Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans
Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2018/030

ASSESSMENT OF CAPELIN IN SA2 AND DIVS. 3KL IN 2017

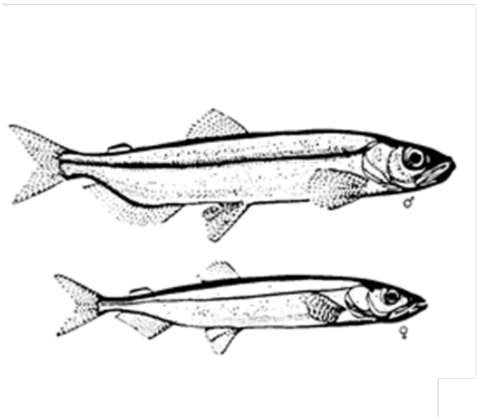


Image adapted from a drawing in C. E. Hollingsworth. 2002. Preface. ICES J. Mar. Sci. 59, p. 861

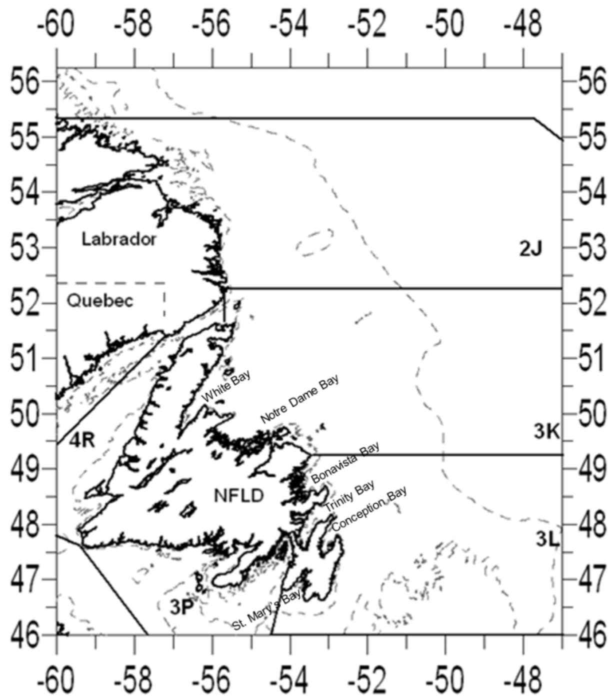


Figure 1. Capelin stock area with 100 m and 500 m contours.

Context:

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

Prior to 1992, capelin in Northwest Atlantic Fisheries Organization (NAFO) SubArea 2 and Divisions 3K and 3L (SA2 + Divs. 3KL) (Fig. 1) were treated as two separate stocks. However, as a result of accumulated evidence, scientists recommended in 1992 that capelin in these areas be considered to be a single stock complex. Four other recognized capelin stocks occurring in Canadian waters are the Southeast Shoal (Divs. 3NO), St. Pierre Bank (Subdiv. 3Ps), Gulf of St. Lawrence (Divs. 4RST), and the Scotian Shelf (Div. 4W).

Historical catches of capelin for food, fertilizer, and bait in Newfoundland and Labrador (NL) have not exceeded 25,000 t. An offshore foreign fishery for capelin occurred in the 1970s with a peak catch of 250,000 t in 1976. The offshore fishery was closed in Div. 3L in 1979 and in Divs. 2J3K in 1992. An inshore fishery started in Divs. 3KL in the late 1970s with peak landings of about 80,000 t from 1988-90. Recent landings have been closer to 25,000 t.

Capelin stocks undergo boom bust cycles, a characteristic of many short lived forage fish species. These cycles are generally associated with environmental conditions. Since the inception of Divs. 2J3KL capelin acoustic surveys, the survey index has ranged two orders of magnitude from millions of tonnes in the late 1980s to less than 200,000 t from 1992 through the mid-2000s.

Capelin are eaten by many predators including seals, whales, cod, Greenland Halibut, Atlantic Salmon and seabirds and are considered to be a key forage species. Because of its prominent position in the ecosystem a conservative approach to their management has been adopted. Since 1979 a conservative exploitation rate not to exceed 10% of the projected spawning biomass was advised for capelin stocks in the NW Atlantic. This advice has not been implemented since 2000 due to the reduction in inshore indices collected, including aerial surveys and egg deposition, and, in absence of these inshore indices, spawning stock biomass cannot be estimated.

The previous assessment for this stock was in January 2015 (DFO 2015) and included research and commercial data up to 2014. Until 2001, stock status had been assessed and a stock status report was produced on an annual basis. Since 2008, assessments have been performed bi-annually. This 2018 assessment is the start of an annual assessment process for capelin. The fishery for capelin in SA2 + Divs. 3KL was managed with three-year capelin management plans from 1999 to 2008 and with single year plans from 2009 to 2011. The current (evergreen) Integrated Fisheries Management Plan (IFMP) commenced in April 2011 and has no fixed term.

This Science Advisory Report is from the March 7-8, 2018 Status of Subarea 2 and Divisions 3KL Capelin. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A warming trend that began in the mid-1990s, peaked in 2010 and has since decreased with colder less saline conditions during the past 4-years.
- Production indices based on ocean colour metrics (e.g., total production, intensity, time of maximum, and duration indices of the spring bloom) and secondary production indices since 1998 were correlated with ocean climate conditions and may be linked to cooling and higher ice extent observed over the NW Atlantic. Cooler conditions are associated with delayed spring blooms.
- Shifts in community composition of zooplankton since 2015 have been characterized by smaller copepod taxa along with a substantial reduction in biomass.
- Fisheries productivity on the Newfoundland Shelf has declined since the early to mid-2010s. This decline was initially associated with a loss of shellfish and in the last two years includes declines in piscivores. Despite this decline in predators, the index of fish predation on capelin increased in 2016 and 2017.
- Landings were 23,065 t, 27,708 t and 19,917 t representing 81%, 97% and 70% of the TAC in 2015, 2016 and 2017 respectively.
- The spring acoustic abundance index in 2017 declined 70% from the 2015 value, returning to values observed during the late 2000s.
- The size composition of capelin landed in the commercial fishery declined in 2017. This was largely due to a high proportion of age 2 spawners. This is consistent with what was observed in the spring acoustic survey.
- Spawning times since 2015 have been delayed. Late spawning is associated with poor cohort strength.
- The 2001-2017 capelin larval index has been positively correlated with abundance at age 2. The larval index has been low for the past four years and year classes entering the fishery in 2018 and 2019 are expected to be small.

- All reviewed information indicates that the year class strength of capelin is primarily environmentally driven. The impact of removals by fisheries and the consumption by predators is unknown at this time.

INTRODUCTION

Species Biology

Adult capelin range in size from 12 to 23 cm and males are larger than females. Historically, the spawning populations were composed of mainly age 3 and 4 fish. Since the early 1990s, spawning populations have consisted primarily of age 2 and 3 fish. The short life span and highly variable recruitment of capelin offer the potential for frequent and dramatic changes in the biomass of mature fish.

Juvenile capelin of the SA2 + Divs. 3KL (Fig. 1) stock can be found both in major bays and offshore waters, although the northern Grand Bank and the Northeast Newfoundland Shelf are thought to be their major nursery areas. At maturity, during June and July, schools of adults migrate inshore to spawn on Newfoundland and Labrador beaches and on demersal (bottom) spawning sites. From 1991 to 2010 the timing of peak spawning has been delayed by up to four weeks, with spawning taking place in July and August (Fig. 2). This delay in spawning post-1991 was attributed to cold water temperatures and a larger presence of younger, smaller spawners (Carscadden et al. 1997). From 2010-2014 the timing of capelin spawning slowly shifted back towards the historic norm, with peak spawning occurring only two weeks later than it did in the 1980s; however, since 2015 spawning has once again become markedly delayed, similar to the early 1990s (Fig. 2). After capelin eggs hatch at beach or nearshore demersal spawning sites, the larvae exit the gravel and most are carried out of the bays by surface currents.

Capelin recruitment 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 1966-1990 (Leggett et al. 1984; Carscadden et al. 2000). Onshore wind events act as mechanism to get the larvae off of beaches as well as instigating a rapid coastal water mass replacement where cold, high-salinity waters are replaced with warmer, less-saline waters (Frank and Leggett 1982). This water mass replacement was positively related to increased availability of small zooplankton prey (< 250 μm) and a decrease in abundance of invertebrate predators (Frank and Leggett 1982). Post-1991, larval survival was no longer related to onshore wind events (Murphy et al. 2018). This lack of relationship may be due to a 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-1991, a match between larval occurrence and prey availability was 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 in 2011-2014. Another important driver of capelin survival is the timing of ice-mediated spring blooms, which may be affecting adult capelin survival (Buren et al. 2014).

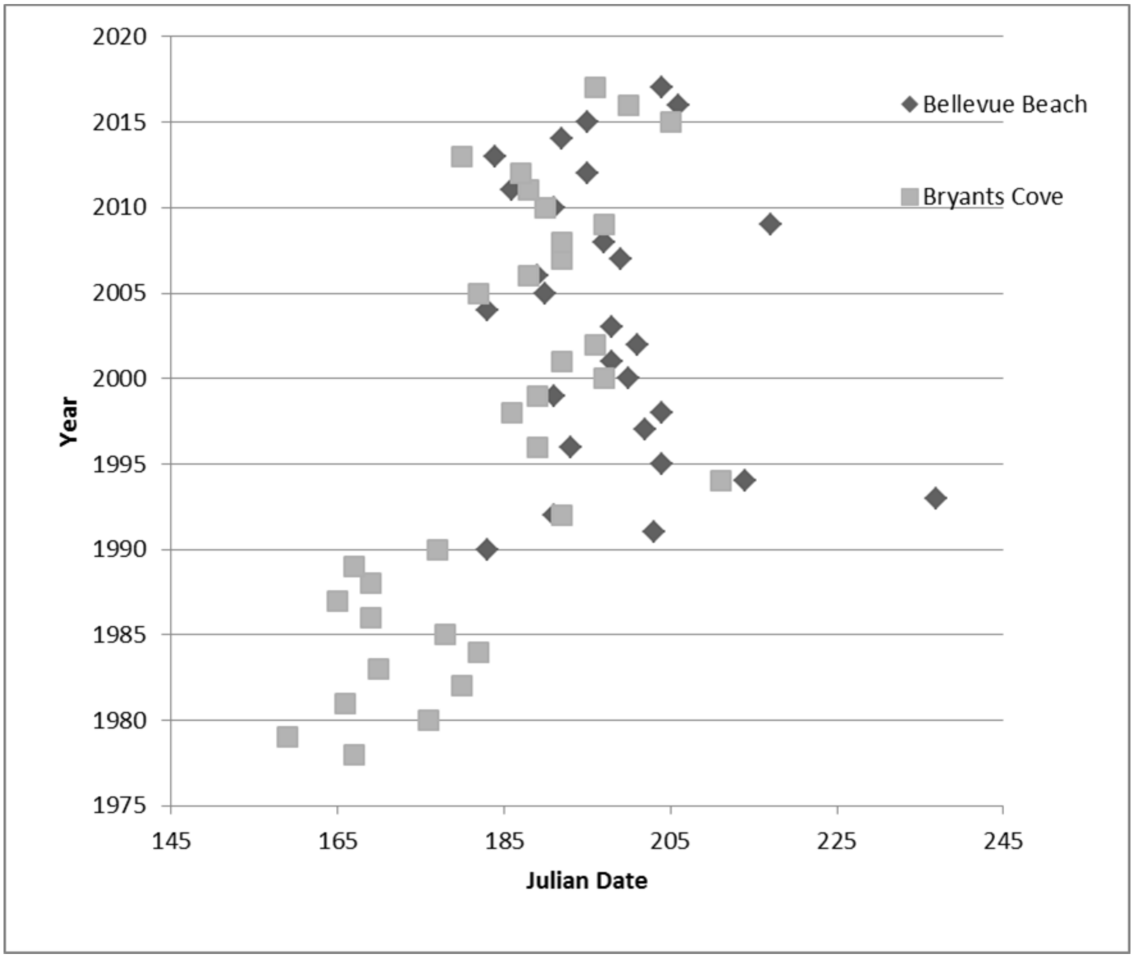


Figure 2. Peak spawning times at Bryants Cove, Conception Bay (light grey square) and Bellevue Beach, Trinity Bay (dark grey diamond).

Fishery

Historically, capelin were fished domestically 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.

During the late 1970s, an inshore fishery for roe-bearing female capelin began. Throughout the 1980s, the inshore fishery usually started by mid-June in the south and finished about mid-July in the north. Since the early 1990s the inshore fishery has operated mainly in July and at times, especially in Div. 3K, in early August. Peak inshore landings of approximately 80,000 t occurred from 1988-1990, and annual inshore harvest is on average 25,000 t from 1991-2017.

The inshore fishery has been prosecuted by capelin traps, purse seines and, to a lesser extent, beach seines. Since 1998, modified beach seines called “tuck seines” have been deployed because capelin stayed in deeper waters and were unavailable to capelin traps and conventional beach seines. The use of tuck seines or capelin traps has varied from location to location. The majority of inshore landings in recent years has come from purse and tuck seines.

The primary market for frozen roe-bearing female capelin in Japan is limited and the demand for quality is high. Inshore TACs were tied to market constraints until the late 1990s. Discarding at sea and dumping of capelin, predominantly males which are unsuitable for the Japanese market, were major concerns in the 1980s and early 1990s. Since 1993, several management measures and access to other markets have helped to lessen these concerns. These management measures include monitoring capelin quality prior to opening the fishery; a relatively short fishery (two to three days) that has significantly reduced at-sea discarding; since 2006, a condition of provincial processing licenses requires full utilization of all capelin captured; and new markets for male capelin, such as zoo food and aquaculture, has increased the utilization of male capelin.

In 1994 and 1995, the average size of female capelin in most areas was too small to meet a market criterion of 50 count/kg (sea run) as identified in the capelin management plan. As a result, the fishery either did not open or opened for only a short time and catches were low. In 1996, this size criterion was removed although size structured pricing is still common.

Landings from 1996-2003 were less than the TAC as a result of reduced fishing effort due to low prices, small females, and lack of interest by processors. Interest in the capelin fishery varies depending on the status of other resources such as Snow Crab and market conditions, which depend heavily on the success of capelin fisheries in the Barents Sea and Iceland, both of which occur in the late winter or early spring. Newfoundland processing capacity also limits the fishery potential.

In the Integrated Fisheries Management Plan (IFMP) for Capelin 2003-05, there was a 40% reduction in TACs attributed to uncertainty around the status of capelin at the time and its role in cod recovery. In the IFMP for Capelin 2006-08, TACs were increased by 33%; at the time there were indications that capelin status was improving based on observations of capelin in northern portions of the stock area, an increase in the size of spawners, and indications of more and earlier beach spawning. Following a year of poor availability and catches in 2010, TACs were lowered again by 20% in 2011. A review of the stock in 2015 indicated that several strong larval cohorts entered the spawning stock in 2012-2014 which resulted in the strongest capelin abundance index in 25 years. As a result the TAC was once again increased by 25%. Preliminary landings in 2015, 2016 and 2017 were 23,065 t, 27,708 t and 19,917 t, respectively, against a TAC of 28,344 t (Fig. 3).

During the 2017 capelin fishery, harvesters observed a high abundance of fish in several Div. 3L bays (Conception, Trinity and Bonavista Bays) relative to recent years (Fig. 1). Capelin were observed by harvesters from St. Mary’s Bay to Notre Dame Bay (Fig. 1). There was no fishery in Labrador. The fishery in 2017 was contracted spatially to Div. 3L due to limitations in processing capacity and the availability of quality fish (i.e. too few fish with empty stomachs).

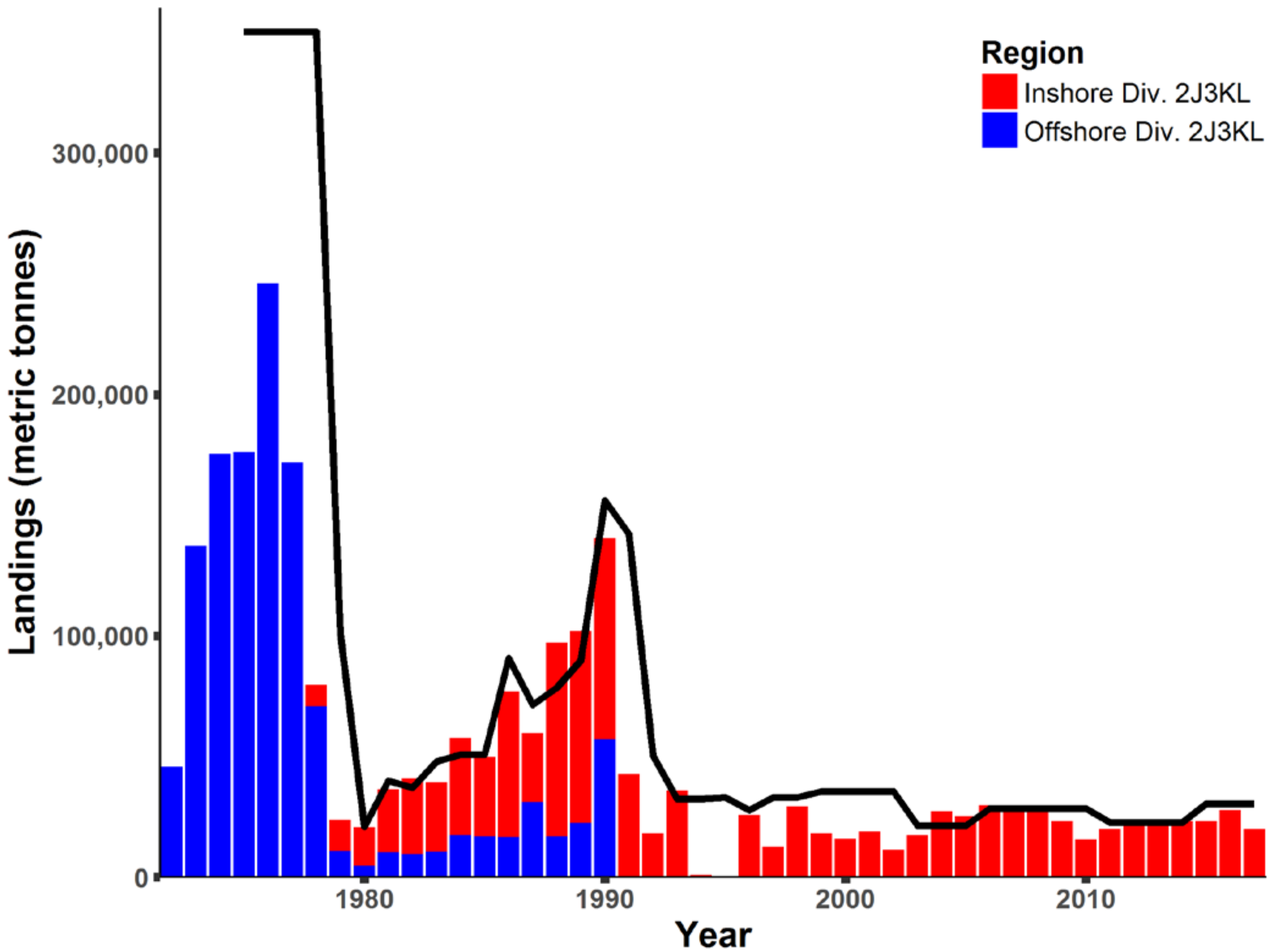
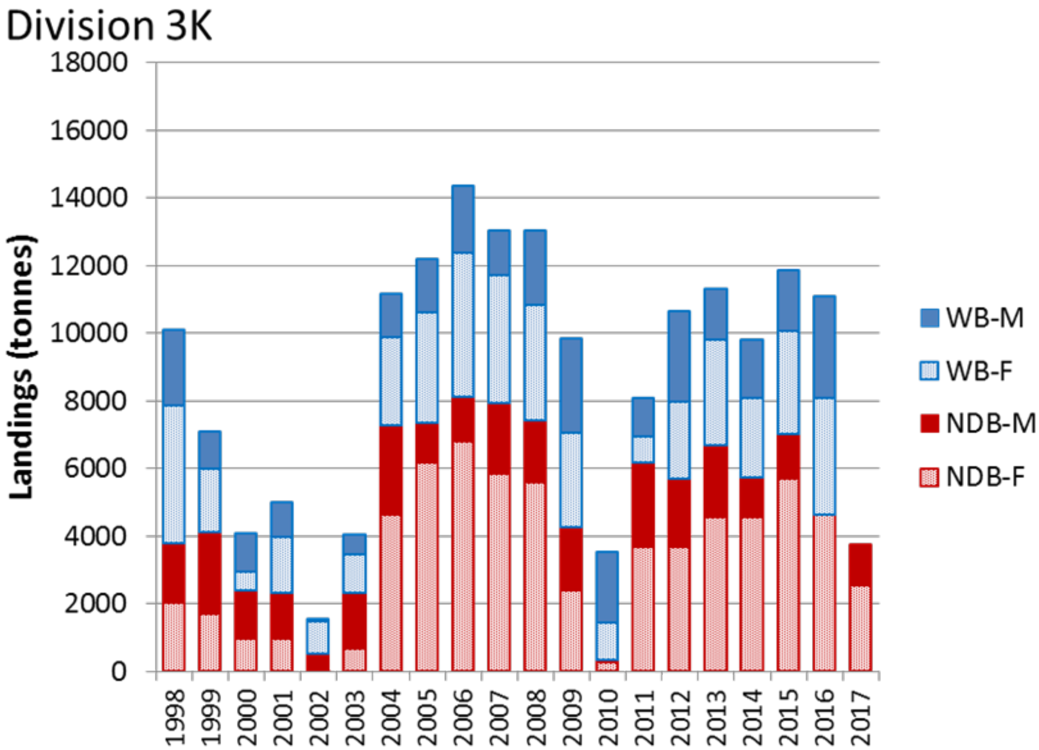


Figure 3. Inshore landings (red bars), offshore landings (blue bars) and TAC (line) for capelin in Divs. 2J3KL in 1972-2017. Note that annual inshore landings were likely greater than 0 t between 1972 and 1977.

The capelin TAC is divided among regions and gear sectors. In 2015-2017, capelin were late returning to spawn and industry encountered difficulties isolating schools with both adequate female maturity development and high percentage of fish with empty stomachs. In 2017, this resulted in the fishery closing before harvesting in northern Div. 3K could occur (Fig. 4).

Capelin landings in St. Mary's Bay and along the Southern Shore have been negligible from 1990-2008 and nil in subsequent years. Impacts from other fisheries' bycatch have never been quantified.



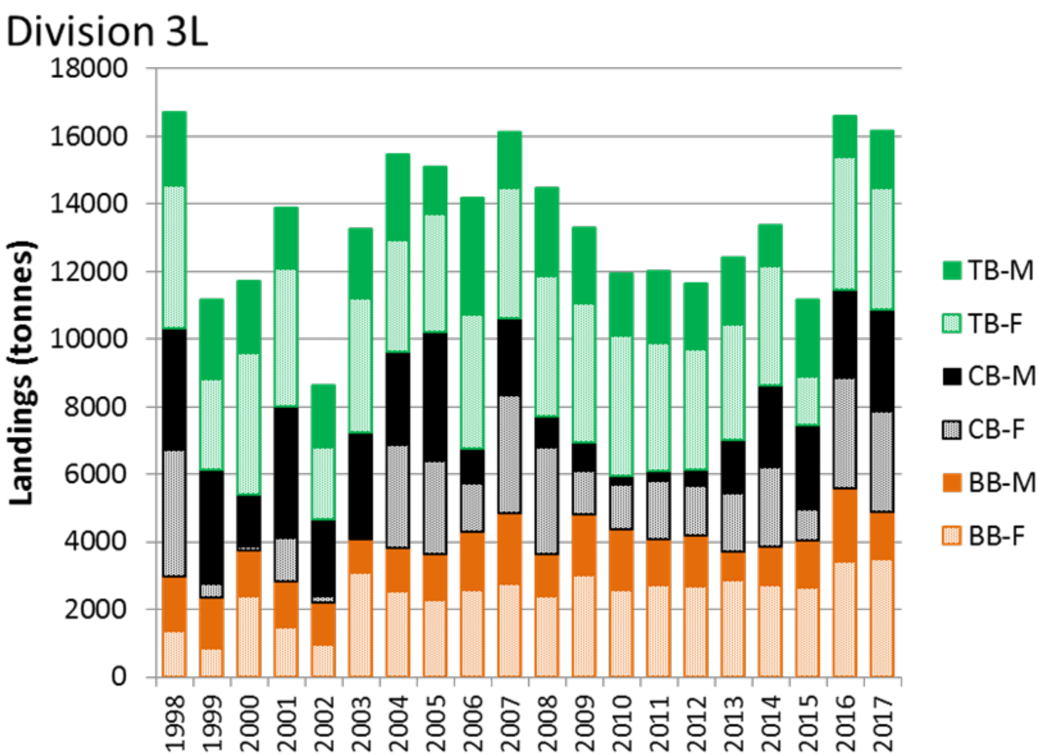


Figure 4. Trends in fixed (F; hatched fill) and mobile (M; solid fill) gear landings (t) from 1998-2017 in Division 3K [Upper panel; Notre Dame Bay – NDB (red), White Bay – WB (blue)] and in Division 3L [lower panel: Conception Bay – CB (black), Trinity Bay – TB (green) and Bonavista Bay – BB (orange)].

ASSESSMENT

The capelin fishery is targeted at spawning fish, but no estimates of spawning stock biomass are available, hence exploitation rates cannot be calculated. Absolute abundance cannot be derived from the spring acoustic survey as it does not survey the entire distributional range of capelin but rather surveys an area that is mainly occupied by juveniles (ages 1 and 2). This assessment was therefore based on trends in the spring acoustic survey abundance index, larval index from Trinity Bay, trends in capelin distribution obtained from the bottom trawl surveys, biological characteristics of the stock and environmental parameters including consumption by predators, and prey availability.

The sources of data considered in this stock assessment are:

1. abundance index and biological samples from the spring offshore acoustic surveys predominantly in Div. 3L (1988-1992, 1996, 1999-2005, 2007-2015, 2017);
2. distribution from spring offshore acoustic surveys and spring and fall multi-species research vessel (RV) bottom trawl surveys in Divs. 2J3KL (1985-2017);
3. index of capelin larvae (less than 12 days old) from Bellevue Beach area, Trinity Bay (2001-2017);
4. spawning times from Bryants Cove, Conception Bay and Bellevue Beach, Trinity Bay (1978-2017);
5. observations of spawning activity at monitored beaches via diaries kept by local and indigenous participants (1991-2017);
6. biological samples collected from the commercial inshore fishery (1981-2017);
7. spring offshore feeding data obtained from May acoustic survey (1999-2014) and fall offshore feeding data obtained from multi-species research vessel bottom trawl surveys (2008-2015);
8. estimates of capelin consumption by predators (1995-2017);
9. primary production indices based on ocean colour metrics (chl a) and secondary (zooplankton) productivity indices (1999-2017);
10. physical oceanographic parameters (1950-2017).

Trends

Spring Acoustic Survey

Information from spring acoustic surveys was presented for 1988-92, 1996, 1999-2005, 2007-15 and 2017. Acoustic data collected in the early 1980s could not be treated in the same manner as more recent estimates and thus was not included. Estimates from earlier years were presented in Mowbray (2013). Estimates of capelin abundance, including 95% confidence limits, were calculated using a simulation technique to capture variability over time associated with advances in hydro-acoustic technology and calibration, changes in spatial and vertical distribution patterns, and changes in the size of capelin. The abundance index at age 3 was found to be well correlated with the abundance index at age 2 in the prior year (all years: $r = 0.77$, $p = 3.66 \times 10^{-5}$; pre-1992: $r = 0.45$, $p = 0.37$; post-1991: $r = 0.53$, $p = 0.04$), indicating that the survey consistently tracks cohort strength in most years.

The acoustic survey abundance index remains below that observed in the late 1980s (Fig. 5). Following a period of very low abundance in the 1990s and early 2000s, the index increased slightly during the period from 2007-2012 with the exception of a record low value recorded in 2010. In 2013-2015, the index values were the highest observed since 1990, ranging from 53-122 billion, and were approximately 25% of the values recorded in the late 1980s. However, in 2017, the acoustic survey abundance index declined markedly, returning to a level similar to that observed during the late 2000s (Fig. 5). Because the spring survey covers only a portion of the stock area these are considered to be minimum abundance estimates and may be subject to unquantified inter-annual variations due to changes in the proportion of the stock within the surveyed area.

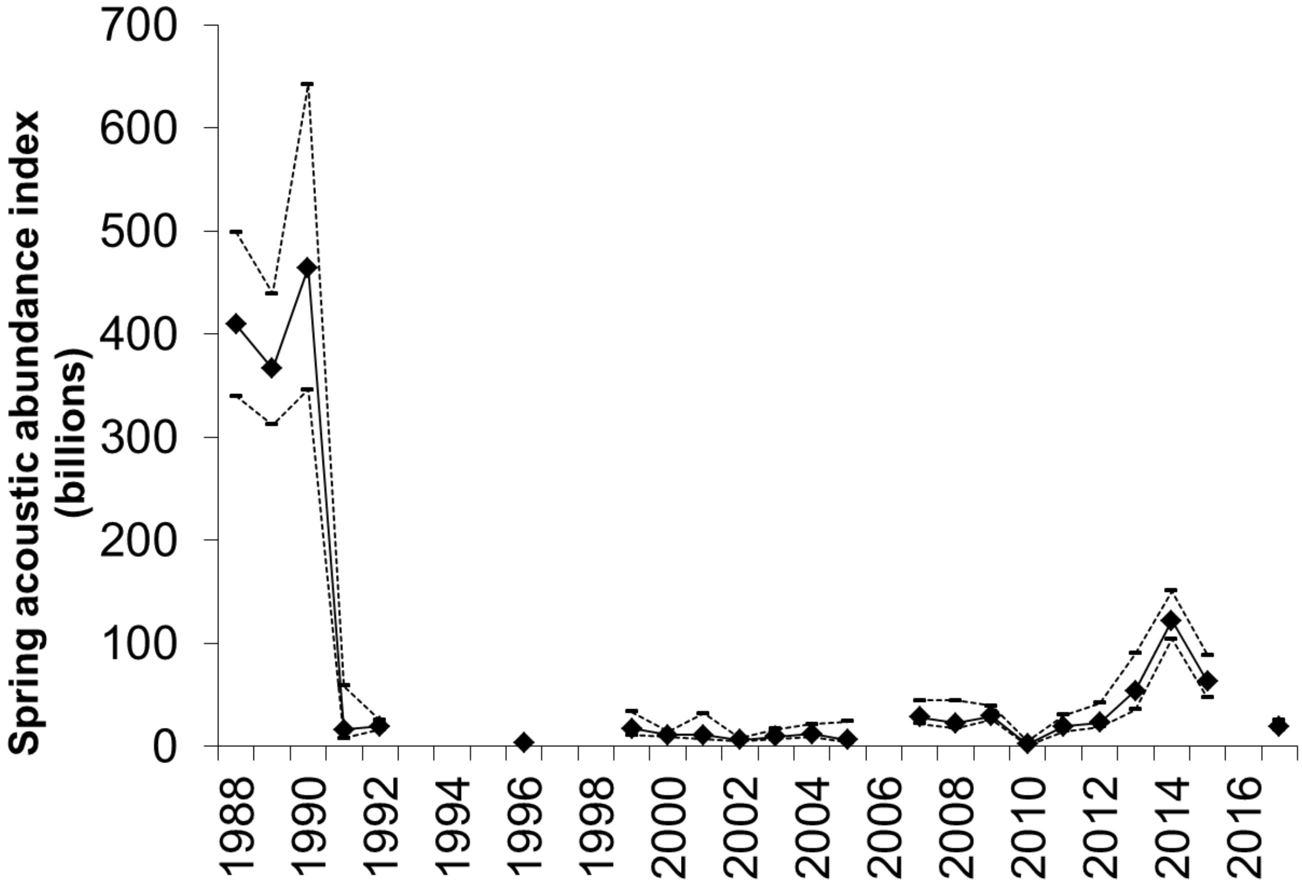


Figure 5. Spring (May) offshore acoustic abundance index of capelin in NAFO Div. 3L and southern Div. 3K (solid line) with 95% confidence intervals (broken lines).

Larval and recruitment indices

Recruitment in capelin has been related to larval survival (e.g., Murphy et al. 2018). The capelin larval index is the primary fisheries-independent inshore index used in the assessment. From 2001-2017, surface tows of 10 minutes duration at a speed of 2.1 knots sampled capelin larval densities (maximum 12 days old) at five stations in the nearshore areas of Bellevue Beach, Trinity Bay (0.5 – 1 nm from the beach; 20 m depth) using a 270 µm mesh ring (Fig. 6). Larval sources into the nearshore area were from one large and four small spawning beaches and two nearshore demersal sites. Surface tows were conducted every 1-2 days from the start of larval emergence to the end of emergence in July and August. Since 2014, the capelin larval index has been below average (Fig. 7). This suggests that spawning biomass in 2018, which will be composed of the 2015 and 2016 year classes, may be smaller than average.

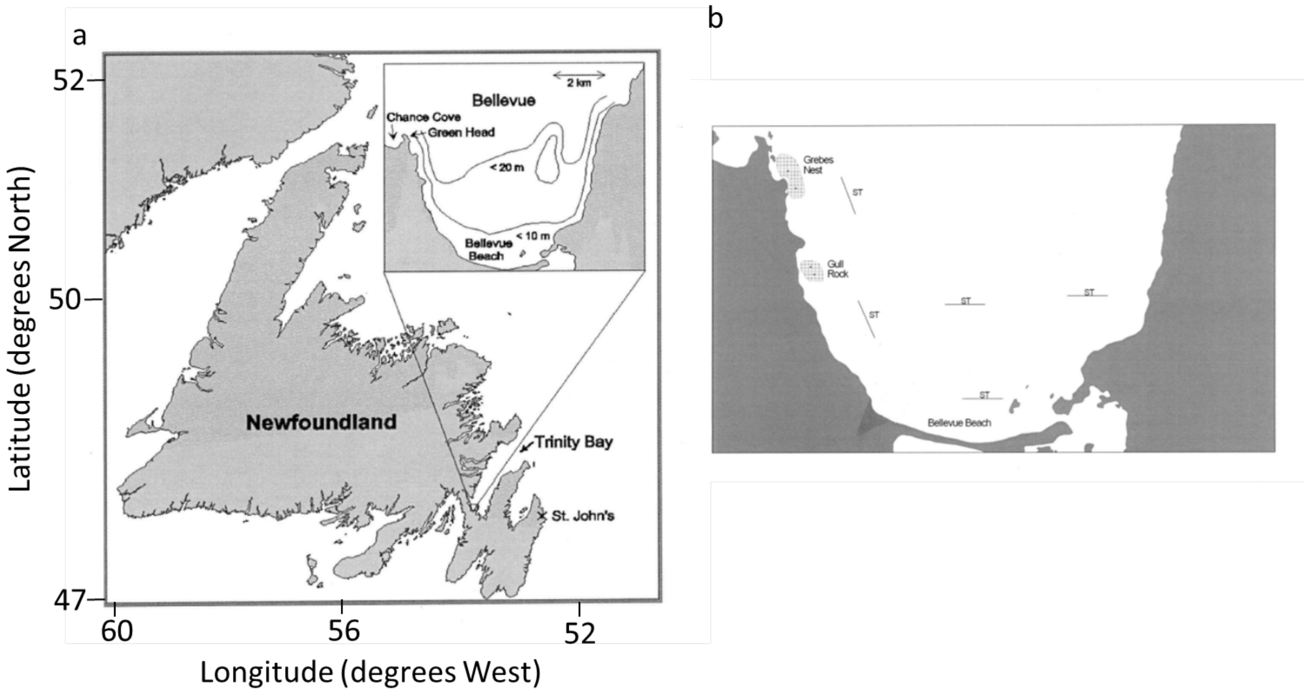


Figure 6. (a) Map of the Bellevue Beach nearshore area, Trinity Bay; (b) map of surface tow sampling stations (ST) in the Bellevue beach nearshore area and the two demersal spawning beds (Grebes Nest and Gull Rock).

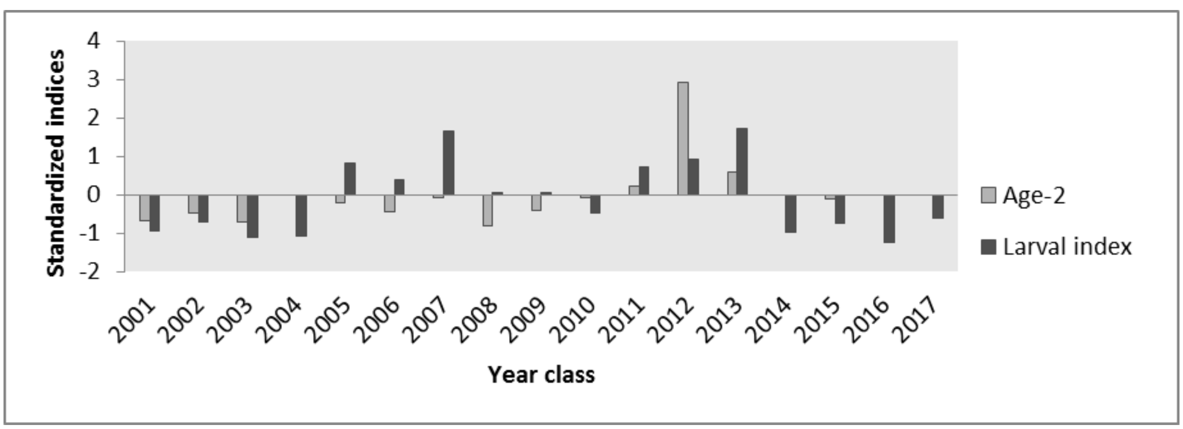


Figure 7. Standardized recruitment indices for age-2 from the Spring acoustic survey (grey) and capelin larvae from Bellevue Beach, Trinity Bay (dark grey) for the 2001 to 2017 year classes.

Behavioural Information

Distribution

In 2017, the spatial distribution of capelin observed during the spring acoustic survey was similar to the pattern common during the 1999-2011 period, with most of the capelin biomass located along the 200 m depth contour of the shelf break and in deeper areas off Bonavista Bay. This contrasts with the spatial distribution in 2013-2015 when capelin shifted west into coastal waters.

During the fall of the year both immature and maturing capelin are distributed offshore in Divs. 2J3KL. The only information on fall capelin distribution comes from multi-species bottom trawl surveys from 1995-2017. When the gear used in these surveys changed from the Engels to Campelen trawl in 1995, more capelin have been sampled in the fall surveys. While bottom trawl surveys cannot provide reliable abundance estimates of pelagic species due to catchability of the trawl and behavior of pelagic fishes, bottom trawl surveys do provide presence/absence data for pelagic fishes. Presence/absence data of capelin from the fall bottom trawl surveys (1995-2017) were used in a center of gravity analysis. This analysis found that capelin exhibits a northern distribution when abundance is high and a southward distribution when abundance is low (Fig. 8). In recent years, the center of gravity of capelin shifted north 2011-2014 and shifted south 2015-2017 (Fig. 8).

Capelin vertical migration patterns in the offshore remain attenuated in comparison to the 1980s (Mowbray 2002). In 2017, similar to 1991-2010, capelin were generally found in areas of greater water depth and were in close proximity to the bottom.

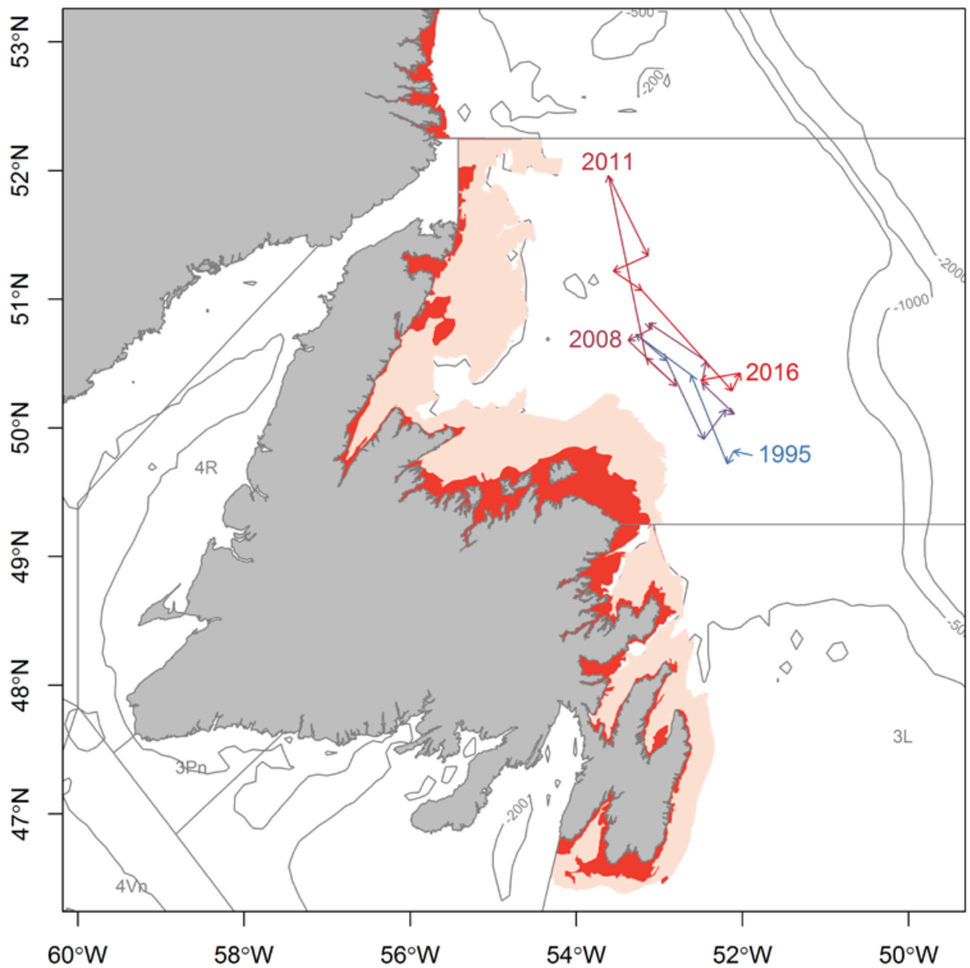


Figure 8. Center of gravity analysis using the VAST package in R (Thorson et al. 2016, Thorson & Barnett 2017) using data from the fall bottom-trawl survey (1995-2017) to fit a geostatistical delta-generalized linear mixed model to estimate the spatial and temporal distribution of capelin. Annual center of gravity estimates are connected by lines through time, where cooler colors (blue) indicate earlier years and warmer colors (red) indicate more recent years. The red area indicates areas not covered by the survey and the pink area indicates inshore strata that are poorly covered by the fall bottom-trawl survey.

Spawning Time

A time-series of peak beach spawning dates of capelin in Div. 3L, which is based on paid participants checking their local beach daily for capelin spawning, has been ongoing since the 1970s at Bryants Cove, Conception Bay (1978-2017) and since the 1990s at Bellevue Beach, Trinity Bay (1990-2017; Fig. 2). Compared to spawning times for Bryants Cove in the 1970s and 1980s, spawning times for both beaches have been delayed by as much as 4 weeks from the early 1990s through 2010. Spawning times improved to only 2 weeks late in 2011-2014. Peak spawning times at Bryants Cove and Bellevue Beach over the last 3 years have been up to 4 weeks later compared to the 1980s. Later spawning times has been related to lower capelin larval survival, which may be related to a mismatch in onshore wind events and less time for larvae to grow before their first winter (Murphy et al. 2018).

From 1991-2017, capelin beach spawning has been monitored throughout the province by paid spawning diarists who checked their local beaches every day during the capelin spawning period (June-August). While participation in this program has varied inter-annually, and has decreased in recent years, this data can be used to track capelin beach spawning timing along the northeast coast of Newfoundland. Spawning diary participation was initiated at one site in Labrador in 2017. Generally, beach spawning occurs earlier in the south and later in the north (Nakashima 1996), but for 2015-2017, beach spawning occurred at similar times on beaches in Divs. 3LK (Fig. 9). For 2015-2017, the peak beach spawning events occurred at similar times and lasted for similar durations, except for protracted spawning in 2016 (10-24 July 2015; 12 July-16 August 2016; 9-25 July 2017). Indigenous knowledge from the Southern Inuit of NunatuKavut indicated that for the first time in known history, no capelin spawned on the beaches in their territory (southern Labrador) in 2016 and 2017.

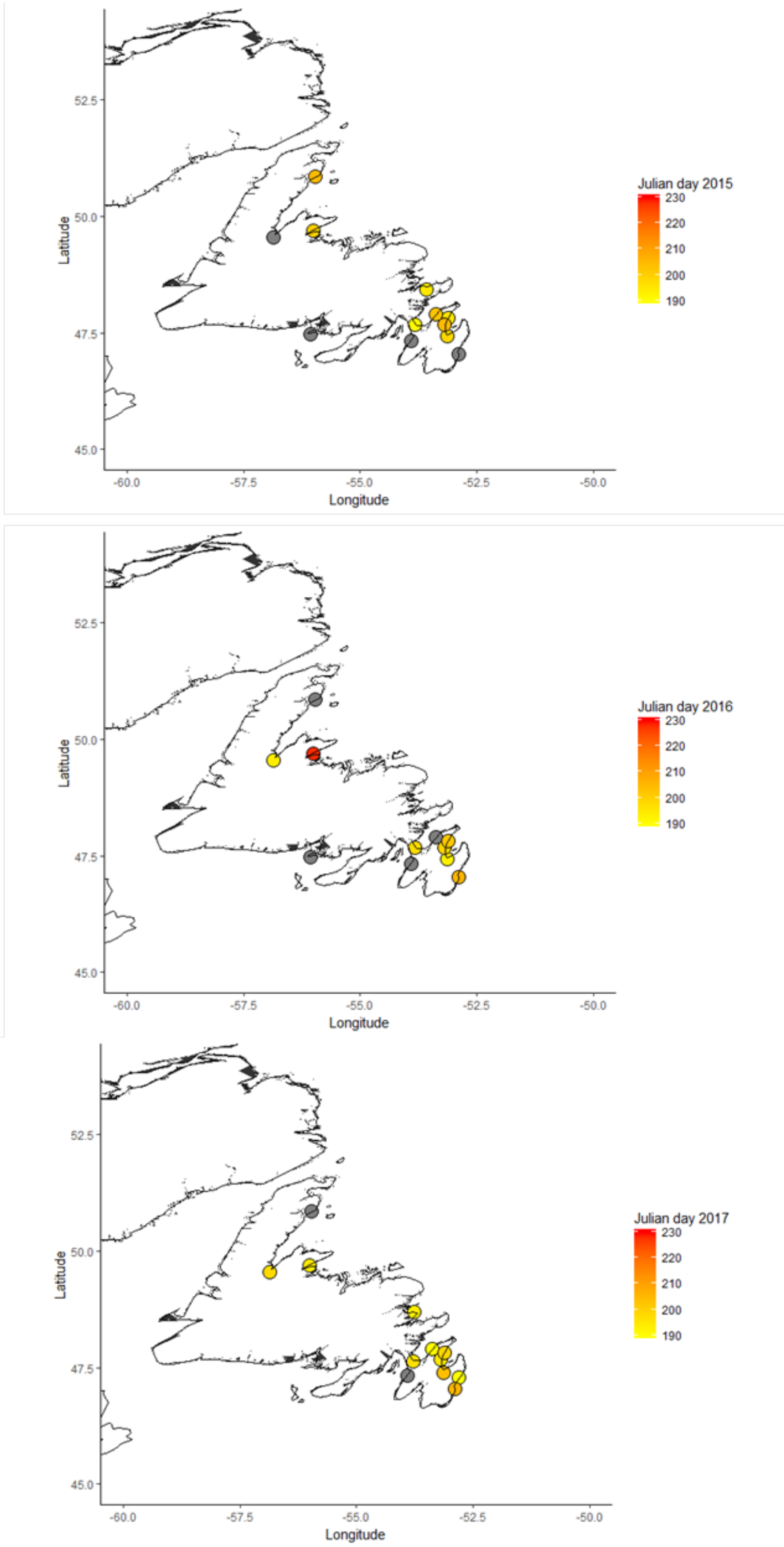


Figure 9. Peak spawning date at monitored beaches in Newfoundland in (a) 2015; (b) 2016; (c) 2017. Grey dots are monitored beaches with no spawning detected.

Biological Information

Biological samples from the commercial inshore capelin fishery in Divs. 3KL have been collected from fish processing plants and processed by DFO Science since 1980. The mean length and weight of capelin landed has declined over the time-series with males and females exhibiting similar trends. This is likely due to changes in capelin biology post-1991, including early maturation and delayed migration (Carscadden et al. 2000). The sizes of capelin landed in 2017 in both Divs. 3K and 3L were the smallest in the time-series (Fig. 10). The small sizes recorded in the fishery were associated with an unusually high proportion of age 2 spawning capelin in both Divs. 3L and 3K in 2017 (Fig. 11).

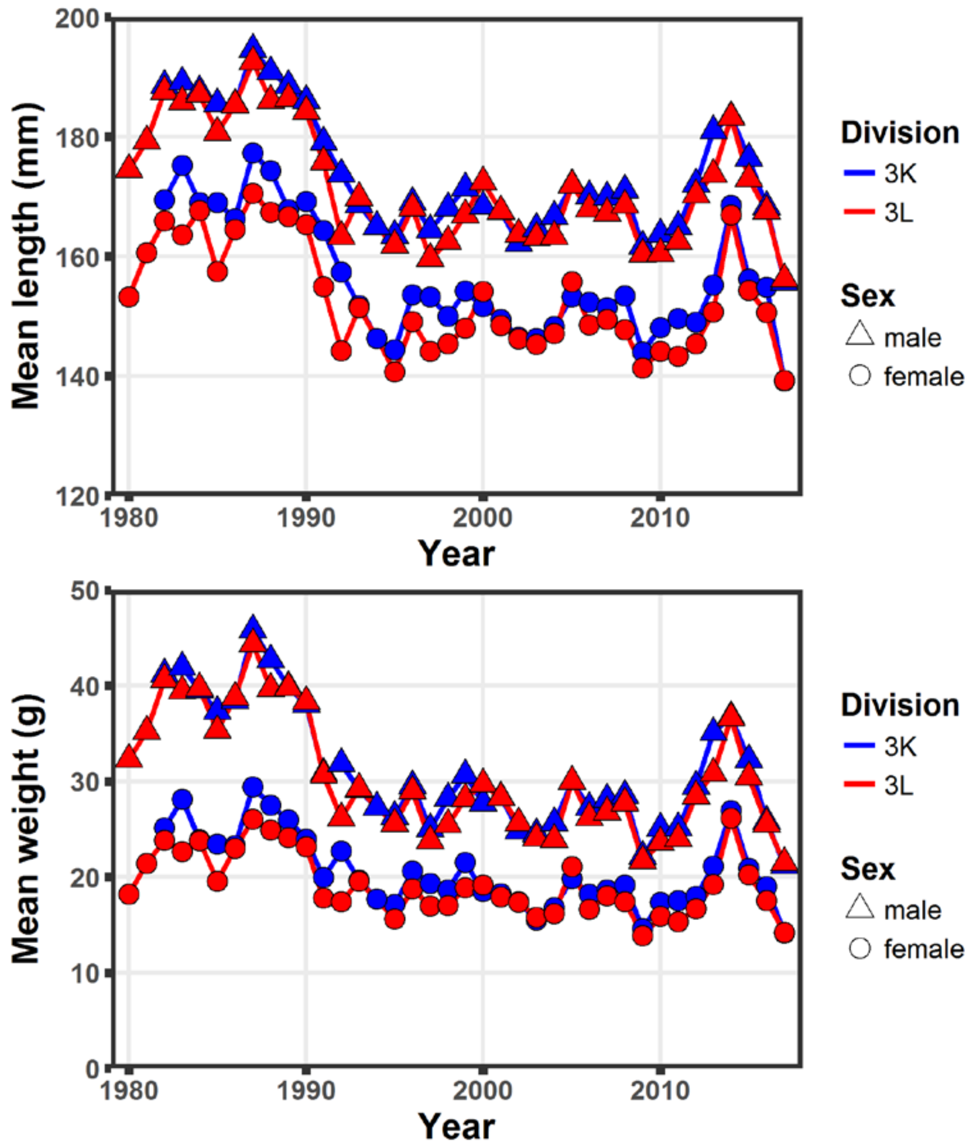


Figure 10. Mean total lengths (upper panel) and weights (lower panel) of spawning males (triangles) and spawning females (circles) taken in the commercial fisheries in Divs. 3L (red) and 3K (blue), 1980-2017.

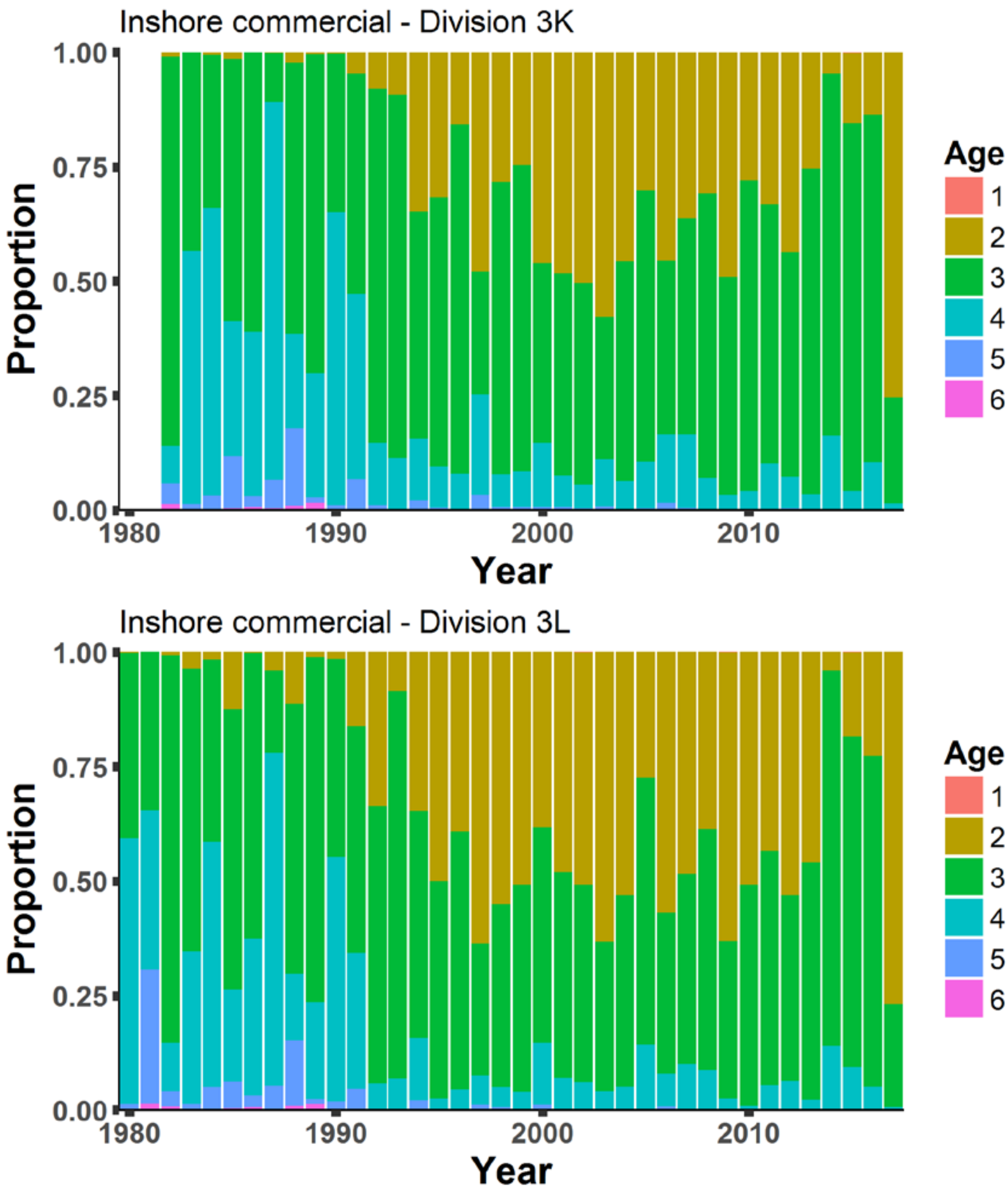


Figure 11. Age composition of capelin landed in the commercial fishery in Divs. 3K (upper) and 3L (lower): 1980-2017.

While the commercial fishery targets spawning capelin, the acoustic survey primarily intercepts younger fish, the majority of which are immature. Consequently, while the age composition of the spawning population has changed over the time-series as a function of the number of age classes present in the spawning population, the age composition of the acoustic survey has been much less variable. Unlike the previous 20 years of acoustic surveys, age 2 capelin dominated the acoustic survey in 2017 (Fig. 12), and the age 2 abundance index was similar to that observed during the late 2000s. However, the abundance index of age 1, 3 and 4 capelin were among the lowest values in the time-series (Fig. 12).

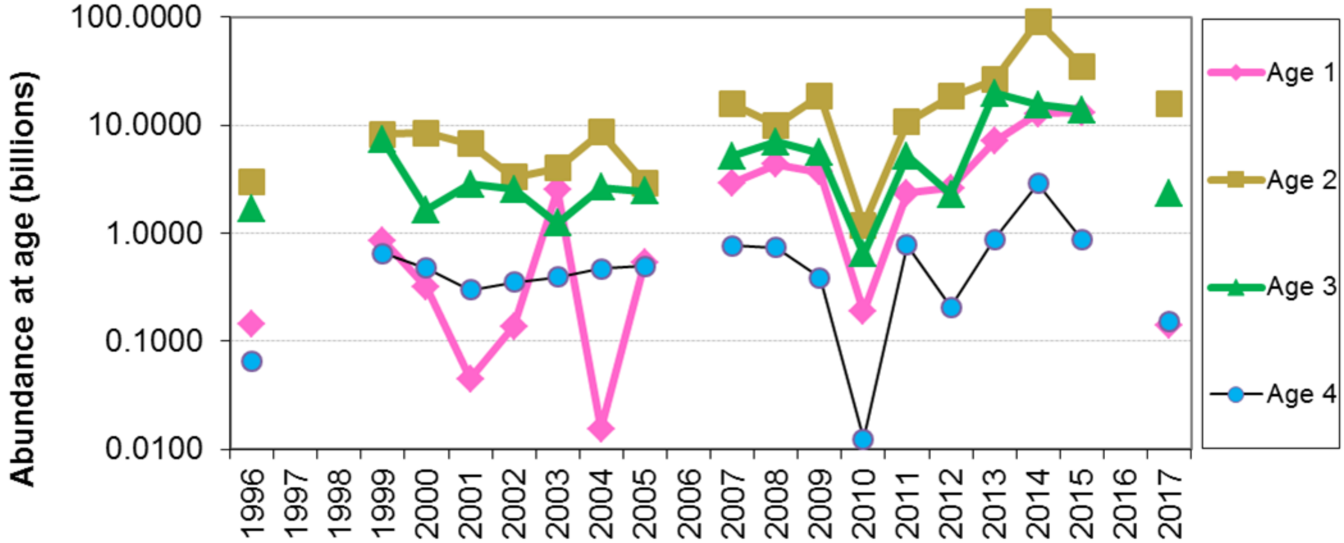


Figure 12. Abundance at age (billions) of capelin enumerated during the spring 3L acoustic survey 1996-2017.

Observed changes in the age composition of spawners are also attributable to changes in the proportion of capelin first maturing at age 2. In the 1980s, age 2 capelin in the offshore acoustic surveys were predominantly immature. From the early 2000s to 2011 the majority of age 2 capelin were maturing. Since 2015, 25-35% of age 2 capelin were maturing (Fig. 13).

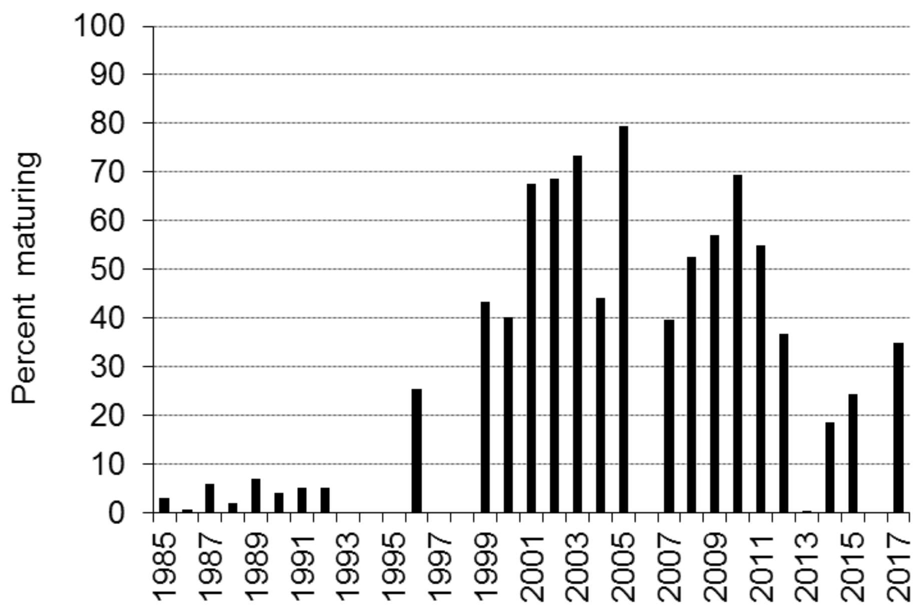


Figure 13. Proportion of two year old capelin maturing during spring acoustic surveys 1985-2017.

The mean length at age of capelin captured during the spring acoustic survey from 1991-2017 increased for ages 1, 2 and 3 but decreased for age 4 fish relative to the 1980s (Fig. 14).

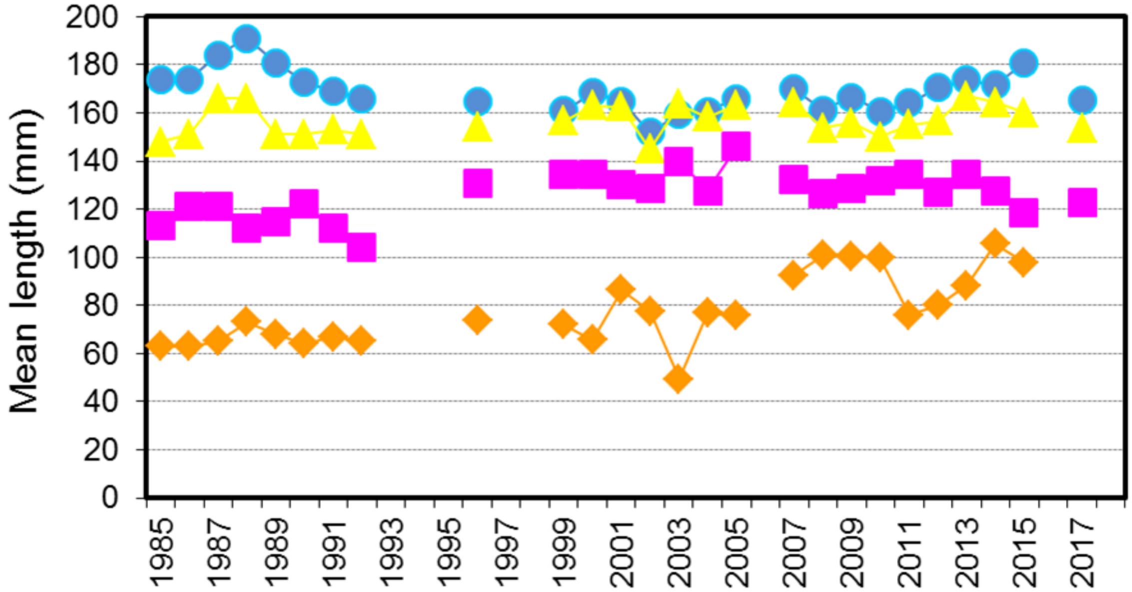


Figure 14. Mean length at age of capelin sampled during spring acoustic surveys 1985-2017 at age 1 (diamond), age 2 (square), age 3 (triangle) and age 4 (circle).

Condition of spawning capelin was lower in the 1990s than in the 1980s (Carscadden and Frank 2002). Condition of maturing females was calculated from the spring survey. In 2017, the condition of the smaller size classes were similar to those observed since 2010, but condition of the largest size class was the second lowest in the time series (Fig. 15).

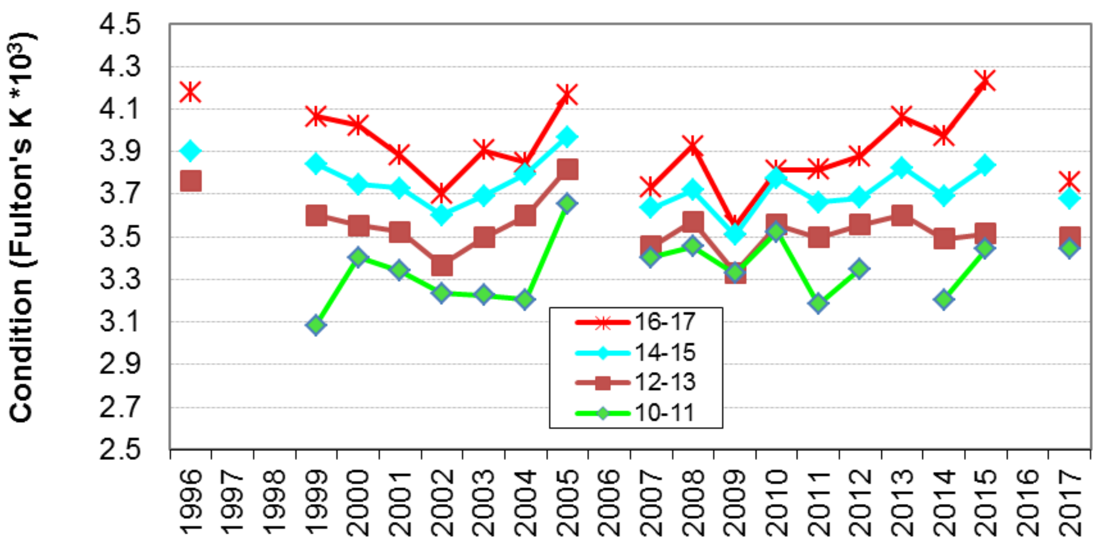


*Figure 15. Fulton's condition (K*10^3) for 2 cm length classes of maturing female capelin sampled during the spring offshore acoustic survey.*

Environmental/Ecosystem Considerations

A warming trend that began in the mid-1990s, peaked in 2010, and has since decreased with colder, less saline conditions during the past 4 years (Fig. 16).

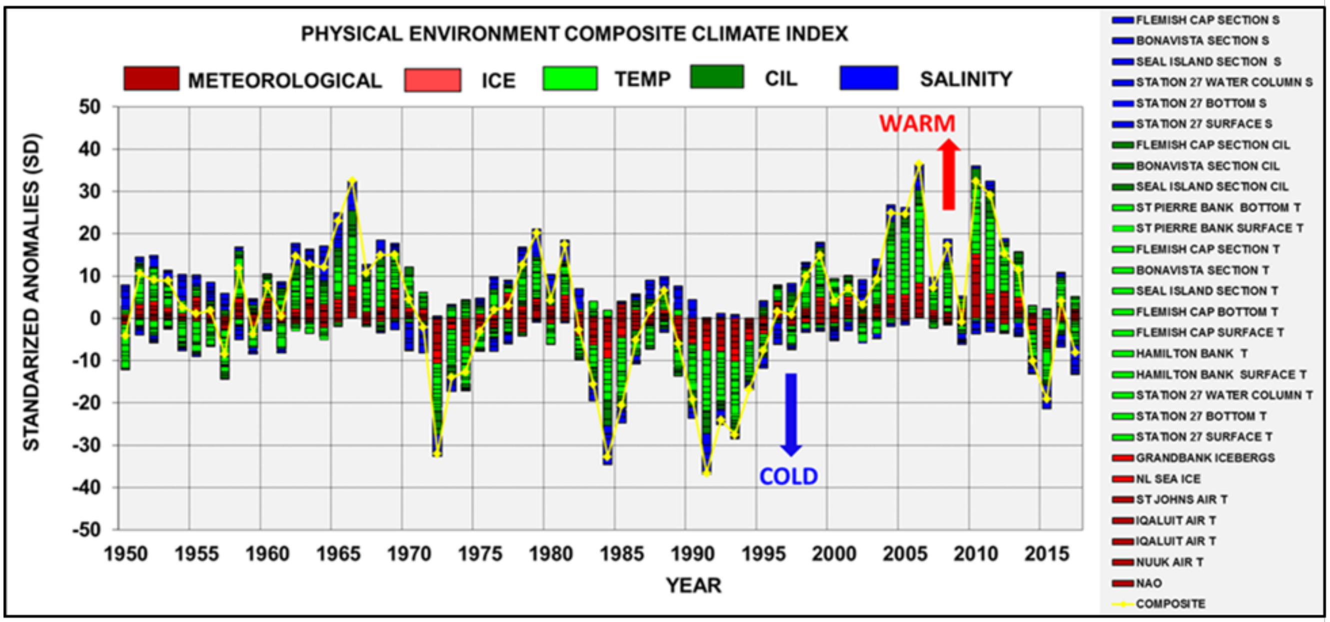


Figure 16. Cumulative climate index from 1950 to 2017.

Production indices based on ocean colour metrics (e.g., total production, intensity, time of maximum, and duration indices of the spring bloom) and secondary production indices since 1998 have been correlated with ocean climate conditions. Cooler conditions are associated with delayed spring blooms (Fig. 17a).

Shifts in community composition of zooplankton since 2015 have been characterized by smaller copepod taxa along with a substantial reduction in biomass. *Calanus finmarchicus*, a large copepod, is an important prey item for post-larval capelin. Abundances of this copepod in the northern area (Divs. 2J3K) have been below average for the last 4 years (Fig. 17b).

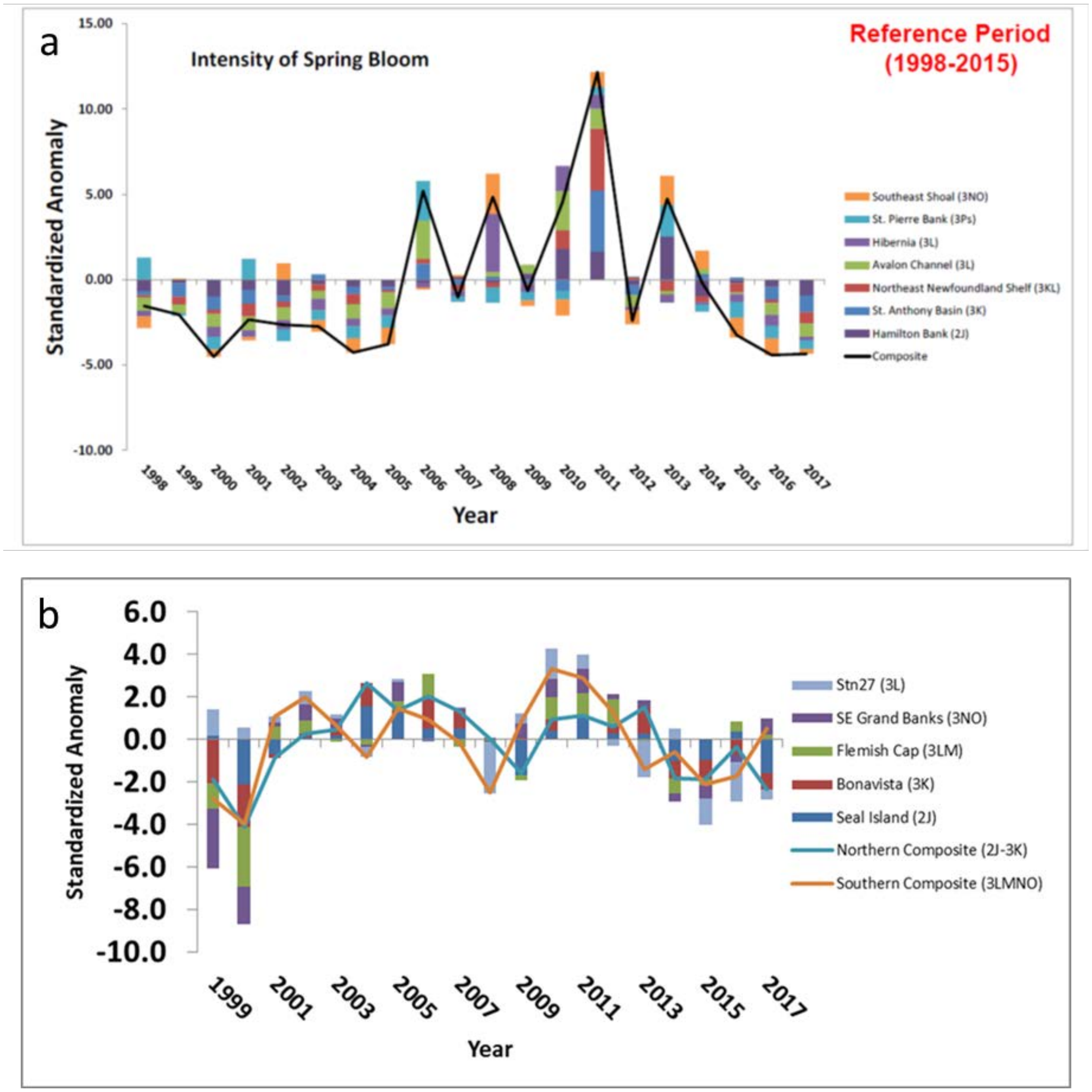


Figure 17. (a) Standardized anomalies of the production indices based on ocean colour metrics from NAFO Divs. 2J3LNO from 1998-2017; (b) Standardized anomalies of the calanoid copepod Calanus finmarchicus *from NAFO Divs. 2J3LNO from 1999-2017.*

Ecosystem conditions in the Newfoundland and Labrador Bioregion are indicative of an overall low productivity state, with low levels of key forage species like capelin and shrimp. Total finfish and shellfish biomasses have both declined since 2013 and the current total biomass level is similar to that observed in the mid-1990s. However, shellfish make up a much lower proportion of that biomass, which is now dominated by finfishes (Fig. 18).

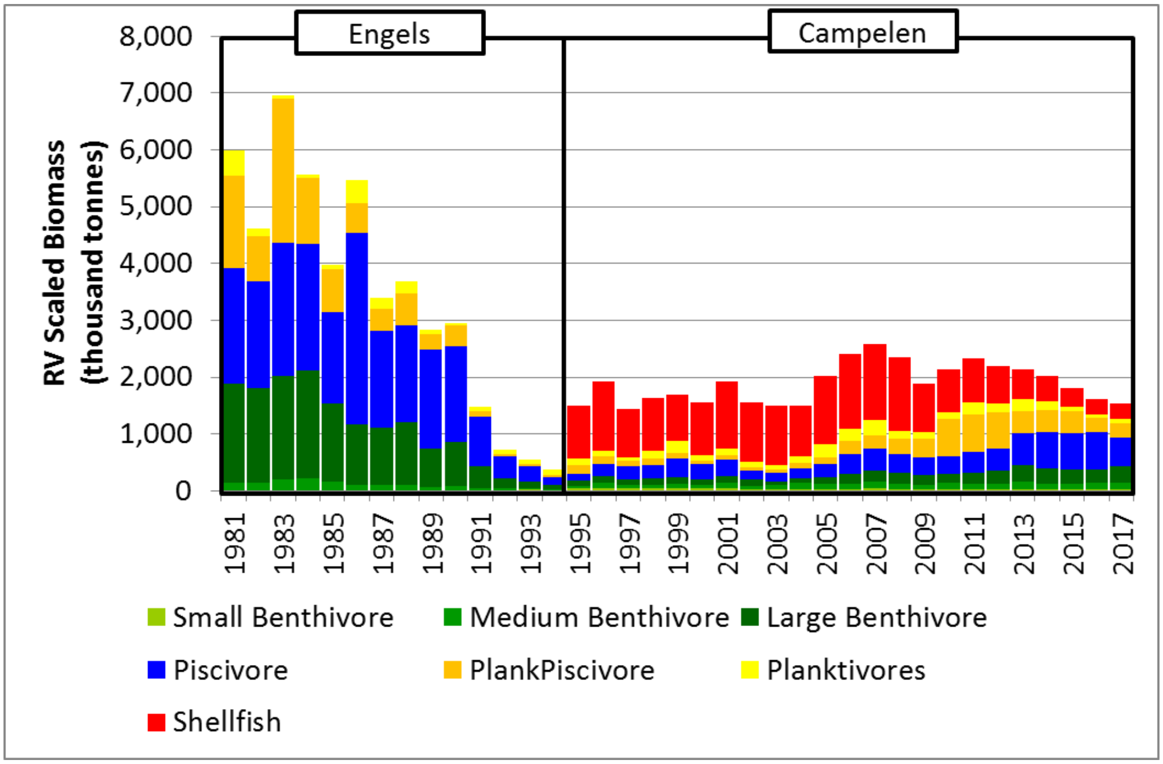


Figure 18. Community composition by functional groups based on DFO RV biomass indices of fish and commercial invertebrates from core strata in the fall DFO multi-species bottom trawl surveys in NAFO Divs. 2J3K.

Ecosystem level estimates of consumption of capelin by predatory fish have been increasing since 2010, with a slight decline in 2016 and 2017, and consumption was estimated to be around 1 million tonnes per year for 2016 and 2017 (Fig. 19). This level of predation is high relative to the past 25 years, but is low relative to the late 1980s. These increases are due to the combined effects of increased biomass of piscivorous fish, an increase in the proportion of capelin in their diets since 2011, and decreases in the abundance of alternative forage species such as shrimp since 2013. An index of predation mortality rate on capelin by finfish in NAFO Divs. 2J3KL, which is a function of the consumption level relative to the capelin stock size, has increased since 2014 (Fig. 20). Marine mammals are also important predators of capelin and significant amounts of capelin are consumed by Harp Seals in Divs. 2J3KL (Stenson 2012). While no updates on the estimates of capelin biomass consumed by seals, whales and seabirds were available for this assessment, it was noted that these species exhibit slow rates of change in population abundance due to the their longevity compared to the short lifespan of capelin, and marine mammals and seabirds are not likely to be responsible for year to year changes in capelin abundance.

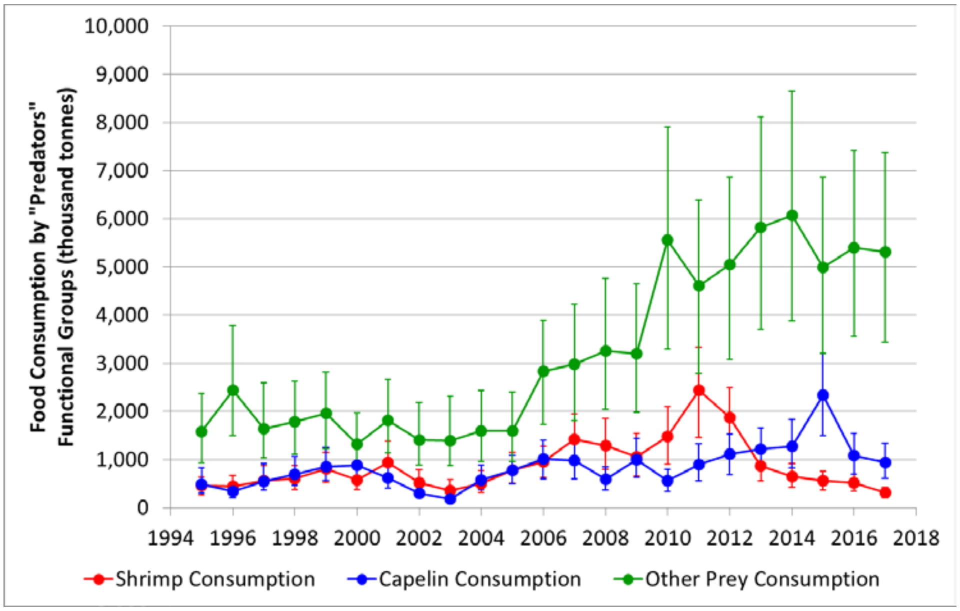


Figure 19. Approximations of consumption of capelin, shrimp and other prey by fish predators in Divs. 2J3KL.

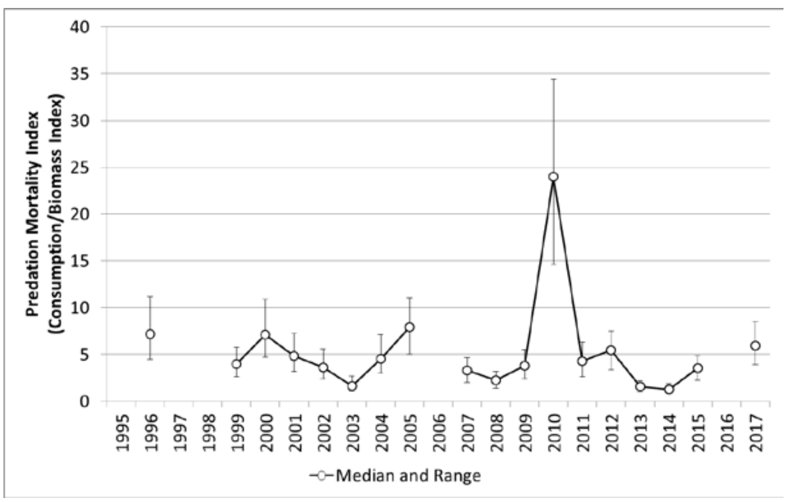


Figure 20. An index of predation mortality of capelin by piscivorous fish in Divs. 2J3KL from 1995-2017. Note values prior to 2008 are estimated with diet fractions from 2008-2017, as individual stomach content data was not available for the previous period.

Sources of Uncertainty

Capelin have a short life span with only two year classes contributing to the spawning biomass each year. As a result, fluctuations in annual recruitment can severely affect spawning stock abundance, resulting in order of magnitude changes in abundance. An increase in the magnitude and frequency of anomalies in environmental parameters is associated with climate change. Capelin can respond rapidly to such environmental changes (Buren et al. 2014). Accordingly, environmental variability may increase uncertainty with regard to capelin stock dynamics.

At present no estimates of absolute abundance (stock size) for capelin in SA2+Divs. 3KL are available. There are two indices for capelin in SA2+Divs. 3KL: a spring acoustic survey and a larval abundance index. 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 these age classes are not fully recruited to the acoustic survey. Consequently, the impact of current commercial catches on spawning biomass cannot be evaluated.

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 has 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 use of bottom trawl survey data in stock assessments of pelagic fish species should always be used with caution.

CONCLUSIONS AND ADVICE

The acoustic abundance index in 2017 declined to the modest values observed during the late 2000s. Most of the 2017 abundance was attributable to age 2 capelin which comprised a record high 91% of the capelin surveyed, while ages 1, 3 and 4 were among the lowest values in the time-series.

Low abundance of age 1 fish was anticipated based on the capelin larval index which has been at low levels for the last 4 years. These recent values are of similar magnitude to those observed during the early 2000s, a period of record low capelin abundance.

Capelin occupy an important role in the ecosystem, acting as a conduit of energy between the lower trophic levels and top predators. Ecosystem level estimates of consumption of capelin by predatory fish have been increasing since 2010, with a slight decline in 2016 and 2017. Consumption is higher than it was for the 1990s and 2000s. The index of predation mortality rate on capelin by finfish has increased since 2014.

The current low values of the two capelin indices (acoustic and larval abundance) are likely attributable to environmental conditions (e.g. bottom-up processes) including poor prey availability during the past 3-4 years. Capelin abundance is also affected by the earlier age of maturation which reduces the total number of older aged individuals due to high post-spawning mortality.

These combined effects have likely reduced the abundance of capelin available for harvest in 2018. The impact of fishing on the spawning stock biomass is unknown.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 7-8, 2018 Assessment of Capelin in SA2 and Divs. 3KL. 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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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2018. Assessment of Capelin in SA2 and Divs. 3KL in 2017. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/030.

Aussi disponible en français :

MPO. 2018. Évaluation de la population de capelans dans la sous-zone 2 et dans les divisions 3KL en 2017. Secr. can. de consult. sci. du MPO, Avis. Sci. 2018/030.