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Capelin in the Estuary and Gulf of St. Lawrence (NAFO 4RST) in 2018, 2019 and 2020

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Capelin landings in the Estuary and the Gulf of St. Lawrence (Northwest Atlantic Fisheries Organization (NAFO) Divisions 4RST) totalled between 8,503, 8,487 and 9,848 t in 2018, 2019, and 2020 respectively. For these 3 years, 96% of the TAC was landed in Division 4R, on average. The performance index of the purse seine fishery in 4R increased from 1996 to 2013 and has remained above the historical average since 2008. Small quantities of capelin are regularly caught as by-catch in the shrimp fishery. In 2018 and 2019, these by-catches amounted to 132 t and 88 t, respectively. Not all data from the Esquiman channel region were available at the time of the assessment for the 2020 season. Mean lengths of females and males caught in 4R reached a maximum in 2014, decreased from 2014 to 2017 and were within 1 standard deviation of the overall mean in the last 2 years. The lengths in 4R are similar or slightly higher than in unit area 4Sw, but are greater than those of capelin caught in 4Tn. Relative condition factors for both males and females in 2018-2020 were close to the time series average, and the sex ratio and gonado somatic indices were within the range of interannual variation. No temporal trends were apparent in the fishery dependent biological data, which may have been indicative of fishery induced evolution and/or directional environmental change.

1. INTRODUCTION

This research document provides a description of the capelin (*Mallotus spp*.) fishery in the Estuary and Gulf of Saint Lawrence (GSL; NAFO Divisions 4RST; Figure 1) as well as a description of the fishery dependent biological data used together with other sources of information (Chamberland et al. 2022; Lehoux et al. 2022; Ouellette-Plante et al. In press.) to assess stock status in 2018, 2019 and 2020. This document supports the Science Advisory Report (SAR) which was requested by Fisheries Management to provide advice for the 2021 and 2022 capelin fishing seasons. Stock assessments for capelin in the GSL are normally undertaken every two years by Fisheries and Oceans Canada (DFO) at the Maurice Lamontagne Institute (MLI) in Mont-Joli, Quebec. The last stock assessment for capelin in the GSL took place in the winter of 2018 and provided advice for the 2018 and 2019 fishing seasons (DFO 2018). This last assessment, along with socio-economic considerations, led the Federal Minister to approve a Total Allowable Catch (TAC) of 9,295 t, a decrease of 5,005 t (35%) from the previous TAC of 14,300 t, which had been in place since 2013. There is currently no stock assessment model used to assess capelin nor are there established reference points with respect to DFO's Precautionary Approach Policy (DFO 2006) or the recent amendment to the Fisheries Act (Bill C-68). All methods and results herein were peer reviewed on March 18th and 19th, 2021 and the main results were incorporated into the Science Advisory Report (DFO 2021).

1.1. STOCK STRUCTURE

Capelin, have a circumpolar distribution and are mostly found in coastal and continental shelf waters. While capelin were previously considered a single species (i.e., *Mallotus villosus*), there is ample morphological, genetic, and genomic evidence indicating that there are multiple parapatric species of capelin (Dodson et al. 2007; Kenchington et al. 2015; Mecklenburg and Steinke 2015; Mecklenburg et al. 2018; Cayuela et al. 2020). There are currently three distinct clades of Atlantic capelin occurring in the Arctic and Atlantic Oceans. These three clades include the Northeast/Central Atlantic clade, the Arctic clade and the Northwest Atlantic clade. Within the Northwest Atlantic clade, three distinct haplotypes have been identified but all are found throughout the Newfoundland and Labrador Shelf, the Gulf of Saint Lawrence, and into the upper Saint Lawrence Estuary (Cayuela et al. 2020). Previous attempts to examine the stock structure of capelin in the Northwest Atlantic including the GSL have highlighted multiple instances of phenotypic variation among spawning sites for traits such as diet, colour, morphology, number of vertebrae and other life-history traits (Templeman 1948; O'Boyle and Lett 1977; Sharp et al. 1977; Carscadden 1979; Carscadden and Misra 1979; Lambert and Bernier 1989; Dodson et al. 2007; Praebel et al. 2008; Kenchington et al. 2015).

1.2. ECOLOGY

Capelin is a small, schooling, pelagic, forage fish. It is a member of the Osmeridae family (smelts) and can live up to 6 years and reach sexual maturity after having survived 2-3 winters. The sexes are indistinguishable from one another until after their second winter, whereupon they become sexually dimorphic. Males grow larger and attain sexual maturity at a larger size relative to females and also develop secondary sexual characteristics such as larger pectoral fins and two pairs of spawning carina (ridges, dorso-lateral and at base of anal fin) which are used during reproduction (Templeman 1948).

Capelin is a cold water species generally preferring temperatures between -1°C and 3-4°C but can be observed over a wider range of temperatures (-2°C - 14°C) (Carcadden 1979; Mowbray 2002; Simard et al. 2002; Rose 2005; Ingvaldsen and Gjøsæter 2013). In the GSL, capelin feed

almost exclusively on zooplankton, the composition of which varies seasonally and with respect to the size of the individual. Larval capelin (< 75mm) mostly consume early stages of small calanoid copepods (90-130 µm) while juveniles and adults (>75 mm) consume larger prey generally dominated by late stages of *Calanus* species and euphausiids (Dalpadado and Mowbray 2013). Their vertical diel migrations coincide with the vertical migrations of their zooplankton prey with daytime feeding being more successful (Templeman 1948; Vesin 1979; Courtois and Dodson 1986; Dalpadado and Mowbray 2013; Aarflot et al. 2020). However, these patterns can differ according to the season and may be disrupted by changes in the physical environment or by the presence of predators (Bailey et al. 1977; Rose 1988; Mowbray 2002).

Capelin are widely distributed throughout the GSL (Carscadden 1979; McQuinn et al. 2012) and play an important role in the marine ecosystem as a forage species for marine fishes such as Greenland halibut (*Reinhardtius hippoglossoides*) and Atlantic cod (*Gadus morua*; Ouellette-Plante et al. 2020), marine mammals, and seabirds. Predation was estimated to be the main source of capelin mortality in the GSL from the mid-1980s and the mid-2010s with variations associated with the abundance of predators (Savenkoff et al. 2004).

1.3. REPRODUCTIVE CYCLE

During the spring and summer, sexually segregated schools of mature capelin migrate inshore to spawn on beaches or at demersal sites which have suitable substrates and temperatures between 2 to 12 °C (Templeman 1948; Parent and Brunel 1976; de Lafontaine et al. 1991; Davoren and Montevecchi 2006; Purchase 2018). Capelin are broadcast spawners, have determinate fecundities and spawn only once per year. Mature female ovaries contain an average of 41,767 eggs (Grégoire et al. 2004). Post spawning adult mortality is high, particularly for males.

The spawning season is protracted and begins in the upper estuary in late April and early May and progresses eastwards and northwards towards the Strait of Belle-Isle in July and August as temperatures increase throughout the GSL (Figure 2). Capelin regularly spawn at multiple sites along Quebec's north shore, the Saguenay Fjord, the Gaspé Peninsula, the Baie des Chaleurs, the northern and southern shores of Anticosti Island, St. George's Bay N.S., and off the west coast of Newfoundland (Templeman 1948; Parent and Brunel 1976; Carscadden 1979; Courtois et al. 1982; Nakashima et al. 1982; Ouellet 1987; Lambert and Bernier 1989; Sirois et al. 2009).

1.3.1. Larval emergence, distribution, and abundance

Egg incubation time varies according to temperature and salinity, but typically lasts 15-20 days at 10 °C (Frank and Leggett 1981; Penton et al. 2012). Emerging larvae are 3-5 mm long and remain in the upper 0-20 m of the water column during their early life (Bailey et al. 1977). In the Estuary and northwestern GSL, they can grow to between 43-56 mm by their first winter. Larvae will metamorphose after their first winter at approximatively 66-71 mm and will grow to approximatively 80-110 mm by their second winter (Bailey et al. 1977; Jacquaz et al. 1977).

Capelin larvae are distributed broadly throughout the GSL (de Lafontaine et al. 1991). Upon rising to surface waters (0 – 20 m) following their emergence, larvae are quickly dispersed by the prevailing water currents, tides, and winds (Jacquaz et al. 1977; Bailey et al. 1977; Fortier and Leggett 1983, 1985; Ouellet et al. 2013). Areas of particularly high larval density include the Saguenay Fjord (Sirois et al. 2009), the Estuary and northwestern GSL (Jacquaz et al. 1977; Ouellet et al. 2013), near the mouth of the Baie des Chaleurs and the Shediac Valley (O'Boyle and Lett 1977; Grégoire and Girard 2014), all along Quebec's North Shore, Saint George's Bay Nova Scotia (Carscadden 1979; Lambert and Bernier 1989), and in the large bays along the west coast of Newfoundland (Carscadden 1979; Grégoire et al. 2013).

1.4. COMMERCIAL FISHERY

The commercial fishery for capelin in the GSL is co-managed by DFO's Newfoundland, Gulf, and Quebec Regions under an evergreen Integrated Fishery Management Plan (IFMP) that was approved in 2017 and updated in 2020. The large majority of the commercial fleet is based on the west coast of Newfoundland (NAFO Division 4R). Fishing seasons are generally short and coincide with the inshore spring migration to spawn.

The decision of when to open the commercial fishery is largely based on the availability of capelin to fishing gear, the weather, socio-economic concerns, and recommendations from the fishing industry, the latter being motivated to maximise the number of larger roe-bearing females in their catch for export to foreign markets. While females and their roe are largely sold for human consumption, males have been traditionally released, discarded, or used as fertilizer. Both males and females are, however, increasingly being exported to zoos and marine parks as animal feed both domestically and abroad.

The TAC for capelin in the GSL has rarely been limiting and landings have historically been market driven (Grégoire et al. 2013). The TAC is currently split by fleet and Northwest Atlantic Fisheries Organization (NAFO) Division (Table 1). The 4R fixed gear fleet, which includes tuck seiners, has an allocation of 37.82% of the TAC and is a fully competitive quota. Large (vessel >19.81 m (65 ft.)) and small (vessel <19.81 m) purse seiners, which compose most of the mobile gear fleet, each have an allocation of 24.15% of the TAC. Small seiners are managed through individual quotas (IQ) while larger seiners are managed as a competitive fishery. The allocation for 4ST is 13.88% of the total TAC and is managed as a competitive fishery across all gear types (Table 1). All licence holders in 4R are required to have their catch monitored at dockside and the return of logbooks are mandatory.

2. METHODS

The data available for this assessment include: reported commercial landings (1960-2020), a fishery performance index derived from commercial landings of the 4R seiner fleet (1986-2020), capelin bycatch by the shrimp trawler fleet in the GSL (2000-2020), biological samples from commercial catches (1984-2020), and biological samples from DFO's summer multispecies bottom-trawl surveys covering the southern (sGSL) and northern GSL (nGSL).

2.1. COMMERCIAL FISHERY

2.1.1. Landings

Detailed commercial fisheries landing data (1985-2020) were extracted from the most recent Zonal Interchange File Format database (ZIFF) compiled by MLI's data management section and DFO's regional statistics bureaus. Landings in Canada's Exclusive Economic Zone (EEZ) from 1960-1985 were extracted from the Northwest Atlantic Fisheries Organisation landings database to obtain information on landings prior to 1985, which were less detailed. At the time of this assessment, landings data for the 2019 and 2020 fishing seasons were still preliminary.

Annual landings data were summarized by year, NAFO Division, and gear type. The seasonality of the capelin fishery was summarized by calculating the cumulative daily percentage of annual landings by year. The spatial distribution of landed catches was not mapped because the majority of capelin ZIFF data between 1985 and 2020 lack geographic coordinates. Landings by NAFO Division were deemed more appropriate for this purpose.

2.1.2. Seiner performance index

Capelin landings on the west coast of Newfoundland (NAFO 4R) are mostly made by the purse seine fishery. This fishery takes place near the coast and fishing vessels generally make one trip per day. We therefore assumed that each entry in the database corresponded to one fishing day per boat.

A standardized index measuring the performance of this fishery was calculated using a multiplicative model (Gavaris 1980) applied to the CPUEs (log(t/day/boat)). Only landings made by purse and tuck seiners from June to August between 1986 to 2020 in 4R were included in the model. Entries with missing or unknown vessel length classes were removed if this information could not be found elsewhere in the database using the unique vessel identification number. Entries where NAFO subdivision information indicated simply the NAFO Division (i.e. 4R) were also omitted.

The following model was fitted with all explanatory variables coded as factors:

$$ln(y_i) = b_0 + b_1x_{i1} + b_2x_{i2} + b_3x_{i3} + b_4x_{i4} + b_5x_{i5} + \varepsilon_i$$

Where y_i: landing (tonne/day/boat)

x_{i1}: year, from 1986 to 2020

x_{i2}: month of the year, where June = 6, July = 7 and August = 8

x_{i3}: length class of vessels where 1 = 1–34.9’ (0.30–10.64 m), 2 = 35–44.9’ (10.67–13.69 m), 3 = 45–64.9’ (13.72–19.78 m), 4 = 65–99.9’ (19.81–30.45 m), 5 = 100– 124.9’ (30.48–38.07 m), and 6 = >125’ (38.10 m)

x_{i4}: NAFO Division 4R subdivision, 4Ra, 4Rb, 4Rc and 4Rd

x_{i5}: Fishing gear: tuck seine and purse seine

ε_i: Error distributed log-normally

The standardized CPUEs were produced using, for each year, the values predicted by the model for the modal level of each standardization factors: June, length class 2, unit area 4Rc and purse seine. Predicted values were back-transformed on the original scale using the Delta method. Residuals and Cook’s distances were examined to verify whether the application conditions were met.

2.1.3. Bycatch in the shrimp fishery

Bycatch of capelin by the commercial shrimp fishery in the GSL has been estimated with catch and effort data acquired by the At-Sea-Observer-Program (ASOP) since 2000. Annual coverage is approximately 5% of total fishing trips by this fleet (Savard et al. 2013; Bourdages et al. 2020b). Estimated annual bycatch (t) of capelin by this fleet was broken down by shrimp fishing areas (SFA; Estuary, Sept-Iles, Anticosti, and Esquiman). Geographic distribution of the estimated bycatch was presented as the mean kg/tow in 5 x 5 minute cells. In 2020, no tows were sampled by ASOP in the estuary even if landings were made in this zone. Also, ASOP data was not available from the Newfoundland fleet at the time of the assessment and therefore current estimates in Esquiman SFA were done using data from the Quebec, New-Brunswick and Nova Scotia fleets. Consequently, 2020 estimates of capelin by-catch in the shrimp fishery are partial.

2.2. COMMERCIAL SAMPLING

2.2.1. Size distribution

The commercial sampling program annually covers key capelin fishing activities in the Estuary and in the GSL. This coverage results in measuring total length (±1 mm) and sex of 150 fish randomly selected fish (hereafter commercial length frequency data). From 1984 to 1987, fish were measured with a precision of 5 mm. These data allowed to calculate the mean size of the females and males capelin of Division 4R for the 1984-2020 period and for Divisions 4S and 4T for disjointed years within the same period.

For each landing surveyed by the port sampling program, a sub-sample of two capelin per sex per 5 mm bin was analyzed in the laboratory at MLI (hereafter commercial biological data). Measurements taken at MLI include: total length (nearest mm), mass (nearest 0.1 g), sex, gonad mass (nearest 0.1 g), maturity stage (immature, maturing, prespawning, spawning, recovering), and age via the extraction and examination of otolith structure. The latter measure had been carried out in the past (1976-1993) and a renewed age reading program is being developed.

2.2.2. Relative condition factor

Annual condition of male and female capelin was estimated by calculating the relative condition factor ($Kn_i = W/W'$; Le Cren 1951), where W is the observed somatic mass, and W' is the estimated mean mass given an individuals length. W' was estimated by fitting the following mass-length relationships for each sex:

$$W_i = aL_i^b e^{\varepsilon_i}$$

where a and b are constants and ε_i is the multiplicative error term for the *i*th fish. Relative condition factors for each sex were standardized for month and gear effects using a Gaussian glm with an identity link. An interaction term between the factors of year and NAFO division was also included in the models.

2.2.3. Sex ratio and gonado-somatic-index

Mean annual sex ratios were calculated for NAFO divisions 4R, 4S, and 4T using commercial port sampling length frequency data (arithmetic mean).

A Gonadosomatic-Index (GSI; (*gonad mass / total mass) * 100*) was calculated for male and female capelin from the commercial fishery. Individuals whose sex could not be identified, individuals weighting <5 g, as well as male capelin with a GSI > 10% were excluded from the analysis. Annual means and standard deviations were computed for each sex by year.

2.3. LENGTH AT MATURITY

Biological samples from the DFO northern GSL (nGSL) August (2018-2020) and the southern GSL (sGSL; 2020) September bottom trawl surveys were analyzed to obtain detailed data on length and maturity. A description of these surveys is available in Bourdages et al. (2020a) and Savoie (2014). Maturity ogives and lengths at 50 percent maturity (L50) were estimated. A Bernouilli glm with a logit link function was fitted with immature/mature as the dependent variable and total length (mm) as the independent variable. A bootstrap procedure was used to estimate 95% confidence intervals. Maturity ogives were not computed by sex because the number of immature fish for which sex could be determined was very low (16 immature females and 31 immature males for these 3 years).

3. RESULTS AND DISCUSSION

3.1. COMMERCIAL FISHERY

3.1.1. Landings

Annual commercial landings of capelin in the GSL were less than 2000 t from 1960 to 1977 but rapidly increased in 1978 and 1979 to about 10 000 t (Table 2, Figure 3). From 1985 to 2020, annual landings varied substantially (mean ± SD of 6903 t ± 3422 t) and were characterized by a number of years where few to no landings occurred (e.g. 1982, 1987, 1994, 1995, 2001, and 2017). Preliminary landings data indicated that landings increased from a ten year low of 1965 t in 2017, to 8503 t, 8487 t, and 9848 t in 2018, 2019 and 2020 respectively (Table 2, Figure 3). During the 2018 4RST capelin assessment, low landings in 2017 were attributed to the presence of later than usual sea ice retreat in some areas and to poor weather conditions limiting harvesting opportunities (DFO 2018). The TAC in this fishery was only exceeded in 1992, 1993 and 2020 (Table 2, Figure 3).

Capelin have continued to be mostly landed by the seiner fleet in NAFO 4R in the northeastern GSL, which have, on average, landed 80% of the total landings in 1985-2020, and 86% of the TAC in 2010-2020 (Table 3, Figure 3). The mobile gear fleet (small and large purse-seiners) landed most of the TAC in the GSL though an increase in landings by fixed gear types since the mid-2000s is largely attributable to the arrival of the Tuck seine in the fleet, which are classed as fixed gear despite their actual mobility (Table 4, Figure 3).

In NAFO Division 4R, landings typically occurred in subdivisions 4Rabc and were more evenly distributed between these 3 subdivisions in the 2018, 2019 and 2020 than in previous years (Figure 4). Since 2012, the large and small purse seiners landed similar proportions of the TAC and landings with trap nets represented a smaller proportion of the total catch in this Division (Figure 4).

In NAFO Divisions 4S and 4T, most of the landings since 2005 occurred in subdivisions 4Sw (Québec's Lower North Shore) and 4Tn (mouth of the Chaleurs Bay) by purse seines and traps (Figure 5).

The capelin fishery in 4R generally occurs in June and July and the timing of the landings has varied little since detailed records have existed (Figure 6). In 4S and 4T, the fishery usually starts earlier than in 4R and shows more interannual variation in the timing of the landings (Figure 7).

3.1.2. Seiner performance index

The model developed to standardize purse seiners CPUE (ln(t/day)) in 4R explained 38.5% of the total variance ($p<0.001$) with all independent variables being significant ($p<0.01$) (Table 5) (see also Grégoire and Bruneau 2012). Residuals (Figure 8A) and standardized residuals (Figure 8B) did not have a pattern indicating a violation of variance homogeneity. The residuals followed a distribution that deviated slightly from normal (Figure 8C) but did not show extreme values that could influence the model (all Cook's distances were less than 0.5, Figure 8D).

The effects (Figure 9) of each independent variable indicated that performance (t/day/boat) were similar among months but were more variable as the season progressed, that larger vessels had a greater performance than smaller vessels, that vessels fishing in the 4Rcd had a greater performance than those fishing in 4Rab, and that purse seiners outperformed tuck seiners. These differences were accounted for in the standardized index.

The index increased from 2004 to attain a time series maximum in 2013 at 57.87 t/day that was followed by a decrease to 37.00 t/day in 2017. The index increased to 50.88 t/day in 2018, and was 46.96 and 44.86 t/day in 2019 and 2020, respectively, and above the 1986-2020 average value (Figure 10). Interestingly, recently developed abundance indices for the northern GSL showed a similar increase during the 2002-2011 period (Chamberland et al. 2022). The interannual variations in the 4R seiner performance index and in the northern GSL abundance index were related to similar oceanographic conditions determining capelin recruitment (i.e., copepod abundance and the timing of the ice retreat) and did not appear to be related to socio-economic factors (Chamberland et al. 2019; Lewis et al. 2019; Lehoux et al. 2022). However, technological improvement could not be ruled out as an additional explanation for this pattern in the performance index nor could factors related to daily catch limits imposed on harvesters by fish processing plants.

The arrival of tuck seine fishing in 4R in 2005 seemed to have a negligible effect on the overall performance index (purse seine and tuck) since the index for purse and tuck seine varied consistently (Chamberland et al. 2019).

3.1.3. Bycatch in the shrimp fishery

Capelin are frequently caught as bycatch by the shrimp fleet in the GSL, occurring in 84% of tows (mean of ~146 t / year) between 2000-2019, 73% of tows (~ 132 t) in 2018, 92% of tows (~ 88 t) in 2019, and 60% of tows (~ 100 t) in 2020. Estimated annual bycatch of capelin by shrimp trawlers in the GSL for 2018 and 2019 were below the time series (2000-2019) mean of 146 t (Table 6, Figure 11). Decreases in capelin bycatch by this fleet are likely related to decreases in Shrimp TAC throughout the GSL, efforts by the industry to avoid capturing capelin, as well as modifications to shrimp fishing gear made to mitigate bycatch (e.g. the Nordmore Grid). The majority of capelin caught as bycatch by this fleet continues to take place in the lower estuary, the Northwest GSL, the Laurentian channel south of Anticosti Island, the Anticosti Channel, and the Esquiman Channel (Figure 11). In recent years, there were fewer instances of reported bycatch in the Esquiman Channel. Capelin bycatch in the 2020 shrimp fishery was incomplete at the time of the assessment and are presented but not included in the time series average.

3.2. COMMERCIAL SAMPLING

The number of commercial length frequency samples measured through the DFO port-sampling program as well as the number of specimens therein are presented in Table 7. On average, 24 samples are measured annually and are generally evenly spread among NAFO Divisions (7-8 samples per Division annually). This corresponds to an average of 5493 individual fish measured annually and an average of about 120-200 fish per NAFO Division depending on the year.

The number of biological samples (a subset of the above as well as some opportunistic samples) analyzed are presented in Table 8. On average, a total of 515 individual fish taken from 24 biological samples are dissected for detailed biological examination annually.

3.2.1. Size distribution

Length distributions and the size differences between males and females caught by the 4R seiner fleet were relatively consistent from one year to another (Figure 12). Differences from one year to another may be due to differences in sampling effort, the dominance of particular cohorts in the fishery, and environmental conditions. Age composition and length-at-age data would aid in the interpretation of these data.

The time series mean (± standard deviation) of total lengths for females and males caught by the 4R seiner fleet were respectively 146.9 mm (± 6.9 mm) and 164.8 (± 6.1 mm) (Figure 13). Both sexes showed similar trends over the years in which data were available (1984-2019). From the mid-1980s to early 1990s, lengths of both male and female capelin were above average. This was followed by a decline in annual mean lengths that persisted until 2003 when these values increased to near the time series mean. The particularly large mean length observed for both sexes in 2014 occurred during a year with a later than normal timing of the fishery (Figure 6), and a low number of samples processed (Table 7). From 2015 to 2018, mean lengths have been lower than average. These values increased to near the time series mean in 2019. No samples were collected by port samplers in 4R in 2020.

As the commercial fishery for capelin using various type of seines has only occurred periodically in NAFO Divisions 4S and 4T, it is difficult to observe trends in length frequencies over time. Size distributions from 4S (seiners only present in 4Sw in recent years) have more similar distributions to 4R whereas samples from 4T generally show a smaller size distribution since at least 2006 (Figure 14).

3.2.2. Relative condition factor

The coefficients of the fitted length-weight relationship were: a = $1.138803*10^{-6}$, b = 3.264489 for females and a = $2.21804*10^{-6}$, b = 3.201267 for males.

Interannual variations of the standardized mean relative condition factors for males and females in June caught by seiners in NAFO divisions 4R, 4S, and 4T were coherent (Figure 15) but differed in scale. For example, relative conditions in 4T were consistently lower than the other two divisions for most of the time series. Relative conditions were generally above average in the late 1980s for all NAFO Divisions, near the time series mean from 1990 to 2000 and then above average from 2000 to 2014 for NAFO Divisions 4R and 4S. Relative condition in 4T stayed near the time series mean during this same time period. Since 2015, relative condition has been near the time series mean in Divisions 4R and 4S while slightly below the average in 4T. A greater number of years with no length data is observed in Division 4S (Figure 14) than there are standardized condition factors for this Division (Figure 15) as beach seines, nets, traps, weirs and other artisanal gears were excluded from the analyses of the former.

3.2.3. Sex ratio and gonado-somatic index

Capelin sex-ratios in the commercial fishery are generally biased towards females in samples from NAFO division 4R (Figure 16), which is likely due to the fact that the commercial fishery there specifically targets ripe females. Samples taken from NAFO Divisions 4S and 4T have higher proportions of males (Figure 16), which could be explained by a higher proportion of opportunistic (dip net) and fixed gear samples in these areas and males being more vulnerable to these gear types as they tend to stay in aggregations in coastal waters longer than females (Templeman 1948; Friis-Rodel and Kanneworff 2002; Maxner et al. 2016).

Female annual mean gonado-somatic indices ranged between 20 and 30% (Figure 17). Male gonad mass represented on average less than 1.5% of total mass. No major temporal trend was apparent in either time series.

3.3. LENGTH-AT-MATURITY

In 2020, 13 samples of approximately 30 fish from the sGSL bottom trawl survey were analyzed at MLI. In the 2018 nGSL bottom trawl survey, 2 samples were analyzed (respectively 50 and 81 fish), while 37 and 21 samples of approximately 30 fish were analyzed in 2019 and 2020 (Table 9). L50 for both sexes in August and September was estimated at 107.9 mm (95% C.I.:

106.8 – 109.0; Figure 18). This L50 is smaller than what was calculated by Carscadden (1978) from offshore areas of NAFO divisions 3LNO in January-July (L50 male: 168 mm, L50 female: 144 mm), and by Forberg and Tjelmeland (1985) for female Barents Sea capelin in September 1978-1983 (L50 from 130 to 140 mm).

4. CONCLUSION

The 2018-2020 4RST fishing seasons were similar to those of the last decade. The TAC was reached or slightly exceeded, most landings were made off the west coast of NL by the purse seine fleet, the timing of the fishery was within the range usually observed, seiner performance indices were above the long term average, and estimated capelin bycatch in the shrimp fishery was close to the 2013-2020 average. The commercial biological data was also representative of the last decade and no temporal trends were apparent which may have indicated signs of fishery induced evolution and/or directional environmental changes. The lack of length-at-age and age composition data (catch-at-age) represent a major source of uncertainty in the interpretation of the commercial biological data.

In summary, this document described the 4RST capelin fishery data, fishery dependent biological data as well as a maturity ogive computed from 2018-2020 bottom trawl research samples. This information was, for the most part, already presented in past stock assessments but is now supplemented with recent efforts to develop biologically sound abundance indices from sGSL and nGSL bottom trawl surveys (Chamberland et al. 2022) that are consistent with proposed bottom-up factors known to influence capelin survival and cohort strength (Lehoux et al. 2022). Other contributions to the assessment include estimates of capelin annual consumption by 2 demersal predators and comparison with fishery landings (Ouellette-Plante et al. In press.), and qualitative network modeling applied to capelin in order to assess the relative importance of top-down and bottom-up ecosystem effects on stock productivity indices (DFO 2021). These efforts were part of a multi-disciplinary approach aimed at integrating ecosystem-based knowledge to improve the assessment of the data-limited 4RST capelin stock.

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TABLES

Table 1: Summary of the Estuary and Gulf of Saint Lawrence capelin fishery quota split by NAFO Division and gear type. Capelin Fishing Areas (CFA) indicated in parentheses.

NAFO division	Gear	Type of Quota	Sharing arrangements (%)
4R (12*-14)	Fixed gear	Competitive	37.82
	Mobile gear <65’	Individual quota	24.15
	Mobile gear >=65’	Competitive	24.15
4ST (15-16)	All gear types	Competitive	13.88

* CFA 12 includes NAFO 3Pn and portions of 3Ps

Table 2: Commercial landings[1,2](t) by NAFO Division and total since 1960 and TAC (t) and percent (%) of TAC caught since 1981 of capelin in NAFO Divisions 4RST. Decadal averages of commercial landings also shown.

Year	DIVISION			Total	TAC	%
	4R	4S	4T			
1960	600	46	32	**678**	-	-
1961	424	50	90	**564**	-	-
1962	514	4	143	**661**	-	-
1963	444	13	94	**551**	-	-
1964	563	33	101	**697**	-	-
1965	755	50	100	**905**	-	-
1966	735	88	43	**866**	-	-
1967	724	39	150	**913**	-	-
1968	734	30	32	**796**	-	-
1969	1,394	92	82	**1,568**	-	-
1970	339	75	42	**456**	-	-
1971	403	15	46	**464**	-	-
1972	370	41	126	**537**	-	-
1973	270	84	75	**429**	-	-
1974	180	113	128	**421**	-	-
1975	68	94	105	**267**	-	-
1976	92	48	336	**476**	-	-
1977	1,514	69	318	**1,901**	-	-
1978	8,341	37	1,323	**9,701**	-	-
1979	5,737	1,132	2,163	**9,032**	-	-
1980	1,939	15	1,566	**3,520**	-	-
1981	2,164	1	237	**2,402**	25,000	**10**
1982	156	2	235	**393**	25,000	**2**
1983	920	0	104	**1,024**	25,000	**4**
1984	1,907	0	180	**2,087**	25,000	**8**
1985	2,573	0	545	**3,118**	25,000	**12**
1986	3,721	0	226	**3,948**	25,000	**16**
1987	906	0	67	**973**	25,000	**4**
1988	4,386	129	248	**4,763**	25,000	**19**
1989	5,257	1,078	444	**6,779**	25,000	**27**
1990	6,105	164	153	**6,422**	25,000	**26**
1991	7,166	59	247	**7,472**	21,300	**35**
1992	7,851	856	56	**8,763**	5,750	**152**
1993	9,398	1,262	237	**10,897**	10,750	**101**
1994	592	208	165	**966**	11,725	**8**
1995	15	90	47	**152**	11,725	**1**
1996	6,265	461	172	**6,898**	9,850	**70**
1997	7,399	252	238	**7,889**	11,725	**67**
1998	8,749	126	776	**9,652**	11,725	**82**

Year	DIVISION			Total	TAC	%
	4R	4S	4T			
1999	4,735	10	166	**4,911**	12,425	**40**
2000	5,129	0	0	**5,129**	12,425	**41**
2001	741	0	0	**741**	12,425	**6**
2002	3,295	77	20	**3,392**	12,425	**27**
2003	5,032	0	0	**5,032**	7,455	**68**
2004	6,521	0	0	**6,521**	7,455	**87**
2005	8,659	305	34	**8,998**	13,000	**69**
2006	9,322	2,039	518	**11,880**	13,000	**91**
2007	6,097	1,344	471	**7,911**	13,000	**61**
2008	7,846	2,126	99	**10,071**	13,000	**77**
2009	10,147	527	1,405	**12,080**	13,000	**93**
2010	8,769	795	1,258	**10,822**	13,000	**83**
2011	9,890	974	1,449	**12,314**	13,000	**95**
2012	8,914	478	147	**9,539**	13,000	**73**
2013	6,350	236	0	**6,587**	14,300	**46**
2014	5,683	20	0	**5,703**	14,300	**40**
2015	11,361	107	357	**11,825**	14,300	**83**
2016	9,326	78	373	**9,777**	14,300	**68**
2017	1,945	19	1	**1,965**	14,300	**14**
2018	8,141	356	6	**8,503**	9,295	**91**
2019	7,569	427	490	**8,487**	9,295	**91**
2020	7,933	1,858	57	**9,848**	9,295	**106**

[1] From 1960 to 1978: ICNAF Statistical Bulletins Vol. 10 to 28; from 1979 to 1984: NAFO Statistical Bulletins Vol. 29 to 34
[2] ZIFF file since 1985

	AVERAGE			
1960-1969	689	45	87	**820**
1970-1979	1,731	171	466	**2,368**
1980-1989	2,393	122	385	**2,901**
1990-1999	5,828	349	226	**6,402**
2000-2009	6,279	642	255	**7,176**
2010-2019	7,795	349	408	**8,552**
2020[3]	7,933	1,858	57	**9,848**

[3] Preliminary data

*Table 3: Commercial landings (t) of capelin by unit area of NAFO Divisions 4R, 4S and 4T since 1985. (NK = not known, * = preliminary data)*

Year	4RA	4RB	4RC	4RD	NK	TOTAL 4R	4SI	4SS	4SV	4SW	4SX	4SY	4SZ	NK	TOTAL 4S	4TF	4TG	4TJ	4TK	4TM	4TN	4TO	4TP	4TQ	NK	TOTAL 4S
1985	169	29	32	0	2,343	2,573	0	0	0	0	0	0	0	0	0	0	0	0	0	3	219	0	321	0	2	545
1986	1,696	17	1,410	174	424	3,721	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	226	0	0	226
1987	624	96	146	1	40	906	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	0	0	67
1988	1,429	18	20	12	2,907	4,386	0	0	0	124	0	5	0	0	129	0	0	0	0	0	0	0	248	0	0	248
1989	1,897	47	585	76	2,652	5,257	0	0	2	1,075	0	1	0	0	1,078	0	0	0	0	0	0	0	402	7	35	444
1990	1,959	479	925	104	2,639	6,105	0	0	9	155	0	0	0	0	164	0	0	0	0	0	0	0	141	11	0	153
1991	154	82	4,907	2,023	0	7,166	0	0	0	7	0	0	51	0	59	0	0	0	0	65	0	0	160	23	0	247
1992	1,554	1,506	4,675	117	0	7,851	0	0	0	855	0	0	1	0	856	0	0	0	0	0	0	0	56	0	0	56
1993	791	1,543	5,142	1,922	0	9,398	0	0	0	1,262	0	0	0	0	1,262	0	0	0	0	0	108	0	129	0	0	237
1994	10	265	245	72	0	592	0	0	2	205	0	0	0	0	208	0	0	0	0	47	22	0	96	0	0	165
1995	15	0	0	0	0	15	0	0	0	90	0	0	0	0	90	0	0	0	0	0	0	3	39	5	0	47
1996	630	1,841	3,364	430	0	6,265	0	0	0	415	0	0	46	0	461	0	0	0	0	0	5	5	152	10	0	172
1997	734	2,480	4,171	14	0	7,399	4	0	0	202	0	30	16	0	252	2	5	0	0	7	2	2	214	5	0	238
1998	1,827	3,791	2,550	581	0	8,749	0	0	0	126	0	0	0	0	126	0	0	0	0	0	697	0	0	0	79	776
1999	29	1,675	3,031	0	0	4,735	0	0	0	10	0	0	0	0	10	0	0	0	0	70	77	0	0	0	19	166
2000	0	356	4,773	0	0	5,129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	605	136	0	741	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	115	856	2,323	0	0	3,295	0	0	0	7	0	0	0	0	7	0	0	0	0	0	0	0	0	2	0	2
2003	513	1,070	3,450	0	0	5,032	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	3,630	645	2,185	61	0	6,521	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	5,025	1,028	2,260	346	0	8,659	0	0	0	305	0	0	0	0	305	0	0	0	0	0	0	0	34	0	0	34
2006	6,027	9	2,530	756	0	9,322	66	149	0	1,317	507	0	0	0	2,039	0	0	0	0	0	474	0	43	0	0	518
2007	5,326	6	691	73	0	6,097	0	0	0	1,344	0	0	0	0	1,344	0	0	0	0	0	430	0	41	0	0	471
2008	883	188	2,692	4,083	0	7,846	0	0	0	1,420	0	0	0	706	2,126	0	0	0	0	0	66	0	33	0	0	99
2009	2,570	2,929	4,116	531	0	10,147	0	0	0	527	0	0	0	0	527	0	0	0	0	0	1,367	0	39	0	0	1,405
2010	2,409	4,785	1,442	133	0	8,769	0	0	0	795	0	0	0	0	795	0	0	0	0	0	1,258	0	0	0	0	1,258
2011	3,378	507	4,021	1,985	0	9,890	0	0	0	974	0	0	0	0	974	24	0	0	16	0	1,409	0	0	0	0	1,449
2012	1,418	1,759	5,590	147	0	8,914	0	0	0	478	0	0	0	0	478	0	0	0	0	0	147	0	0	0	0	147
2013	5,557	344	16	378	54	6,350	0	0	0	236	0	0	0	0	236	0	0	0	0	0	0	0	0	0	0	0
2014	5,197	322	10	154	0	5,683	0	0	0	20	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0

Year	4RA	4RB	4RC	4RD	NK	TOTAL 4R	4SI	4SS	4SV	4SW	4SX	4SY	4SZ	NK	TOTAL 4S	4TF	4TG	4TJ	4TK	4TM	4TN	4TO	4TP	4TQ	NK	TOTAL 4S
2015	8,048	1,746	1,309	258	0	11,361	0	0	0	107	0	0	0	0	107	0	0	0	0	0	357	0	0	0	0	357
2016	6,026	2,425	811	65	0	9,326	0	78	0	0	0	0	0	0	78	0	0	0	0	0	373	0	0	0	0	373
2017	223	1,481	240	0	0	1,945	0	0	0	19	0	0	0	0	19	0	0	0	0	0	0	0	1	0	0	1
2018	2,375	2,633	2,988	145	0	8,141	0	0	0	356	0	0	0	0	356	0	0	0	0	0	0	0	3	0	2	6
2019*	3,029	2,500	1,598	442	0	7,569	0	0	0	427	0	0	0	0	427	0	0	0	0	0	480	0	11	0	0	490
2020*	2,441	1,945	2,978	570	0	7,933	0	0	0	1,856	0	1	0	0	1,858	0	0	0	0	0	0	0	53	0	4	57

Table 4: Commercial landings (t) of capelin by fishing gear in NAFO Divisions 4RST since 1985.

Year	Purse seine <65	Purse seine >=65	Trap net	Tuck seine	Misc.	Total
1985	36	2,519	3	0	560	3,118
1986	61	3,455	82	0	349	3,948
1987	80	761	57	0	75	973
1988	33	2,907	1,494	0	329	4,763
1989	464	2,615	3,166	0	535	6,779
1990	2,576	1,598	1,700	0	548	6,422
1991	1,729	5,288	161	0	294	7,472
1992	2,848	3,925	1,911	0	80	8,763
1993	3,559	3,767	3,387	0	184	10,897
1994	432	217	210	0	107	966
1995	0	0	103	0	49	152
1996	2,883	2,596	1,306	0	113	6,898
1997	3,787	2,724	1,204	0	175	7,889
1998	3,295	3,186	2,435	0	736	9,652
1999	1,834	2,957	11	0	110	4,911
2000	1,985	3,143	1	0	0	5,129
2001	176	565	0	0	0	741
2002	1,814	1,481	7	0	90	3,392
2003	2,234	2,419	379	0	0	5,032
2004	2,128	2,511	1,694	0	188	6,521
2005	1,812	3,673	3,073	324	116	8,998
2006	2,955	4,380	3,562	788	193	11,879
2007	2,727	2,370	2,151	530	133	7,911
2008	3,506	3,410	2,135	967	54	10,071
2009	3,259	4,186	2,837	1,657	141	12,080
2010	3,251	3,946	2,067	1,558	0	10,822
2011	3,475	4,285	3,189	1,271	93	12,314
2012	3,617	2,951	684	2,204	82	9,539
2013	2,461	2,173	906	1,047	0	6,587
2014	2,537	1,129	370	1,477	190	5,703
2015	3,142	3,867	940	3,834	41	11,825
2016	3,257	3,780	623	2,116	0	9,777
2017	654	802	25	483	0	1,965
2018	2,729	2,213	951	2,462	148	8,503
2019*	2,466	2,759	204	3,058	0	8,487
2020*	3,657	2,340	417	3,175	259	9,848
Average 1985-2018	**2,098**	**2,700**	**1,259**	**609**	**168**	**6,835**

* Preliminary data

Table 5: Results of the multiplicative model used to standardize the CPUE (performance index) of capelin in purse and tuck seine commercial fishery in NAFO Division 4R. The following abbreviations are used: df, degree of freedom; SS, sum of squares; Pr, probability; Std. Err., standard error.

ANOVA table

	df	SS	F	Pr(>F)	
YEAR	33.0	712.7	31.675	< 2e-16	***
MONTH	2.0	19	13.906	9.5e-7	***
LENGTH_CL	5.0	1290.4	378.512	< 2e-16	***
UNIT_AREA	3.0	83.9	41.036	< 2e-16	***
FISH_GEAR	1.0	126	184.732	< 2e-16	***
Residuals	5104.0	3480	-	-	-

Signif, : 0 *** 0.001 ** 0.01 * 0.05

Model: lpue ~ YEAR + MONTH + UNIT_AREA + LENGHT_CL

Residuals:	Min,	1Q	Median	3Q	Max.

Coefficients:	Estimate	Std. Err.	Value t	Pr(>|t|)	
intercept	1.008	0.117	8.606	< 2e-16	***
YEAR1987	-0.031	0.187	-0.163	0.870	
YEAR1988	0.457	0.592	0.772	0.440	
YEAR1989	1.069	0.264	4.044	0.000	***
YEAR1990	0.364	0.246	1.479	0.139	
YEAR1991	0.855	0.119	7.198	0.000	***
YEAR1992	0.481	0.108	4.463	0.000	***
YEAR1993	0.310	0.106	2.929	0.003	**
YEAR1994	0.096	0.185	0.519	0.604	
YEAR1996	-0.057	0.103	-0.554	0.580	
YEAR1997	0.083	0.105	0.792	0.428	
YEAR1998	0.538	0.109	4.956	0.000	***
YEAR1999	0.442	0.114	3.886	0.000	***
YEAR2000	0.450	0.114	3.956	0.000	***
YEAR2001	0.539	0.211	2.549	0.011	*
YEAR2002	0.548	0.120	4.553	0.000	***
YEAR2003	0.519	0.115	4.522	0.000	***
YEAR2004	0.391	0.111	3.517	0.000	***
YEAR2005	0.529	0.108	4.908	0.000	***
YEAR2006	0.838	0.107	7.823	0.000	***
YEAR2007	0.755	0.116	6.538	0.000	***
YEAR2008	0.977	0.114	8.545	< 2e-16	***
YEAR2009	0.948	0.110	8.647	< 2e-16	***
YEAR2010	1.248	0.114	10.971	< 2e-16	***
YEAR2011	1.310	0.117	11.232	< 2e-16	***
YEAR2012	1.094	0.111	9.851	< 2e-16	***
YEAR2013	1.475	0.124	11.913	< 2e-16	***
YEAR2014	1.422	0.124	11.446	< 2e-16	***
YEAR2015	1.343	0.109	12.315	< 2e-16	***
YEAR2016	1.250	0.113	11.089	< 2e-16	***
YEAR2017	1.028	0.157	6.567	0.000	***
YEAR2018	1.347	0.116	11.648	< 2e-16	***
YEAR2019	1.267	0.112	11.281	< 2e-16	***
YEAR2020	1.221	0.110	11.087	< 2e-16	***
MONTH7	0.134	0.041	3.279	0.001	**
MONTH8	0.209	0.189	1.102	0.270	
LENGTH_CL2	0.388	0.071	5.464	0.000	***
LENGTH_CL3	0.704	0.074	9.518	< 2e-16	***
LENGTH_CL4	1.485	0.078	19.027	< 2e-16	***
LENGTH_CL5	1.608	0.080	19.986	< 2e-16	***
LENGTH_CL6	1.501	0.095	15.790	< 2e-16	***
UNIT_AREA4Rb	0.125	0.045	2.793	0.005	**
UNIT_AREA4Rc	0.353	0.044	8.093	0.000	***
UNIT_AREA4Rd	0.292	0.060	4.855	0.000	***

Model:	lpue ~ YEAR + MONTH + UNIT_AREA + LENGHT_CL				
Residuals:	Min,	1Q	Median	3Q	Max.
FISH_GEAR31	0.492	0.036	13.592	< 2e-16	***
Std. Err. Residuals: 0.8257 sur / on 5104 dl / df					
R2 multiple: 0.3907, R2 adjusted: 0.3855					
F: 74.4 on 44 and 5104 df, p: <2.2E-16					

Table 6: Capelin by-catch by the shrimp fishery (in kg) in the Estuary and Gulf of St. Lawrence, from 2000 to 2020 (See Appendix 1: Shrimp fishing areas in the Estuary and Gulf of St. Lawrence.. (NA : not available)

	SHRIMP FISHING AREA (SFA)								
	12	**10**	**10**	**10**	**10**	**9**	**9**	**9**	**8**
	NAFO UNIT AREA								
Year	4Tp 4Tq	4To 4Tn 4Tk	4Tq 4Sz	4Si 4Sy	4Ss	4Tf 4Tk	4Ss	4Sx 4sy 4Sv	4Sv 4Ra 4Rb 4Rc 4R
2000	4,723	5,189	33,021	3,461	30,396	1,785	9,901	12,489	25,574
2001	2,023	3,642	12,965	2,325	8,225	42	2,266	5,718	39,999
2002	678	1,759	15,037	3,472	56,865	490	3,947	25,922	200,824
2003	1,866	10,283	19,371	1,392	65,348	40	6,044	1,764	31,734
2004	440	2,199	13,482	1,247	137,677	221	9,728	2,541	144,647
2005	2,972	1,097	7,131	15,586	53,059	171	8,451	3,590	125,892
2006	393	5,086	21,064	5,329	17,334	29	3,461	28,797	14,113
2007	1,967	2,064	7,807	3,162	35,326	5	602	38,244	4,380
2008	720	6,585	10,984	1,231	14,011	2	211	30,664	29,581
2009	3,724	4,183	41,938	4,531	10,971	2	1,287	16,266	241,633
2010	5,307	6,463	11,756	4,855	34,098	NA	412	63,368	29,176
2011	1,210	96,941	11,786	16,674	47,746	NA	703	26,509	12,077
2012	531	20,354	34,654	8,917	34,755	10	95	26,883	23,344
2013	7,342	13,059	29,155	16,058	10,839	21	24	20,276	14,662
2014	3,155	1,675	12,443	3,090	606	NA	NA	4,464	11,879
2015	NA	2,311	8,199	1,165	140	NA	NA	71,426	728
2016	3,777	4,950	12,262	6,397	94	NA	NA	24,711	33,011
2017	17,910	807	7,121	2,477	15	NA	NA	20,075	30,943
2018	39,343	110	77,600	3,149	NA	NA	111	4,073	7,463
2019	33,708	3	17,460	4,814	NA	NA	NA	30,597	1,642
2020	NA	NA	96,354	1,405	NA	NA	NA	879	1,095

Table 6 (continued)

	CAPELIN BY-CATCH IN THE SHRIMP FISHERY				
	TOTAL BY SFA				TOTAL ESTUARY AND NORTHERN DU GULF
	12	10	9	8	
2000	4,723	72,067	24,174	25,574	126,538
2001	2,023	27,158	8,025	39,999	77,205
2002	0,678	77,133	30,359	200,824	308,994
2003	1,866	96,393	7,848	31,734	137,841
2004	0,440	154,605	12,490	144,647	312,182
2005	2,972	76,873	12,212	125,892	217,949
2006	0,393	48,813	32,288	14,113	95,607
2007	1,967	48,359	38,851	4,380	93,557
2008	0,720	32,811	30,877	29,581	93,988
2009	3,724	61,623	17,555	241,633	324,534
2010	5,307	57,172	63,780	29,176	155,436
2011	1,210	173,148	27,213	12,077	213,648
2012	0,531	98,680	26,988	23,344	149,542
2013	7,342	69,111	20,320	14,662	111,436
2014	3,155	17,814	4,464	11,879	37,312
2015	NA	11,815	71,426	0,728	83,969
2016	3,777	23,703	24,711	33,011	85,201
2017	17,910	10,419	20,075	30,943	79,347
2018	39,343	80,858	4,184	7,463	131,848
2019	33,708	22,278	30,597	1,642	88,224
2020	NA	97,759	0,879	1,095	99,732

Table 7: Number (#) of samples collected and capelin measured by port samplers in NAFO Divisions 4RST since 1984.

Year	# Samples			# Fish			Total # Samples 4RST	Total # Fish 4RST
	4R	4T	4S	4R	4T	4S		
1984	6	0	1	1193	0	351	7	1544
1985	7	0	1	1954	0	375	8	2329
1986	12	5	9	3072	1163	2077	26	6312
1987	3	3	7	826	740	1766	13	3332
1988	17	9	17	4484	2078	4405	43	10967
1989	10	5	6	2470	1331	1506	21	5307
1990	10	17	28	2585	4469	7448	55	14502
1991	8	14	11	2036	3517	2826	33	8379
1992	9	12	10	2302	3130	2555	31	7987
1993	12	10	5	3141	2626	1247	27	7014
1994	1	10	7	256	2616	1657	18	4529
1995	6	15	11	1606	4333	2986	32	8925
1996	13	15	15	3479	6200	3811	43	13490
1997	10	29	25	2575	7322	6433	64	16330
1998	9	8	5	2245	2080	1359	22	5684
1999	9	2	8	2448	515	2212	19	5175
2000	6	0	3	1553	0	553	9	2106
2001	2	0	0	478	0	0	2	478
2002	7	0	0	1974	0	0	7	1974
2003	9	5	12	2367	1177	3270	26	6814
2004	8	6	4	2070	1524	1015	18	4609
2005	7	10	9	1053	1523	1702	26	4278
2006	10	3	4	1980	542	1019	17	3541
2007	7	3	4	1959	570	981	14	3510
2008	7	4	2	1360	770	517	13	2647
2009	15	4	5	2640	733	819	24	4192
2010	6	8	17	1032	1317	3261	31	5610
2011	4	7	7	722	1189	1277	18	3188
2012	10	3	9	1941	486	1507	22	3934
2013	7	3	13	1333	504	2137	23	3974
2014	4	4	8	783	717	1240	16	2740
2015	7	9	11	1752	1512	1810	27	5074
2016	6	4	19	1047	627	3433	29	5107
2017	4	5	5	723	871	923	14	2517
2018	9	19	19	1620	3144	3403	47	8167
2019	7	12	11	1189	1895	1744	30	4828
2020	0	8	5	0	1355	780	13	2135

Table 8: Number (#) of capelin collected by port samplers and analysed in the laboratory since 1984.

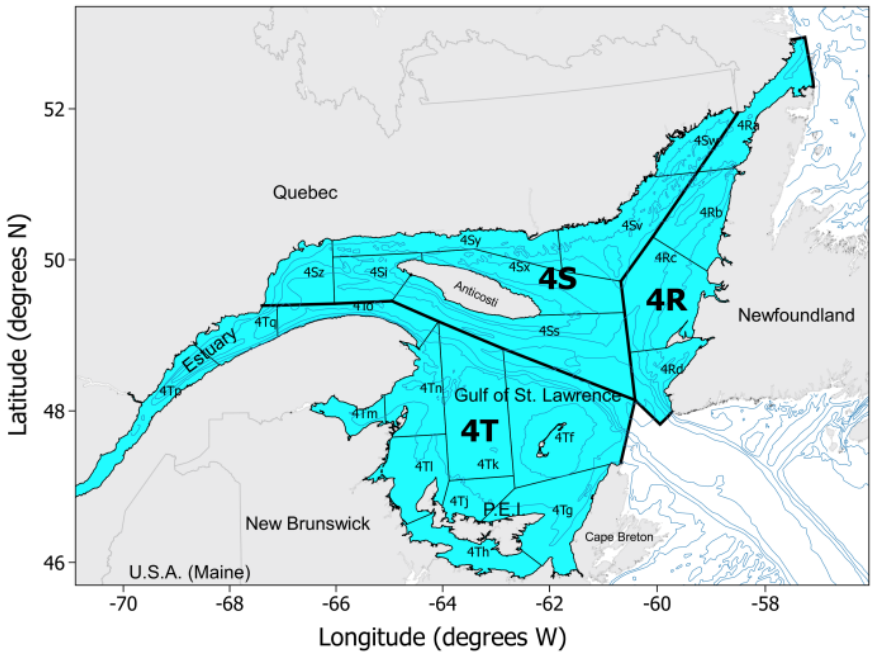
Year	# Samples			# Fish			Total # Samples 4RST	Total # Fish 4RST
	4R	4T	4S	4R	4T	4S		
1984	6	0	1	191	0	50	7	241
1985	7	0	1	235	0	31	8	266
1986	12	5	9	164	62	98	26	324
1987	3	3	7	114	80	172	13	366
1988	17	9	17	513	188	376	43	1077
1989	10	5	6	208	401	204	21	813
1990	10	17	27	177	222	207	54	606
1991	8	14	11	129	173	157	33	459
1992	9	12	10	169	85	113	31	367
1993	12	10	5	202	157	67	27	426
1994	1	10	8	17	509	306	19	832
1995	6	15	11	202	148	127	32	477
1996	13	15	15	169	162	170	43	501
1997	10	29	25	169	339	343	64	851
1998	9	8	5	139	120	52	22	311
1999	9	2	8	241	36	100	19	377
2000	8	0	3	661	0	58	11	719
2001	2	0	0	54	0	0	2	54
2002	7	0	0	204	0	0	7	204
2003	9	5	12	159	77	135	26	371
2004	8	6	4	238	107	95	18	440
2005	7	10	9	211	176	226	26	613
2006	10	3	4	302	50	94	17	446
2007	7	3	4	218	49	72	14	339
2008	7	4	2	211	60	40	13	311
2009	15	4	5	237	70	66	24	373
2010	6	8	17	157	128	243	31	528
2011	4	7	7	158	148	258	18	564
2012	10	3	9	252	52	109	22	413
2013	7	5	13	204	77	166	25	447
2014	4	6	8	170	61	90	18	321
2015	7	9	11	217	132	141	27	490
2016	6	4	20	177	60	280	30	517
2017	4	5	5	144	71	55	14	270
2018	9	19	19	238	220	365	47	823
2019	7	12	11	209	162	131	30	502
2020	0	8	5	0	134	51	13	185

Table 9: Number (#) of biological samples and number of fish by year collected in the multispecies bottom trawl surveys (sGSL: southern Gulf of St. Lawrence; nGSL: northern Gulf of St. Lawrence) and sent to MLI for detailed biological measurements.

Year	# Samples		# Fish	
	sGSL	nGSL	sGSL	nGSL
2018	-	2	-	131
2019	-	37	-	1069
2020	13	21	403	689

FIGURES

A



B

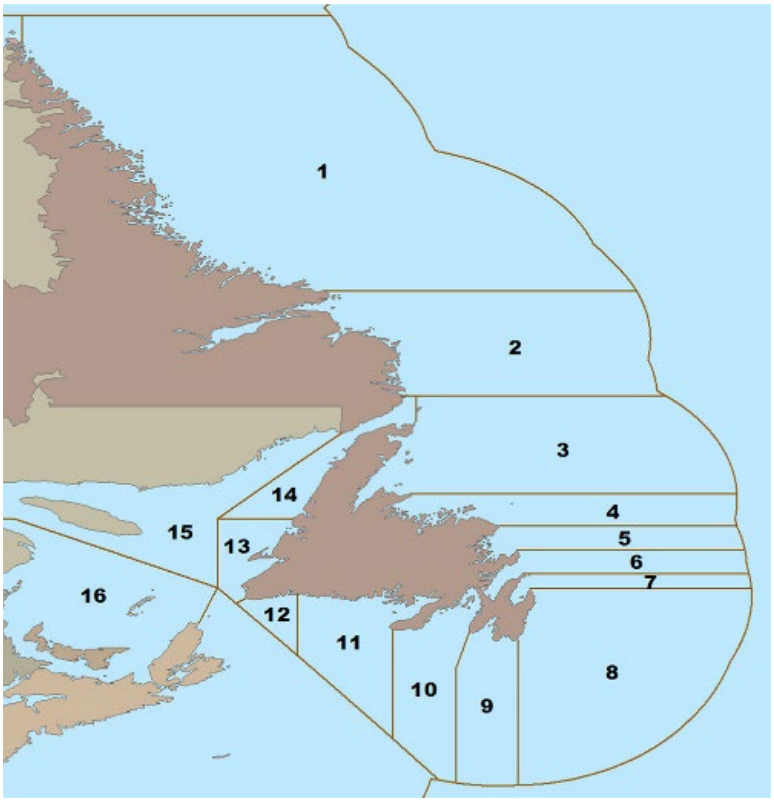


Figure 1: Maps of A) NAFO subdivisions of the Estuary and Gulf of St. Lawrence. B) capelin fishing areas.

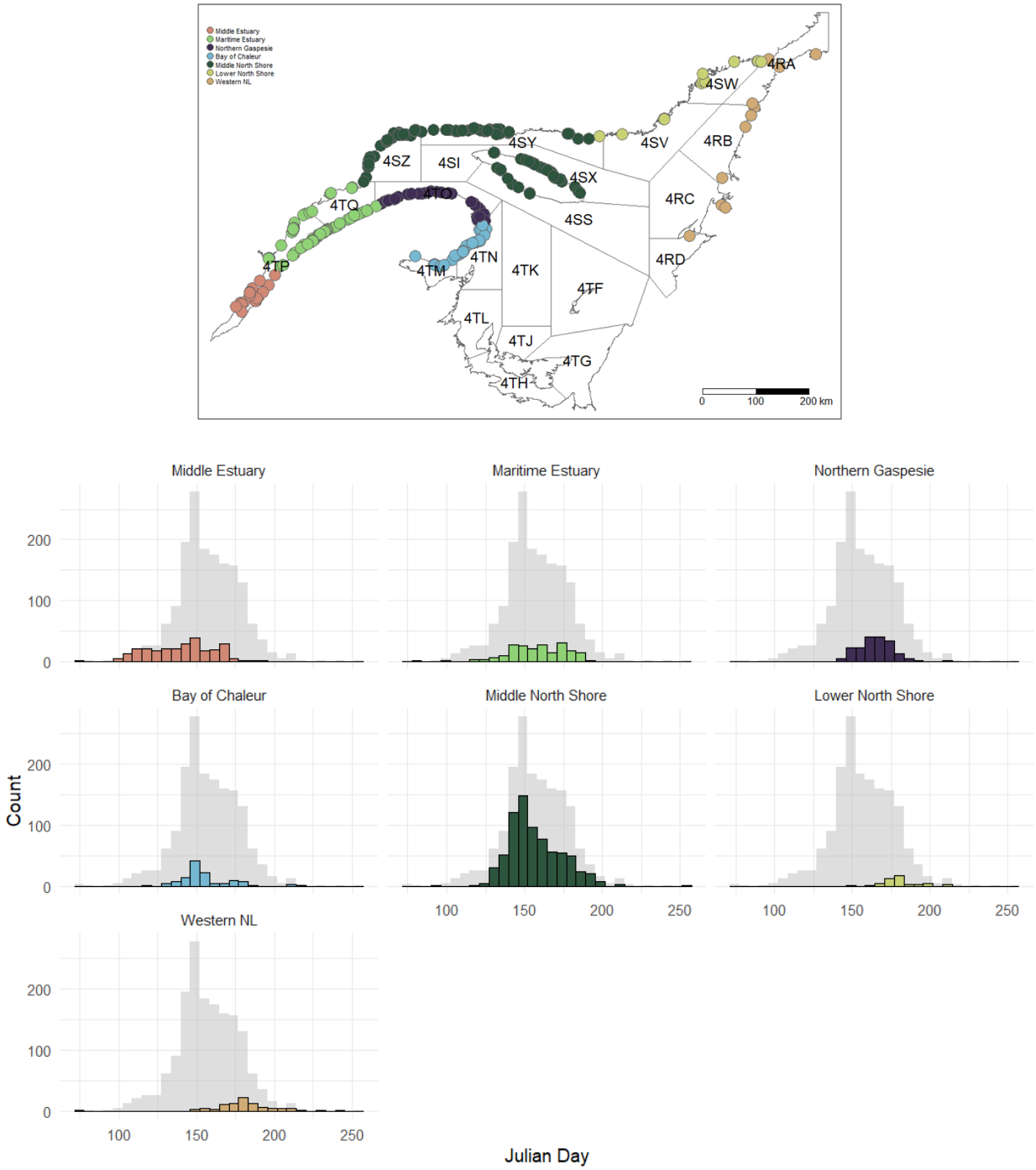


Figure 2: Map of Capelin Observers Network (Source: OGSL) beach spawning observations, regions and NAFO subdivisions (upper panel), and histograms of observed spawning activity binned by week (lower panel). In the lower panel, the sum of all observations by week are presented in grey and colored histograms represent observations disaggregated by region.

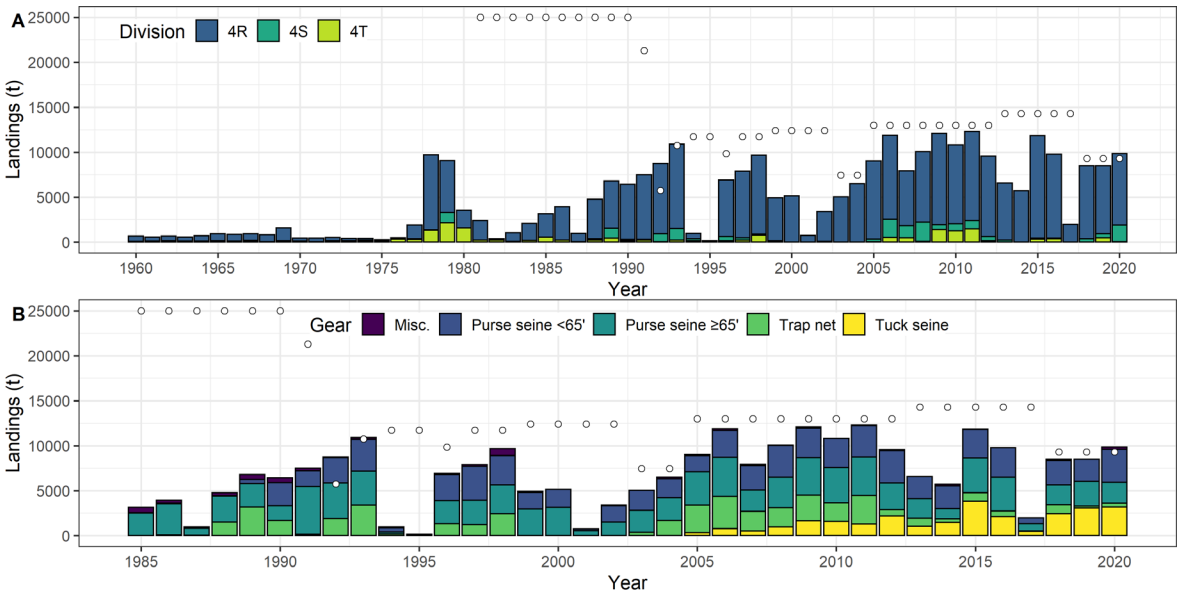


Figure 3: Capelin landings (t) by (A) NAFO Division from 1960 to 2020 and (B) by main fishing gear for the 1985-2020 period. The white circles represent the TAC. 2019 and 2020 landings are preliminary. (Misc. = Miscellaneous)

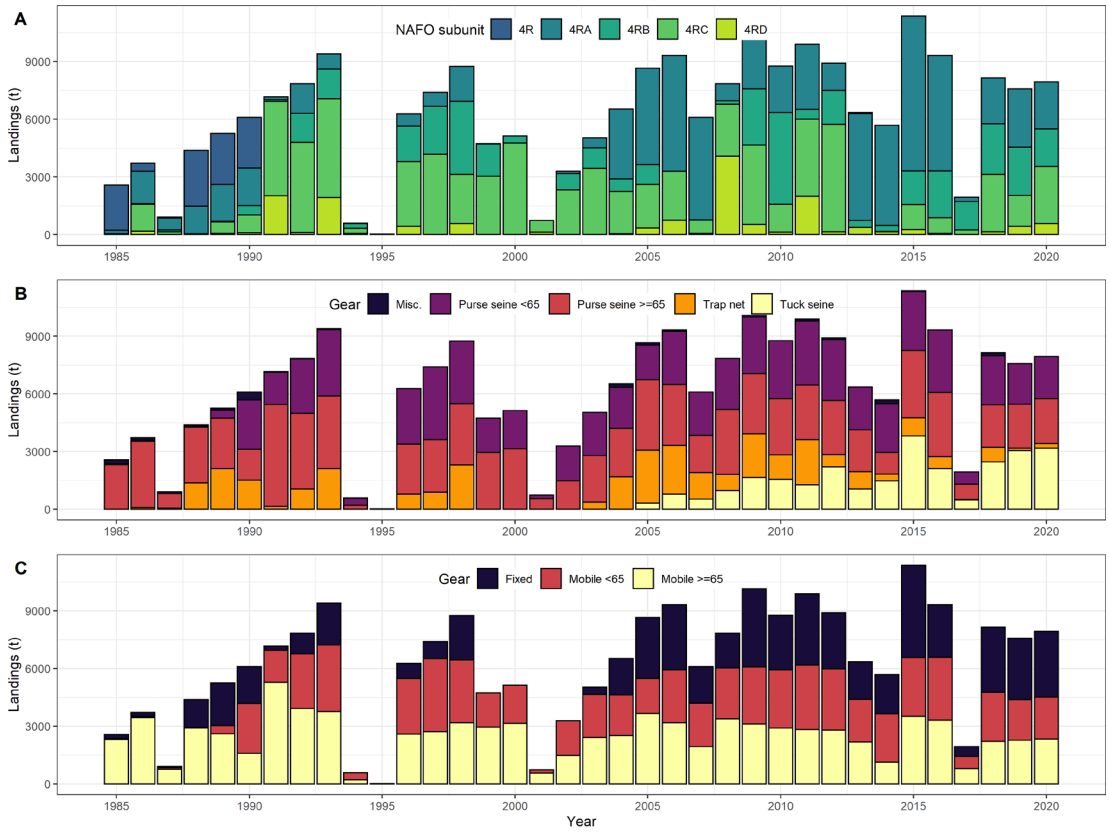


Figure 4: Annual commercial landings (t) of capelin within NAFO division 4R from 1985-2020. A) Landings by NAFO subdivision. B) Landings by major fishing gear type. C) Landings divided according to existing allocation. Landings for 2019 and 2020 are preliminary.

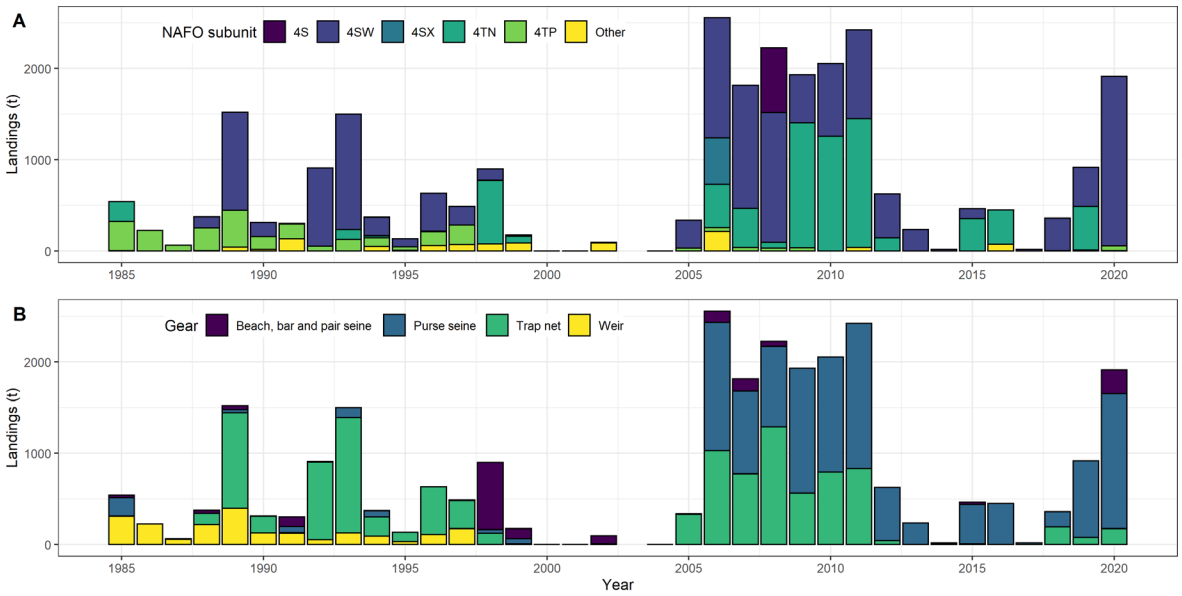


Figure 5: Annual commercial landings (t) of capelin within NAFO divisions 4S and 4T from 1985-2020. A) Landings by NAFO subdivisions. B) Landings by major fishing gear type. Landings for 2019 and 2020 are preliminary.

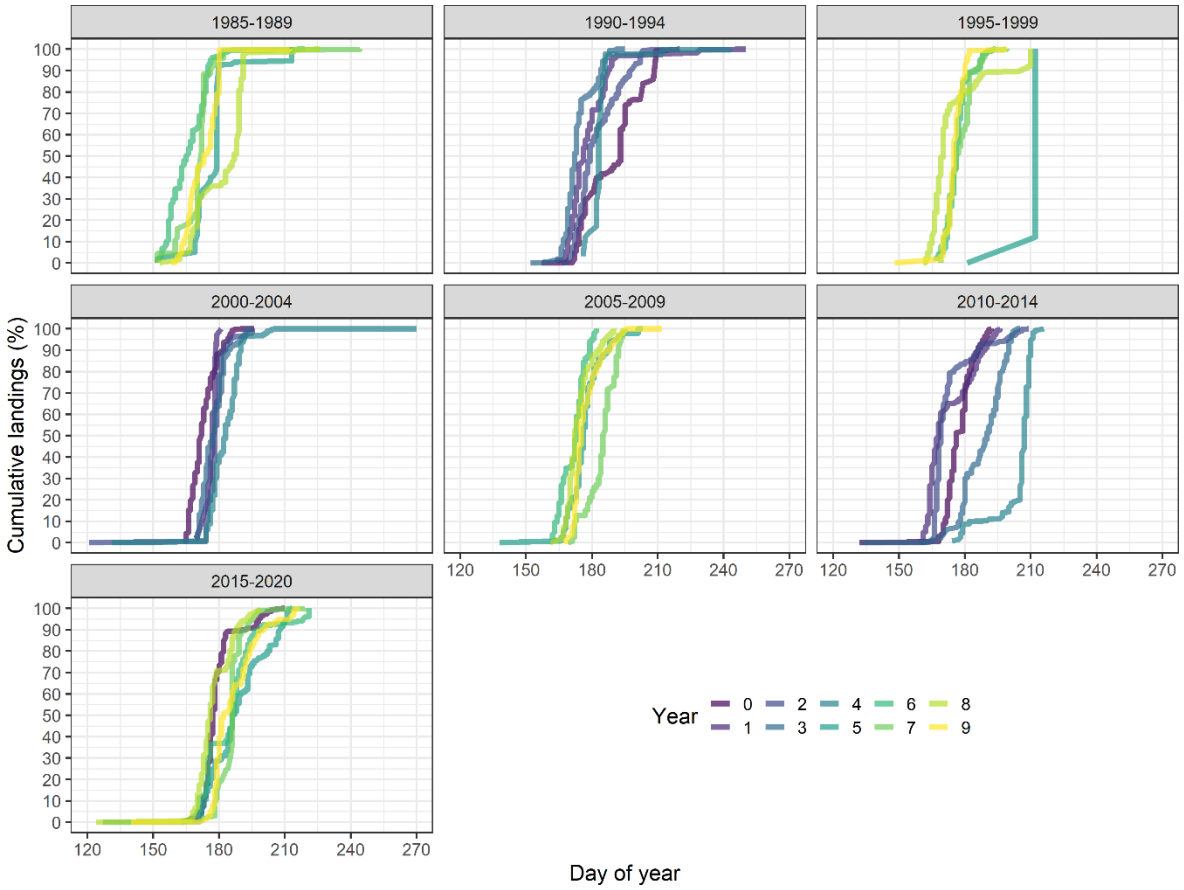


Figure 6: Cumulative commercial landings (%) in function of day of the year, for NAFO division 4R. Line colours progress from violet to yellow based upon the year in the decade (0-9).

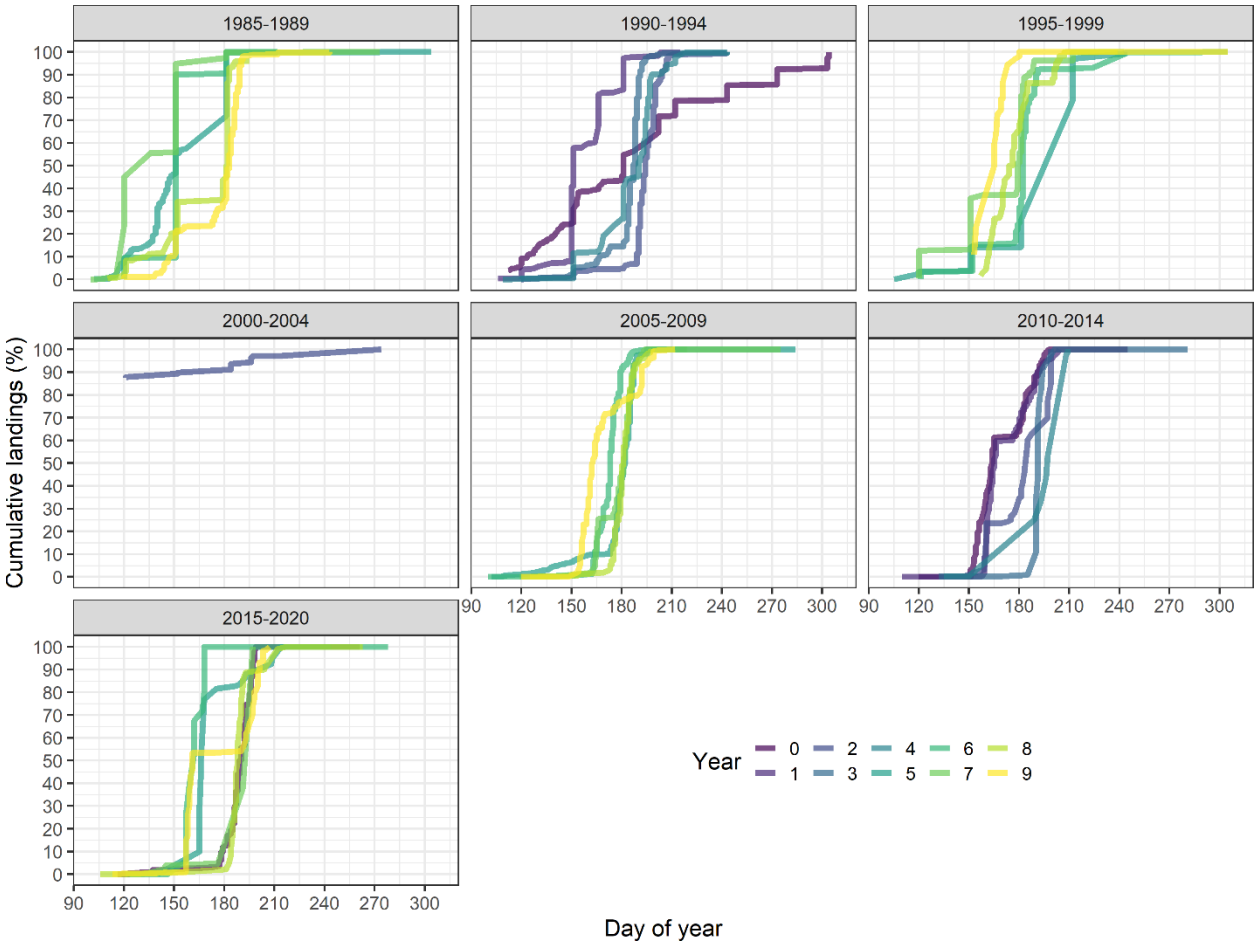


Figure 7: Cumulative commercial landings (%) in function of day of the year, for NAFO division 4ST. Line colours progress from violet to yellow based upon the year in the decade (0-9).

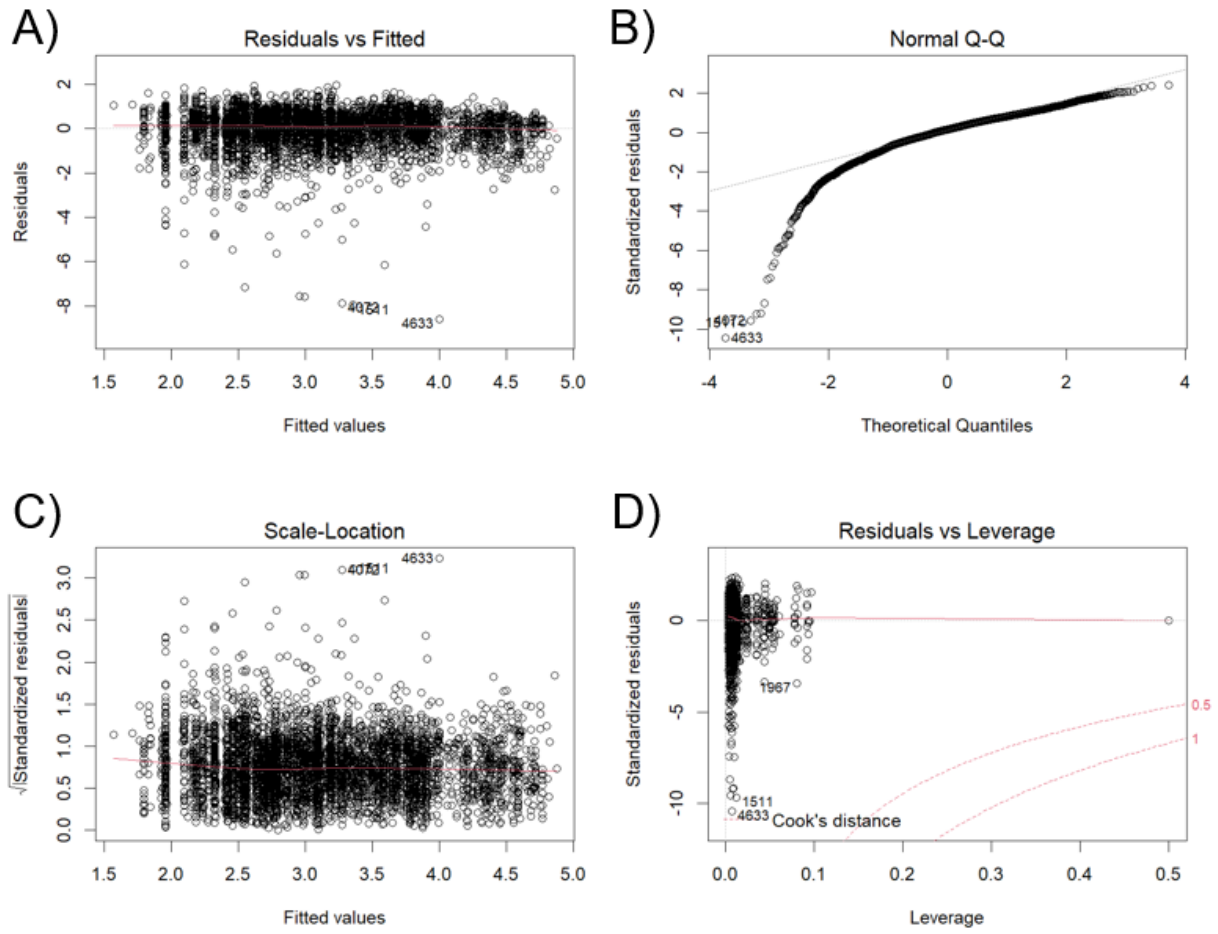


Figure 8: Diagnostics of the multiplicative model used to standardize the capelin CPUE (performance index) in purse and tuck seine fishery in NAFO Division 4R. (A: residuals vs fitted values of the model, B: quantile-quantile graph of the standardized residuals, C: square root of the absolute values of the standardized residuals vs fitted values of the model and D: standardized residuals vs. leverage graph and Cook's distances of 0.5 and 1)

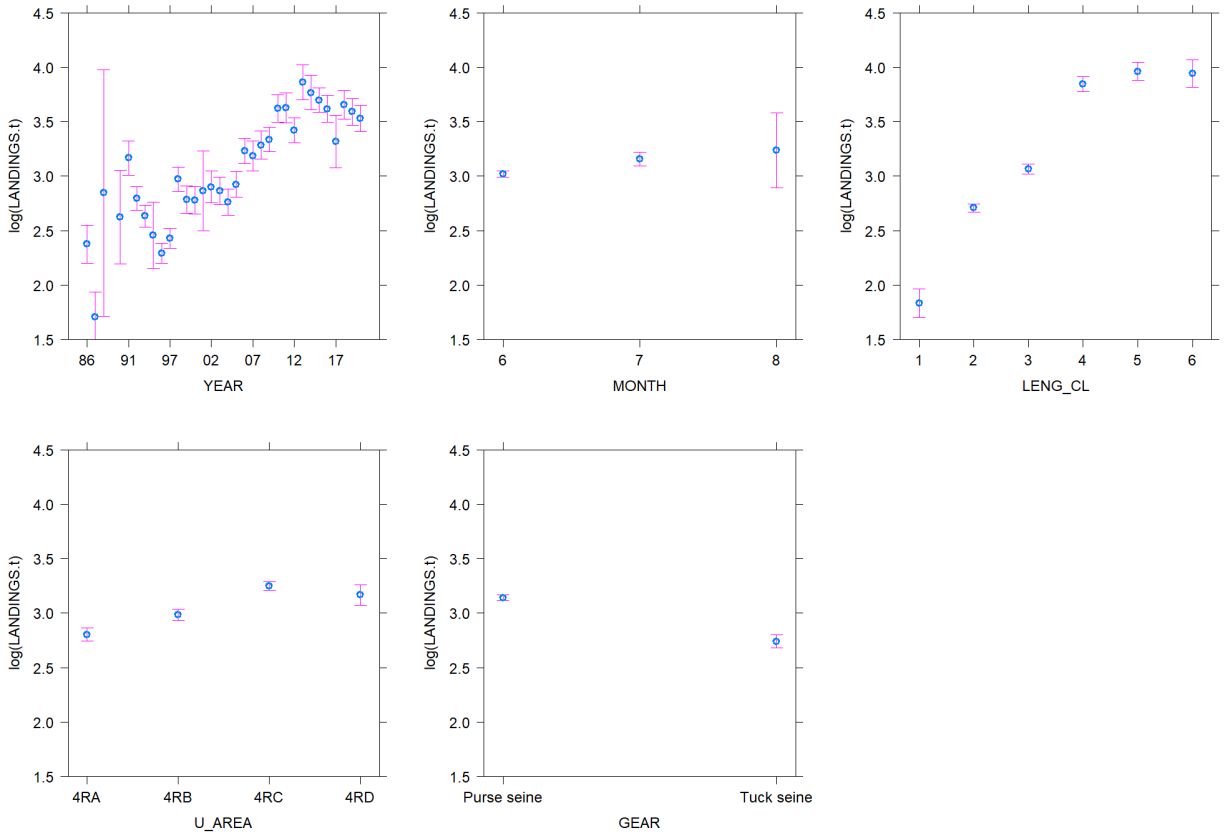


Figure 9: Effects and standard errors of the different levels of standardization factors on the performance index for the NAFO Division 4R commercial capelin fishery. The y-axes are expressed on the linear predictor scale. (LENG_CL: Vessel length class; U_AREA: NAFO subdivision).

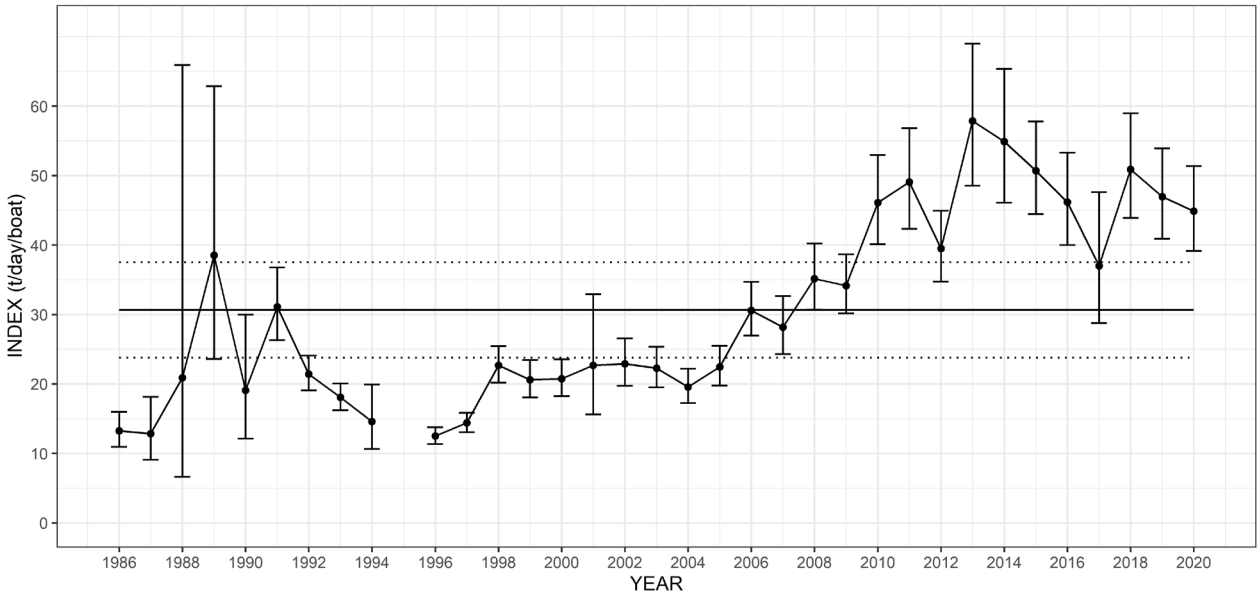


Figure 10: Performance (t/day/boat) of the purse and tuck seine fishery on the west coast of Newfoundland (NAFO Division 4R) as measured by a standardized catch-per-unit-effort index. The reference levels used in standardization are: MONTH = 6, LENG_CL=2, U_AREA = 4Rc and GEAR=31. The solid horizontal line represents the mean of the series and the dotted lines the mean ± 0.5 standard deviation. Vertical lines on the point estimates are the 95% confidence intervals.

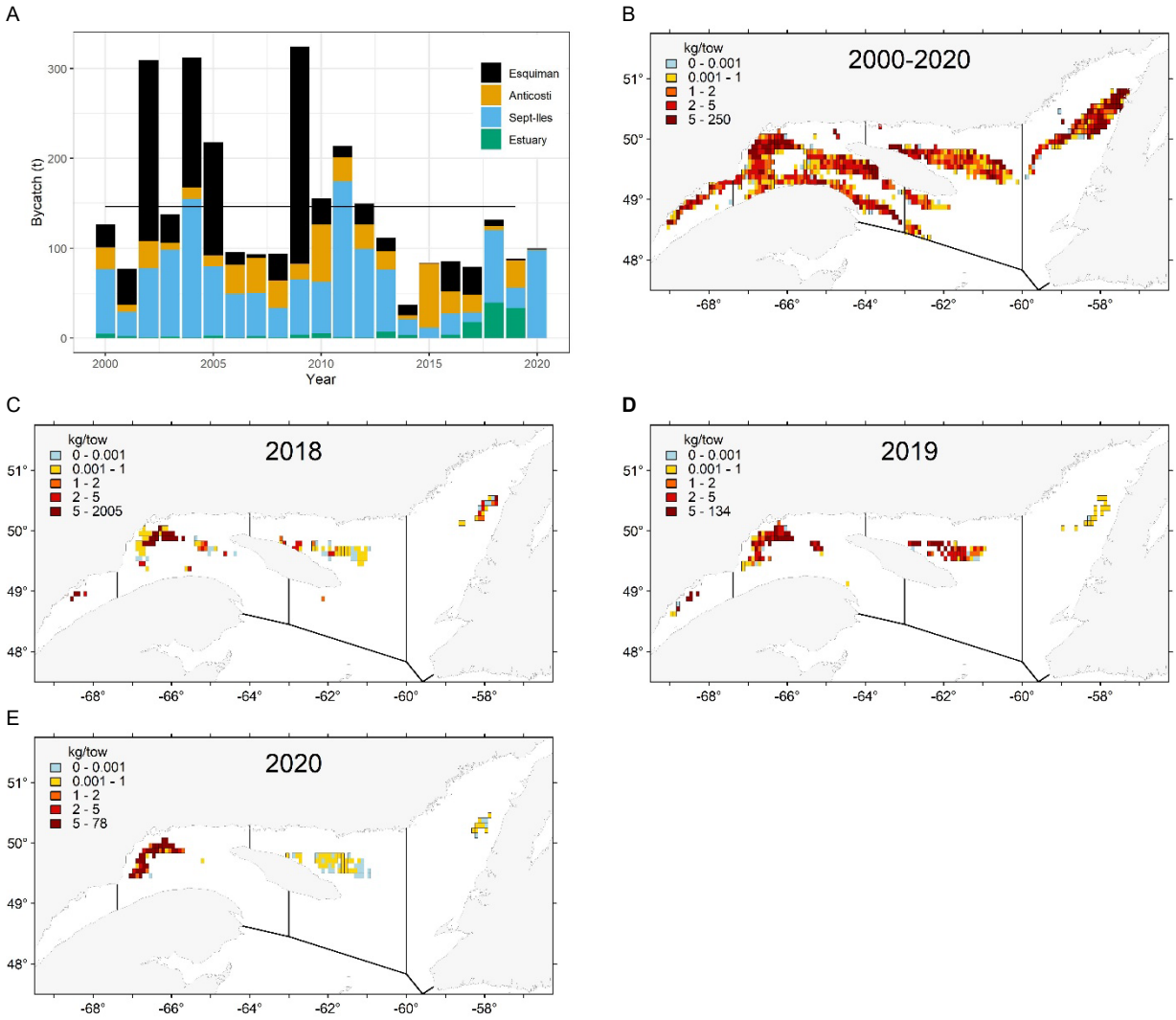


Figure 11: A) Annual estimates of capelin caught as bycatch (t) in the Gulf of St. Lawrence shrimp fishery. B) Geographic distribution of the capelin bycatch represented by estimated kg/tow in 5 by 5 minute cells for the years 2000-2020, 2018 (C), 2019 (D) and 2020 (E). Source: H. Bourdages, DFO personal communication.

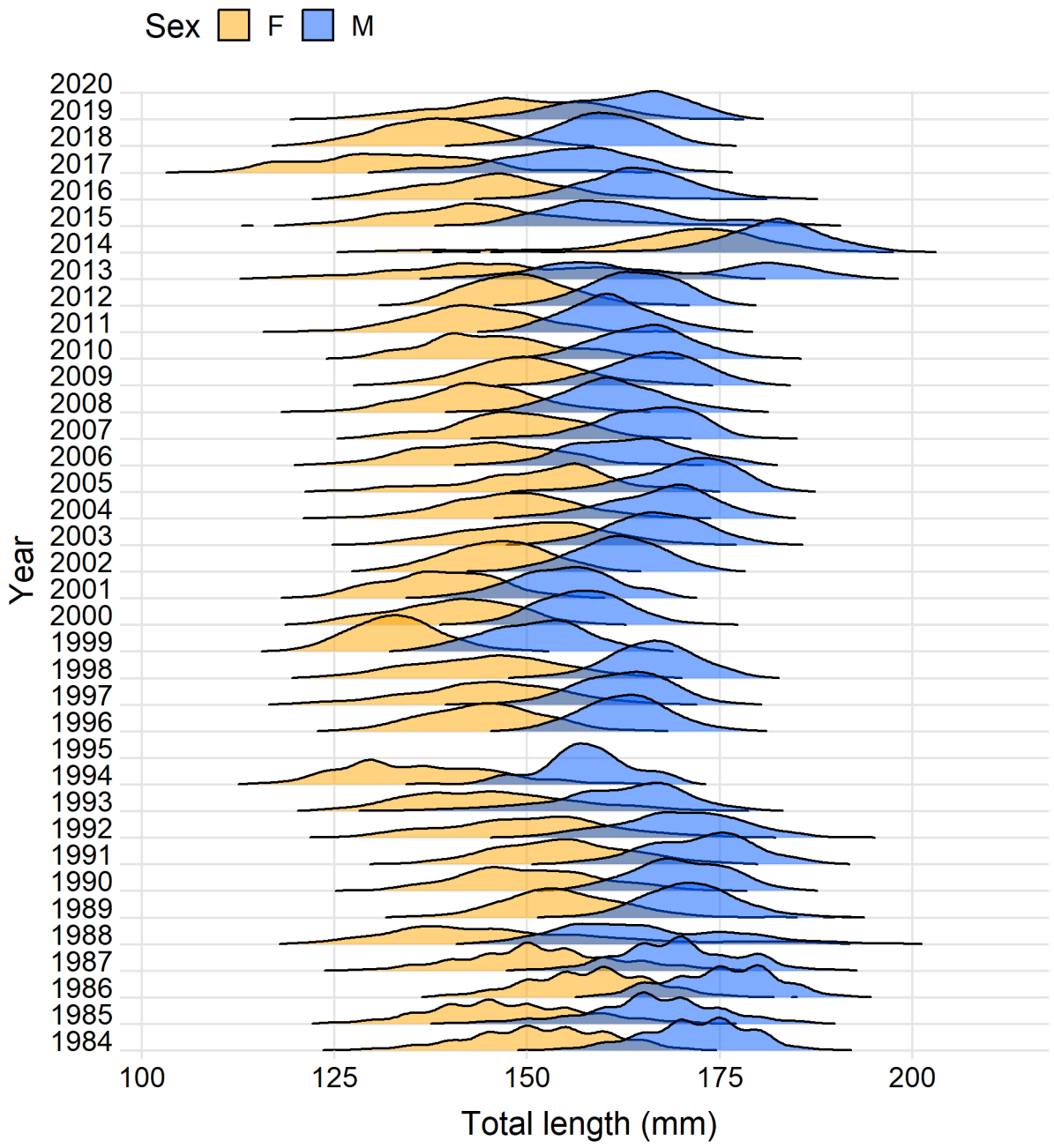


Figure 12: Total length (mm) composition (kernel density estimates) of female and male capelin caught with seines (purse and "Tuck") in NAFO Division 4R from 1984 to 2020. No samples were available in 1995 and 2020.

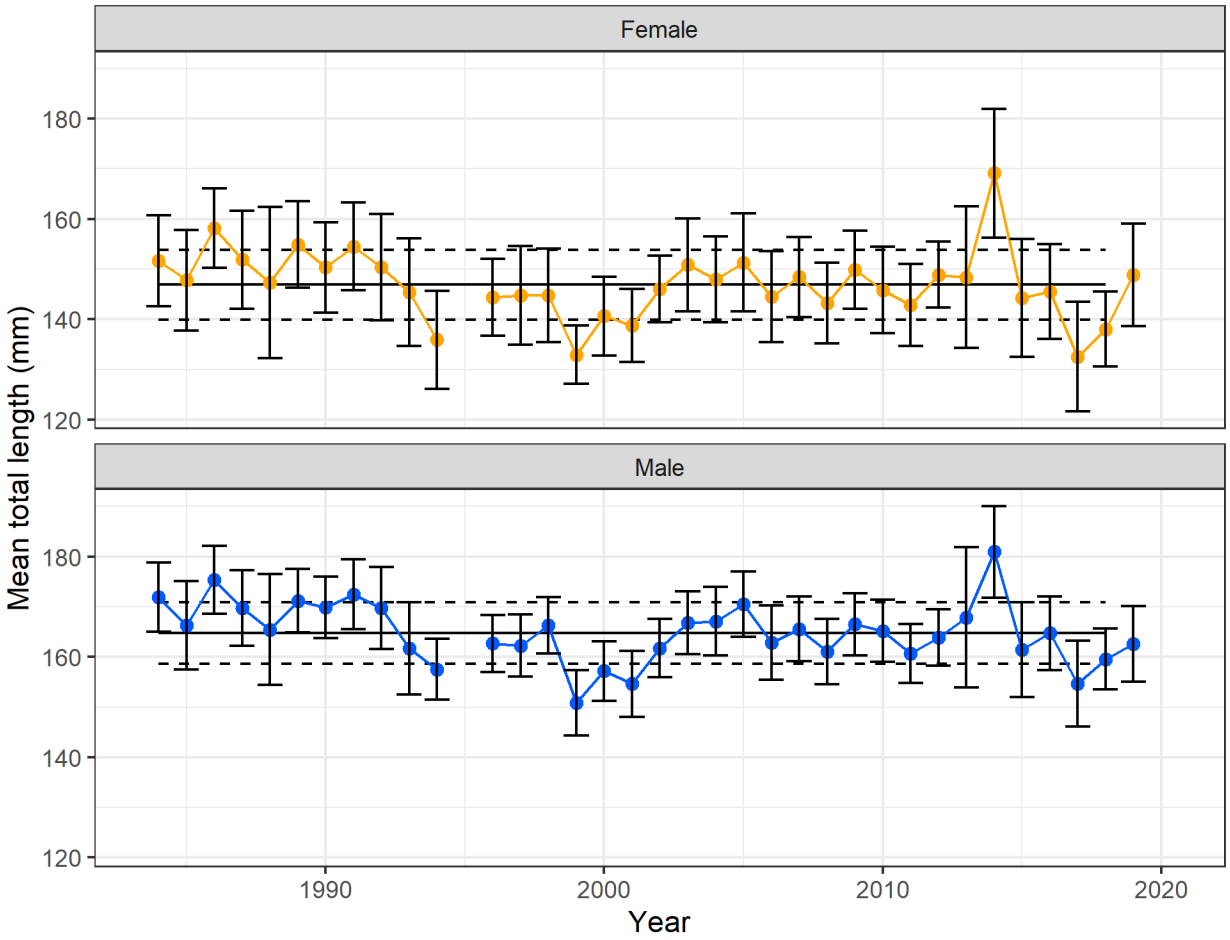


Figure 13: Mean total length (mm) of female and male capelin caught with seines (purse and "Tuck") in NAFO Division 4R since 1984. The horizontal lines indicate the averages of the 1984-2018 period ± 1 standard deviation for Division 4R. Error bars represent the annual standard deviations.

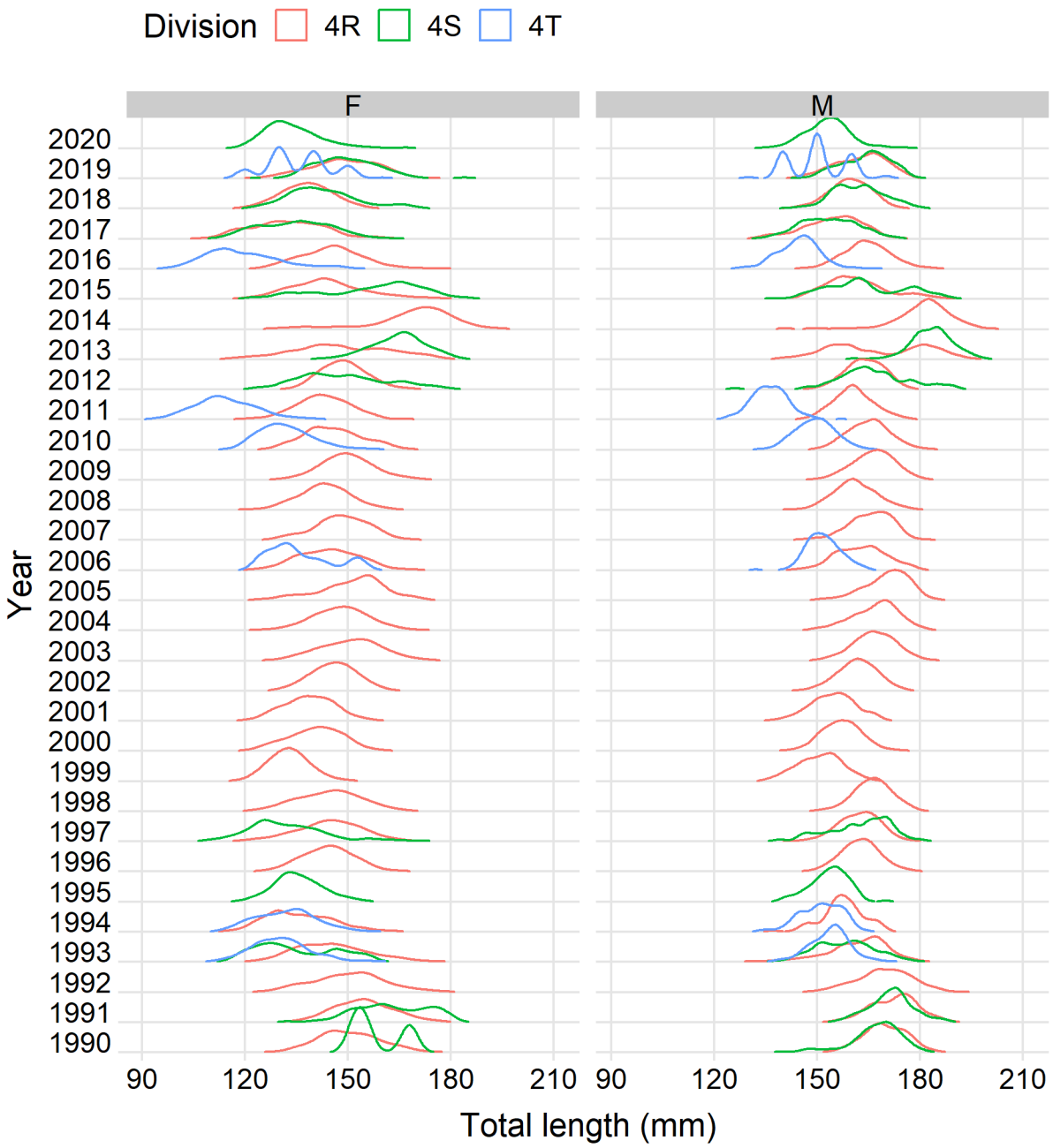


Figure 14: Total length (mm) composition (kernel density estimates) of females and males capelin caught with seines (purse and "Tuck") in NAFO Division 4R, 4S and 4T from 1990 to 2020.

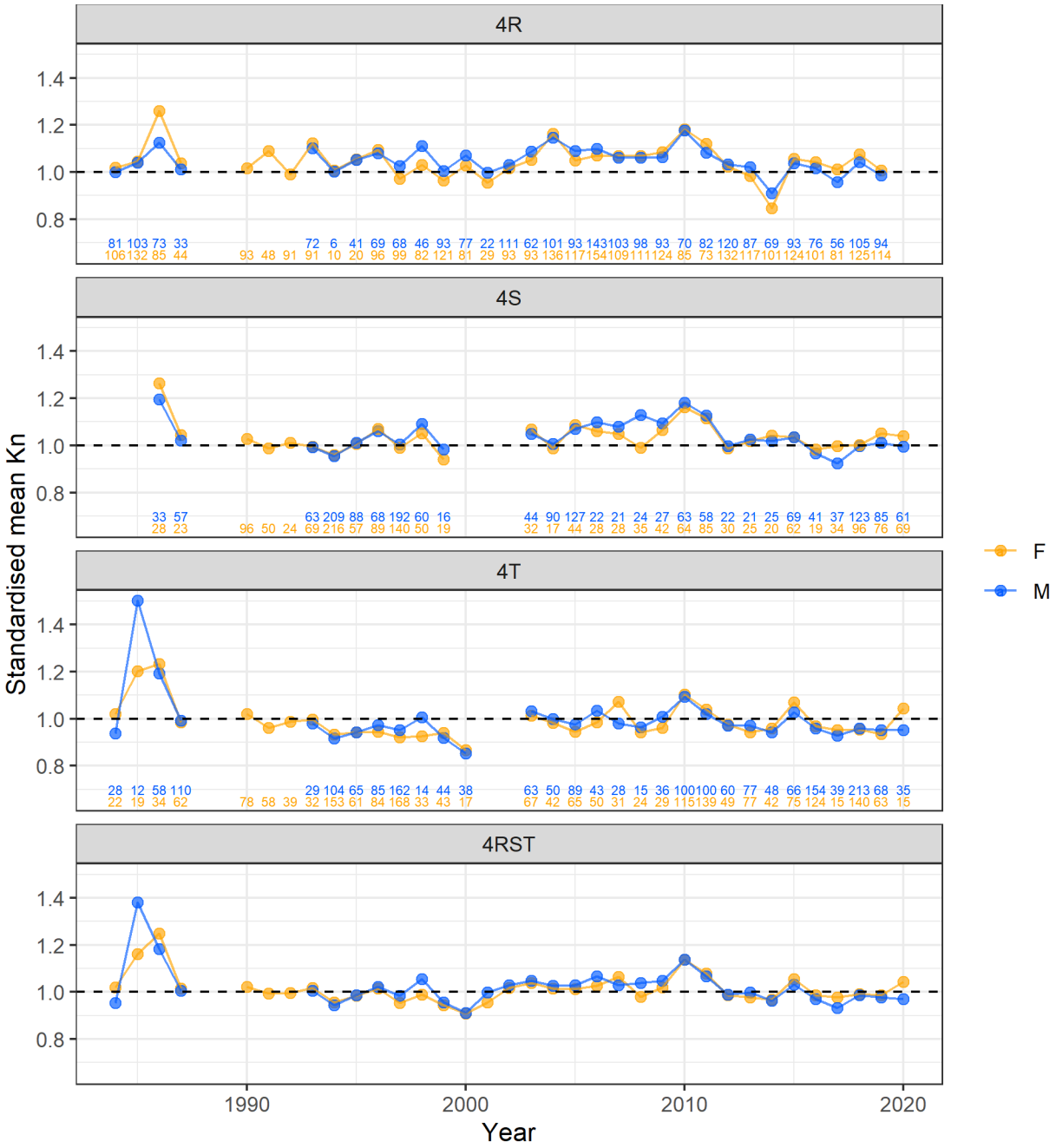


Figure 15: Standardized annual relative condition factor (Kn) of male (blue) and female (yellow) capelin from commercial samples sent at MLI. Kn were standardized for the following reference levels: gear = seine (all types), month = June. Number of fish per sex is indicated over the abscissa.

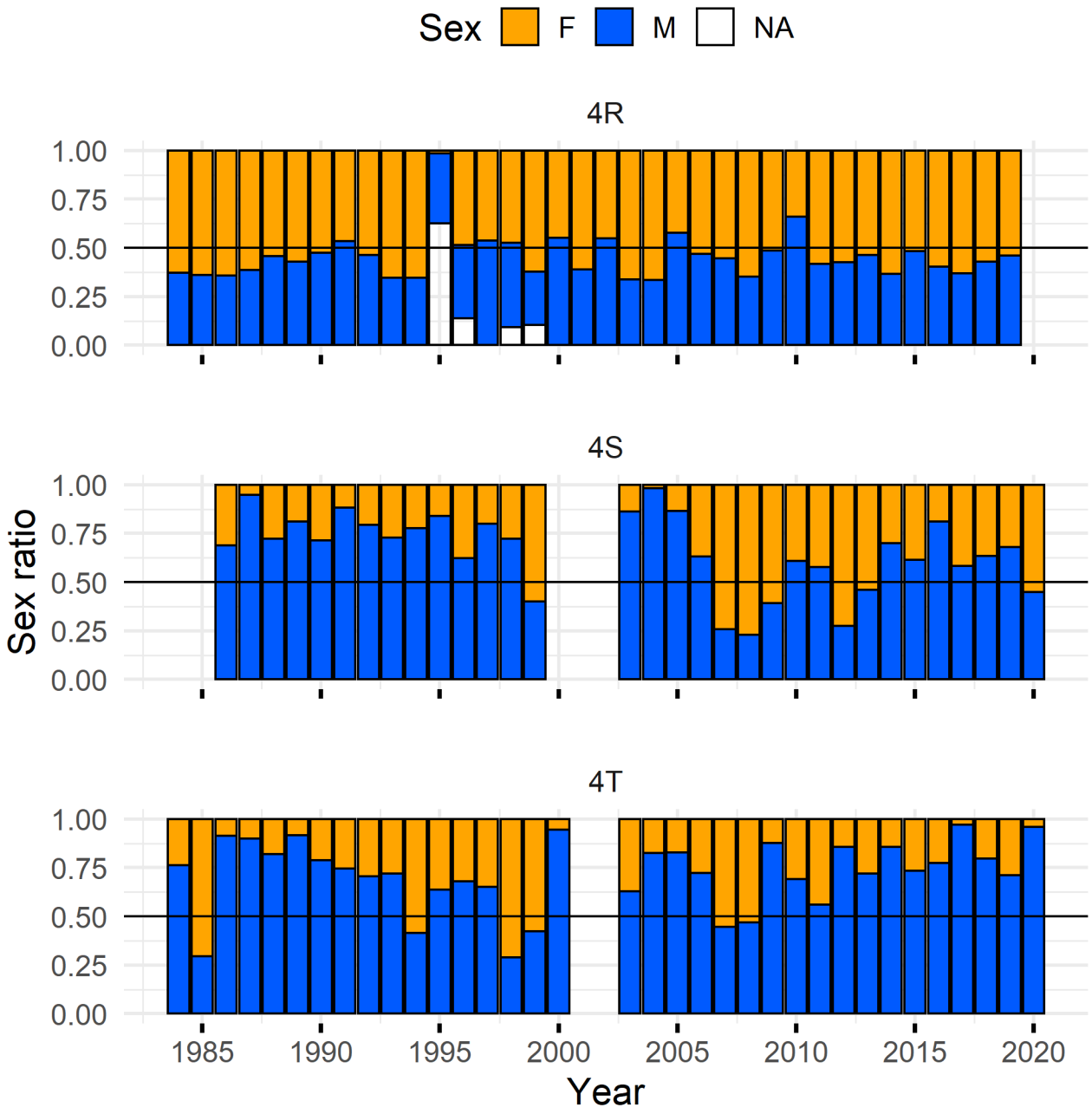


Figure 16: Annual sex ratio in capelin commercial length frequency data, by NAFO Division. (NA: not available)

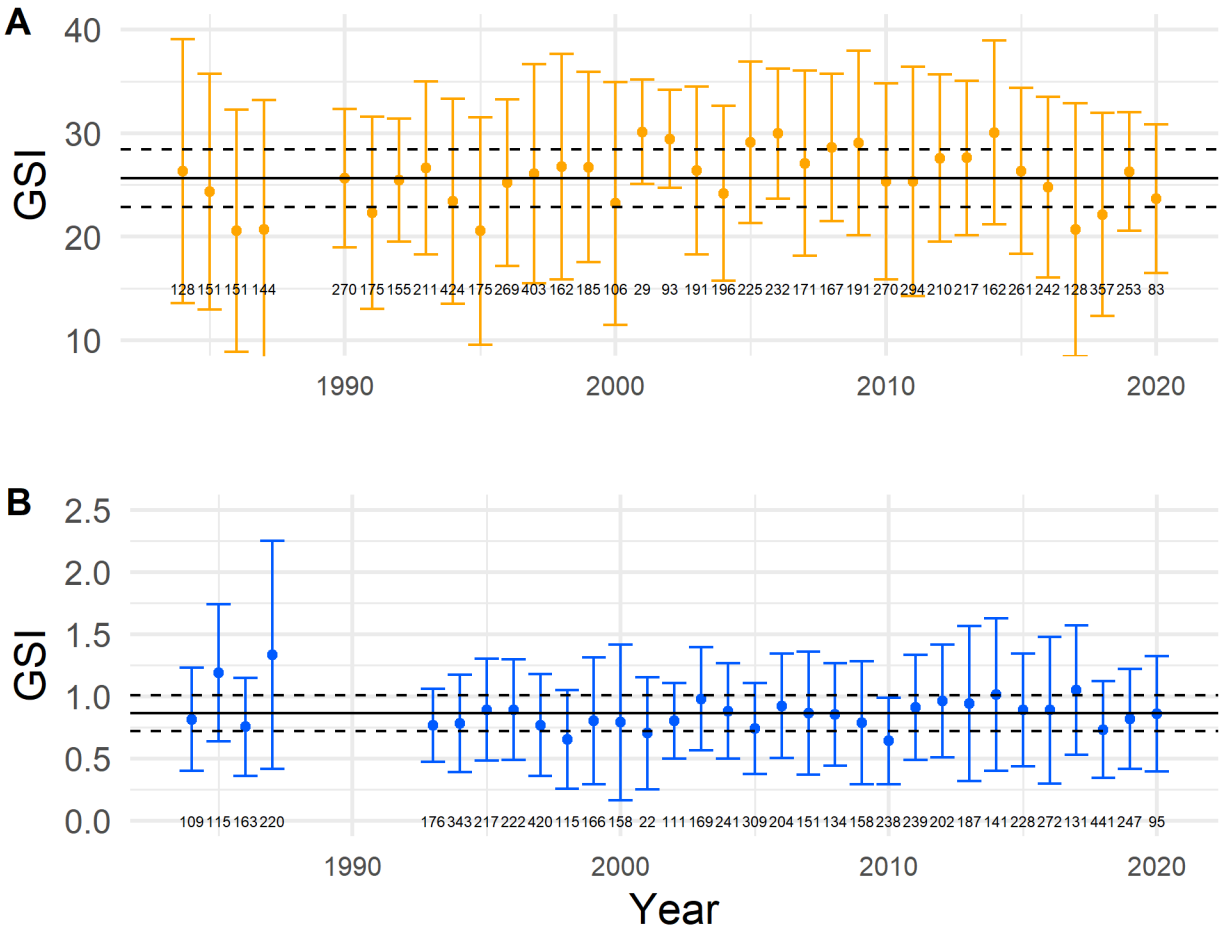


Figure 17: Estimated annual mean (and standard deviation) Gonadosomatic-Index (GSI) of female (A) and male (B) capelin. Individuals without secondary sexual traits distinguishing them were removed from the calculation. Error bars represent the annual standard deviations. Numbers represent sample size.

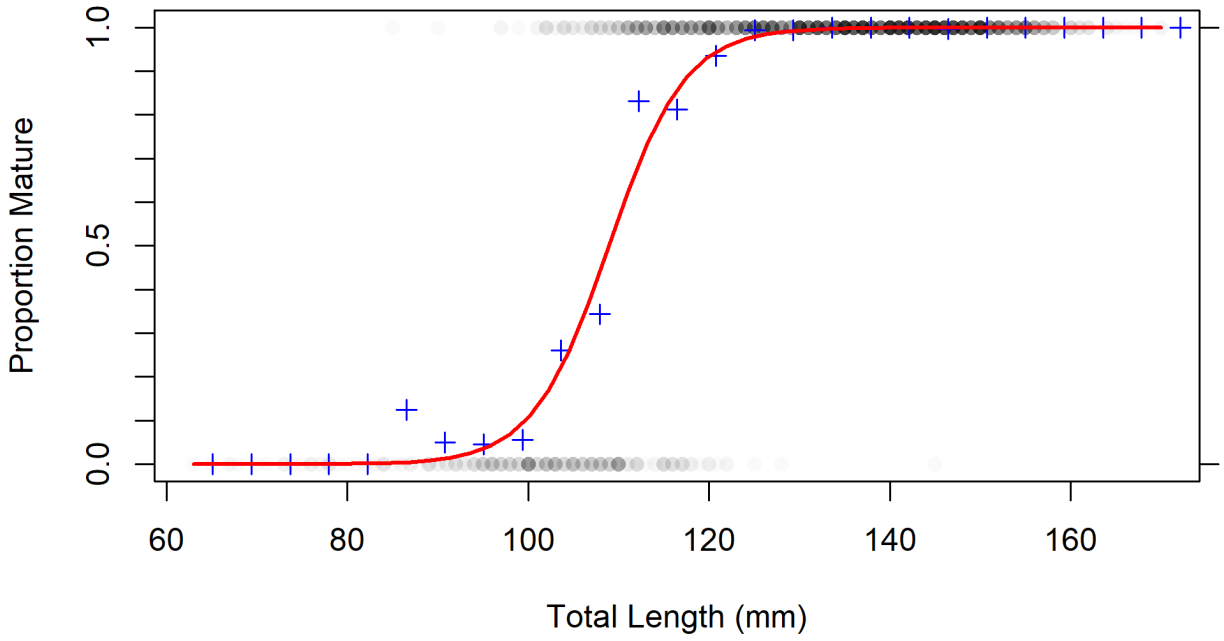


Figure 18: Capelin maturity ogive using biological data from 2018 to 2020 bottom trawl surveys. Length at 50% was estimated at 108.9 mm. Blue crosses: proportion mature; black dots observed mature and immature capelin; red line: estimated maturity ogive.

APPENDIX 1: SHRIMP FISHING AREAS IN THE ESTUARY AND GULF OF ST. LAWRENCE

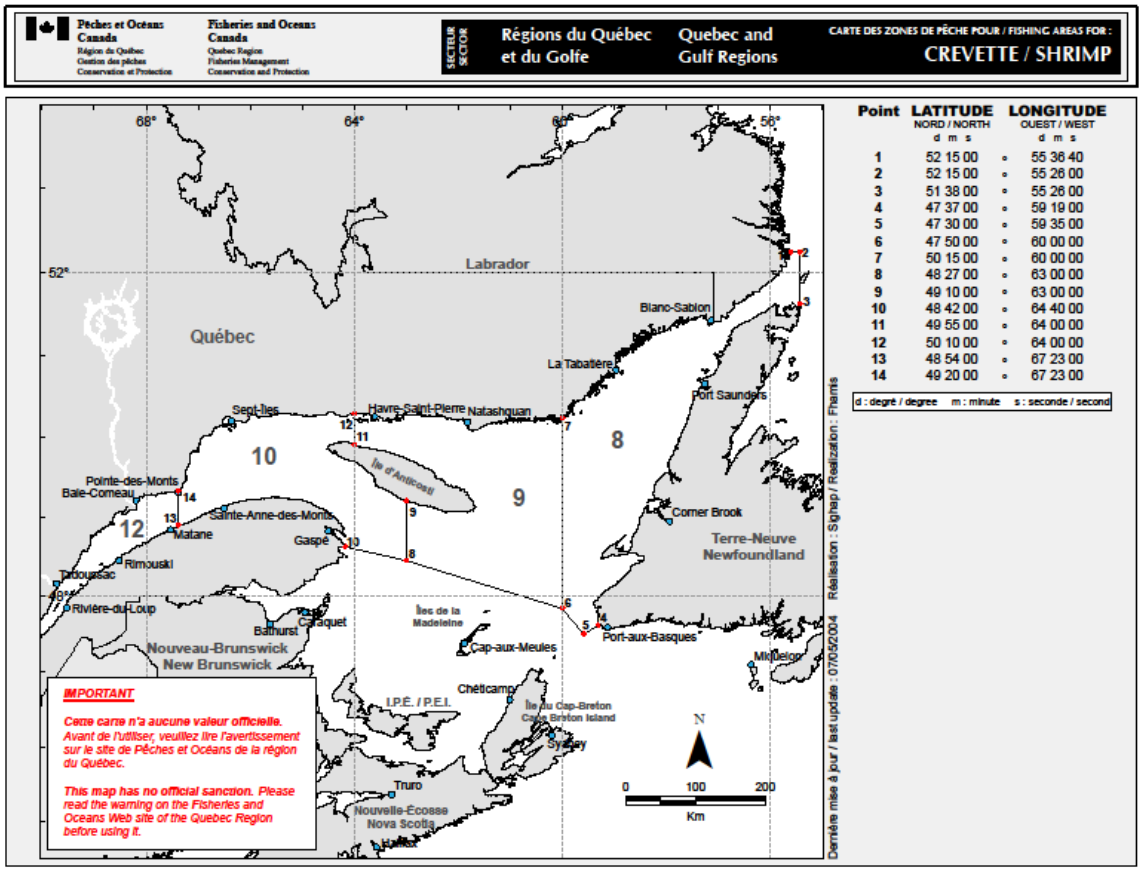


Figure 19: Shrimp fishery areas in the Estuary and Gulf of St. Lawrence. (8-Esquiman, 9-Anticosti, 10-Sept-Îles, 12-Estuaire / Estuary).