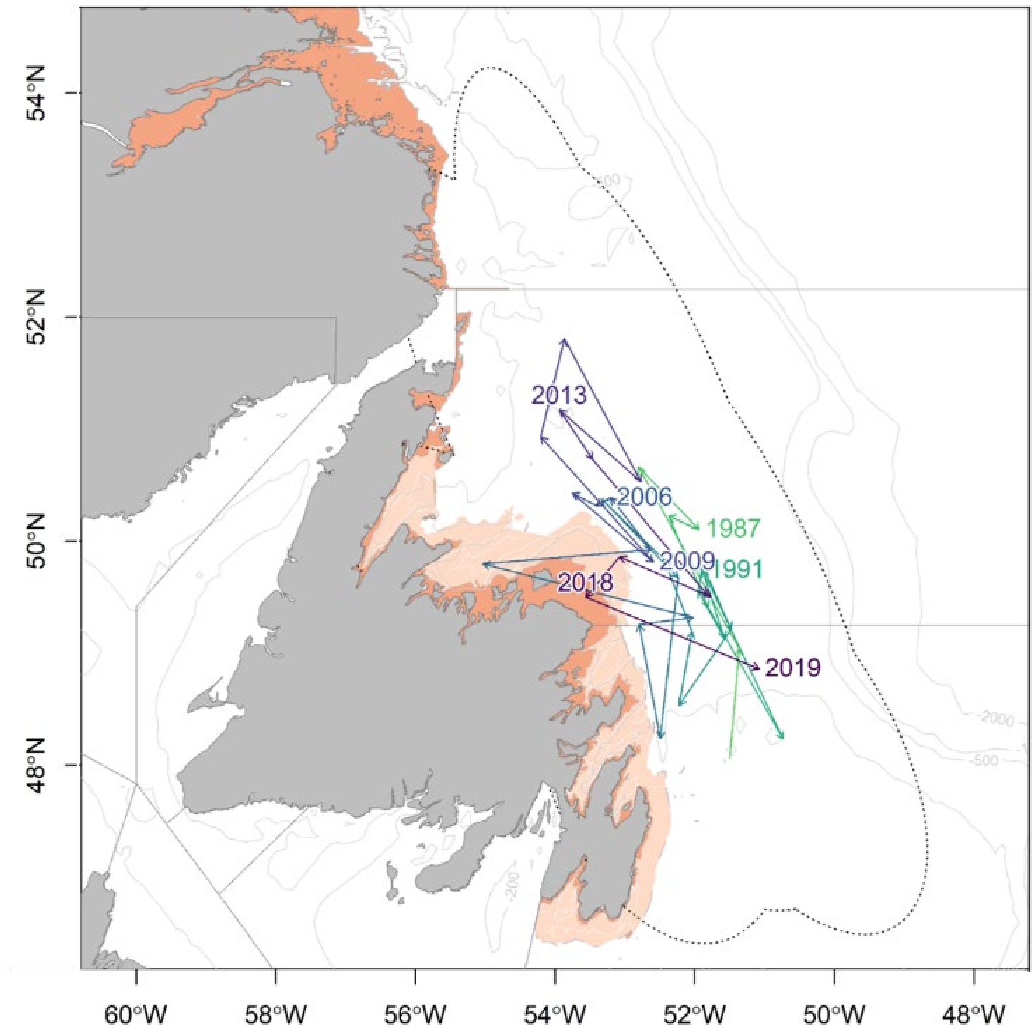

Figure 12. Distribution of the center of gravity of Capelin computed from the fall bottom-trawl survey in NAFO Divs. 2J3KL from 1983 to 2019. Annual center of gravity estimates are connected by lines through time, and composite ellipses of deviation around these estimates (i.e. inertia) are indicated by the dotted black line. Center of gravity and inertia were calculated using equations found in Woillez et al. (2007). The orange area indicates areas not covered by the fall survey and the light cream area indicates inshore strata that are poorly covered by the fall bottom-trawl survey. Based on an analysis in Buren et al. (2019).

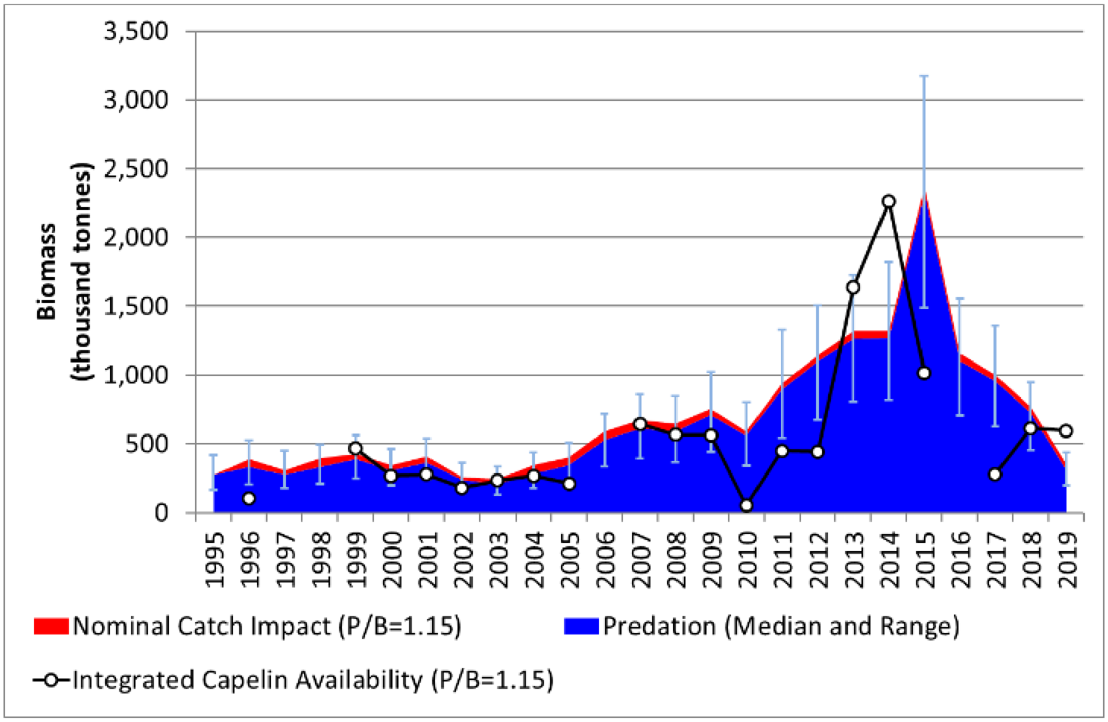

Figure 13. Consumption of Capelin in 2J3KL by fish predators (blue area; error bars indicate the range of the estimated envelop of consumption) and the Nominal Catch Impact from fishery catches from 1995-2019 (red area). Black line indicates the Integrated Capelin Availability derived from spring acoustic surveys and the Capelin Production/Biomass ratio (P/B=1.15).

Evaluating the scope of the likely impacts of consumption by predators and fishing on the Capelin stock needs to consider these factors on equal footing. The estimated consumption by predators integrates consumption removals over the year, while the Capelin acoustic biomass index, even if it were to be scaled to represent absolute biomass, is still be an estimate of standing stock size at a given point in time, not of the integrated Capelin availability over the year. Therefore, to make an appropriate comparison with consumption, we need to estimate the amount of Capelin likely available in the ecosystem integrated over the year. This was coarsely approximated by a) assuming that the acoustic Capelin index is an adequate proxy for the order of magnitude of the stock size (this is a minimum estimate), and b) considering a production/biomass (P/B) ratio for Capelin of 1.15 (Tam and Bundy 2019). These considerations allowed calculating the Integrated Capelin Availability as Acoustic Biomass+1.15*Acoustic Biomass. Following a similar logic, the Nominal Catch Impact from fishing was estimated by taking into account the nominal Capelin catches plus the loss of production from those catches, also assuming a P/B ratio of 1.15. These estimates are intended as order of magnitude approximations to allow for general level comparisons among these factors.

Consumption of Capelin by finfish tracks reasonably well the Integrated Capelin Availability derived from the spring acoustic survey, with both showing low levels in the 1990s, an increase in the mid-2000s, further elevated levels in the mid-2010s, and a decline in the late 2010s (Fig. 13). While current analyses are only intended to capture orders of magnitude, and the estimated Integrated Capelin Availability is by construction known to be a minimum estimate, the overall concordance between consumption and availability estimates, both in trajectory and general magnitude, suggests that these results are reasonable approximations to these processes. Overall, current removals from predation by fishes are large compared to the expected removals from the fishery (Fig. 13). However, with declining predation and declining stock size, the proportional impact of fishing relative to consumption has increased, reaching in 2019 similar levels to those of the mid to late-2000s.

Observations of prey consumption by fish predators, Capelin distribution, growth rates, and maturation at age in 2019 are consistent with historical patterns of low Capelin abundance.

Forecast Model

A Capelin forecast model, (Lewis et al. 2019) is used to project the spring acoustic index for the coming years. A variety of mechanisms have been previously explored to explain inter-annual variations in Capelin biomass. Murphy et al. (2018) found Capelin larval abundance and larval food availability explained ~40% of the variability in age 2 Capelin recruitment variability. Buren et al. (2014) found a dome-shaped relationship between Capelin biomass and timing of the sea ice retreat (as a proxy for timing of the spring bloom). Additionally, the model includes the relationship between fall condition of age 1 and 2 Capelin and overwinter survival. The Capelin forecast model was developed using a Bayesian approach in a multi-model inference framework (see Lewis et al. 2019 for more details on model development). The most parsimonious model included larval abundance from Bellevue Beach, timing of the sea ice retreat, and adult Capelin condition in the fall (Lewis et al. 2019). The model uses various time lags in the data time series: the Bellevue Beach larval index and condition of adult Capelin in the fall were lagged by two years and one year, respectively, while timing of the sea ice retreat is from the current year (Lewis et al. 2019). For example, the 2020 model forecast is based on the 2018 larval index, 2019 fall condition index for adult Capelin, and 2020 day of sea ice retreat. The 2021 model forecast is based on the 2019 larval index, and the averages over the lengths of their respective time series for the adult Capelin fall condition index and the date that sea ice began to retreat**.** The forecast model projects that the spring acoustic biomass index in 2020 will be lower than 2019 with a high probability (90%) that the index will return to levels similar to those observed in 2017. The probability of an increase is low (10%) (Fig. 14).

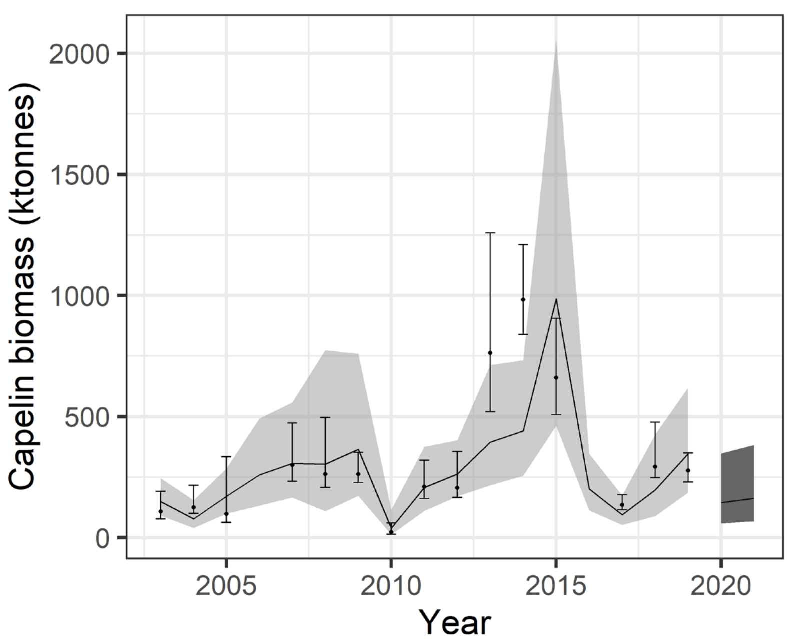

Figure 14. The results from the Capelin forecast model including the 95% credible (light grey) and 80% prediction intervals (dark grey) for expected values of Capelin biomass in the spring acoustic survey (solid line) and observed values (point estimates with ±95% confidence intervals). The model forecasts a probable decrease in the Capelin biomass in the 2020 spring acoustic survey.

Sources of Uncertainty

Capelin have a short life span, typically with only two year classes contributing significantly to the spawning biomass each year and few individuals living more than four years. Capelin can produce large quantities of eggs; however, mortality rates during their egg and larval stages are extremely high – this creates the potential for small fluctuations in environmental conditions to lead to order of magnitude changes in recruitment (Houde 1987). An increase in the magnitude and frequency of anomalies in environmental parameters is associated with climate change; environmental variability may increase uncertainty with regard to Capelin stock dynamics.

At present, no estimates of absolute abundance or biomass of the Divs. 2J3KL Capelin stock are available. The spring acoustic survey provides an index of Capelin abundance as it surveys only Div. 3L and the southern portion of Div. 3K. While the Capelin acoustic abundance index provides consistent information on cohort strength of age 2 fish, information on age 1 and older age classes is incomplete as they are not fully recruited to the acoustic survey. A small portion of the stock (largely immature age 1 and 2) may reside inshore at the time of the spring survey, this portion is relatively small relatively to that offshore (Buren et al. 2019).

While the larval index is collected in one nearshore area of Trinity Bay and may not be reflective of larval productivity in other bays or regions, previous research found a synchronous release of Capelin larvae in the northeastern bays of Newfoundland (Nakashima 1996). Furthermore, the larval index has been positively related to the spring acoustic index, which suggests that larval sampling at Bellevue beach provides a proxy for larval productivity in other bays in Newfoundland (Murphy et al. 2018). The potential contribution of demersal spawning to Capelin recruitment was a major point discussed during the assessment process. Updates were provided on a number of ongoing research projects that aim to contribute to the understanding of the contribution of demersal spawning to this stock.

Total Capelin consumption estimates are unknown. Consumption estimates in this assessment do not include consumption by seals, whales and seabirds.

Similarly estimates of ecosystem productivity do not include information on the distribution and abundance of seals, whales and seabirds, such as the steady increase in harp seal abundance since 2011 (DFO 2020).

The impact of fishing mortality on the Capelin stock is not quantified and is poorly understood.

CONCLUSION

The acoustic abundance index in the 2019 spring survey was 18.5 billion, below the average levels observed from 1999 to 2019 (26.6 billion), and the late1980s (1988-90, 413.3 billion). Observations of prey consumption by fish predators, Capelin distribution, growth rates, and maturation at age in 2019 are consistent with historical patterns of low Capelin abundance. In 2019, there was a lower than average proportion of age 2 Capelin in the spring acoustic survey, 80% of which were maturing. Due to the high rate of post-spawning mortality, a decrease in the availability of these Capelin to the fishery and predators, at age 3, is expected in 2020. There have been six consecutive low larval abundance years (2014-19) including all of the year-classes available to the fishery in 2020. The forecast model projects that the spring acoustic biomass index in 2020 will be lower than 2019 with a high probability (90%) of returning to levels similar to those observed in 2017. The probability of an increase in the biomass index is low (10%). The commercial fishery in 2019 landed 20,405 t, which is consistent with average landings for the past 10 years (22,000 t). Overall, current removals from predation are large compared to the fishery. However, with declining predation by groundfish and declining stock size, the proportional impact of fishing has increased.

LIST OF MEETING PARTICIPANTS

NAME	AFFILIATION
Erika Parrill	DFO - Centre for Science Advice
Laura Wheeland	Chair
Erin Dunne	DFO - Resource Management
Rod Drover	DFO - Communications
Aaron Adamack	DFO - Science
Andrew Cuff	DFO - Science
Christina Bourne	DFO - Science
Dave Bélanger	DFO - Science
Fran Mowbray	DFO - Science
Frédéric Cyr	DFO - Science
Hannah Munro	DFO - Science
Hannah Murphy	DFO - Science
Hannah Polaczek	DFO - Science
Karen Dwyer	DFO - Science
Kate Dalley	DFO - Science
Keith Lewis	DFO - Science
Mariano Koen-Alonso	DFO - Science
Meredith Terry	DFO - Science
Nicolas Le Corre	DFO - Science
Paul Regular	DFO - Science
Paula Lundrigan	DFO - Science
Nancy Pond	NL Fisheries and Land Resources
Höskuldur Björnsson	Iceland - Marine Environmental Research Institute
George Russell	NunatuKavut Community Council
Dennis Chaulk	Fish, Food and Allied Workers Union
Eldred Woodford	Fish, Food and Allied Workers Union
Erin Carruthers	Fish, Food and Allied Workers Union
Steven Miller	Fish, Food and Allied Workers Union
Maxime Geoffroy	Memorial University - Marine Institute
Chelsea Boaler	Memorial University - Marine Institute
Jessica Randall	Memorial University - Marine Institute
Jin Gao	Memorial University - Marine Institute
Julek Chawarski	Memorial University - Marine Institute
Tyler Eddy	Memorial University - Marine Institute
Ashley Tripp	University of Manitoba
Gail Davoren	University of Manitoba
Scott Morrison	University of Manitoba
Victoria Neville	World Wildlife Fund

SOURCES OF INFORMATION

This Science Advisory Report is from the March 11-13, 2020 Regional Peer Review for the Assessment of Divisions 2J and 3KL Capelin. 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 W.A. Montevecchi. 2014. Bottom-up regulation of Capelin, a keystone forage species. PLoS ONE. 9(2):e87589.

Buren, A.D., Murphy, H.M., Adamack, A.T., Davoren, G.K., Koen-Alonso, M., Montevecchi, W.A., Mowbray, F.K., Pepin, P., Regular, P.M., Robert, D., Rose, G.A., Stenson, G., and D. Varkey. 2019. The collapse and continued low productivity of a keystone forage species. Marine Ecology Progress Series. 616: 155-170.

Carscadden, J.E., Frank, K.T., and W.C. Leggett. 2000. Evaluation of an environment-recruitment model for Capelin (*Mallotus villosus*). ICES J. Mar. Sci. 57: 412-418.

Cyr, F., Colbourne, E., Galbraith, P.S., Gibb, O., Snook, S., Bishop, C., Chen, N., Han, G., and D. Senciall. 2020. Physical Oceanographic Conditions on the Newfoundland and Labrador Shelf during 2018. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/018. iv + 48 p.

Dalley, E.L., Anderson, J.T., and B. DeYoung. 2002. Atmospheric forcing, larval drift, and recruitment of Capelin (*Mallotus villosus*). ICES J. Mar. Sci. 59: 929-941.

DFO. 2019a. Oceanographic Conditions in the Atlantic Zone in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/034.

DFO. 2019b. Assessment of 2J3KLCapelin in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/048.

DFO. 2020. 2019 Status of Northwest Atlantic Harp Seals, *Pagophilus groenlandicus.* DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/020.

Frank, K.T. and W.C. Leggett. 1981. Wind regulation of emergence times and early larval survival in Capelin (*Mallotus villosus*). Can. J. Fish. Aquat. Sci. 38: 215-223.

Frank, K.T. and W.C. Leggett. 1982. Coastal water mass replacement: its effect on zooplankton dynamics and the predator-prey complex associated with larval Capelin (*Mallotus villosus*). Can. J. Fish. Aquat. Sci. 39: 991-1003.

Koen-Alonso, M and A. Cuff. 2018. Status and trends of the fish community in the Newfoundland Shelf (NAFO Div. 2J3K), Grand Bank (NAFO Div. 3LNO) and Southern Newfoundland Shelf (NAFO Div. 3Ps) Ecosystem Production Units. NAFO SCR Doc. 18/070.

Houde, E.D. 1987. Fish early life dynamics and recruitment variability. Transactions of the American Fisheries Society Symposium Series 2: 17-29.

Leggett, W.C., Frank, K.T., and J.E. Carscadden. 1984. Meteorological and hydrographic regulation of year-class strength in Capelin (*Mallotus villosus*). Can. J. Fish. Aquat. Sci. 41: 1193-1201.

Lewis, K.P., Buren, A. D., Regular, P.M., Mowbray, F., and H.M. Murphy. 2019. Forecasting capelin *Mallotus villosus* biomass on the Newfoundland shelf. Mar Ecol Prog Ser 616:171-183.

McQuinn, I.H. 2009. Pelagic fish outburst or suprabenthic habitat occupation: legacy of the Atlantic cod (*Gadus morhua*) collapse in eastern Canada. Can. J. Fish. Aquat. Sci. 66: 2256–2262.

Mowbray, F.K. 2014. Recent spring offshore acoustic survey results for Capelin, *Mallotus villosus*, in NAFO Division 3L. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/040. v + 25 p.

Mullowney, D., Coffey, W., Baker, K., Evans, G., Fiander, D., Colbourne, E., Maddock Parsons, D., Koen-Alonso, M., and N. Wells. 2017. An Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/081. viii + 172 p.

Murphy, H.M., Pepin, P., and D. Robert. 2018. Re-visiting the drivers of Capelin recruitment in Newfoundland since 1991. Fisheries Research 200:1-10.

NAFO. 2013. Report of the 6th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA) [Formerly WGEAFM]. NAFO SCS Doc. 13/024.

Nakashima, B. 1996. The relationship between oceanographic conditions in the 1990s and changes in spawning behaviour, growth and early life history of Capelin (*Mallotus villosus*). NAFO Sci Coun Studies 24: 55-68.

Nakashima, B., and F.K. Mowbray. 2014. Capelin (*Mallotus villosus*) recruitment indices in NAFO Division 3KL. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/091. v + 27 p.

Shackell, N.L., Shelton P.A., Hoenig, J.M., and J.E. Carscadden. 1994. Age- and sex-specific survival of Northern Grand Bank Capelin (*Mallotus villosus*). Can. J. Fish. Aquat. Sci. 51: 642-649.

Tam, J.C. and A. Bundy. 2019. Mass-balance models of the Newfoundland and Labrador Shelf ecosystem for 1985-1987 and 2013-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3328: vii + 78 p.

Warren, W.G. 1997. Report on the comparative fishing trial between the *Gadus Atlantica* and *Teleost.* NAFO SCR. Doc. 96/28.

Woillez, M., Poulard, J-C., Rivoirard, J., Petitgas, P., and N. Bez. 2007. Indices for capturing spatial patterns and their evolution in time, with application to European hake *(Merluccius merluccius*) in the Bay of Biscay. ICES Journal of Marine Science 64: 537-550.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Newfoundland and Labrador Region
Fisheries and Oceans Canada
PO Box 5667
St. John's, NL
A1C 5X1

Telephone: 709-772-8892
E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-40375-5 Cat. No. Fs70-6/2021-045E-PDF

Correct Citation for this Publication:

DFO. 2021. Assessment of 2J3KL Capelin in 2019[1]. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/045. (Erratum: November 2021)

Aussi disponible en français :

MPO. 2021. Évaluation du capelan des divisions 2J3KL en 2019[1]. Secr. can.de consult. sci. du MPO. Avis sci. 2021/045. (Erratum : Novembre 2021)

[1] Erratum: year corrected to reflect when data was collected rather than when the stock assessment occurred.