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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2022/013

ASSESSMENT OF 2J3KL CAPELIN IN 2020

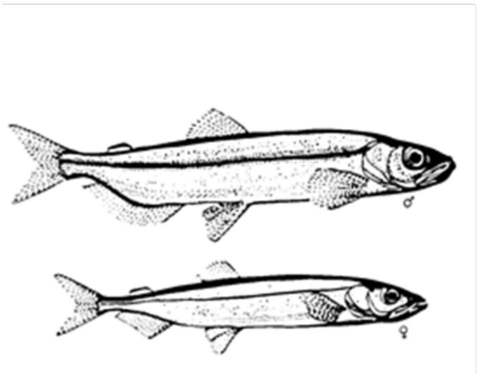

Image: Capelin, adapted from a drawing in C.E. Hollingsworth. 2002. Preface. ICES J. Mar. Sci. 59, p. 861.

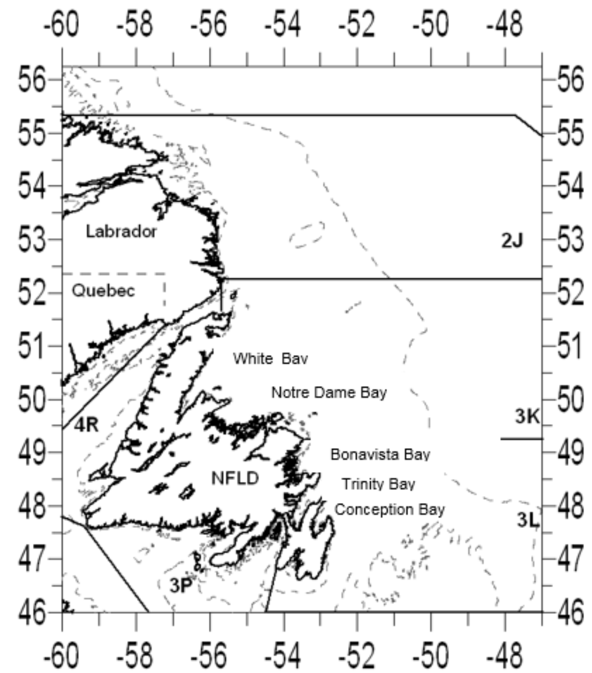

Figure 1. Capelin stock area with 100 m and 500 m contours.

Context:

This Science Advisory Report is from the March 9-12, 2021 Assessment of Divisions 2J+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 2020 (DFO 2021) and included research and commercial fishery data up to 2019. 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

- Due to COVID-19 limitations, the spring acoustic survey was not conducted in 2020. However, Capelin larval indices, fall bottom trawl survey data, the Capelin forecast model, commercial landings and samples, and other ecosystem and environmental variables were used in the assessment.

- Based on all available evidence, Capelin abundance remains very low and this stock is experiencing reduced productivity. Under current ecosystem conditions and exploitation levels, no sustained growth has been observed for 30 years, and prospects remain poor.
- Capelin is an integral component of the ecosystem on the Newfoundland and Labrador Shelf. Continued low abundance is inhibiting the production and/or recovery potential of other finfish (e.g., Northern cod).
- The Newfoundland and Labrador climate experiences important fluctuations at decadal time scales, with potential impacts on ecosystem productivity. The Capelin collapse in 1990-91 and the recent declines (2015-17) were associated with cold periods, while the modest increases between the mid-2000s to mid-2010s were observed in generally warm periods. A modest increase in Capelin was observed (2013-15) in the warmer-than-average 2000s. This increase, however, was short-lived and followed by a colder period and return to low levels of Capelin. Since 2018, a warming trend has been observed.
- Higher nitrate inventories since approximately 2015 have resulted in improved primary (chlorophyll) and secondary (zooplankton biomass) production indices over the past four to five years. Ongoing changes in zooplankton seasonality and community structure (fewer large, energy-rich calanoids and more small copepods) may impact Capelin recovery. Increased summer and fall zooplankton biomass since 2016 may have contributed to the recent improvement of the fall adult Capelin condition index. However, Capelin larval productivity has remained low since 2014 despite an increase in abundance of a preferred prey (*Pseudocalanus*) over the same period.
- Ecosystem conditions in the Newfoundland Shelf and Northern Grand Bank (Northwest Atlantic Fisheries Organization [NAFO] Divs. 2J3KL) remain indicative of overall limited productivity of the fish community, with the total Research Vessel (RV) biomass index still much lower than prior to the collapse in the early-1990s. While there has been some recovery since this collapse, declines were observed after the mid-2010s. The current total RV biomass index remains below the early-2010s level, but with some positive signals in 2020.
- The increase in groundfish biomass observed from the mid-2000s to the mid-2010s appears stalled. These increases have been associated with bottom-up processes, including an improved prey field. Groundfish declines observed in recent years are associated with simultaneous reductions in Capelin and shrimp availability.
- Estimates of consumption by fishes and the occurrence of Capelin in cod and Greenland Halibut stomachs indicate low Capelin availability in 2020, with levels comparable to the 2017-19 period.
- The estimate of the spring acoustic biomass index from the forecast model for 2021 is near the average of the post-collapse period. The projection for 2021 is approximately 24% of the post-collapse high (forecast model estimate for 2015) and approximately 6% of the spring acoustic biomass index values observed in the late-1980s (1985-90). There is a 65% probability that the spring 2021 index will be about the same as 2020, and a 32% probability of an increase. The preliminary 2022 projection suggests a decline in the biomass index from 2021.
- There have been seven consecutive low larval abundance years (2014-20) including all of the year-classes available to the fishery in 2021.

- The commercial fishery landed 89% of the Total Allowable Catch (TAC) for Divs. 2J3KL in 2020 (16,114 tonnes). Overall, current removals from all predation are large compared to the fishery.
- Delays in beach spawning have persisted since 1991 and are associated with low larval productivity and smaller year classes.
- The large size of age-1 Capelin during the fall of 2020 suggests a high proportion of age-2 fish will be maturing in 2021. Due to the high rate of post-spawning mortality, this is expected to result in low numbers of age-3 Capelin in 2022.
- Low larval production has resulted in impaired recruitment for this stock. Late spawning, early maturation, and changes in feeding conditions for Capelin in Divs. 2J3KL are associated with low Capelin productivity during the last five years and poor prospects for 2021 and 2022.
- Given this stock's continued low levels, significant ecological role, and poor prospects – including record low larval production in four of the last five years – it is advised that removals from all sources be kept at the lowest possible level.

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 two other assessed Capelin stocks in Canadian waters: the Gulf of St. Lawrence (Divs. 4RST), and the Southeast Shoal (Divs. 3NO; assessed by NAFO).

Capelin are a key forage species in the Newfoundland and Labrador (NL) ecosystem. Capelin feed on zooplankton and transfer energy to higher trophic level predators including finfishes (e.g., Atlantic cod and turbot), marine mammals, and seabirds. Capelin are a short-lived species (4-6 years) that undergo 'boom-and-bust' population cycles, typically in response to changing environmental conditions. Capelin recruitment is highly variable and year-class strength is set early during the larval stage (Frank and Leggett 1981a; Leggett et al. 1984; Dalley et al. 2002; Murphy et al. 2018). Capelin are primarily distributed offshore on the shelf break in Div. 2J3KL and move inshore to the coast and bays of NL to spawn in the summer. Capelin spawn sticky eggs in beach sediments as well as at demersal (<40 m) spawning sites close to beaches. Choice of spawning site is primarily based on temperature with an increase in demersal spawning when beaches reach 12 °C (Templeman 1948, Nakashima and Wheeler 2002, Crook et al. 2017). Egg development is temperature dependent with lakerrvae emerging from beach sites 2-3 weeks after spawning (Frank and Leggett 1981b) and from demersal sites in 4+ weeks after spawning (Penton and Davoren 2013). Larvae grow and develop in the bays of Newfoundland before moving offshore. The larval stage is prolonged in Capelin with metamorphosis to the juvenile stage occurring 8-12 months after hatch (<75 mm Total Length [TL]) (Vesin et al. 1981). The primary nursery area for 2J3KL Capelin is offshore in Div. 3L. During the fall, both immature and maturing Capelin are distributed offshore in Divs. 2J3KL where they feed and overwinter. Adults range in size from 12 to 23 cm with males larger at age compared to females.

The 2J3KL Capelin stock experienced a collapse in the early-1990s (reviewed in Buren et al. 2019). The annual spring acoustic survey index of largely immature (age-2) Capelin declined by an order of magnitude from 6 million t in the late-1980s to less than 150,000 t in 1991. Since 1991, the index has remained low, averaging 250,000 t over the past three decades. Historically, Capelin matured and spawned at ages 3-4. Following the collapse of the 2J3KL Capelin stock in the early 1990's, the stock experienced faster growth of immature fish, likely a compensatory response to less competition for food, and consequently, fish matured earlier at ages 2-3. During periods where immature fish have high growth rates, year-classes will mature and spawn at a younger age (e.g., Ricker 1981); since the majority of NL Capelin are semelparous (Shackell et al. 1994), increased immature growth rates and earlier maturation results in a spawning population that is both younger and smaller in length compared to fish maturing and spawning at older ages.

Before the stock collapse, the timing of peak Capelin beach spawning was between late-June and mid-July. Since 1991, peak beach spawning times have been persistently delayed by approximately 18 days compared to earlier in the 20th century (1919-90; Murphy et al. 2021). For the years 1978-2019, a delay in spawning timing is predicted when there are negative anomalies in the summer (June – August) North Atlantic Oscillation (NAO) and NL climate indices; and a decrease in the mean length of the spawning stock. Weak year-classes are predicted to occur when spawning is later in the summer (Murphy et al. 2021), likely due to match/mismatch dynamics where late emerging larvae may miss ideal environmental conditions for survival (e.g., onshore wind events, zooplankton availability) (Frank and Leggett 1982; Leggett et al. 1984; Carscadden et al. 2000; Murphy et al. 2018).

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 NAO and changes in large-scale ocean circulation (e.g., increased Labrador Current transport along the NL shelf edge) (Cyr et al. 2020). Currently, the impact of large-scale variations in ocean climate on Capelin is unknown, but it has been hypothesized 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. However, recent changes in zooplankton community structure have resulted in fewer large, lipid-rich copepods, which are an important energy source for adult Capelin, and an increased abundance of small copepods (DFO 2019). These changes suggest that there are currently poor foraging conditions for adult Capelin (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 (1981-2020). 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), during which time Capelin also collapsed (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.

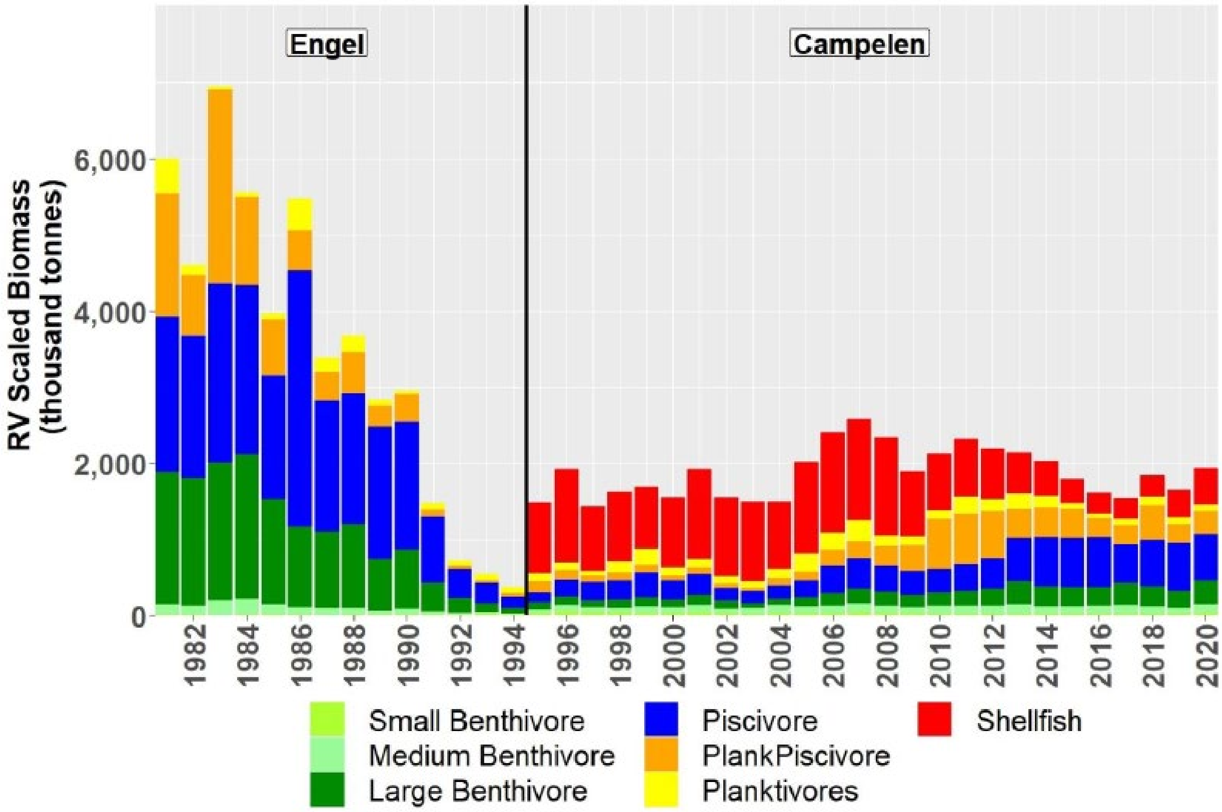

Figure 2. Total RV Biomass index trend of the fish community in the Newfoundland Shelf and northern Grand Bank (Divs. 2J3KL) discriminated by fish functional groups. Indices for the Engel period have been scaled to be comparable to the Campelen series (Koen-Alonso and Cuff 2018). Shellfish data were 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 recent 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). Consumption of Capelin by fishes (Fig. 3) declined from 2017 to 2020 suggesting reduced availability of Capelin in the system. However, consumption of Capelin improved in 2020 compared to 2019, suggesting there were more Capelin in the system in 2020.

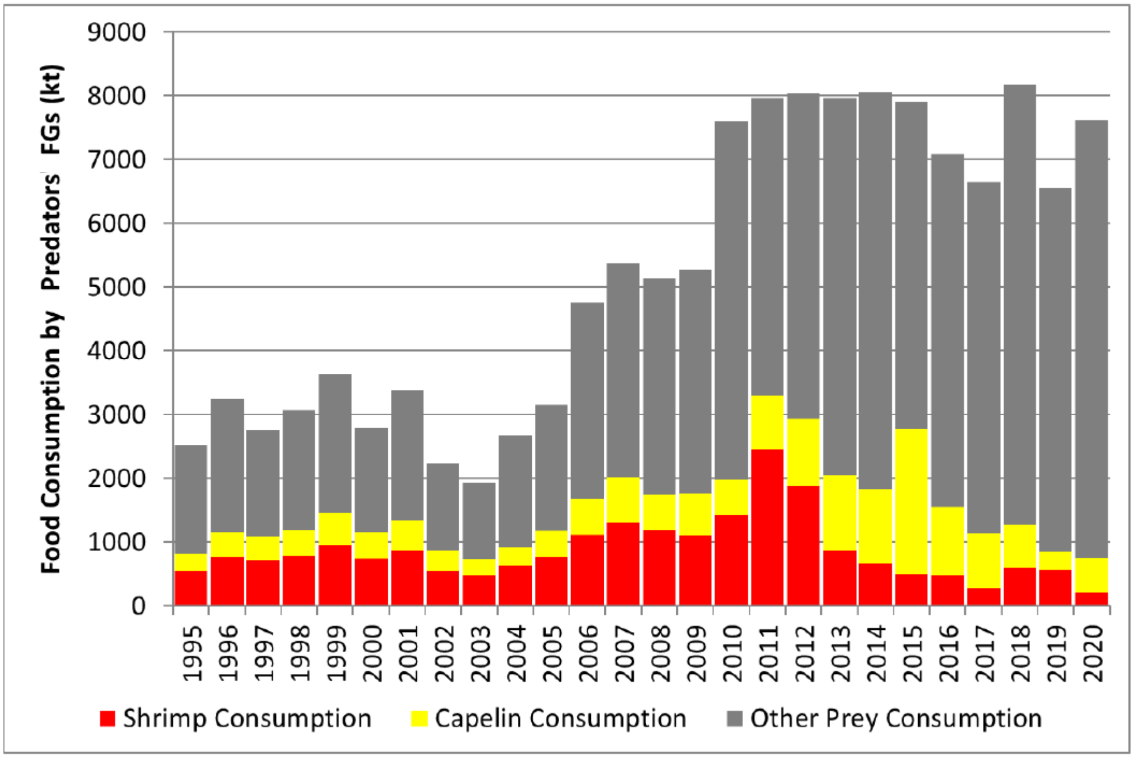

Figure 3. Estimated magnitude of consumption of Capelin, shrimp, and other prey by the fish functional groups (FGs) considered predators of these key forage species (i.e., medium and large benthivores, plankpiscivores, and piscivores) from 1995-2020. The estimated magnitudes of consumption are based 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/or the relative profitability of competing fisheries such as Snow Crab. These factors may result in reduced participation in the fishery within particular bays and/or years, resulting in Total Allowable Catches (TACs) not being attained. In other years, the arrival of Capelin in specific bays may be much later than expected resulting in fish plants switching to processing other species.

There are a number of different markets for Capelin, with the highest demand being for frozen roe-bearing females in Japan, where quality standards are high. During the 1980s and early-1990s this demand for large females led to high levels of discarding at sea and dumping of male and undersized female Capelin. To address these issues, several management measures were implemented from the early-1990s onward. These included monitoring of Capelin for quality standards prior to opening the fishery (i.e., the test fishery), which results in a relatively short (two to three days) openings within individual bays to fulfill TAC; and, since 2006, license conditions require harvesters to land all Capelin captured (both male and female). Improved markets for male Capelin, including for use as animal feed for zoos and aquaculture, have also contributed to full utilization of the landed catch in most areas. 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 2019).

The commercial fishery in 2J3KL in 2020 landed 16,114 t (89% of the TAC) (Fig. 4). TAC and landings in 2020 were below the average TAC for the past 10 years (22,000 t). In 2020, age-2 fish dominated the commercial catch. The size and age structure of Capelin landed in 2020 was amongst the smallest and youngest of the time series (1980-2020).

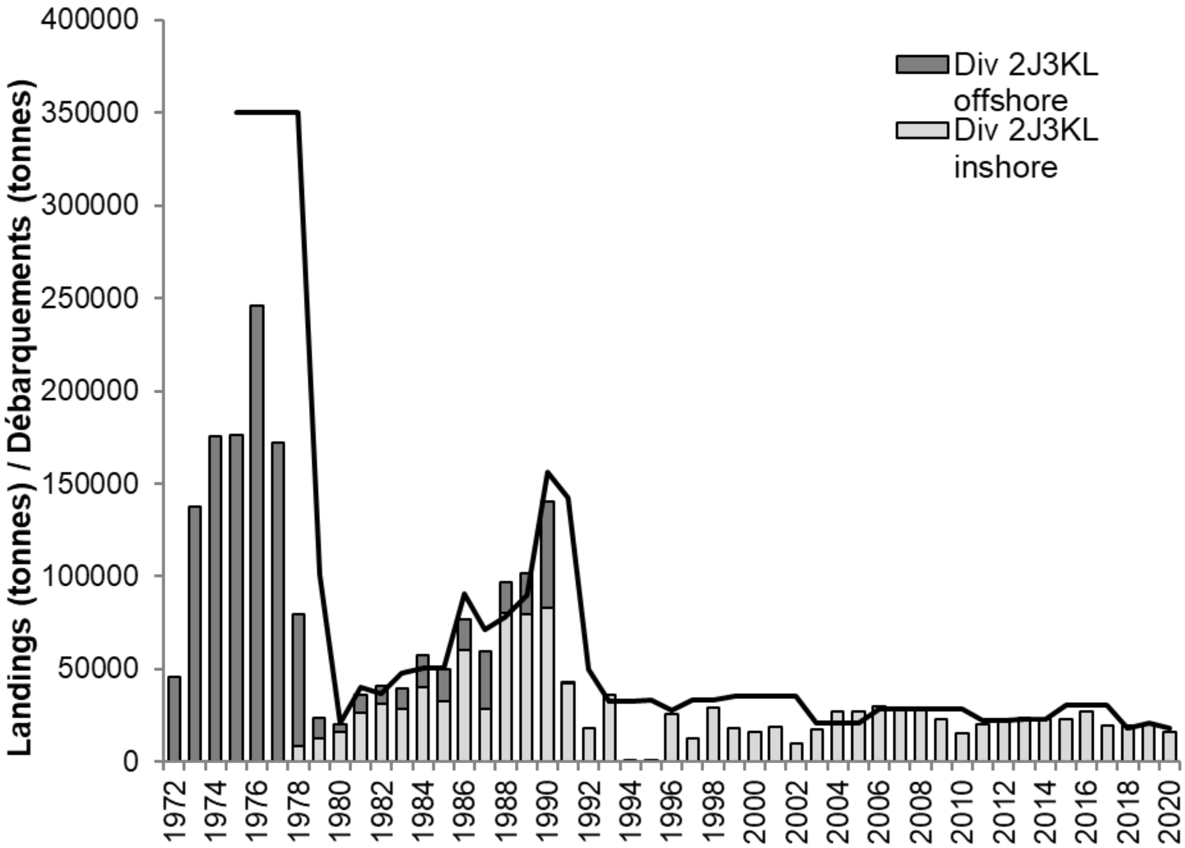

Figure 4. Inshore landings (light grey bars), offshore landings (dark grey bars) and TAC (line) for Capelin in Divs. 2J3KL from 1972 to 2020. Note that annual inshore landings were likely greater than 0 t between 1972 and 1977, but they were not recorded prior to 1978.

ASSESSMENT

The Capelin assessment is based primarily on two main data sources: an index of abundance of Capelin (primarily age-2) from the spring acoustic survey of NAFO Div. 3L and southern Div. 3K, and an index of larval Capelin abundance from Bellevue Beach, Trinity Bay. Due to the COVID-19 pandemic, there was no spring acoustic survey in May 2020. 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, biological data of spawning fish from the commercial catch, 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 spawning stock biomass is available.

Spawning

For Capelin, stronger year-classes are predicted in years when beach spawning is earlier (Murphy et al. 2021). Data on peak beach spawning timing has been collected at two reference beaches on the Avalon Peninsula: Bryants Cove, Conception Bay (1978-90) and Bellevue Beach, Trinity Bay (1990-present); and by a network of citizen scientists who check their local beaches in Divs. 3KLPs every 1-2 days in the summer (June – August) and provide data on Capelin beach spawning behavior (Murphy et al. 2021). Capelin beach spawning diaries are returned to DFO each fall. In order to construct a century of beach spawning times in NL, newspaper archives and grey and primary literature were searched for Capelin beach spawning timing for the years 1919-90. Timing of peak beach spawning continues to occur approximately 18 days later than the long-term average between 1919 and 1990 (Murphy et al. 2021) with median peak spawning in 2020 (July 15 in Divs. 3KLPs) similar to the post-collapse average (July 14 in Divs. 3KLPs; 1991-2019) (Fig. 5, based on Figure 2 in Murphy et al. 2021).

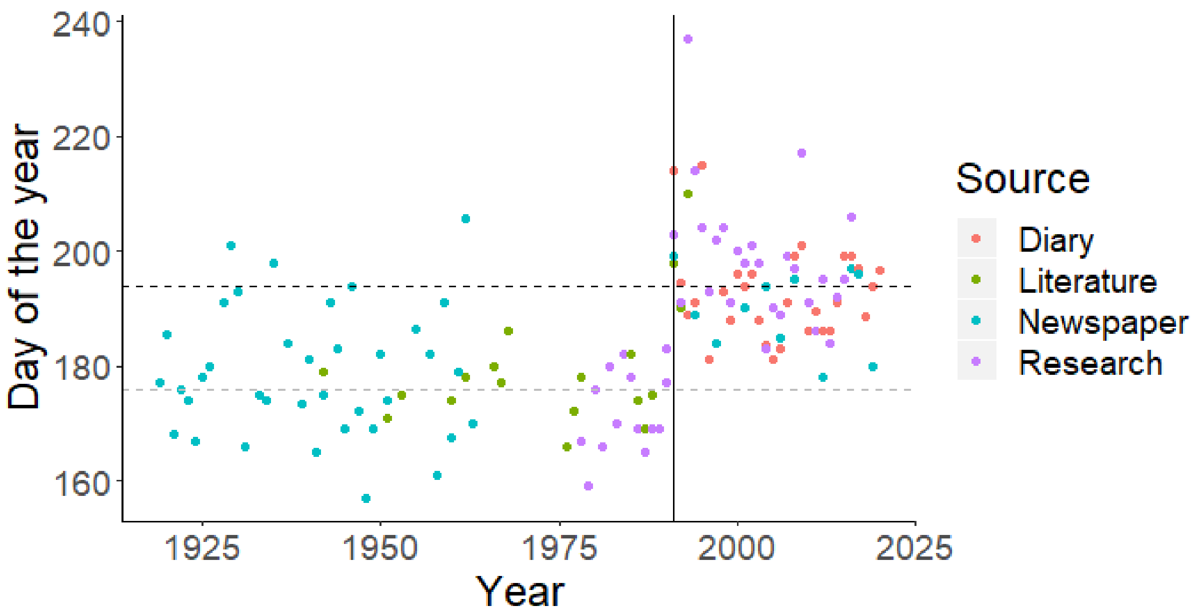

Figure 5. Annual median peak Capelin spawning day using four data sources (i.e., newspaper archives, research beaches [Bryant's Cove and Bellevue Beach], primary and grey literature, and Capelin spawning diaries) from NAFO Divs. 2J3KLPs. Solid vertical line is 1991 (timing of collapse; Buren et al. 2019). Horizontal lines are mean peak spawning times pre-1991 (June 25; day-of-year [DOY]: 176; grey dashed line) and post-1990 (July 14; DOY: 195; black dashed line). Based on Figure 2 in Murphy et al. 2021.

Larval index

Recruitment in Capelin is related to larval density (Murphy et al. 2018). The Capelin larval index is the main fishery-independent inshore index used in the assessment. From 2001-20, 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 demersal (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 2020 (Fig. 6). There have been seven consecutive low larval abundance years (2014-20) including all year-classes available to the fishery in 2021.

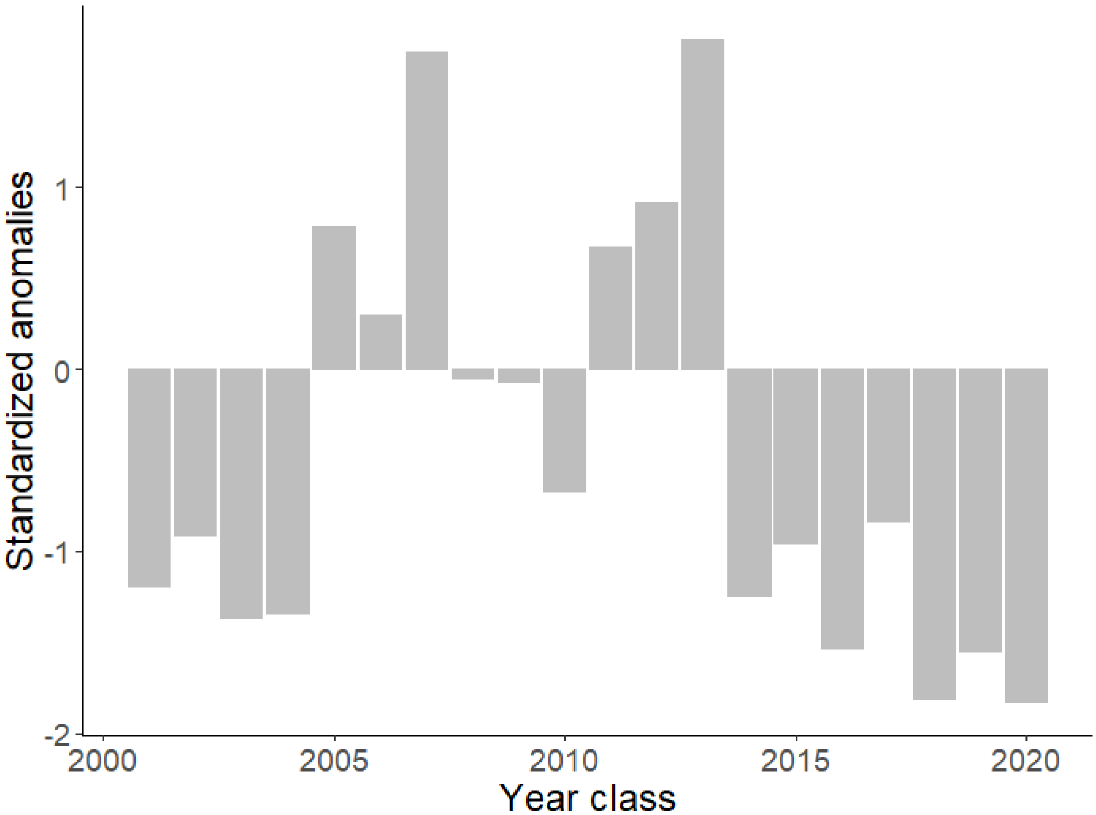

Figure 6. Standardized Capelin larval index from Bellevue Beach, Trinity Bay for the 2001 to 2020 year classes. Negative anomalies indicate below time series average annual larval production.

Spring Acoustic Survey Indices

An acoustic survey was not conducted in 2020 due to COVID-19 health precautions. Data from spring acoustic surveys conducted from 1988-92, 1996, 1999-2005, 2007-15 and 2017-19 were presented at the assessment. Details on how the abundance and biomass indices and their confidence limits were calculated can be found in Mowbray (2014). The spring acoustic survey targets the primary area of distribution of age-2 fish but some age-1 and age-3+ are observed as well. For the age-2 and age-3 cohorts, cohort strength tracks well between surveys (i.e., a strong cohort sampled at age-2 tends to appear as a strong cohort at age-3 in the following year). The spring acoustic survey covers only a portion of the stock area. Thus, the abundance and biomass indices are considered to be minimum estimates and may be subject to unquantified inter-annual variations due to changes in the spatial distribution of the stock across the stock area and their overlap with the surveyed area.

The acoustic survey abundance index peaked at 6 Mt in the late-1980s and fell by well over an order of magnitude in 1991 (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 18.5-32.1

billion individuals, comparable to levels observed in the 2000s. The Capelin biomass index for the 2019 spring acoustic survey was 283 kt (95% confidence interval: 239-356 kt), which is similar to the average from 1999 to 2019 (272 kt), though remaining well below the average observed in the late 1980s (1988-90; 4,593 kt). The biomass and abundance indices generally follow the same trend with occasional differences due to variability in the size of Capelin between years and changes in the relative strength of year-classes.

An abundance index for Capelin in the surveyed inshore area (Trinity Bay) is available for most years. This inshore component of the spring acoustic survey is attempted each year in order to evaluate the inshore-offshore distribution of Capelin since a portion of the stock (largely immature age-1 and -2) may reside inshore at the time of the spring survey. This portion of the stock was found to be relatively small (<10% of offshore surveyed biomass) in most years (Buren et al. 2019). The Capelin abundance index in Trinity Bay in 2019 was 1.7 billion individuals which was similar to the early-2000s (Fig. 7).

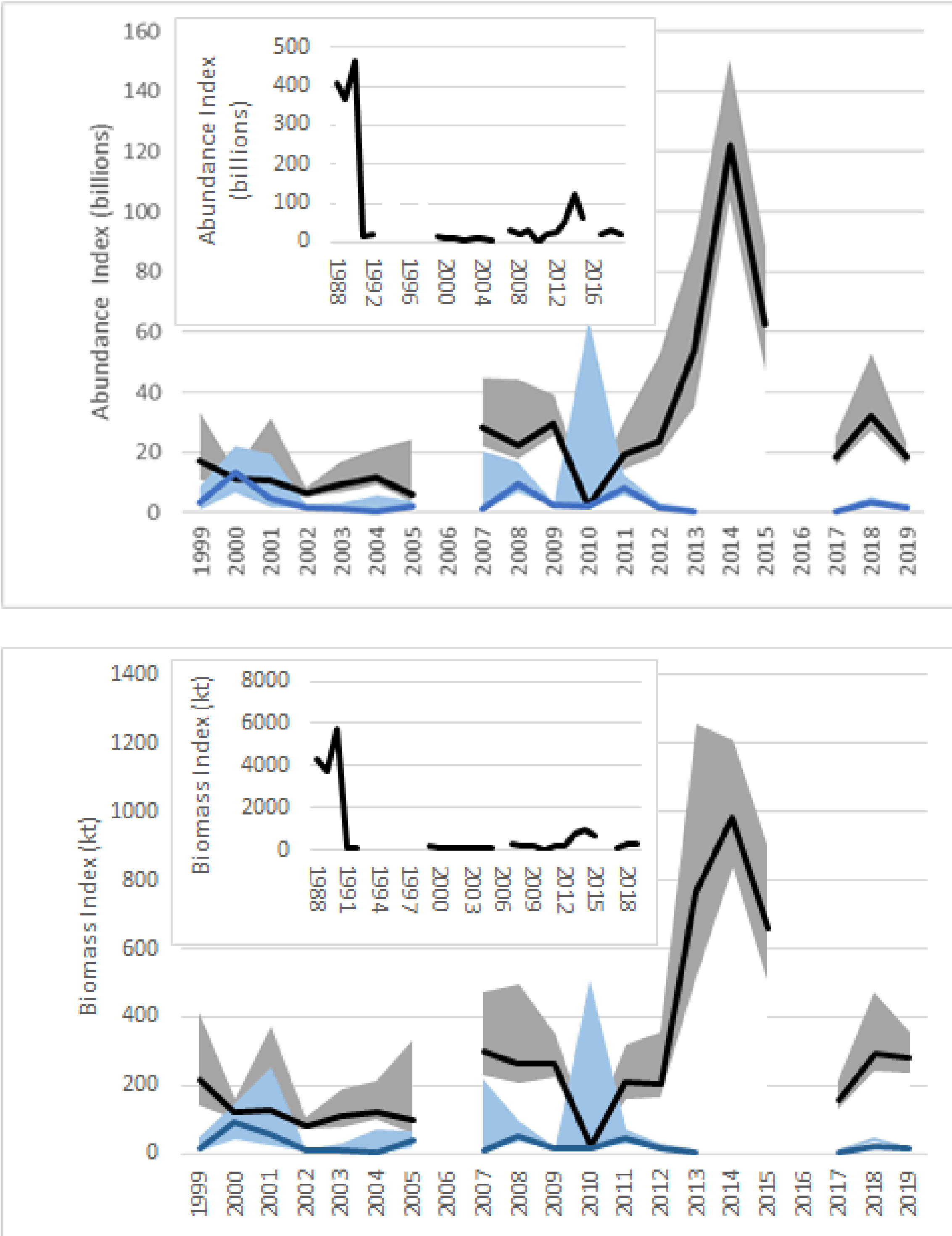

Figure 7. Spring (May) offshore acoustic indices of Capelin abundance (upper panel) and biomass (lower panel) in NAFO Divs. 3L and southern Divs. 3K (solid line) with 95% confidence intervals (shaded area) (1988-92, 1996, 1999-2005, 2007-15, 2017-19) The offshore index is presented in black/grey and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

Biological characteristics, distribution and consumption of Capelin

Biological characteristics

Age and growth characteristics of Capelin are used to assess the status of the stock. By design, the spring acoustic survey primarily intercepts age-2 Capelin, but some age-1 and age-3+ maturing age classes are also caught (Fig. 8). Age-1 Capelin have been poorly represented in the survey in the past three years, although poor representation at age-1 is not linked with poor cohort strength at age-2 since age-1 Capelin are not fully recruited to the survey trawl gear. In 2019, age-3 Capelin formed a slightly larger proportion of the surveyed abundance and there was a lower than average proportion of age-2 Capelin in the spring acoustic survey, 80% of which were maturing (Fig. 9). With such a high proportion of age-2 fish maturing in 2019 (and experiencing high spawning mortality), we expected the spawning stock in 2020 to have few age-3 fish. As anticipated, the commercial fishery in 2020 was dominated by age-2 fish (i.e., the 2018 year-class).

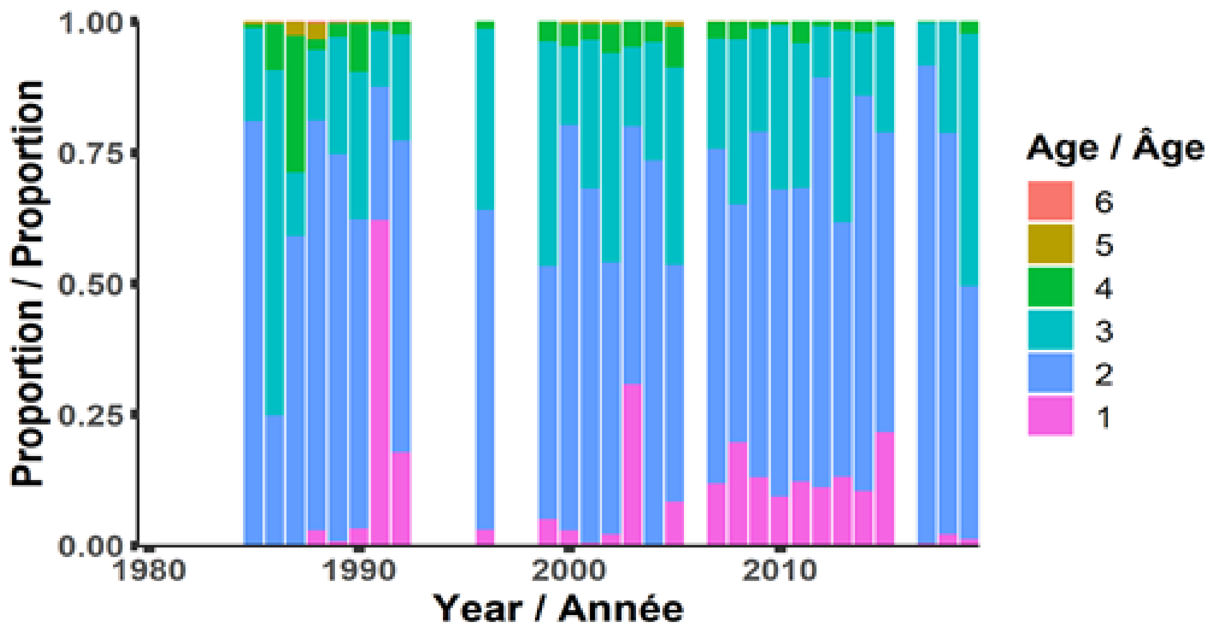

Figure 8. Age composition of Capelin surveyed during the spring (May) Divs. 3L acoustic survey (1985-92, 1996, 1999-2005, 2007-15, 2017-19).

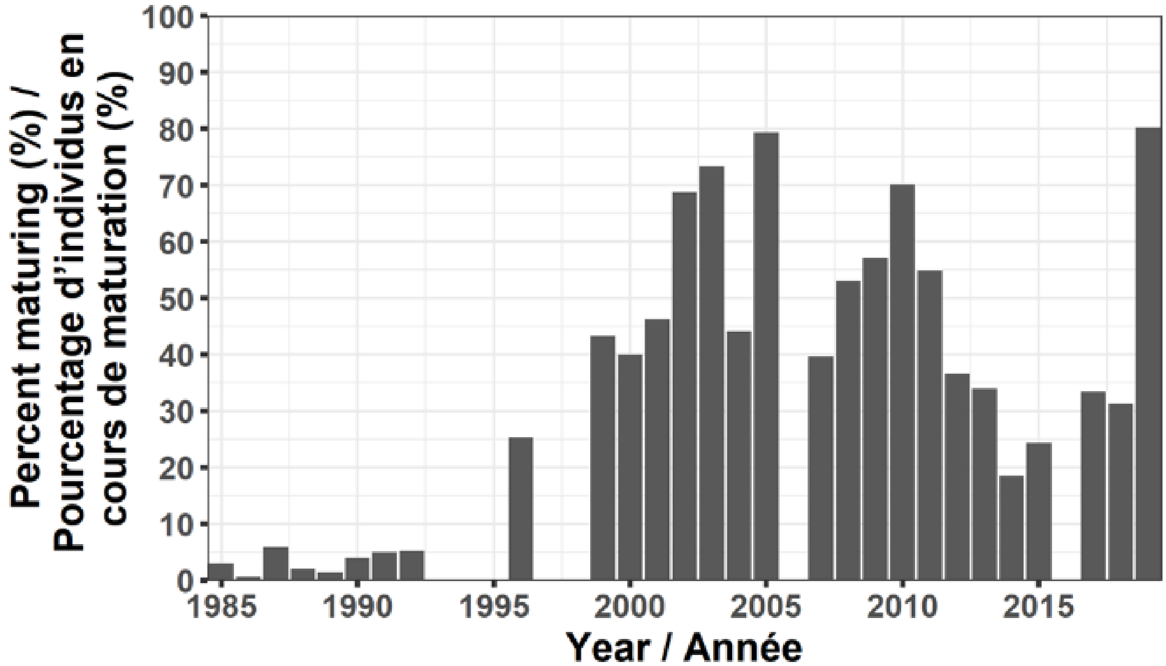

Figure 9. Proportion of maturing age-2 Capelin which were mature as determined from spring (May) Div. 3L acoustic surveys (1985-92, 1996, 1999-2005, 2007-15, 2017-19).

The mean length-at-age of Capelin aged 1-2 increased after the stock collapsed, while mean length-at-age of Capelin aged 3+ remained similar or decreased after the stock collapsed (Fig. 10). In 2019, aged 2-4 Capelin sampled during the spring acoustic survey increased slightly in length compared to 2018 and mean lengths of aged 2-3 are currently at or near the time series high and age-4 Capelin were around the time series average (Fig. 10). Age-1 Capelin were smaller in 2019 than in 2018 (Fig. 10), with lengths near the time series mean.

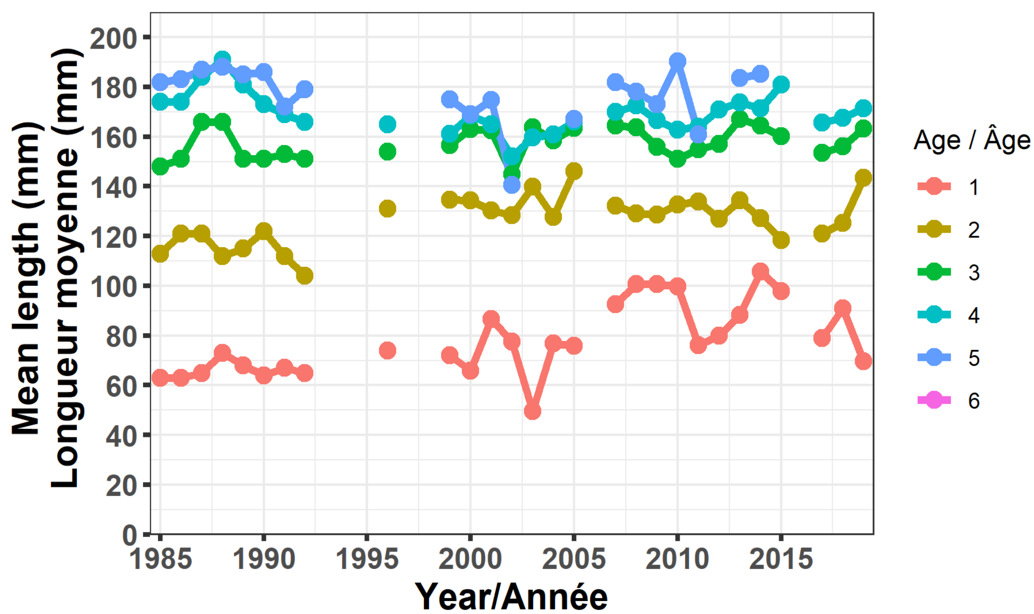

Figure 10. Mean length-at-age of Capelin sampled during spring acoustic surveys (1985-92, 1996, 1999-2005, 2007-15, 2017-19).

Condition of Capelin in the fall may impact overwintering survival. Relative condition of age-1 and age-2 Capelin collected during the fall multi-species survey was calculated for each age group and then the overall mean of the relative conditions of age-1 and age-2 Capelin was determined. The mean fall condition of Capelin in 2017-20 has been above average (Fig. 11). Increased fall condition may act to reduce overwintering mortality (Lewis et al. 2019).

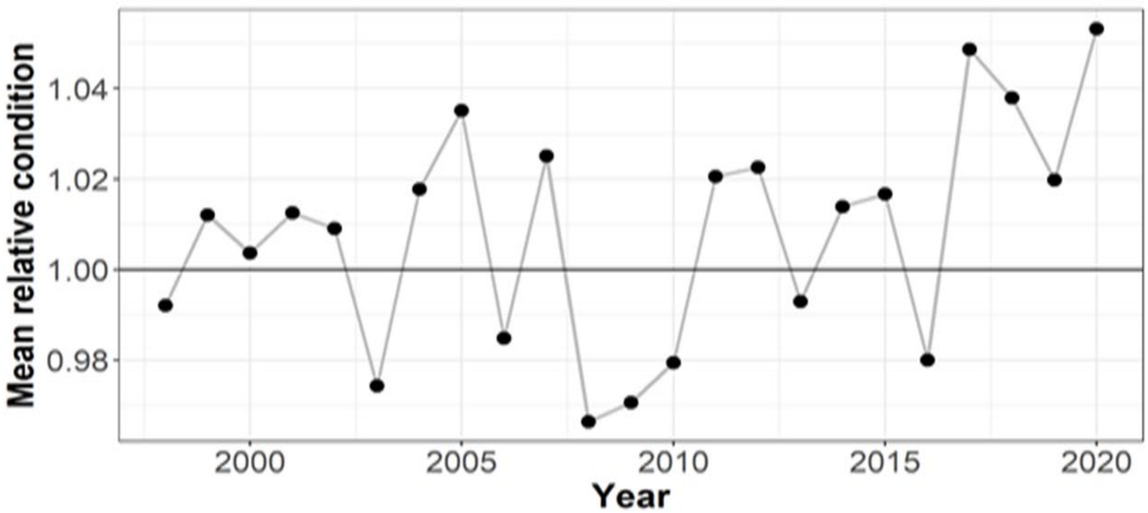

Figure 11. Mean relative condition of age-1 and -2 Capelin sampled in the fall multi-species bottom trawl survey by year (1995-2020).

Spatial distribution

In 2019, the spatial distribution of Capelin during the spring acoustic survey was typical of patterns observed during the 2000s with most Capelin being observed offshore in deeper water (200 m) and along the shelf break.

There is a general trend of a more northerly distribution of the Capelin stock in the fall multi-species bottom trawl surveys when the stock abundance increases (e.g., 2013, 2014), although some higher abundance years in the 1980s were at mid-latitude (i.e., 1987). Information on fall Capelin distribution comes from multi-species bottom trawl surveys from 1983-2020. 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. Bottom trawl surveys, however, cannot provide abundance estimates for pelagic species (McQuinn 2009). A center of gravity (COG) analysis of the fall bottom trawl data found that Capelin are primarily distributed along the north-south axis, rather than east-west, with COG in 2020 at mid-latitude (Fig. 12).

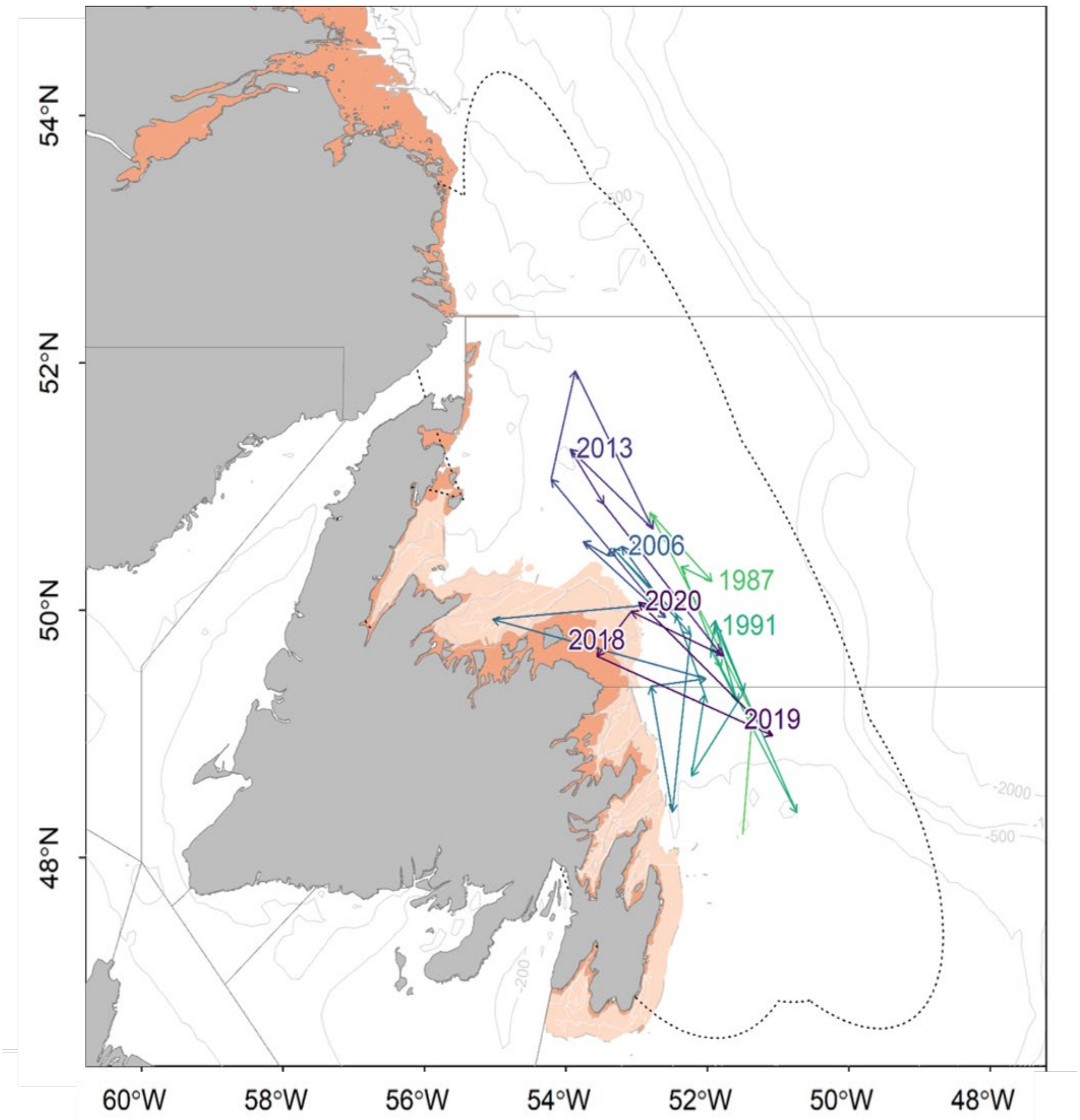

Figure 12. Distribution of the center of gravity of Capelin computed from the fall bottom-trawl survey in NAFO Divs. 2J3KL from 1983 to 2020. Annual center of gravity estimates are connected by lines through time, and composite ellipses of deviation around these estimates (i.e., inertia) are indicated 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).

Consumption

Capelin is a key forage species in the NL shelf ecosystem. Evaluating the potential impacts of annual Capelin removals by both predators and fishing on the Capelin stock is an important consideration when evaluating the status of this stock. To do this, we needed to calculate the annual availability of Capelin in the system (i.e., Integrated Capelin Availability). The Capelin acoustic biomass index, even if it were to be scaled to represent absolute biomass, is still 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 annual predator consumption, the amount of Capelin likely available to the ecosystem integrated over the year needed to be estimated. This was coarsely approximated by assuming that the acoustic Capelin index is an adequate proxy for the order of magnitude of the stock size, which is a minimum estimate, and using a production/biomass (P/B) ratio for Capelin of 1.15 (see Tam and Bundy 2019 for more details). Integrated Capelin Availability was calculated as Spring Acoustic Biomass + 1.15*Spring 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 of Integrated Capelin Availability and Nominal Catch Impact are intended as order of magnitude approximations to allow for general level comparisons among these two factors and annual finfish consumption.

Consumption of Capelin by finfish tracks reasonably well with 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 then a decline in the late 2010s (Fig. 13). These current analyses are only intended to capture changes by orders of magnitude, and the estimated Integrated Capelin Availability is, by construction, known to be a minimum estimate. However, the overall concordance between consumption and availability estimates, both in trajectory and general magnitude, suggests that these results are reasonable approximations to these processes. Current removals from predation by fishes are large compared to the expected removals from the fishery (Fig. 13), although the impact of timing of removals may be important for the stock as predation by finfishes occurs throughout the life of Capelin while the fishery removes a specific life-stage and sex: roe-bearing pre-spawning females. With declining predation and declining stock size, the proportional impact of fishing relative to consumption has increased, with the impact of fishing in 2020 reaching similar levels to those of the mid to late-2000s.

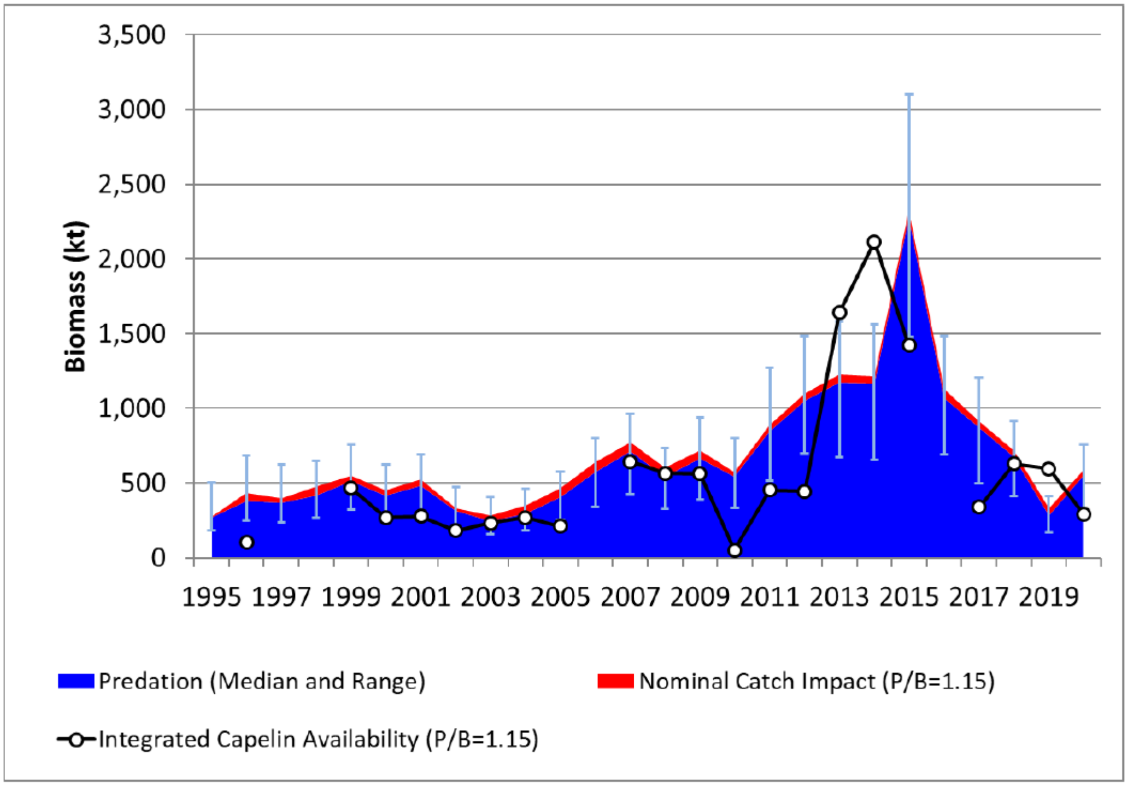

Figure 13. Consumption of Capelin in 2J3KL by fish predators (blue area; light blue error bars indicate the range of the estimated envelop of consumption) and the Nominal Catch Impact from fishery catches from 1995-2020 (red area). Black line indicates the Integrated Capelin Availability derived from spring acoustic surveys and the Capelin Production/Biomass ratio (P/B=1.15).

Forecast Model

A Capelin forecast model (Lewis et al. 2019) was used to project the spring acoustic index for the current year's (2021) spring acoustic survey and provide a partial forecast for the 2022 spring acoustic survey (Fig. 14). 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). In addition to these two previously described mechanisms, the forecast model includes fall condition of age-1 and -2 Capelin that, combined with sea ice retreat, are proxies for 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).

Since there was no spring acoustic survey in 2020, we were not able to refit the model with the 2020 observed acoustic biomass index. However, as we had both the 2019 and 2020 larval data as well as fall condition for 2020 and sea ice for 2021, we were able to forecast the spring biomass indices for 2021 (2019 larval index, 2020 fall condition, 2021 sea ice retreat as of

March 9) and for 2022 (2020 larval index, average values for fall condition and sea ice retreat) using the model fit to spring acoustic surveys through 2019. The 2021 forecasted spring acoustic biomass index is ~233 kt which is near the average of the post-collapse period. The projection for 2021 is approximately 24% of the post-collapse high and approximately 6% of values observed in the late-1980s (1985-90).

As the final value for the timing of sea ice retreat for the current year may not be known at the time of the assessment, we performed a sensitivity analysis to determine what the forecast would be if the timing of sea ice retreat for the current year were to happen on a different date than the one used in the forecast model at the assessment. For the sensitivity analysis, we used the same model inputs as for the forecast model run, except we set the timing of sea ice retreat to each week from March 1st through April 5th and conducted a separate run using that timing. The sensitivity analysis (Fig. 15) indicated that the Capelin biomass index for the spring acoustic survey would be maximized if sea ice retreat began the week of March 15th. Sea ice retreating earlier than or later than that week would result in a reduced estimate for the biomass index. The median biomass estimate for each of the weekly simulations in the sensitivity analysis were predicted to be greater than the median estimate for 2020 (Fig. 15).

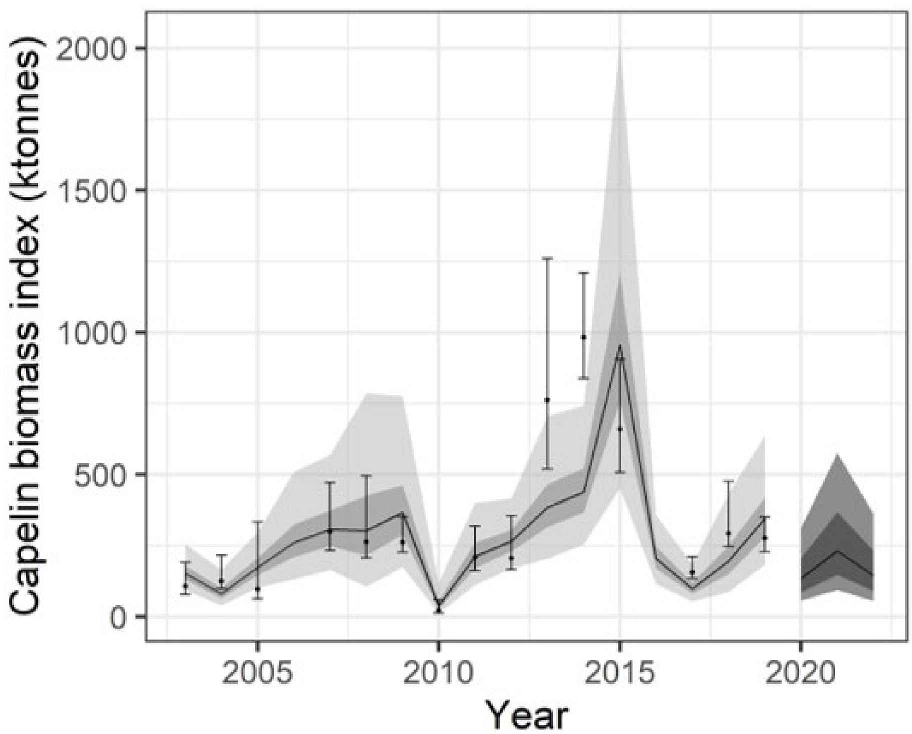

Figure 14. The results from the Capelin forecast model including the 95% credible (light grey) and 80% prediction intervals (dark grey) for expected values of Capelin biomass in the spring acoustic survey (solid line) and observed values (point estimates with ±95% confidence intervals). The model forecasts a probable increase in the Capelin biomass in the 2021 spring acoustic survey compared to 2020. The projection for 2021 is approximately 24% of the post-collapse high and approximately 6% of values observed in the late-1980s.

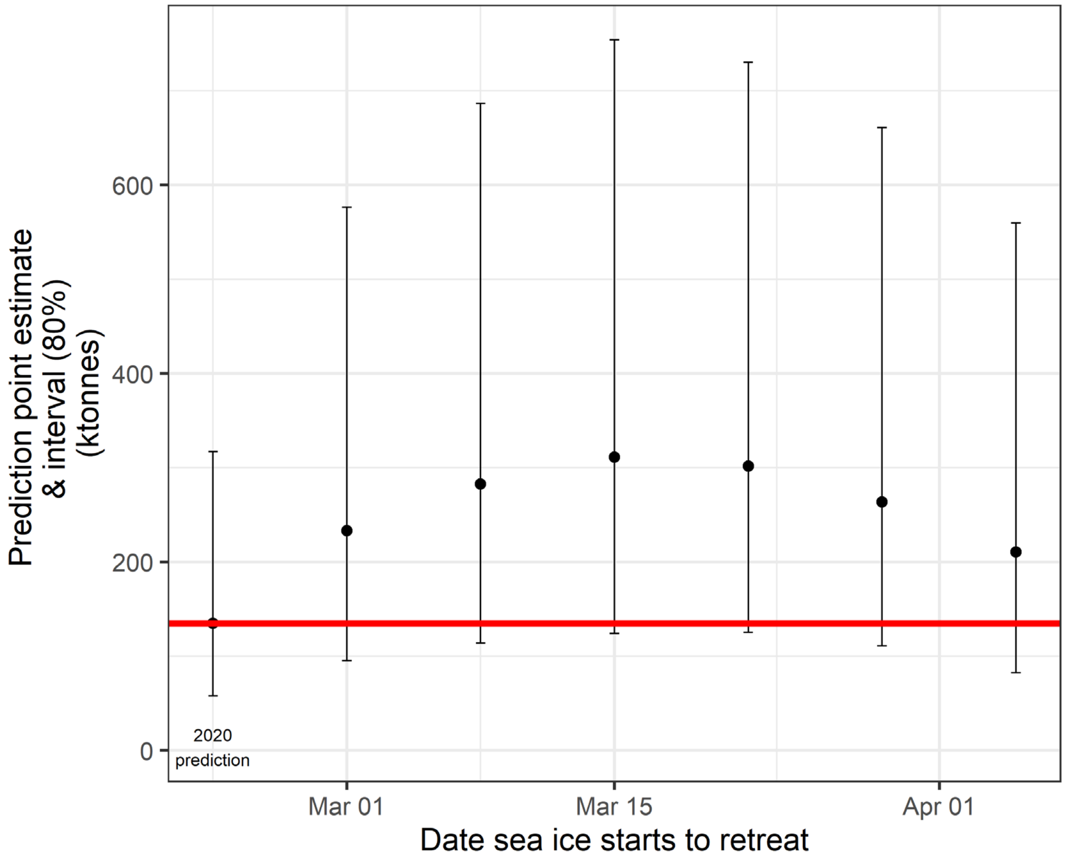

Figure 15. A sensitivity analysis investigating the effects of different timings for the beginning of the sea ice retreat on the predicted biomass index value for the spring acoustic survey. Weekly dates from March 1st through April 5th 2021 were tested for the beginning of sea ice retreat. Black points indicate the median estimate for each date while the whisker intervals show the 10th and 90th percentiles of the estimate biomass. The red line shows the median biomass index estimate for the 2020 forecast for comparison.

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 relatively 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 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 of the stock is small relative 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 is a current research focus.

Total Capelin consumption estimates are unknown. Consumption estimates in this assessment do not include up-to-date consumption estimates of harp seals, whales, and seabirds.

The impact of fishing mortality on the Capelin stock is not quantified and is poorly understood. However, with declining predation and declining stock size, the proportional impact of fishing relative to consumption has increased.

CONCLUSION

Following the collapse of this stock in the early-1990s (Buren et al. 2019), there was a change in population dynamics where the size at age of younger Capelin (ages 1-2) increased while the age at maturity decreased from age-3 to age-2. Delays in beach spawning, which are associated with low larval productivity and smaller year classes, have persisted since 1991. There have been no strong indications of recovery of the stock since its collapse. The emergent larval index from Bellevue Beach in 2020 was one of the lowest larval productivity years in the 19 year time series. Larval production from 2016-20 included the four lowest values in the time series. A forecast model for this stock suggests a modest increase in the spring acoustic survey biomass index for 2021 compared to the 2020 value, but projected values remain depressed, approaching the low levels observed in the early-2000s. Current stock and environmental conditions have many characteristics in common with those observed during the early-2000s, when Capelin biomass was sustained at a low biomass for the longest period in the time-series. These low biomass levels may have strong negative implications on the potential availability of Capelin as prey for the ecosystem. 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. Given this stock’s continued low levels, significant ecological role, and poor prospects – including record low larval production in four of the last five years – it is advised that removals from all sources be kept at the lowest possible level.

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SOURCES OF INFORMATION

This Science Advisory Report is from the March 9-12, 2021 Regional Advisory Meeting on the Assessment of Divisions 2J+3KL Capelin. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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