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Assessment of the NAFO Division 4TVn southern Gulf of St. Lawrence Atlantic Herring (*Clupea harengus*) in 2020-2021

N. Rolland, F. Turcotte, J.L. McDermid, R.A. DeJong, L. Landry

Fisheries and Oceans Canada
Gulf Fisheries Centre
343 Université Avenue, P.O. Box 5030
Moncton, NB, E1C 9B6

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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

Atlantic Herring (*Clupea harengus*) in Northwest Atlantic Fisheries Organization (NAFO) Division 4T, referred to as the southern Gulf of St. Lawrence (sGSL), consists of two spawning components, spring spawners and fall spawners. This document presents the most recent information on trends in abundance, distribution, and harvest for the spring and fall spawning Herring components in NAFO Division 4T. This includes catch-at-age and catch-per-unit-effort (CPUE) indices, fisheries-independent acoustic indices, experimental gillnet survey indices, mesh selectivity, fishery-dependent acoustic indices and catches in the multi-species bottom trawl survey of the sGSL. The data and indices are reported for the sGSL for the spring spawners, and regionally-disaggregated (North, Middle, and South regions) for the fall spawners where applicable.

Spring spawners were assessed using a statistical catch at age (SCA) model that allowed for time-varying catchability to the gillnet fishery and time-varying natural mortality. The model estimated that spawning stock biomass (SSB) has been in the critical zone of the Precautionary Approach framework since 2002. The SSB median estimate in April 1 2022 is estimated to be 28,835 tons (t); 62% of the limit reference point (LRP = 46,340 t). Under current low recruitment and high natural mortality conditions, this stock is not expected to recover in the short or the long term. Reducing fishing mortality will have marginal effects on the projected SSB trends. By 2027, the probability of exceeding the LRP was not more than 20% at all catch levels, with SSB values ranging between 32,500 and 35,400 t.

Fall spawners were assessed as regionally-disaggregated populations using a SCA model that allowed for time-varying catchability to the gillnet fishery and time-varying natural mortality. Estimated SSB has been declining in all three regions in recent years and is currently in the Cautious Zone of the Precautionary Approach framework. At the target catch level in 2021 (~12,000 t), the probabilities of a 5% increase in SSB by 2024 are all under 40%. Long-term projections show a continuous decline of SSB, however the probability of moving into the Critical Zone (under the LRP) by 2027 was 0% at all catch levels. As a consequence of low productivity and high natural mortality, exploitation of this stock should assert caution until high recruitment is observed for consecutive years.

INTRODUCTION

Atlantic Herring in the southern Gulf of St. Lawrence (sGSL) are found in the area extending from the north shore of the Gaspé Peninsula to the northern tip of Cape Breton Island, including the Magdalen Islands. Adults overwinter off the north and east coast of Cape Breton in the Northwest Atlantic Fisheries Organization (NAFO) Divisions 4T and 4Vn (Claytor 2001; Simon and Stobo 1983; Figure 1). Studies in the early 1970s indicated that southern Gulf Herring also overwintered off the south coast of Newfoundland, but an exploratory fishery in 2006 did not detect any concentrations (Wheeler et al. 2006). Herring is a pelagic species that schools particularly during feeding, spawning periods, and annual migrations. Eggs are attached to the sea floor and large females can produce up to 360,000 eggs (Messieh 1988). First spawning behavior typically occurs at four years of age.

Herring in the sGSL are managed across seven Herring Fishing Areas (HFA) (16A-16G; Figure 1a). These HFAs cover the same region as NAFO Division 4T (Figure 1b). The Herring population in the sGSL consists of two spawning components: spring spawners and fall spawners. Spring spawning occurs primarily in April-May but extends to June 30 at depths < 10 m. Fall spawning occurs from mid-August to mid-October at depths of 5 to 20 m, but can occur as early as July 1. Both spawning behaviors are explained by the genetic differentiation between these stocks (Lamichhaney et al. 2017). Spring and fall herring spawners within 4T are therefore considered distinct stocks and are assessed separately. Herring also show high spawning site fidelity (Winters and Wheeler 1985; McQuinn 1997; Brophy et al. 2006) and local stocks are targeted by the gillnet fishery which takes place on the spawning grounds. Fall spawning Herring in the sGSL are therefore assessed using regionally-disaggregated assessment models (North, Middle, South regions; Figure 1b).

The sGSL Herring are harvested by a gillnet fleet (referred to as “fixed” gear fleet) and a purse seine fleet (“mobile” gear fleet). The mobile gear fleet mainly consist of large vessels (> 19.8 m), but some small seiners (< 19.8 m) can also participate in the inshore fishery as part of the gillnet fleet. The fixed gear fishery is focused in NAFO Division 4T, whereas the mobile gear fishery occurs in 4T and historically, occasionally in 4Vn (Figure 1b). During the spring and fall fishing seasons, the mobile fleet are prohibited from fishing in areas set aside exclusively for the fixed gear fleet (Claytor et al. 1998). In the spring fishing season, mobile gear fleets fish along the northern boundary of NAFO region 4Tf, which is referred to as the “Edge” fishery. In the fall fishing season, mobile gear fleets fish in the Baie-des-Chaleurs area. Both spring and fall spawning Herring are harvested in the spring and fall fishing seasons and must therefore be separated into the appropriate groups for assessment purposes.

Prior to 1967, sGSL Herring was mainly exploited by fixed gear and average landings from 1935 to 1966 were 34,000 tons (t). In the mid-1960s, a mobile gear fishery was introduced and average landings by both fleets were 166,000 t from 1967 to 1972. Since 1981, fishing effort was reduced in the mobile gear fleets and the fixed gear fleet has accounted for most of the catch of spring and fall spawners (McDermid et al. 2018).

A global allocation or Total Allowable Catch (TAC) was introduced in 1972 at 166,000 t, and reduced to 40,000 t in 1973. Separate TAC for the spring and fall spawners components began in 1985. The TAC were first allotted by fishing season (spring and fall) and later attributed to spring or fall spawners landings based on biological samples taken during the fishery. The percentage of spring and fall spawners in the catch varies according to season and gear type. As a result, landings during the spring and fall fishing seasons must be separated into the appropriate spring and fall spawners groups to determine if the TAC for these groups has been attained.

For this assessment, the population modelling is conducted for spring and fall spawning Herring to the end of 2021, with projections for 2022, 2023, and 2027.

DATA SOURCES

For the spring spawning Herring assessment, data collected in NAFO Div. 4T is used to model the population at the scale of the sGSL. The spatial distribution of the data collected during the spring fishery does not permit, for now, the use of a regionally-disaggregated model as for the fall spawning stock.

For the fall spawning Herring assessment, a regionally-disaggregated model is used to evaluate the population in three regions (North, Middle, and South) that encompass the entire NAFO Div. 4T. The regions are defined on the basis of traditional Herring spawning beds and fishing areas (Figure 1):

- North (Gaspé and Miscou; 4Tmnopq),
- Middle (Escuminac-Richibucto and west Prince Edward Island; 4Tkl), and
- South (east Prince Edward Island and Pictou; 4Tfghj).

The choice of three regions was dictated by geographic proximity of spawning beds and is the finest level of disaggregation that can presently be supported by the available data. The regionally-disaggregated models include inputs that are region-specific (e.g., catch-at-age, catch-per-unit-effort, experimental nets proportions-at-age (PAA), selectivity-at-age, biomass indices from hydroacoustic surveys on spawning grounds) and inputs that are common to the entire area (e.g., acoustic survey index, RV survey index).

LANDINGS

Catch data were extracted from purchase slips and ZIFF (Zonal Interchange File Format) files collected by the Statistics Branch of Fisheries and Oceans Canada (DFO). Catch data to 1985 are available by fishery (fixed and mobile) and by fishing area. Beginning in 1986, the catch data are further reported by vessel and trip. The ZIFF files are based on information collected by the Dockside Monitoring Program (DMP). This program provides accurate, timely, and independent third-party verification of fish landings. Contracted companies are hired by the fishing industry to observe the offloading of fish and to record and report the landings information to DFO.

The fishery TACs within NAFO Div. 4T are set for the sGSL spring spawners and fall spawners components, separately. In 2020 and 2021, the TACs were set at 500 t for the spring spawners and 12,000 t for the fall spawners, for a total of 12,500 t (Table 1; Figure 2). Bait removals were not counted against the TAC. Seventy-seven percent of the TAC for each spawning component was allocated to the fixed gear fleet with the remaining 23% for the mobile gear fleet (Table 1).

The preliminary estimated landings of spring spawning Herring in both the spring and fall fishing season were 603 t and 403 t for 2020 and 2021, respectively (Table 1; Figure 3). Most of the spring spawning Herring were estimated to have been landed in the fixed gear fleet over the 1981 to 2021 period. In 2020 and 2021, the fixed gear fleet was estimated to have landed 59% and 98%, respectively, of the total harvests of spring spawning Herring (Table 1; Figure 3a). The 2021 value was exceptionally high as the mobile fleet had a fairly limited activity that year. For 2020 and 2021, more than 95% of the spring spawning Herring landed by the fixed gear fleet was landed during the spring fishing season, whereas 100% of the spring spawning Herring landed by the mobile fleet was landed in the fall season (Table 1). Historically and on average, more than 80% of the spring spawning Herring landed by the fixed gear fleet has been landed during the spring fishing season, whereas more than 80% of the spring spawning Herring landed by the mobile fleet has been landed in the fall season (Figure 3b, c).

The preliminary landings of fall spawners in 2020 and 2021 were 10,065 t and 10,834 t, respectively (Table 1; Figure 3d). Over the 1978 to 2021 period, most of the fall spawning Herring have been landed in the fixed gear fleet. In 2020 and 2021, the fixed gear fleet was estimated to have landed 97% and 99.9%, of the total harvests of fall spawning Herring, respectively (Figure 3). The majority (nearly 100%) of the fall spawning Herring captured in the fixed gear fishery are landed during the fall fishing season (Figure 3e). Of all the fall spawners landed by the mobile fleet, 100% were landed in the fall fishing season in 2020 and 2021 (Figure 3f).

The recent 2017 to 2021 mean proportion of the total catch caught by fixed gear was 74% of the spring spawners and 96% of the fall spawners (Table 1). Over 37% and 29% of the 2020 and 2021 spring fishery fixed gear catches occurred in Herring areas 4Th (South) and 4Tmn (North), respectively (Table 2). Meanwhile, 55% of the 2020-2021 fall fishery fixed gear catches occurred in Herring area 4Tmn (North; Figure 1; Table 2). The mobile gear (Edge) spring fishery was not active in both 2020 and 2021. However the fall fishery 2020 and 2021 mobile gear catches were 646.2 t and 13.8 t, respectively, and both from 4Tmn (North; Figure 1; Table 2).

In 2020, 120.6% of the spring spawners TAC was attained compared to 80.6% in 2021 (Table 1). For fall spawners, 83.9% and 90.3% of the TAC was attained in 2020 and 2021, respectively (Table 1). Herring fishing area landings information can be found in Table 2.

A rebuilding plan was introduced for the spring spawners in 2010. This plan includes:

- fishing closure on some spawning areas in all HFA except 16A and 16F,
- weekly landing limits of 10,206 kg in all HFA except 16A, 16D, and 16F, where no restrictions apply, and
- no nets or Herring allowed on board during a fishing trip between 18:00 and 04:00 (ADT) in 16C-G and between 22:00 and 03:00 (ADT) in 16A and 16B.

Spawning stock assignment

Gulf Region Science uses three methods to assign Herring samples to either spring or fall spawners based on gonad maturity stages (Cleary et al. 1982):

1. For immature Herring of maturity stages 1 and 2 (juveniles), the season of hatching is based on the size at capture and visual examination of otolith characteristics (Messieh 1972). The spawning component assignment for juvenile Herring is its hatching season (Cleary et al. 1982). Juveniles represent a small percentage of commercial catch, but are a higher proportion in the research survey samples.
2. Adult Herring with ripe or spent gonads are assigned their maturity stage by macroscopic laboratory examination of the gonads. The fish are assumed to belong to the spawning component of the season in which they were caught. These represent over 90% of the gillnet catches and 75% of the total yearly landings.
3. Adult Herring with unripe gonads are assigned their maturity stage by using a gonadosomatic index (GSI) based on a discriminant function model. The GSI is based on the length of the fish and its gonad weight (McQuinn 1989). Once the maturity stage is determined by GSI, the spawning component is assigned by using a maturity schedule decision rule (a table cross-referencing maturity stage assigned by GSI and the date of capture to assign a spawning component) (Cleary et al. 1982).

For the month of June, the GSI and macroscopic examination methods historically resulted in different assignment of samples to spawning components. In particular, the 2012 and 2013 Cabot Strait Edge fishery samples were not well classified by the GSI method. The macroscopic examination identified at least 95% of the gonads as developing gonads therefore classifying them as fall spawners. The GSI discriminant function reclassified at least 20% of these developing gonads as spent gonads resulting in a classification of spring spawners. A change was made to the decision rules for the GSI method such that a "spent" gonad in June is classified as a fall spawner.

TELEPHONE SURVEY

A telephone survey has been conducted annually since 1986 to collect information on the fixed gear fishery and opinions on abundance trends (details in LeBlanc and LeBlanc 1996). The sGSL was divided into eight telephone survey areas corresponding to the areas where the major fisheries occur (Figure 1c). Active commercial licence holders were asked a series of questions concerning the number, dimensions, and mesh size of nets used, the frequency of fishing and how the abundance in the current year compared to the previous year and the medium-term trend. A 2008 review of the consistency of the abundance relationship among years concluded that this index should not be used as a biomass index in the population model. The telephone survey responses inform the fishing effort calculation for the CPUE in the gillnet fishery.

The 2020 fixed gear telephone survey contacted 251 fishermen randomly selected out of approximately 421 active commercial licence holders in both seasons combined. A total of 37 fishermen responded to the spring fishing season survey and 139 fishermen responded to the fall fishing season survey for a total of 176. The 2021 fixed gear telephone survey contacted 269 fishermen randomly selected out of approximately 452 active commercial licence holders in both seasons combined. A total of 55 fishermen responded to the spring fishery survey and 130 fishermen responded to the fall fishery survey for a total of 185. The distribution of respondents across the 8 telephone survey areas, mean net hauls, net lengths, and trend in the abundance from the previous year are shown in Table 3. Overall, fishermen felt that abundances in the 2021 spring fishery were slightly higher than those of 2020 and to those in the previous years. For the fall fishery there was a sense that the 2020 abundance in both the North and Middle regions has increased slightly compared to 2019, and decreased in the South. When comparing 2021 to 2020 in the fall fishing season, the North region respondents indicated a status quo, the Middle region a slight decrease and a strong increase in the South (Table 3).

In each year, the data source (either DMP or phone survey) with the greater number of responses was used to calculate the fixed gear CPUE abundance index. In the spring fishery, mesh sizes of gillnets has been relatively constant at 2½". In the fall fishery, 2⅝" mesh is the most common. However, many fishers started using bigger mesh sizes (2¾") in 1992. By 2002, the proportion of 2⅝" mesh reverted to pre-1992 numbers. The proportion of 2⅝" mesh in 2020 and 2021 was 100% (Table 3).

FISHERY SAMPLING

Commercial fishery catches are sampled dockside by DFO scientific personnel for the fixed and mobile fisheries, and at sea by fisheries observers in the mobile fishery. Sampling procedures are designed to obtain samples that are spatially and temporally representative of landings. The landings and samples by area used to calculate catch-at-age are shown in Table 2. The samples are used to determine the size, age, and spawning component (spring spawners or fall spawners) composition of the catch. Yearly age reading consistency tests are done in order to evaluate and ensure the consistency of age reading over time (Appendix A).

FISHERY-INDEPENDENT ACOUSTIC SURVEY

Since 1991, an annual fishery-independent acoustic survey of early fall (September-October) concentrations of Herring has been conducted in the sGSL. The standard annual survey area occurs in the 4Tmno areas where both NAFO Div. 4T Herring spawning components aggregate in the fall. The survey uses a random stratified design of parallel transects within predefined strata. Surveys are conducted at night and use two vessels: an acoustic vessel to quantify the fish schools biomass using a hull-mounted 120 KHz split-beam transducer, and a fishing vessel to sample aggregates of fish with a pelagic trawl (details in LeBlanc et al. 2015; see also LeBlanc and Dale 1996). The acoustic survey covered a total transect distance of 886 km and 1,022 km in 2020 and 2021, respectively (Appendix B Figure B1). All strata were covered in 2021, but in 2020 the northern strata along the coast of New-Richmond, with historically low abundance of fish, were skipped due to time constrain and vessel availability. The trawl samples are used to separate the estimated biomass by spawning component and age, determine species composition, and size distribution for the estimation of the target strength (LeBlanc and Dale 1996; LeBlanc et al. 2015).

EXPERIMENTAL NETS

Part of an industry partnership project between DFO and fishery associations, experimental gillnets consisting of multiple panels of varying mesh size were weekly deployed by fishermen during the fall fishing season. These modified gillnets catch a wider range of fish sizes and provide information on the relative selectivity of various mesh sizes. Each experimental gillnet had five panels, each with a different mesh size, from a set of seven possible mesh sizes, ranging from 2” to 2¾” in ⅛” increments. All gillnets had panels with mesh sizes of 2½”, 2⅝”, and 2¾”, plus two smaller mesh sizes that varied among fishermen. Harvesters in the fall fishing season participated in the study on the following spawning grounds (Figure 1a): Miscou Bank (North region; 16B), Gaspé (North; 16B), Escuminac (Middle; 16C), West PEI (Middle; 16E), Fisherman’s Bank (South; 16G), and Pictou (South; 16F). The target fishing procedure was a one hour soak and nets were set on the fishing grounds during the commercial fishery. Data from Pictou prior to 2015 were corrected for gillnet depth as nets in this region were 5 m (17 ft) deep compared with the standard 2.4 m (8 ft) used on other spawning grounds. A correction factor of 8/17 (in ft) was applied to the Pictou nets to address the difference in net depth size.

Catches from the experimental nets has been used to estimate the relative size-selectivity of gillnets of different mesh sizes (details in Surette et al. 2016) and to produce PAA. Both are inputs to the fall spawners assessment model.

SPAWNING GROUND ACOUSTIC SURVEYS

In 2015, a spawning ground acoustic survey that follows the design of the fishery-independent acoustic survey described above was initiated. This survey is the result of a partnership between DFO and fishery associations. The survey design uses random parallel transects within predefined strata that cover the same spawning grounds as the experimental nets (Appendix C). Surveys are conducted by fishermen in the fall fishing season according to protocols developed by DFO. The survey is conducted at night, during the weekend fishery closures except in Herring fishing area 16C and 16E in 2015 to 2017 (Middle; Figure 1a), where this region didn’t have weekend closures. The spawning ground acoustic survey is meant to provide a nightly estimate of spawning biomass among regions. It is analyzed in the same manner as the fishery-independent acoustic survey. The catches from the experimental nets are used to calibrate the spawning group specific target strength in order to obtain the nightly estimates of spawning biomass.

In this assessment, this biomass index has been incorporated into the fall population model for the first time. The detailed results of the 2020-2021 surveys are available in Appendix C.

MULTISPECIES BOTTOM-TRAWL SURVEY

The annual multi-species bottom trawl survey, conducted each September since 1971, provides information on the abundance and distribution of NAFO Div. 4T Herring throughout the sGSL in September (Savoie 2014). Total catch weights and numbers, representative length frequency and representative individual length-weight data has been recorded for each fish species in each survey set since 1971. Since 1994, additional sampling of Herring catches has been undertaken to disaggregate catches by spawning group and age (additional details in Hurlbut and Clay 1990). Herring were primarily caught near shore in waters < 30 fathoms, mostly off northeast P.E.I., west of Cape Breton, as well as in the Northumberland Strait, and Baie-des-Chaleurs (Appendix D Figure D1).

ECOSYSTEM INFORMATION

The abundance of major predators of Herring has changed over the time-series of the assessment. Abundance information for age 5+ Atlantic Cod and for Grey Seals was obtained from Neuenhoff et al. 2019. Atlantic Bluefin Tuna abundance information specific to the sGSL was obtained from the rod and reel CPUE index in ICCAT 2020. White Hake abundance data was obtained from Rolland et al. (2022), and mature Northern Gannet abundance data was obtained from (Rail 2021). Missing values in northern Gannet time series were obtained using linear interpolation (zoo R package, Zeileis et al. 2021). The proportion of immature Gannets, who also consume Herring, in the population was estimated to be 28% (J-F Rail, personal communication). Annual Gannet abundance was calculated by adding the equivalent of 28% of the mature Gannet population to the yearly abundance estimate (Benoît and Rail 2016). As predator data were in different units, values of abundance indices for each predator and natural mortality estimates were scaled by subtracting the mean and dividing by the standard deviation of the individual data vector. Correlation between variables was assessed using a correlation matrix, bivariate scatterplots and the Pearson's correlation coefficient. Environmental effects on spring spawning Herring recruitment, stock-recruit relationships and population projections were assessed in Turcotte 2022. The GSLEA R package (Duplisea et al. 2020) was used to obtain a matrix of environmental variables for the ecosystem approach region 5 (Magdalen Shallows). For the assessment, time-series of zooplankton abundance data was only available for years 2001 to 2019. Recruitment results interpretation for spring spawning Herring were based from Turcotte 2022. Environmental effects on fall spawning Herring was assessed in a qualitative manner, using recent literature to infer the relationship between recent estimates of recruitment and recruitment drivers.

INPUTS AND INDICES

CATCH-AT-AGE AND WEIGHT-AT-AGE MATRICES

Catch-at-age and weight-at-age matrices for 4T Herring spring spawners and fall spawners include catches from both fixed and mobile gear fleets. These were calculated using age-length keys and length-weight relationships for each spawning component, gear type, and fishing season (Table 2). For missing length cells, the age-length keys were completed by assigning a distribution of probability of an age based on data available for each season in a defined strata. Historically, when fewer than 30 fish were sampled for detailed analysis, the overall length-weight relationship and age-length key most similar and adjacent in gear, geography, and time were used to estimate the catch-at-age. However for both 2020 and 2021, that threshold was decreased to 25 to compensate for the lack of specimens in some samples. Catch-at-age and weights-at-age are presented for fixed gear (spring spawners: Table 4-Table 5, fall spawners: Table 6-Table 7) and mobile gear (spring spawners: Table 8-Table 9, fall spawners: Table 10-Table 11).

The dominant age in the 2020 spring spawners catch was age 7 belonging to the 2013 year-class. In 2021 the dominant age was the same year-class, now age 8 (Table 4 and Table 8; Figure 4). For fall spawners, the dominant age was 7 (2020) and 8 (2021) in the North (2013-2014 cohorts), age 8 in the Middle for both years (2011-2012 cohorts), ages 7 to 8 in 2020 (2013 to 2012 cohorts) and age 8 in 2021 (2013 cohort) in the South (Table 6 and Table 10; Figure 5).

Beginning of year weights-at-age are calculated from the weight-at-age for fixed and mobile gear combined. For age *a* at the beginning of year *t*, it is the geometric mean of weight-at-age *a*-1 in the fishery in year *t*-1 and the weight-at-age *a* in the fishery in year *t*. Mean weight-at-age of the spring spawners caught in the mobile and fixed gears in the spring season have declined since the 1990s for mobile gears, and since the mid-1980s for the fixed gears (Table 5 and Table 9; Figure 6). The average weight-at-age declined by 39.6% between 1978 and 2021. Mean weight-at-age of fall spawning Herring from fixed and mobile gears has declined almost continuously over the time period 1978 to 2015 and has then stabilized until 2021 (Table 7 and Table 11; Figure 6). The mean weight-at-age declined by 30.2% between 1978 and 2021. Mean weight-at-age is an indication of stock status, affecting stock biomass for a given stock abundance. Similar to the previous assessment, seiner catch from 4vn was re-distributed to the North, Middle and South regions in proportion to the region's fixed gear landing. Historically, re-distribution was based on seiner landings in each region, resulting in regions without seiner landings receiving no catch redistribution from 4Vn seiner landings. Similarly, seiner catch from the edge fishery was re-distributed to North, Middle and South regions in proportion to their fixed gear landings. Prior to the last assessment, these landings were all attributed to the South region.

CATCH-PER-UNIT EFFORT

The fixed gear fisheries occur on the spawning grounds. Landings from this fishery in 2020 account for approximately 59% of the spring spawners catch and 97% of the fall spawners catch. In 2021, this fishery account for more than 98% for both spawning groups. Fixed gear catch and effort data were used to construct CPUE abundance indices for spring and fall spawners. The fixed gear CPUE indices are defined as catches in kg/net-haul/day (or kg/net-haul/trip). Before 2014, a default 15 fathoms (27.4 m) net length was used when the information was not recorded, while starting in 2014 a value of 14 fathoms (25.6 m) is used. For all years all net length have been standardized to 14 fathoms. Total CPUE indices and PAA for ages 4-10 are used in the assessments for both stocks.

Catch data were taken from the landings data. From 1990 to 2021, spring fishing season use landing data from DMP and complete the missing statistical districts with landings from purchase slips and ZIFF (Claytor et al. 1998, LeBlanc et al. 2002). Since 1978, fall fishing season use landing data from purchase slip and ZIFF. Fishing effort was calculated as the average number of gillnets deployed by season and area for the sGSL since 1978. From 1978 to 1985, the average number of nets used was collected by questionnaires done on wharves and by mail (Clay and Chouinard 1986). Since 1986, the fishing effort was calculated as the number of trips (purchase slips) multiplied by the estimated number of standard net hauls, which were determined from the DMP records (since 1990, see LeBlanc et al. 2008) and the annual telephone survey depending on which has the most data (Table 3). The number of hauls, available since 1986, is used only for the fall fishing season (Claytor et al. 1998; LeBlanc et al. 2009).

The percent of fixed gear fishing days with no catch has been recorded since 2006 based on responses to the telephone survey (Table 12). The percentage of days without catch in spring for both 2020 and 2021 was 24.3%, which is below the average of 32.7%. In the fall, the days without catch are still among the highest in the time series for the both years of the fall fixed gear fishery at 37.3% while the average is at 29.3%. As this information is only available for the most recent period, it is not yet included in the calculation of fishing effort.

A multiplicative model (GLM) was used to calculate the standardized CPUE indices, based on the following formulation:

$$ln\left(CPUE_{ijk}\right) = \alpha + \beta_1 I + \beta_2 J + \beta_3 K + \epsilon$$

where I indexes year, J indexes herring management area by province, K indexes week and $\in$ is the residual error. For spring, data was aggregated by day and area and weighted by the catch for that area. For fall, data was aggregated by week. For the spring spawners, the model was applied to the data for the whole stock area. For the fall spawners, GLMs were run by region (North, Middle, and South) and did not include the area term. The spring spawner analysis was limited to weeks 11 to 22, whereas the fall spawner analysis was restricted to weeks 27 to 43 (see table 19 in LeBlanc et al. (2012)). Days by area (for spring) or by region (for fall) with less than 5 trips were also removed from the analysis. In order to improve the year to year repeatability of the CPUE estimations used by the population model, the historical method using SAS (Statistical Analysis Software) was translated into R (R Foundation for Statistical Computing Platform) programming language. The similarities between both methods are presented in Appendix E and the new method is proposed to become the standard for future assessments. This assessment uses the historical method.

The models explained 40% of the variance in the spring data and the factors for year, week, and area were statistically significant. For the fall data, models explained between 51% and 69% of the variance in the data and the factors for year and week were statistically significant (Table 13). Age-specific CPUE indices for ages 4 to 10 was derived by dividing the gillnet catch-at-age by the standardized effort (CPUE) from the multiplicative GLM model. The CPUE age-specific abundance index included the years 1990 to 2021 for spring spawners and 1986 to 2021 for fall spawners.

The indices presented in Table 14-Table 15 and Figure 7-Figure 8 account only for catch and effort, and do not account for possible changes in selectivity or catchability, which are addressed as part of the population modelling. The CPUE index for spring and fall spawners shows internal consistency as the abundance of cohorts is correlated between years (Figure 7-Figure 8). Fixed gear catches of spring spawners were composed mostly of ages 5 to 7 for 2020 and ages 6 to 8 for 2021 (Table 4). The CPUE of spring spawners in 2020 and 2021 has increased compared to the low values of 2018-2019 and for ages 7 and 8 has returned to the higher values observed in 2017. For 2021 the dominant ages were 7 and 8 (2013-2014 cohorts, Table 14; Figure 7). In the North region, catches of fall spawners in 2020 were dominated by ages 7 to 9 (2011 to 2013 cohorts), while in 2021 age 8 (2013 cohort) was the most abundant. In the Middle region, catches of fall spawners in 2020 were dominated by ages 7-9 (2011-2013 cohorts), and in 2021 age 8 (cohort 2013) was the most abundant. In the South region, catches of fall spawners in 2020 and 2021 were dominated by ages 7 to 8 and 6 to 9, respectively (2011 to 2015 cohorts; Table 6). Except for the South region in 2021, overall catch in all three regions is much lower compared to the last assessment period of 2018-2019. The CPUE of fall spawning Herring increased in 2020 for both the North and Middle regions but decrease in the South. In 2021, the CPUE decreased in the North, but increased in the Middle and South regions (Figure E2, SAS method). Across regions, the CPUE of fall spawning younger fish (ages 4 and 5) has remained low since 2011, although the values are slightly higher for both North and Middle regions compared to 2018-2019 (Table 15; Figure 8).

FISHERY-INDEPENDENT ACOUSTIC SURVEY INDEX

A second standardized abundance index is generated from the annual fishery-independent acoustic survey. This index includes catch-at-age data from NAFO areas 4Tmno which has been surveyed yearly since 1994. The age-disaggregated acoustic abundance index for ages 2 to 10 for spring spawners and fall spawners is presented in Table 16.

The 2020 and 2021 acoustic biomass index of the 4Tmno areas for spring and fall spawners combined were 30,081.8 t, and 37,953.1 t, respectively. In 2020, the biomass was composed of 30% spring spawners and 70% fall spawners. In 2021, the biomass was composed of 37% spring spawners and 63% fall spawners. A summary of the acoustic survey results is available in Appendix B.

The spring spawner assessment model uses results for ages 4-8. For 2020 and 2021, the acoustic survey estimated that catch rates (in numbers) of spring spawners ages 4 to 8 were overall slightly higher than those observed in 2018 and 2019. The catch was dominated by ages 4 and 6 in 2019, ages 5 and 7 in 2020 and age 4 in 2021, indicating the 2013 cohort was relatively strong, as also seen in the CPUE index but also that the 2017 cohort appears to be stronger than expected. The observed trend is consistent with the low numbers experienced since the early 2000s (Table 16; Figure 9).

For the fall spawner assessment model, the acoustic survey provides an abundance index of recruiting Herring (ages 2 and 3; LeBlanc et al. 2015). It is not thought to provide a useful abundance index for older ages given that the survey is limited to a restricted portion of the sGSL at a time when older Herring are spawning in areas throughout the sGSL. The acoustic abundance of ages 2 and 3 were much higher in both 2020 and 2021 than those of 2019, with the most abundant being age 3 (2017-2018 cohorts) in both years (Table 16; Figure 9).

SPAWNING GROUND ACOUSTIC SURVEYS

The sampling effort varied between regions and years, generating data with missing values, which can create biased biomass estimates when the mean annual value is calculated. To account for missing samples, a predictive model of nightly Herring biomass by year, region and Julian day was used to obtain a complete data grid and produce unbiased biomass indices (Turcotte et al. 2022). The average North region nightly biomass showed a general decline through the time series, from a peak of 7,667 t in 2016 to 600 t in 2021. The Middle region has seen a slower decline than the North region, with more interannual variation. Average nightly biomass declined from 3,175 t in 2015 to 1,036 t in 2021. The South region average nightly biomass declined between 2015 (3,563 t) and 2018 (335 t), but then increased until 2021 to reach a value of 2,816 t (Figure 10).

EXPERIMENTAL NET INDICES

Relative selectivity index

A relative selectivity index was developed to account for changes in the proportion of 2⅝”, and 2¾” meshes used by commercial fishermen (Figure 12), as well as changes in mean length-at-age which have generally decreased over time. Selectivity-at-age (Table 17) and selectivity-adjusted CPUE calculations are described in the fall spawner model below.

Catch-at-age of experimental nets

Similar to the previous assessment, the observed catch-at-length of each mesh size was summed per day and per region, and then the mean catch-at-length per region and per year was calculated. The catch-at-age data was then constructed using age-length keys as described above. The selectivity of the different mesh sizes was dealt with within the model (see fall spawner model).

The experimental net index catch-at-age shows a greater proportion of fish ages 3 to 4 until 2009, after which the numbers decline. No major trend was observed in older Herring over the time series. No data was available for the North region in 2021 and in 2020 the proportion in the catch-at-age was much less than what was observed in 2018 and 2019. For both middle and south regions, proportions in the catch-at-age show greater catches of fish ages 5 to 8 (Figure 11). The fall spawning Herring population model uses proportions-at-age from the catch-at-age in experimental nets as a data input for years where the spawning ground acoustic survey are available (2015 to 2021).

MULTISPECIES BOTTOM TRAWL INDEX

This index consists of an age-disaggregated index using data from 1994-2021 for the fall spawners only (Table 18; Figure 13). Since the last assessment, the diel adjustment factor was not used to calculate the bottom-trawl survey index (see Turcotte et al. 2021b for details). The spatial distribution since 1971 is provided in Appendix D.

The annual stratified mean catch-at-age values (standardized for tow distance) from the survey were used to produce an index of abundance. The results suggest an increase to relatively high abundance of ages 4-6 in 2010-2014 followed by a steady decline to very low abundance of these ages down to 2020 and an increase in 2021 to values previously observed in 2017 (Figure 13).

MATURITY OGIVE

For the purposes of the assessment, Herring are assumed to follow a knife-edged maturity schedule, with 100% maturation occurring between the ages of 3 and 4.

SPRING SPAWNER COMPONENT ASSESSMENT

Similar to last assessment, a SCA model with time-varying parameters was used. Such SCA model 1) assumes that there is observation error in the PAA in the fishery catches, 2) fits to the age-aggregated biomass indices and to the PAA in the fishery and survey catches; which accounts for the lack of independence between catches at different ages in the same year, and 3) is forward projecting from abundance-at-age in the first year and at the first age in all years. The model allows fishery catchability and natural mortality to vary over time which ensure the best fit to indices, minimized the residuals and showed no retrospective pattern in SSB estimates (Turcotte et al. 2021a). Fisheries stock assessment is often based on the assumption that natural mortality is constant through time, yet numerous examples show that predator-prey interactions are dynamic. Failure to account for increases in natural mortality due to changes in predator-prey interactions in stock assessment can result in biased estimates of population parameters and vital rates. Natural mortality also includes mortality from disease and unreported catches, including the bait fishery removals, for which no information is available. This component of the fishery has raised many questions over the year and is included in the assessment, although its effect cannot be distinguished from other sources of mortality. Disease mortality is expected to be a low fraction of total natural mortality, as no mortality event due to disease were recorded during the time series.

SPRING SPAWNER MODEL

The SCA model of the spring spawners component was implemented using AD Model Builder (Fournier et al. 2012). Data inputs to the model included:

- total fishery catches, and catches-at-ages 2 to 11+ from 1978 to 2021 in PAA;
- catch-per-unit-effort (CPUE) index PAA and age-aggregated biomass index from 1990 to 2021 (ages 4 to 10);
- fishery-independent acoustic survey index PAA and age-aggregated biomass index from 1994 to 2021 (ages 4 to 8).

For yearly PAA in all data sources, where PAA was smaller than 0.01, plus or minus groups were created with adjacent ages until PAA was greater than 0.01.

Estimated model parameters included the numbers-at-age in the initial year (1978), yearly recruitment (average recruitment and yearly recruitment deviations in numbers of age 2 fish), selectivity parameters in three time blocks to account for changes in selectivity and gear proportion in the catch, initial fishing mortality prior to 1978, CPUE and acoustic survey *q* and yearly *q* deviations for the CPUE index, initial *M* and yearly *M* deviations for two age groups (2-6 and 7-11+) and the observation error to the indices. All parameters were estimated on the log scale.

Independent time-series of *M* for two age groups were estimated: ages 2-6 ($j = 1$) and 7-11+ ($j = 2$). These time series were estimated on the log scale as random walks:

$$\log(M_{j,t}) = \log M_j^{init} \text{ where } t = 1978$$

$$\log(M_{j,t}) = \log(M_{j,t-1}) + Mdev_{j,t} \text{ where } t > 1978$$

$$Mdev_{j,t} \sim Normal(0, \sigma_j^M)$$

where $\log\,(M_j^{init})$ and $Mdev_{j,t}$ are parameters estimated by the model. The *M* deviations ($Mdev_{j,t}$) were assumed to be normally distributed with a mean of 0 and standard deviation σ_j^M fixed at 0.075 for all j. The random walk started in 1979. Priors were supplied for M^{init}. These priors were normally distributed with means of 0.2 and standard deviations of 0.1 for both age groups (i.e., $M_j^{init} \sim N(0.2, 0.1)$).

The model likelihood included penalty terms due to the priors on *M*:

$$0.5 \sum_{j,y} (Mdev_{j,t}^2)/(\sigma_j^M)^2 + 0.5 \sum_J \exp\,(\log(M_j^{init}) - 0.2)^2/0.1^2$$

The model allowed for process error in fully-recruited catchability (*q*) to the fixed gear fishery. The initial value of *q* in 1990 (the first year with CPUE data) was a model parameter and the subsequent values of *q* were estimated as a random walk:

$$q_t = \exp\,(\log q) \text{ where } t = 1990$$

$$q_t = q_{t-1} * \exp\,(qdev_t) \text{ where } t > 1990$$

$$qdev_t \sim Normal(0, \sigma^q)$$

where $\log(q_t)$ and $qdev_t$ are parameters estimated by the model. The q deviations ($qdev_t$) were assumed to be normally distributed with a mean of 0 and a standard deviation σ^q fixed at 0.1.

The model likelihood included a penalty term due to the prior on the *q* deviations:

$$0.5\sum_t (qdev_t^2)/(\sigma^q)^2$$

Selectivity $S_{g,a,t}$ was indexed by catch source *g*, age *a* and year *t*. Fishery selectivity (*g* =1), selectivity to the CPUE in the gillnet fishery (*g* =2) and to the acoustic survey (*g* =3) were assumed to be logistic functions of age. It could be argued that selectivity to the CPUE index and to the fishery may be dome shaped due to the use of gillnets. Selectivity models that allowed for a dome shape (e.g., double logistic, gamma, exponential logistic) were also examined and they did estimate that selectivity was dome shaped. The descending limb of the dome was steeper and declined to a lower level in the 2005-2017 period than in the 1990-2004 period. For example, using the above three selectivity models, selectivity-at-age 10 in the gillnet fishery was estimated to be about 0.5, 0.8 or 0.9 in 1990-2004 respectively and 0.2, 0.2 and 0.8 in 2005 to 2017 (see Turcotte et al. 2021a Appendix 2 for details). However, size-at-age of herring has been declining since the mid-1980s (Figure 6). If selectivity was dome-shaped, old herring (e.g., age-10) would be on the descending limb. Consequently, decreases in size-at-age would increase their selectivity to the gillnet gear, not decrease it. Independent estimates of relative selectivity-at-age of fall spawners confirms that their selectivity at older ages has increased, not decreased, as their size-at-age has declined. Declining abundance at old ages that is not accounted for by fishery catches and estimated natural mortality can be spuriously accounted for by estimating declining selectivity at old ages. Consequently, these estimates of declining selectivity for older herring in recent years were judged to be spurious and the decision was made to use logistic selectivity models.

For the commercial fishery and the CPUE index, separate selectivity functions were fit to three time periods:

1. 1978 to 1989 (p =1),
2. 1990 to 2004 (p =2), and
3. 2005 to 2021 (*p* =3) (i.e $S_{1,p} = f(s_{1,a,t})$ and *t* ∈ 1978,1979, ... ,1989 for *p* =1, etc.).

These time periods were chosen based on an examination of the yearly fixed/mobile gear proportions in the commercial fishery.

Population abundance-at-age 2 (recruitment) in year *t* was estimated based on log average recruitment ($\bar{R}$) and annual recruitment deviations $Rdev_t$:

$$R_t = \exp\,(\bar{R} + \; Rdev_t)$$

$$Rdev_t \sim Normal(0, \sigma^R)$$

where $\bar{R}$ and $Rdev_t$ are parameters estimated by the model. The recruitment deviations ($Rdev_t$) were assumed to be normally distributed with a mean of 0 and standard deviation σ^R fixed at 0.5. For older ages *a* (*a* ∈ 3, 4, ... 11+) in year 1, population abundance was estimated by projecting cohorts forward from age 2 in year 1 minus (*a*-2) to their age in year 1, as follows.

For abundance-at-age *a* ∈ 3,4, ... A-1 in year 1, where A is the last age (11+):

$$N_{a,1} = \exp\,(\bar{R} + Rdev_a^{r1} - \sum_{b=2}^{b=a-1} \left(s_{b,1}Fi + M_{b,1}\right))$$

For abundance-at-age *A* in year 1:

$$N_{A,1} = \frac{\exp\left(\bar{R} + Rdev_A^{r1} - \sum_{b=2}^{b=A-1}\left(s_{b,1}Fi + M_{b,1}\right)\right)}{1 - \exp\left(-\left(s_{A,1}Fi + M_{A,1}\right)\right)}$$

where $N_{a,1}$ is abundance-at-age *a* in year 1, $Rdev_a^{r1}$ are recruitment deviations used to initialize abundance-at-age *a* in year 1, $s_{b,1}$ is fishery selectivity-at-age *b* in year 1, Fi is fully-recruited fishing mortality for initializing abundance-at-age in year 1, $M_{b,1}$ is natural mortality-at-age *b* in year 1, and *b* indexes age in the summations.

The model likelihood included penalty terms due to the priors on the recruitment deviations used to initialize abundance-at-age 2 in all years and at older ages in year 1:

$$0.5\sum_t (Rdev_t^2)/(\sigma^R)^2 + 0.5\sum_a (Rdev_a^{ri})^2/(s^R)^2$$

After recruitment to age 2, cohorts were projected forward in the usual manner:

$$N_{a,t} = N_{a-1,t-1} \times \exp\left(-Z_{a-1,t-1}\right)$$

$$Z_{a,t} = s_{1,a,t} \times F_t + M_{a,t}$$

where *a* and *t* index age and year, N denotes abundance, Z is total mortality, M denotes natural mortality, F is fully-recruited fishing mortality and $s_{1,a,t}$is selectivity-at-age *a* in year *t* in the fishery.

The objective function for the model included the following components:

- discrepancies between observed and predicted values of the age-aggregated biomass indices for the CPUE in the gillnet fishery and acoustic survey. Indices were assumed to be lognormally distributed with standard deviations estimated by the model. The model allowed for weighing of the biomass indices likelihood,
- discrepancies between observed and predicted PAA in the fishery, CPUE and acoustic survey catches. The PAA were assumed to follow a multivariate logistic distribution, which estimates data variances,
- a normal prior for the log M deviations,
- a normal prior for the initial values of log M,
- a normal prior for the log q deviations,
- a normal prior for the log recruitment deviations in years 1979 to 2021 and
- a normal prior for the log recruitment deviations used to calculate abundance-at-age in 1978.

Based on preliminary analysis of model fit to the age-aggregated indices, the CPUE biomass index likelihood was given a weight of one, while the acoustic biomass index likelihood was given a weight of three. Approximate 95% credible intervals were obtained for quantities estimated by the model based on 210,000 Markov chain Monte Carlo (MCMC) samples with the first 10,000 samples discarded and every 40th of the subsequent samples saved. Population estimates are posterior medians based on the MCMC sampling. Goodness-of-fit to indices was assessed by visual examination of estimated and observed aggregated biomass plots. Discrepancies between predicted and observed PAA were assessed by plotting the residuals by year and age, and looking for “blocking” through ages or years. Residuals were calculated in log space as observed values minus predicted values, minus the average difference by year. The sum of squares of the residuals were calculated for each index of abundance. Retrospective patterns in SSB estimates were assessed by plotting SSB time-series estimated by sequentially removing the terminal year of data, for 4 years (2018 to 2021).

SPRING SPAWNER RESULTS

Residual patterns indicated an acceptable fit of the model to the age-disaggregated CPUE and acoustic indices, without apparent blocking (Figure 14). Fits to the age-aggregated indices are good for both the CPUE and acoustic indices (Figure 15). The SSB retrospective pattern analysis doesn't show any progressive changes in a consistent direction as additional data are added to the model for the recent past (Figure 16).

Catchability to the CPUE index averaged about 0.0019 in the early 1990s, increasing to a peak of approximately 0.0062 in 2007-2008, and stabilizing at 0.0056 on average between 2017 and 2021 (Figure 17). Estimated CPUE index catchability increased as the SSB declined (Figure 18).

Natural mortality estimates for the age group 2-6 varied between 0.24 and 0.51 (between 21% and 40% annual mortality) over the time series (Figure 19). Estimates decreased slightly from 1978 to 1988, values were then relatively stable until 1995 when *M* increased to reach its highest values between 2000 and 2011. *M* decreased from 0.51 in 2009 to 0.27 in 2017, and has stayed at that level up to 2021. For the age group 7-11+, *M* increased gradually from 0.30 to 0.56 (between 26% and 43% annual mortality) between 1978 and 2006, before decreasing down to 0.47 (37% annual mortality) in 2009 (Figure 19). Starting in 2010, estimates sharply increased to reach a maximum of 1.05 (65% annual mortality) in 2018 before decreasing down to a mean value of 0.9 (59% annual mortality) in 2020 and 2021.

Before the last assessment, models used to show estimates to the beginning of the year (January 1) while assuming a constant natural mortality of 0.2 (18% annually), meaning that SSB declined by only 5% between January 1 and April 1 (when the spring herring fishery started). Since the last assessment, the model uses time-varying natural mortality estimates, which has been very high in recent years. It is therefore important to account for the timing of the fishery in the estimates of stock status. Since the fixed-gear fishery is restricted to a limited period of the year, and *M* is estimated to be very high in some years for some ages of Herring, April 1 was used to estimate SSB, calculate the reference points, and to make projections.

The limit reference point (LRP) in 4T Herring is $B_{recover}$, which is the lowest biomass from which the stock has been observed to readily recover. It is calculated as the average of the 4 lowest SSB estimates in the early 1980s (i.e., 1979-1982). Consequently, this value is model dependent. If the model changes, stock biomass may be re-scaled upwards or downwards. For this assessment, the LRP was estimated to be 46,340 t which is ~1.9% lower than the 47,250 t presented in the last assessment (Turcotte et al. 2021b).

The upper stock reference (USR) was determined in 2005 as an interim reference point (Chouinard et al. 2005). Calculations used a yield per recruit analysis assuming *M* = 0.2 and specific partial recruitment vectors to the fishery that would not apply for the current model and SSB estimates based on time varying *M*. Consequently, since the last assessment, the USR was scaled upwards by the same proportion as the LRP. The historical USR was 54,000 t of SSB, and the re-scaled USR is 129,994 t. The LRP and USR were calculated to April 1 to account for three months of natural mortality for both age groups. The fishing removal reference in the Healthy Zone was defined as $F_{0.1}$ and this assessment used the same value of 0.35 as used in previous assessments.

Estimated SSB increased from low levels in the early 1980s to highest levels in the mid-1980s to mid-1990s. SSB declined in the mid-1990s to reach the Critical Zone in 2002. SSB increased slightly until 2010, still in the Critical Zone, but then declined again and fluctuated around a mean value of 39,550 t until 2021. The MCMC estimates of April 1 SSB in 2020 and 2021 were 38,402 t (95% confidence interval: 23,771 – 69,893) and 35,626 t (95% CI: 22,012 – 66,950), respectively. The estimate for 2021 is 77% of the LRP. The probabilities that April 1 SSB was under the LRP (in the critical zone of the Precautionary Approach) were 23% in 2020 and 30% in 2021 (Figure 20). SSB has been declining since 2018.

Estimated recruitment (number of age 2 fish) was highest in the early 1980s, 1990 and 1993 (Figure 21). Recruitment has been relatively stable at lower values since 1993, with slightly higher values between 2006 and 2008. Recruitment declined to lowest values of the time-series after 2008 up to 2020, except a small peak in 2015. Recruitment rate (number of age-2 fish per kg SSB) was highest in the early 1980s and around 2005, and at its lowest between 1992 and 2000. Since 2006, recruitment rates have declined to low values except for a small peak in 2013 and another in 2019 (Figure 23).

Estimated abundances of recruits to the fishery (age-4 fish) were highest in the mid-1980s, 1992 and 1995 (Figure 22). The number of fishery recruits declined from 1995 to the lowest level observed in 2004 and has remained at a very low level since then (average 102.8 million Herring, Figure 22; Table 20). The 2020 MCMC median spawner (4+) abundance estimate is 284.5 million Herring (95% CI: 175.5 – 515.3), while the 2021 MCMC median is 250.2 million Herring (95% CI: 155.5 – 469.5) about 34.2% of the average spawner abundance in 1985 to 1995.

Estimated fishing mortality (abundance weighted $F_{6\text{-}8}$) was high in 1979-1980, decreased until 1984 and then increased steadily to 0.59 in 2004. *F* then decreased rapidly to a low value (0.03) in 2012 and has since remained at this low value. The lowest value was observed in 2021 (<0.02) (Figure 24; *F* values in Table 21). Fully recruited $F_{6\text{-}8}$ median MCMC estimate was 0.025 (95% CI: 0.013 – 0.041) and 0.018 (95% CI: 0.009 – 0.030) in 2020 and 2021, respectively (annual mortality of 2.5% and 1.8%).

The spring spawning Herring population trajectory with respect to SSB and fishing mortality levels is shown in Figure 25. The figure shows the Healthy, Cautious and Critical Zones of the Precautionary Approach. The removal reference in the Healthy zone for the spring spawning Herring stock is $F_{0.1}$ = 0.35. There are no harvest control rules in the cautious and critical zone for this stock. The provisional Precautionary Approach removal reference is thus provided but may not be as restrictive as formally developed harvest control rules. Fishing mortality exceeded the removal reference level in 28 of the 44 years of the time series. Fishing mortality exceeded the Precautionary Approach removal reference in all years after 1998 and was especially high during and soon after the SSB decline, between 1999 and 2007.

SPRING SPAWNER PROJECTIONS

The population model was projected forward to 2023, 2024 and 6 years forward to 2027 during the MCMC sampling of the joint posterior distribution of the parameters. This takes into account uncertainties in the parameter estimates. Projections were conducted at several levels of annual catch (0, 250, 500 and 1,250 t). Recruitment has been stable at low values in recent years, projections were thus conducted using random recruitment values of the last five years (2017-2021). Natural mortality for age group 2-6 has been stable for the last 5 years. For age group 7-11+, natural mortality increased in the last decade to highest values in 2018 and 2019 and slightly decrease in 2020 and 2021 (Figure 19). Projections were thus conducted using the average of the 2017-2021 *M* values for each age groups. Two year projections of SSB to April 1 and abundance weighted fishing mortality for ages 6 to 8 are shown in Figure 26 and Figure 27, and the probabilities of meeting various objectives are given in Table 22 for each catch level, for six years. Six year SSB projections are shown in Figure 28.

Projected April 1 2022 SSB is 28,835 t (95% CI: 17,255 – 55,772), keeping the stock in the Critical Zone of the Precautionary Approach.

Short term projections

At annual catches of 0, 250, 500 or 1,250 t in 2022 and 2023, SSB was expected to increase slightly from 2022 to 2023, and to remain stable from 2023 to 2024 (Figure 26, Table 22). The probability of an increase in SSB between April 1 2022 and April 1 2023 was between 64.5 and 68.5% at all catch levels. The probability of a greater than 5% increase in SSB between April 1 2023 and April 1 2024 was between 42.3% and 44.3% at all catch levels. For the short term projections, all catch levels (including no catch) resulted in under a 20% probability that SSB would exceed the LRP to reach the Cautious Zone in 2024. In the short term, there is no chance that the population would reach the USR by 2024.

Catches of 250 t would result in abundance-weighted ages 6 to 8 fishing mortality (*F*) values of 0.017 in 2022 (1.7% annual mortality) and 0.016 in 2023 (1.6% annual mortality), which correspond to lower values than *F* in recent years. Catches of 500 t would result in *F* values of 0.034 in 2022 (3.3% annual mortality) and 0.032 in 2023 (3.1% annual mortality), values similar to recent *F*. Catches of 1,250 t would result in an increase in *F* from recent years, with values of 0.085 in 2022 (8.1% annual mortality) and 0.083 in 2023 (8.0% annual mortality) (Figure 27, Table 22).

Long term projections

Six years projections in SSB show no changes from 2022 to 2027. By 2027, the probability of exceeding the LRP was between 15.8 and 20.4% at all catch levels, with SSB values ranging between 32,477 and 35,445 t (Figure 28, Table 22).

FALL SPAWNER COMPONENT ASSESSMENT

FALL SPAWNER MODEL

The fall spawning Herring component was assessed using a SCA model implemented using AD Model Builder (Fournier et al. 2012). This model estimates time varying CPUE catchability (*q*) and natural mortality (*M*) (Turcotte et al. 2021a).

Data inputs to the models included:

- fishery catches-at-ages 2 to 11+ by region from 1978 to 2021, in PAA,
- catch-per-unit-effort (CPUE) PAA index and age-aggregated CPUE biomass index by region from 1986 to 2021 (ages 4 to 10),
- PAA in experimental nets and the average nightly biomass from the spawning grounds acoustic survey by region from 2015 to 2021 (ages 3 to 9),
- fishery-independent acoustic survey PAA and age-aggregated biomass index from 1994-2021 (ages 2 and 3),
- multispecies bottom trawl survey (RV survey) PAA index and age-aggregated biomass index across the sGSL from 1994 to 2021 (ages 4 to 6),

- the proportion of gillnets with 2 ⅝ inch mesh and the relative selectivity to the gillnet fishery and the experimental nets by age, year and mesh size in each region,

Estimated model parameters include for each region (North, Middle, South), the numbers-at-age in the initial year (1978), yearly recruitment (average recruitment and yearly recruitment deviations in numbers of age 2 fish), selectivity parameters for each source of catch, initial fishing mortality (*F*) prior to 1978, initial *q* for each index and yearly *q* deviations for the CPUE index, initial *M* and yearly *M* deviations for two age groups (2-6 and 7-11+) and the observation error to the indices. All parameters were estimated on the log scale.

Time-varying natural mortality *M* and catchability to the CPUE gillnet fishery *q*, initial abundance in 1978 and recruitment in 1979 to 2021 were all estimated as described in the spring spawning Herring assessment models section, with parameters independently estimated for each region (North, Middle, South). The population was projected forward as described for the spring spawning Herring assessment, except that the beginning of the fishing season was set at August 1 instead of April 1. This SCA model has the same objective function components has described for the spring spawning Herring assessment model.

Size-at-age of 4T Herring has been declining since at least the mid-1980s. This is expected to result in changes in the selectivity-at-age of Herring to the gill-net fishery. Historically, two mesh sizes has been used in this fishery, 2 5/8” and 2 3/4”. Changes in selectivity-at-age to these mesh sizes were estimated as follows. First, relative selectivity-at-length was estimated for these mesh-sizes using data from the experimental nets (Surette et al. 2016). These nets consisted of a range of mesh sizes from 2” to 2 ¾”. Then selectivity-at-length was converted to relative selectivity-at-age in each year based on the age-length keys for each year. Annual age-length keys were derived from age samples collected from the commercial gillnet fishery from 1986 to 2021 and the experimental gillnet study from 2002 to 2021 during the months of August to October. Annual selectivity-at-age functions for the CPUE indices ($S_{p,t,a}^{Ca}$) were incorporated in the models as follows:

$$S_{p,t,a}^{Ca} = S_{p,a}^{C} * \left(\left(Pr_{p,t}^{258} * rS_{t,a}^{258} \right) + \left(1 - Pr_{p,t}^{258} \right) * rS_{t,a}^{234} \right)$$

where $S_{p,a}^{C}$ is a time-invariant population-specific logistic selectivity curve for the CPUE fishery, $Pr_{p,t}^{258}$ is the proportion of nets in year *t* and population *p* that are of mesh size 2 5/8”, $rS_{t,a}^{258}$ is relative selectivity to mesh size 2 5/8” for age *a* in year *t*, $rS_{t,a}^{234}$ is relative selectivity to mesh size 2 3/4” for age *a* in year *t*, and $S_{p,t,a}^{Ca}$ is selectivity to the CPUE fishery for age *a* in population *p* and year *t*. $S_{p,a}^{C}$was included in the equation to convert from the relative to absolute scale. A similar procedure was used to adjust selectivity of the multi-mesh experimental nets and the fishery for changes in size-at-age. For the experimental nets, selectivity-at-length was the average of the values for the seven mesh sizes used. For the commercial fishery, $S_{p,a}^{C}$ was estimated separately for three time periods to take into account changes in the proportion of mobile gear catches in the fishery.

Based on preliminary analysis of model fit to the age-aggregated indices and retrospective analysis, biomass indices likelihoods were given different weights. The CPUE biomass index likelihood was given a weight of 1, the biomass index from acoustic surveys on spawning grounds likelihood was given a weight of 4, the RV survey biomass index likelihood was given a weight of 1 and the acoustic survey biomass index likelihood was given a weight of 1. This improved fit to indices and reduced retrospective patterns. Approximate 95% credible intervals were estimated based on 210,000 MCMC samples with the first 10,000 samples discarded and every 40th of the subsequent samples saved. All population estimates are posterior medians based on the MCMC sampling. Goodness-of-fit was assessed as described for spring models, but retrospective analysis results was also assessed using Mohn's *rho* (Mohn 1999), using the icesAdvice R package (Magnusson et al. 2018).

FALL SPAWNER RESULTS

Some blocking was evident between observed and predicted fishery PAA (Figure 29). In the North region, residuals were mostly positive for ages 3 and ages between 8 to 11 between 1980 and 2008. Residuals were mostly negative for ages 4 and 5. Recent years showed larger negative residuals for younger and older ages, and positive residuals for ages 5 to 8. The Middle and South regions showed negative residuals in ages 5 and 6 between 1978 and 2006. Overall, larger residuals were observed for ages 1, 2, 10 and 11. Residuals were generally smaller for ages between 3 and 7.

Residual patterns for the CPUE indices indicated an adequate fit to these indices (Figure 30). There was a tendency to overestimate PAA 4 and 5 between 1995 and 2007. In recent years and for all regions, PAA were more likely to be underestimated for ages 6 to 9. However, there was no severe blocking of residuals.

Residual patterns for the experimental net PAA showed adequate fit for all three regions (Figure 31). There was a block of negative residuals for ages 5 to 7 from 2015 to 2017, with stronger values for the North region. Residuals were mostly positive for ages 3 to 4 in the last two years. The sum of squared residuals of experimental nets PAA was lower for the Middle region. No major residuals pattern is apparent in the RV survey and acoustic survey PAA (Figure 32).

Fits to the age-aggregated commercial gillnet CPUE indices were very good for all three regions, with predicted values consistent with the general trends in the indices (Figure 33). The fit to the age-aggregated RV index was good but showed that biomass values tended to be underestimated in early years of the index until 2015, and then slightly overestimated until 2021 (Figure 34). Similarly, the acoustic index biomass values tented to be underestimated until 2015. However the fit was very good until 2021 (Figure 34). The fit to the biomass index from acoustic surveys on the spawning grounds was good in the North and Middle regions. The fit was acceptable in the South region but predicted values showed less variation than observed values. Biomass values were underestimated in 2015 and 2021, and overestimated in 2018 (Figure 35).

Similar to previous assessments, retrospective patterns in SSB were apparent (Figure 36). The model showed important patterns in all regions. The retrospective patterns were in a constant negative direction as peels were removed from the analysis. In the North region Mohn's *rho* value was -0.31, while for the Middle region Mohn's *rho* value was slightly better at -0.27. The patterns were more severe in the South region, with a Mohn's *rho* value of -0.49. Total SSB showed a negative pattern with a Mohn's *rho* value of -0.36. However, the strength of the retrospective signal appears to be strongly driven by the last peel (year 2017), as other peels produce estimates that are more similar with each other.

Estimated changes in fully-recruited catchability to the gillnet fishery are presented in Figure 37. Catchability increased in all regions between 1986 and 2000 followed by a decrease until 2012 and a small but constant increase until 2021. The variation in estimated catchability values was greatest in the North region. Variation was intermediate in the Middle region, while variation in estimates was lesser and at low values in the South region. For both North and South regions, the catchability increased as SSB declined, but seemed to be less dependent of SSB in the South region (Figure 38). However, the South region has not seen as low SSB values (and associated high q values) as in the North and Middle regions.

For ages 2-6, estimated *M* was stable early in the time series at a level near 0.2 (North) or 0.4 (Middle, South) (Figure 39). *M* estimates then began to decline near 1990, reaching very low levels in recent years (around 0.05 in all regions). For the age group 7-11+, estimates from all regions were stables at around 0.15 until 1986 before rapidly increasing to reach maximum values of 1.1 (North), 0.8 (Middle) and 1.0 (South). Values then declined to reach 0.9, 0.5 and 0.6 in 2021 for the North, Middle and South regions, respectively.

This assessment is using a model estimating time-varying natural mortality which has been estimated to be very high in recent years. As a consequence, it is important to account for the timing of the fishery in the calendar year when estimating the stock status. Therefore August 1 was used to estimate SSB, calculate the reference points, and to make projections. This accounts for seven months of natural mortality in population estimates.

The limit reference point (LRP) in 4T Herring is $B_{recover}$, which is the lowest biomass from which the stock has been observed to readily recover, calculated here as the average of the 4 lowest August 1 SSB estimates at the beginning of the time series (i.e., 1978-1981). Consequently, this value is model dependent. If the model changes, stock biomass may be re-scaled upwards or downwards. For this assessment, the LRP was estimated to be 53,154 t which is ~0.6% higher than the 52,825 t presented in the last assessment (Turcotte et al. 2021b).

The upper stock reference (USR) was determined in 2005 as an interim reference point (Chouinard et al. 2005). Calculations used a yield per recruit analysis assuming *M* = 0.2 and specific partial recruitment vectors to the fishery, methods that would not be adequate for the current model and SSB estimates based on time varying *M*. Consequently, since the last assessment the USR is estimated as being equivalent to 60% of the maximum August 1 SSB of the time series. For this assessment the USR is then estimated to be 307,000 t. The fishing removal reference in the Healthy Zone was defined as $F_{0.1}$ and this assessment used the same value of 0.32 as used in previous assessments.

Estimated SSB trends were mostly similar between regions (Figure 40). In the North region, SSB increased from lowest values in 1980 to high values from the mid-1980s to the early 1990s, before declining to a moderate level in the mid-90s. Values then increased slightly between 1999 and 2007, before rapidly reaching maximum of the time series between 2008 and 2013. SSB has since been declining rapidly between 2014 and 2021 (Table 23 and Table 24). In the Middle region, estimated SSB increased gradually from 1980 to the late 2000s, but has since declined consistently from 2010 to 2021 (Table 25 and Table 26). SSB in the South region increased rapidly from 1980 to the mid-1980s. SSB then decreased to moderate levels in the late 1990s, before increasing again until early 2010s. SSB then rapidly declined to low level by 2021 (Table 27 and Table 28). Trends of total SSB was similar to the one observed for North region, with an increase from lowest levels in 1980 to the mid-80s. Values then stayed stable until the mid-90s and then declined to moderate levels in the late 90s. SSB then increased to reach a maximum in 2011, before rapidly declining until 2021 (Table 29 and Table 30).

The MCMC estimates of August 1 SSB in 2020 and 2021 were 168,849 t (95% CI: 140,076 – 211,198) and 144,007 t (95% CI: 116,994 – 185,443), respectively. The estimate for 2021 was 171% of the LRP. The probabilities that August 1 SSB was under the LRP (in the Critical Zone of the Precautionary Approach) were 0% in 2020 and 0% in 2021. The probabilities that August 1 SSB was above the USR (in the Healthy Zone of the Precautionary Approach) were 0% in 2020 and 0% in 2021. SSB has been declining since 2011.

Until the early 1990s, the recruitment in all three regions was generally very low and without trend, with the exception of short pulses for the South region and, to a lesser extent, for the North region in 1982, 1985 and 1989. During that same time period, the contribution of the South region to the sGSL Herring recruitment was the highest. However, starting in 1993, the recruitment in the North region rapidly increased and reached higher values than those estimated for the other regions. Over the time series, the recruitment in the Middle region has been consistently poor. The total recruitment peaked in 2006 and has since declined rapidly to the lowest values of the time series, with the exception of a small pulse in 2020 (Figure 41).

Variation in estimated abundance of herring aged 4 years and older (4+) largely reflected variation in recruitment to age 4 (Figure 42). In all regions and at the scale of the sGSL, age-4 recruitment remained at low levels in most years until the late 1990s and then improved to reach its maximum in the late 2000s but has since declined, reaching very low levels in 2020 and 2021, comparable to the levels in the mid-1980s.

Estimated recruitment rates (age 2 recruit abundance divided by the SSB producing them) were high around 1980 and from the mid-90s to the early 2000s across regions. Rates started declining in 2004 to reach values comparable to or lower than the lowest values of the time series. Uncertainty was high in 2021 recruitment rate estimates (Figure 43).

The selectivity to the gillnet fishery has been declining over the years and for all ages (Figure 44). As size-at-age declined in the 1990s, selectivity increased for the oldest ages, which translate into a sharp increase in selectivity with age. Over the years, as size-at-age declined further, selectivity-at-age declined but the selectivity curve did not plateau at older ages. For the experimental nets, the selectivity-at-age was flat-topped and varied little over time despite the declining size-at-age. This reflected the range of mesh-sizes occurring in these nets. Because the fishery catches included catches by purse seines in addition to gillnets, fishery selectivity-at-age could not be based on the estimates of gillnet selectivity obtained from the experimental nets. Instead, logistic selectivity functions were used, with separate estimates obtained for three time blocks. In most cases, selectivity plateaued between ages 4 and 8, with the plateau generally occurring at an older age in recent years when size-at-age was relatively low.

At the scale of the sGSL, estimated abundance-weighted fishing mortality for ages 5 to 10 ($F_{5\text{-}10}$) was at its highest (average value of 0.81, 55.5% annual mortality) in the early 1980s before declining to stable low levels (average of 0.27, 23.7% annual mortality) between 1984 to 1993 (Figure 45, Table 31, Table 32, Table 33, and Table 34). Starting in 1994 $F_{5\text{-}10}$ increased to a mean value of 0.61 (45.7% annual mortality) until 2003 before rapidly declining to reach the lowest estimated average value of 0.09 in 2020 and 2021 (8.6% annual mortality). Both North and Middle regions had similar trends and values, with the exception of the early 1980s when the Middle peaked at a mean value of 1.04 (64.7% annual mortality). Since 2018, $F_{5\text{-}10}$ for the North region showed a positive trend moving from a value of 0.09 in 2018 (8.6% annual mortality) to a value of 0.15 in 2021 (13.9% annual mortality). Meanwhile for the Middle region the trend is negative moving from a value of 0.10 in 2019 (9.5% annual mortality) to 0.06 in 2021 (5.8% annual mortality). Overall, the South region had the lowest estimated $F_{5\text{-}10}$ of all regions, but showed similar patterns with a mean value of 0.05 (5.1% annual mortality) for the period 2017 to 2021.

The fall spawning Herring population stock status and its trajectory with respect to SSB/USR and fishing mortality ($F/F_{0.1}$) levels is shown in Figure 46, with the Healthy, Cautious and Critical Zones of the Precautionary Approach. The removal reference in the Healthy Zone for the fall stock is $F/F_{0.1}$ = 1.0. Fishing mortality exceeded the Precautionary Approach removal reference from 1978 to 1983, in 1987, 1990, from 1994 to 2007 and since 2020.

FALL SPAWNER PROJECTIONS

The population model was projected forward to August 1 2023 and August 1 2024 during the MCMC sampling of the joint posterior distribution of the parameters. This takes into account uncertainties in the parameter estimates. Considering that the recruitment has been stable at low values over the past 5 years, projections were conducted using random recruitment deviations in the last five years (2017-2021). Natural mortality for age group 2-6 has been stable for the last 5 years. For age group 7-11+, natural mortality increased in the last decade, reached the highest values in 2015-2016, before decreasing slightly in 2020-2021. Projections were conducted using the average of the 2017-2021 *M* values for each age group. Projections were conducted at annual catch options of 0 to 18,000 t in increments of 2,000 t. Two year projections of August 1 SSB and $F_{5\text{-}10}$ are shown in Figure 47 and Figure 48. The probabilities of meeting various objectives are given in Table 35 for each catch level, and for six years. Six years SSB projections are shown in Figure 49.

Under a 0 catch scenario, predicted August 1 SSB in 2022 was 172,426 t (95% CI: 125,807 – 260,255), keeping the stock in the Cautious Zone of the Precautionary Approach. For 2023, predicted August 1 SSB was 182,029 t (95% CI: 114,796 – 327,860).

Short term projections

Probabilities of increasing SSB by 2024 decreases slightly as catch increases. SSB is expected to increase slightly from 2022 to 2023 at catch levels below 10,000 t (probabilities of ≥ 5% increase in SSB between 50 and 54%), and decrease at all catch levels from 2023 to 2024 (probabilities of ≥ 5% increase in SSB between 35 and 40%) (Figure 47; Table 35). At the target catch level in 2021 (~12,000 t), the probabilities of a ≥ 5% increase in SSB between 2022 and 2023 are 49%, and 37% between 2023 and 2024. At a catch level of 2,000 t, the probabilities of a ≥ 5% increase in SSB between 2022 and 2023 are 54%, and 40% between 2023 and 2024.

Probabilities of SSB being in the Critical Zone (under the LRP) by 2023 and 2024 were 0% for all catch options (Table 35). In the short term, probabilities of SSB being in the Healthy Zone (SSB > USR) by 2024 were between 1 and 2% for all catch options.

The 2022 median value of $F_{5\text{-}10}$ at all catch levels increased from 0.01 (2,000 t) to 0.13 (18,000 t). For 2023, the increase ranged from 0.01 (2,000 t) to 0.14 (18,000 t) (Figure 48, Table 35). At the target 2021 landings (~12,000 t), projected $F_{5\text{-}10}$ is 0.09 (8.6% annual mortality) in both 2022 and 2023.

Long term projections

Six-year SSB projections show a small increase until 2023 followed by a sharp decline until 2027 for all catch options (Figure 49). The probabilities that the stock will reach the Healthy Zone (above the USR) under all catch options is 1%. By 2027, at all catch levels, the probability of SSB being in the Critical Zone (under the LRP) were 0% (Table 35).

Predicted SSB in 2027 ranged from 132,957 t and 156,315 t, depending on annual catch options.

PREDATOR PREY INTERACTIONS

Abundances of a number of the key predators of Herring in the sGSL have changed during the time series (Figure 50). Atlantic Cod collapsed in the early 1990s and have declined further since then. Grey Seals abundance has increased continuously over the time series. Northern Gannets abundance increased gradually between 1978 and 2009, and then reached a plateau at a slightly lower level. Atlantic Bluefin Tuna in the sGSL have increased about five-fold beginning in the mid-2000s and reached a plateau since 2010. White Hake abundance declined in the early 1990s and remained at low levels ever since.

The correlation matrix between predators abundance and Herring natural mortality estimates showed that the decrease in Cod abundance correlated with the decline in younger (age group 2-6) fall herring natural mortality (Pearson's r = 0.92). Grey Seals and Tuna abundance correlated with the increase in older (age group 7-11+) spring (Pearson's r = 0.85 and 0.68, respectively) and fall (Pearson's r = 0.94 and 0.91, respectively) Herring natural mortality. Northern Gannet abundance correlated with older fall spawning Herring natural mortality (Pearson's r = 0.83), and to a lesser extent, with spring spawning Herring natural mortality (Pearson's r = 0.52 and 0.66 for both age groups) (Figure 51).

DISCUSSION AND CONCLUSION

SPRING SPAWNING HERRING

As with previous 4T spring spawning Herring assessments, a model for that allowed catchability to the fishery to vary over time was used (Swain 2016, McDermid et al. 2018, Turcotte et al. 2021b). Estimated catchability increased from the 1990s to 2006 before stabilizing at a slightly lower level. The variation in fishery catchability (q) appeared to be density dependent, which has been observed in other Herring stocks (Winters and Wheeler 1985). Fishery catchability is often expected to increase as population size decreases (Paloheimo and Dickie 1964; Winters and Wheeler 1985; Swain and Sinclair 1994; Rose and Kulka 1999). This is expected to occur because the area occupied by a stock is expected to decrease as stock size decreases (MacCall 1990) and fish harvesters target fish aggregations (e.g., spawning aggregations). Thus, the proportion of the stock removed by a unit of fishing effort is expected to increase as a declining stock becomes increasingly concentrated in a smaller area. In a gillnet fishery, increased catchability at low population size can result in hyperstability in the CPUE–biomass relationship. Finally, catchability by fisheries is expected to increase over time due to technological improvements and improvements in fishing tactics.

The population model used for this stock allows natural mortality to vary over time. Potential sources of natural mortality include: unreported catches, disease and predation. Unreported catches of Herring probably mostly come from the bait fisheries, and discards at sea. Catches in bait fisheries were historically not accounted for in the assessments of either spring or fall spawning Herring components. Catches in these fisheries are meant to be recorded in harvester logbooks but compliance with the requirement to complete and return logbooks to DFO is low. Catches of Herring in the bait fishery are expected to be much lower than landings in the commercial fishery. Since 2020, bait removals are under a mandatory self-reporting management measure but the level of compliance is unknown. Nonetheless, this unaccounted fishing mortality is now accounted for in the natural mortality estimates. Disease mortality is expected to be relatively small in 4T Herring, as no disease-related mortality event was recorded in the time period covered by the assessment.

Spring spawning Herring recruitment has been demonstrated to be driven by environmental effects, while recruitment variations are not driven strongly by spawning biomass (Brosset et al. 2018; Turcotte 2022), findings that were similar for other Herring stocks (Szuwalski et al. 2019). The Gulf of St. Lawrence is seeing a trend towards warmer waters, shorter duration of ice season, lower ice volume (Galbraith et al. 2021), changes in primary and secondary production phenology, a decrease of cold-water copepods abundance and an increase of warm water copepods abundance (Blais et al. 2021). Both the sea surface temperature of the sGSL and the spring spawning Herring recruitment abruptly shifted from a cold water/high recruitment regime (1978-1991) to a warmer water/low recruitment (1992-2017) regime in the early 1990s (Turcotte 2022). By fitting stock recruit relationships to the whole time series, and to the distinct time-series defined by a regime shift analysis, it was shown that the expected number of recruits per SSB is lower in the recent period than in the beginning of the period covered by the assessment (Turcotte 2022). The spring spawning Herring stock is therefore less likely to rebuild in the current regime than it was in the former regime. This is consistent with a model suggesting that cold environmental conditions favour spring spawners, whereas warm conditions favour fall spawners in Western Atlantic Herring stocks (Melvin et al. 2009). Even if current natural mortality levels were to remain, if recruitment was to increase to levels observed in the high recruitment regime, the stock would rebuild (Turcotte 2022), indicating that low recruitment is the main process keeping this stock in the critical zone.

Variation in Herring recruitment in the GSL is driven by environmental conditions, and the specific environmental drivers differ among areas (Brosset et al. 2018). In the sGSL, spring spawning Herring recruitment variations are explained by changes in three zooplankton abundance and/or composition variables; the abundance large calanoid copepods early in the summer, the ratio of *Calanus hyperboreus* copepodite stage IV/copepodite stage I-IV abundance in the month of June and the sum of the annual abundances of various zooplankton species that are typical of warmer water (Turcotte 2022). The variables are hypothesized to reflect the abundance of prey items for larvae, the timing of their availability for the larvae, and the quality of the food items available to Herring larvae, as a result of water temperature effects on the zooplankton community. This model could be used in future assessments to predict the spring spawning Herring recruitment two years in advance, a process that is actually not well informed by the data inputs in the current form of the assessment.

The decline in spring spawning Herring SSB in the 1990s and the following lack of recovery can be explained by the following processes. The number of recruits produced after the maximums in 1990 and 1993 reached stable low levels starting in 1994. The decrease in SSB started in 1994 and reached a minimum value in 2004, under the LRP. At the same time, fishing mortality increased from 0.20 in 1997 to 0.59 in 2004. Fishing effort was reduced after 2004 and fishing mortality sharply declined until 2012 and has since continued to decline at the lower rate since then. Recruitment increased slightly between 2002 and 2008, resulting in a slow increase in SSB. However, natural mortality increased rapidly since 2010, and recruitment decreased again after 2008, driving another decrease in SSB. Recruitment was slightly variable at low levels in the last 5 years, and natural mortality was highest, keeping SSB low. Moreover, the decline in weight-at-age over the time-series also contributed to the decline in SSB.

Under the current high temperature/low recruitment regime, reduced weight-at-age and high natural mortality conditions, this stock is not expected to recover in the short or the long term. Reducing fishing mortality slightly decreases the probabilities of SSB to decline during projections. This stock has been in the Critical Zone since 2002. The Precautionary Approach framework states that management actions must promote stock growth and removals by all human sources must be kept to the lowest possible level (DFO 2006).

FALL SPAWNING HERRING

As in the previous assessment, this assessment used a population model that allowed for the estimation of time-varying *q* and natural mortality (*M*), and treated fall spawning Herring as independent populations in three spawning regions (Turcotte et al. 2021b). Large changes in the abundance of predators of Herring have occurred in the sGSL over the past 30 years. Therefore it is expected that natural mortality of Herring have varied over time because of these changes. The population model estimated changes in *M* that are consistent between populations and with the observed changes in predator abundance.

As seen in the retrospective analysis pattern, SSB is underestimated every year. Mohn's *rho* negative value was similar in the North and Middle regions and the Total SSB. The bias towards

SSB underestimation can then be expected to be similar over these regions and overall. The South region showed a stronger retrospective pattern, but mostly because of the last peel from the analysis. When considering the frequency of the assessment (every two years), the scale of the retrospective pattern is less of a concern, as estimates from the terminal year and each of the two previous years are quite similar. As in the last assessment, the SSB retrospective pattern may be a consequence in the delay of estimating changes in *M* because of the penalty on non-zero *M* deviations. As new years of data supporting a change in *M* are added to the model, the penalty is out-weighted by the data, and *M* is allowed to change, generating a change in SSB. The addition of the spawning grounds survey biomass indices to the population model should reduce this retrospective pattern as years of data will be added in the future, as this index is believed to be the most representative of the population trends of all indices.

The decline in fall spawning Herring total SSB in the last decade can be explained by the following processes. The number of age-2 recruits produced after the high value in 2006 declined rapidly to reach the lowest values of the time series from 2016 to 2019 and then again in 2021. The decrease in SSB started in 2011 and has been constantly declining until 2021. At the same time, fishing mortality remained stable as SSB decreased, and natural mortality increased rapidly since the mid-2000s to reach maximum values in the mid-2010s. As few fish enters the SSB, and more fish are removed by natural mortality than ever in the time series, with constant fishing mortality, SSB can only decrease.

Variability in fall Herring recruitment has been correlated with sea surface temperature and zooplankton community composition. High recruitment occurs in warm water conditions and higher abundance of copepods typical of these conditions (small copepods such as *Acartia sp.*). Fall spawning Herring recruitment is especially sensitive to the timing of multiple environmental variable that did not align in recent years to produce strong recruitment events (Brosset et al. 2018), explaining the decline in age-2 recruitment. 4T fall spawning Herring recruitment rate has been at extremely low values from 2014 to 2019 but was slightly higher in 2020 and 2021, although both higher values are associated to larger uncertainties. The occurrence of future environmental conditions for successful fall spawning Herring cannot be predicted. Hence, prospects for this stock to rebuild are uncertain. As the sGSL ecosystem is changing, the synchronicity of the required zooplankton abundance and quality with the timing of the release of Herring larvae is unpredictable.

As a consequence of low productivity, reduced weight-at-age, and high natural mortality, exploitation of this stock should assert caution until high recruitment is observed for consecutive years. Until high recruitment events occur, the decline in SSB is more likely to continue. As the stock is deep in the Cautious Zone, the Precautionary Approach framework states that actions should promote stock rebuilding towards the Healthy zone (DFO 2006). For the first time since 2007, the stock has moved above the provisional removal reference ($F/F_{0.1}$) of the PA, indicating a state of overfishing that could prevent any growth over the short and long term. Projections have showed that reducing fishing mortality would slightly reduce the probabilities of a decline for the 2022 and 2023 seasons. The annual catch levels offering the greatest probabilities of increasing SSB in the short and long term are 0, 2,000 and 4,000 t. Long-term projections do not show any increase of SSB by 2027, but considering that the model have proven to slightly underestimate SSB (Turcotte et al. 2021b), and therefore provide pessimistic long-term projections, the projected decline in SSB until 2027 should be interpreted with caution. As the stock is assessed on a two-year cycle, short-term projections are still the best option to provide the most reliable projections for sound management measures.

NATURAL MORTALITY AND ECOSYSTEM INTERACTIONS: SPRING AND FALL HERRING

Natural mortality estimates of both stocks are expected to be mostly predation driven. Herring is an important pelagic prey species for numerous predators in the sGSL including Grey Seal (*Halichoerus grypus;* Hammill and Stenson 2000; Hammill et al. 2007, 2014), seabirds (mostly Northern Gannets (Cairns et al. 1991)), cetaceans (Fontaine et al. 1994; Benoît and Rail 2016), Atlantic Cod (*Gadus morua*; Hanson and Chouinard 2002), White Hake (*Urophycis tenuis*; Benoît and Rail 2016) and Atlantic Bluefin Tuna (*Thunnus thynnus*; Pleizier et al. 2012; Varela et al. 2020; Turcotte et al. 2021a). Of these major predators, Atlantic Cod, Grey Seals, Atlantic Bluefin Tuna and Northern Gannets have undergone large changes in abundance in the sGSL in the last decades. Hence, Herring natural mortality was expected to have changed over time.

Grey Seals are the main pinniped predators of marine fish in the sGSL (Hammill and Stenson 2000). The increase in the abundance of Grey Seal in the sGSL has been linked with important increases in the mortality of several demersal fish stocks that are declining in abundance or failing to recover from fishery-induced collapse (Benoît et al. 2011; Swain and Benoît 2015; Neuenhoff et al. 2019).

Evidence from genetic studies revealed that there is mixing of both Atlantic Bluefin Tuna stocks in the sGSL (Hanke et al. 2017). The Eastern and Western Atlantic Bluefin Tuna SSB both declined in the 1970s and remained low until the 2000s, before increasing sharply in the late 2000s and reaching a plateau to 2018. The eastern stock SSB remained stable to 2020, but the western stock SSB has showed a decline (ICCAT 2020). In the sGSL, Atlantic Bluefin Tuna has showed an increasing occurrence on fall Herring spawning grounds between 2002 and 2012, and could be the biggest Herring consumer in the sGSL (Turcotte et al. 2021c). The recent decline in older Herring (ages 7-11+) natural mortality could the potentially be explained by the recent decline in the Western Atlantic Bluefin Tuna stock SSB. Interestingly, the Atlantic Bluefin Tuna relative index of abundance in the sGSL fishery data did not show a decline in recent years (Hanke 2021), but the Atlantic Bluefin Tuna index of abundance from the Herring acoustic survey did (Minch and Gillespie 2021).

Abundance of Cod ages 5+ was high in the late 1970s before the stock collapsed in the late 1980s and early 1990s, and continued to decline since then (Neuenhoff et al. 2019). Spawning stock biomass of the sGSL White Hake population declined rapidly in the late 1980s and the 1990s and has remained low since then (Rolland et al. 2022). Northern Gannets (*Morus bassanus*), Double-crested Cormorants (*Phalacrocorax auritus*) and Great Cormorants (*Phalacrocorax carbo*) abundance also increased in the sGSL between the 1970s and the 2000s, and all are Herring consumers (Benoit and Rail 2016). Information on consumption by cetaceans was very scarce.

For both Herring stocks, the increase in natural mortality for the age group 7-11+ correlated with the increases in the abundance indices of Grey Seal, Atlantic Bluefin Tuna and Northern Gannets, the most important Herring consumers in the sGSL (Benoit and Rail 2016, Turcotte et al. 2021c). Changes in natural mortality of younger Herring (ages 2-6) over the time-series were of a lesser magnitude, but fall spawning Herring changes in M correlated with decline in Atlantic Cod and White Hake abundance. Further analysis of predator abundance, spatial distribution, size distribution, diet and functional response of predators to prey will be necessary to quantify the effects of the different predators on spring and fall spawning Herring natural mortality.

The general decline in both sGSL Herring stocks not only has negative impacts on the fishery, but is likely to have negative impacts on the ecosystem as well. Forage fish feed on zooplankton and phytoplankton and are important conduits of energy transfer in food webs, making them key components of ecosystems. For many predators, forage fish constitute a substantial percentage of their diet, possibly making them vulnerable to reductions or fluctuations in forage fish biomass (Pikitch et al. 2014). In recent decades, Herring comprised 20 to 50% (up to 90%) of sGSL Atlantic Cod diet, depending on Cod size and changes in diet as a result of changes in the abundance of Herring and other prey (Benoit and Rail 2016). Atlantic Bluefin Tuna diet in the sGSL is estimated to be 50% Herring, and Tuna is also targeted by a commercial and a recreational fishery. The Herring proportion in Grey Seal diet is region, season and sex dependent, but varied between 2 and 25% (Benoit and Rail 2016). There is very limited information available to estimate the possible consumption of Herring by cetaceans in the sGSL, but White-Sided Dolphins, Harbour Porpoises and Minke Whales are known to be feeding on 4T Herring (Benoit and Rail 2016). Clupeids (mainly Atlantic Herring) can constitute between 10 and 92% of the diet of Northern Gannets in the GSL (Benoit and Rail 2016). As Herring can constitute important proportions of the diet of many predators, the low biomass of both 4T Herring stocks is expected to can have negative impacts on several components of the ecosystem.

SOURCES OF UNCERTAINTY

Uncertainty in SSB estimates have been reduced since the adoption of the new SCA population models for both spring and fall spawning stocks. Natural mortality estimation accounts for disappearing age classes through time that cannot be explained by fishery removals, and allows for recruitment estimation that better fits the data. Accurate natural mortality, recruitment, and SSB estimates are therefore crucial for projections accuracy, providing more realistic outcomes of management measures (Total Allowable Catch).

The estimation of time-varying natural mortality in the model generated some retrospective patterns in SSB, while seemingly less important for the recent years. Incorporating the spawning grounds acoustic survey data the model, as suggested in the last assessment, seem to have lessen such patterns. The spawning grounds acoustic survey started in 2015 and now offers six years of data. This industry collaborative survey provides an average nightly biomass estimate on each spawning ground, surveyed up to five times during the spawning season. Due to its large spatial and temporal coverage of biomass dynamics on all major spawning grounds, the addition of this data to the population model have provided a better-informed biomass index. Age-composition for the index was obtained from the experimental nets survey, sampled at the same locations at the same frequency.

The retrospective pattern in the model is a source of uncertainty. As Mohn's *rho* is mostly similar between the three regions (while slightly stronger in the South), the scale of the bias towards SSB underestimation can be expected to be similar. Retrospective analysis and Mohn's *rho* should be investigated every year to detect changes in the direction and scale of patterns. A negative value for the rho statistic means that the quantity being evaluated is consistently being underestimated (when compared with the estimate from the full time-series) and is potentially less problematic than overestimation in terms of sustainability (Hurtado-Ferro et al. 2015).

The modelling approach considers the dynamics of fall spawning Herring in three regions. The dynamics are modelled independently among regions and assume closed populations. This is a strong assumption that can have consequences on region-specific estimates of abundance and dynamics. Empirical evidence for spawning bed fidelity has been documented in fall spawning Herring based on tagging studies. Nevertheless, elemental analyses of otolith structures did not detect region-specific differences among fall spawners despite showing distinct differences between spring spawners and fall spawners in the sGSL. Genetic research has been unable to identify population-level differences between regions for fall spawners (Lamichhaney et al. 2017).

The weight-at-age of Herring has declined and remains at near record low levels. The causes of these declines in weight-at-age and the consequences to recruitment rate are unknown.

Catches of spring and fall spawning Herring in bait fisheries are presently accounted for in the assessments through natural mortality estimates, but the proportion of unreported catch, disease, or predation mortality cannot be disentangled. Catches in the bait fisheries are meant to be recorded in harvester logbooks but compliance with the requirement to complete and return logbooks to DFO is low. Catches of Herring in the bait fishery are expected to be much lower than landings in the commercial fishery, nonetheless this constitutes a source of uncertainty in the total fishing mortality. We expect that for the next assessment, the development of a mandatory electronic logbook will increase reporting of bait fishery.

Fishery dependent indices, such as the commercial gillnet CPUE indices, may not be proportional to abundance due to changes in catchability over time. On one hand, catch rates can remain high despite decreases in abundance (increased catchability) due to contractions in stock distribution and targeting of aggregations by fishing fleets, and due to improved fishing technology and fishing practices. On the other hand, catch rates can be negatively affected by boat limits, saturation of nets at high abundance and closure of prime fishing areas that redirect fishing effort to other locations. Catch rates calculated on the basis of realized landings and available fishing effort information would be subject to such effects. The estimation of time-varying catchabilities in the spring and fall spawning Herring assessments accounts for some of the effects listed above.

The commercial CPUE calculations are subject to uncertainty. The estimates are mostly based on regional average seasonal values of fishing effort data (number of nets, number of hauls, and net length of gillnets) from the telephone survey and not trip-specific information. Trips with no catch are not documented prior to 2006 and therefore not incorporated in the effort data. A CPUE index for this time period should be calculated with the null tows for comparison with the traditional CPUE index. No information is collected on the soak time of nets. There are also potential inconsistencies in the reporting of effort data within and among regions and seasons.

The fishery-independent acoustic survey has been conducted at the same time each year and over the same number of weeks. Inter-annual variability is expected but it is unlikely that the catchability has changed over time, given that the survey spans more than three weeks and covers a large area. Such variability is common among annual surveys, and also applies to the multispecies bottom trawl survey conducted in September. Changes in the spatial distribution of herring over time are also not expected to have biased the biomass estimates from the acoustic survey because the transects extend well beyond the depths preferred by herring and the spatial coverage is broad enough to encompass several environments historically inhabited by herring.

Reference points, especially the USR and the F0.1 removal reference in the Healthy Zone, will be re-visited for future assessments. This work will occur in the development of the rebuilding plans of both stocks. For this assessment, USRs were scaled to be similar to what was used in previous assessments. As neither stocks are headed for the USRs in the short or long-term, the uncertainty around the appropriateness of the USRs and F0.1 is not expected to have a big impact on the assessment and risk analysis of catch options.

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TABLES

Table 1. Landings (in tons) of 4T Herring in the spring and fall fisheries by gear (fixed and mobile) and spawning group (SS=spring spawners and FS=fall spawners). TAC allocations and target catches are also provided, as TAC is higher than the targeted catch decision due to historical shares between regions.

		4T catch								
		Spring fishery		Fall fishery						
Year	Spawning group	Fixed	Mobile	Fixed	Mobile	Annual 4T catch	Annual 4Vn catch	Total catch 4TVn	TAC 4TVn	Target catch
1981	SS	6,287	20	293	589	7,189	822	-	-	-
	FS	1,212	1	10,932	2,599	14,744	2,594	-	-	-
	Total	7,499	21	11,225	3,188	21,933	3,416	25,349	*19,000*	-
1982	SS	5,692	57	292	574	6,615	834	-	-	-
	FS	230	5	12,691	2,003	14,929	2,674	-	-	-
	Total	5,922	62	12,983	2,577	21,544	3,508	25,052	*18,000*	-
1983	SS	7,655	17	423	1,466	9,561	1,307	-	-	-
	FS	865	2	13,415	2,023	16,305	2,672	-	-	-
	Total	8,520	19	13,838	3,489	25,866	3,979	29,845	*25,000*	-
1984	SS	4,434	3	303	895	5,635	1,376	-	-	-
	FS	847	1	15,672	1,384	17,904	2,549	-	-	-
	Total	5,281	4	15,975	2,279	23,539	3,925	27,464	*22,500*	-
1985	SS	6,720	0	1,287	2,154	10,161	1,082	-	-	-
	FS	498	0	22,420	4,867	27,785	2,388	-	-	-
	Total	7,218	0	23,707	7,021	37,946	3,470	41,416	*36,000*	-
1986	SS	7,154	0	3,181	6,773	17,108	2,782	-	-	-
	FS	1,397	0	36,710	4,143	42,250	1,568	-	-	-
	Total	8,551	0	39,891	10,916	59,358	4,350	63,708	*47,600*	-
1987	SS	10,419	0	2,538	9,460	22,417	1,446	-	-	-
	FS	1,340	0	49,585	4,273	55,198	917	-	-	-
	Total	11,759	0	52,123	13,733	77,615	2,363	79,978	*77,000*	-
1988	SS	9,166	0	2,843	12,036	24,045	1,766	-	-	-
	FS	3,719	0	38,367	5,496	47,582	806	-	-	-
	Total	12,885	0	41,210	17,532	71,627	2,572	74,199	*83,100*	-
1989	SS	9,062	0	1,691	8,778	19,531	1,302	-	-	-
	FS	2,032	0	32,157	5,492	39,681	815	-	-	-
	Total	11,094	0	33,848	14,270	59,212	2,117	61,329	*91,100*	-
1990	SS	4,083	1	2,146	6,756	12,986	3,088	-	-	-
	FS	818	0	59,138	3,551	63,507	1,623	-	-	-
	Total	4,901	1	61,284	10,307	76,493	4,711	81,204	*91,100*	-
1991	SS	12,073	5	178	3,319	15,575	1,902	17,477	*21,000*	-
	FS	817	13	26,965	4,741	32,536	2,888	35,424	*70,100*	-
	Total	12,890	18	27,143	8,060	48,111	4,790	52,901	*91,100*	-
1992	SS	12,291	641	322	3,327	16,581	493	17,074	*21,000*	-
	FS	186	478	32,760	3,789	37,213	3,735	40,948	*70,100*	-
	Total	12,477	1,119	33,082	7,116	53,794	4,228	58,022	*91,100*	-
1993	SS	14,643	1,526	780	3,741	20,690	434	21,124	*21,000*	-
	FS	538	1,190	22,319	2,487	26,534	3,517	30,051	*85,000*	-
	Total	15,181	2,716	23,099	6,228	47,224	3,951	51,175	*106,000*	-
1994	SS	18,498	883	481	3,357	23,219	568	23,787	*21,000*	-
	FS	517	3,049	53,333	3,603	60,502	2,681	63,183	*85,000*	-
	Total	19,015	3,932	53,814	6,960	83,721	3,249	86,970	*106,000*	-

Year	Spawning group	4T catch: Spring fishery: Fixed	4T catch: Spring fishery: Mobile	4T catch: Fall fishery: Fixed	4T catch: Fall fishery: Mobile	Annual 4T catch	Annual 4Vn catch	Total catch 4TVn	TAC 4TVn	Target catch
1995	SS	15,137	950	2,102	7,671	25,860	470	26,330	*21,000*	-
	FS	836	875	54,161	7,595	63,467	3,674	67,141	*85,000*	-
	Total	15,973	1,825	56,263	15,266	89,327	4,144	93,471	*106,000*	-
1996	SS	15,409	441	1,365	3,977	21,192	1,033	22,225	*15,114*	-
	FS	668	1,466	44,408	4,044	50,586	3,234	53,820	*58,749*	-
	Total	16,077	1,907	45,773	8,021	71,778	4,267	76,045	*73,863*	-
1997	SS	12,846	614	98	3,627	17,185	231	17,416	*16,500*	-
	FS	380	888	34,974	2,175	38,417	3,299	41,716	*50,000*	-
	Total	13,226	1,502	35,072	5,802	55,602	3,530	59,132	*66,500*	-
1998	SS	13,382	297	121	1,418	15,218	2	15,220	*16,500*	-
	FS	528	707	39,009	3,158	43,402	50	43,452	*57,568*	-
	Total	13,910	1,004	39,130	4,576	58,620	52	58,672	*74,068*	-
1999	SS	10,256	688	176	3,770	14,890	0	14,890	*18,500*	-
	FS	1,625	4,130	44,615	5,334	55,704	0	55,704	*60,500*	-
	Total	11,881	4,818	44,791	9,104	70,594	0	70,594	*79,000*	-
2000	SS	14,586	10	706	2,324	17,626	0	17,626	*16,500*	-
	FS	1,596	538	49,676	6,373	58,183	0	58,183	*71,000*	-
	Total	16,182	548	50,382	8,697	75,809	0	75,809	*87,500*	-
2001	SS	9,938	459	736	2,986	14,119	0	14,119	*12,500*	-
	FS	659	638	44,786	7,285	53,368	0	53,368	*60,500*	-
	Total	10,597	1,097	45,522	10,271	67,487	0	67,487	*73,000*	-
2002	SS	8,142	420	673	704	9,939	0	9,939	*8,000*	-
	FS	966	464	41,290	10,898	53,618	0	53,618	*51,500*	-
	Total	9,108	884	41,963	11,602	63,557	0	63,557	*59,500*	-
2003	SS	8,458	41	37	449	8,985	0	8,985	*11,000*	-
	FS	608	60	47,766	12,779	61,213	0	61,213	*62,000*	-
	Total	9,066	101	47,803	13,228	70,198	0	70,198	*73,000*	-
2004	SS	7,671	21	122	410	8,224	0	8,224	*13,500*	-
	FS	374	31	35,904	7,090	43,399	0	43,399	*73,000*	-
	Total	8,045	52	36,026	7,500	51,623	0	51,623	*86,500*	-
2005	SS	3,571	0	14	1,084	4,669	0	4,669	*11,000*	-
	FS	925	0	51,715	7,756	60,396	0	60,396	*70,000*	-
	Total	4,496	0	51,729	8,840	65,065	0	65,065	*81,000*	-
2006	SS	1,409	0	293	745	2,447	0	2,447	*9,000*	-
	FS	1,257	0	47,630	4,409	53,296	0	53,296	*68,800*	-
	Total	2,666	0	47,923	5,154	55,743	0	55,743	*77,800*	-
2007	SS	1,734	0	10	2,414	4,158	0	4,158	*5,000*	-
	FS	496	0	43,161	4,426	48,083	0	48,083	*68,800*	-
	Total	2,230	0	43,171	6,840	52,241	0	52,241	*73,800*	-
2008	SS	1,503	0	35	1,473	3,011	0	3,011	*2,500*	-
	FS	187	0	38,831	2,738	41,756	0	41,756	*68,800*	-
	Total	1,690	0	38,866	4,211	44,767	0	44,767	*71,300*	-
2009	SS	1,256	0	70	519	1,845	0	1,845	*2,500*	-
	FS	94	0	44,780	1,939	46,813	0	46,813	*65,000*	-
	Total	1,350	0	44,850	2,458	48,658	0	48,658	*67,500*	-
2010	SS	769	5	2	595	1,371	0	1,371	*2,000*	-
	FS	386	297	42,458	4,154	47,295	0	47,295	*65,000*	-
	Total	1,155	302	42,460	4,749	48,666	0	48,666	*67,000*	-

		4T catch								
		Spring fishery		Fall fishery						
Year	Spawning group	Fixed	Mobile	Fixed	Mobile	Annual 4T catch	Annual 4Vn catch	Total catch 4TVn	TAC 4TVn	Target catch
2011	SS	833	0	21	664	1,518	0	1,518	*2,000*	-
	FS	210	0	36,882	1,372	38,464	0	38,464	*65,000*	-
	Total	1,043	0	36,903	2,036	39,982	0	39,982	*67,000*	-
2012	SS	265	5	68	262	600	0	600	*2,000*	-
	FS	152	223	31,820	381	32,576	0	32,576	*43,500*	-
	Total	417	228	31,888	643	33,176	0	33,176	*45,500*	-
2013	SS	874	180	1	649	1,704	0	1,704	*2,000*	-
	FS	24	3,025	29,911	1,409	34,369	0	34,369	*43,500*	-
	Total	898	3,205	29,912	2,058	36,073	0	36,073	*45,500*	-
2014	SS	634	56	132	429	1,250	0	1,250	*2,000*	-
	FS	71	1,886	25,786	1,471	29,214	0	29,214	*35,000*	-
	Total	705	1,941	25,918	1,901	30,464	0	30,464	*37,000*	-
2015	SS	578	43	3	565	1,190	0	1,190	*2,000*	-
	FS	7	1,390	25,964	777	28,138	0	28,138	*40,000*	-
	Total	586	1,433	25,967	1,343	29,328	0	29,328	*42,000*	-
2016	SS	745	29	45	147	966	0	966	*2,000*	-
	FS	82	776	23,195	624	24,677	0	24,677	*35,000*	-
	Total	827	805	23,240	771	25,643	0	25,643	*37,000*	-
2017	SS	928	4	215	42	1,189	0	1,189	*2,000*	-
	FS	18	86	20,381	38	20,523	0	20,523	*35,000*	-
	Total	946	90	20,595	81	21,712	0	21,712	*37,000*	-
2018	SS	438	58	99	203	798	0	798	*500*	500
	FS	39	1,187	15,186	330	16,742	0	16,742	*25,200*	16,000
	Total	477	1,245	15,285	533	17,540	0	17,540	*25,200*	16,500
2019	SS	485	0	44	518	1,047	0	1,047	*1,250*	500
	FS	56	0	14,844	644	15,544	0	15,544	*22,250*	16,000
	Total	541	0	14,888	1,162	16,591	0	16,591	*23,500*	16,500
2020	SS	342	0	16	245	603	0	603	*500*	-
	FS	77	0	9,659	329	10,065	0	10,065	*12,000*	-
	Total	419	0	9,678	574	10,668	0	10,668	*12,500*	-
2021	SS	379	0	17	6	403	0	403	*500*	-
	FS	24	0	10,800	9	10,834	0	10,834	*12,000*	-
	Total	403	0	10,818	16	11,237	0	11,237	*12,500*	-

Table 2. Commercial fishery samples collected, number of fish processed (N), landings, and % TAC landed by zone in the spring (April 1-June 30) and fall (July 1-December 31). These data are used to derive the 2020 and 2021 catch and weight-at-age matrices for 4T Herring.

Gear/Region	Fishery	Zone	Samples	N	Landings (tons)	% TAC landed
2020: Fixed Gear / Gillnets						
Spring						
	Gaspé (16A) May-June	4Topq	1	31	16.4	413.0
	Chaleur (16B) April-May-June	4Tmn	1	22	158.2	232.3
	East P.E.I. April	4Tgj	2	48	72.1	114.4
	East P.E.I. May-June	4Tgj	3	84	24.0	
	Northumberland Strait (16E) April-May-June	4Th	4	165	67.7	121.9
	West P.E.I. (16E) April-May	4Tl	0	0	79.0	
	I. de la Madeleine (16D) April-May	4Tf	0	0	1.6	11.0
Fall						
North	Gaspé (16A) July	4Topq	0	0	0.6	2.7
North	Chaleur (16B) July	4Tmn	2	48	200.3	
North	Chaleur (16B) August	4Tmn	3	45	1,509.8	96.5
North	Chaleur (16B) September	4Tmn	9	209	4,285.4	
Middle	Escuminac-W P.E.I. (16CE) July - September	4Tl	4	91	2,337.3	85.2
South	I. de la Madeleine (16D) September-October	4Tf	0	0	9.9	11.0
South	Pictou (16F) July - September	4Th	6	135	888.3	32.5
South	East P.E.I. (16G) August - October	4Tgj	5	95	452.4	24.9
Total Fixed gear		4T	40	973	10,102.9	54.2
2020: Mobile Gear						
North	East of Grande-Anse (16B) September-November	4Tmn	5	183	573.8	91.2
North	East of Grande-Anse (16B) September-November	4Tmn	1	46	72.4	
Total Mobile Gear		4T	6	229	646.2	3.5
2021: Fixed Gear / Gillnets						
Spring						
	Gaspé (16A) April-May-June	4Topq	0	0	5.5	197.9
	Chaleur (16B) April-May-June	4Tmn	6	163	149.2	219.1
	East P.E.I. April	4Tgj	2	57	34.3	376.0

Gear/Region	Fishery	Zone	Samples	N	Landings (tons)	% TAC landed
	East P.E.I. May-June	4Tgj	0	0	3.0	
	Northumberland Strait (16E) April-May-June	4Th	8	192	173.7	105.0
	West P.E.I. (16E) April-May-June	4Tl	0	0	38.3	
	I. de la Madeleine (16D) April-May	4Tf	1	32	2.5	100.0
Fall						
North	Gaspé (16A) July	4Topq	0	0	1.0	4.3
North	Chaleur (16B) July-August	4Tmn	2	48	1,796.6	84.0
North	Chaleur (16B) September	4Tmn	11	267	3,512.0	
Middle	Escuminac-W P.E.I. (16CE) August - September	4Tl	9	217	1,797.1	72.2
Middle	Escuminac-W P.E.I. (16CE) October	4Tl	1	30	125.8	
South	I. de la Madeleine (16D) September-October	4Tf	0	0	0.0	0.0
South	Pictou (16F) July - September - October	4Th	8	155	2,734.2	100.0
South	East P.E.I. (16G) September - October	4Tgj	0	0	851.9	46.9
Total Fixed gear		4T	48	1,161	11,225.0	72.1
2021: Mobile Gear						
North	East of Grande-Anse (16B) November	4Tmn	0	0	13.8	1.2
Total Mobile Gear		4T	0	0	13.8	0.1

Table 3. Comparison of 2020 and 2021 DMP and telephone survey results including number of respondents, mean net length (fathoms), numbers of nets set, percentage of nets of mesh size 2⅝" in the fall fishery, and a comparative index abundance from 2020 and 2021, respectively [scale 1 (poor) to 10 (excellent)].

Region	Telephone survey area	Source	Number of responses	Net length (fathom)	Number of nets set	% of 2⅝ mesh size	Comparison to previous year
2020							
Spring fishery							
South	1 - Magdalen Islands	DMP Phone	- 1	- 15.0	- 9.6	- 86	- 5.0
North	2- Quebec	DMP Phone	- 11	- 14.5	- 18.2	- 86	- 6.2
North	3- Acadian Peninsula	DMP Phone	- 9	- 13.6	- 14.4	- 86	- 8.0
Middle	4- Escuminac	DMP Phone	- 3	- 11.7	- 17.0	- 86	- 5.0
Middle	5- Southeast NB	DMP Phone	1 7	13.1 14.1	14.5 19.2	86 86	- 5.1
South	6- Nova Scotia	DMP Phone	- -	- -	- -	- -	- -
South	7- East P.E.I.	DMP Phone	- -	- -	- -	- -	- -
Middle	8- West P.E.I.	DMP Phone	1 6	12.0 13.4	10.3 15.3	86 86	- 6.5
Fall fishery							
South	1 - Magdalen Islands	DMP Phone	2 -	14.0 -	- -	- -	- -
North	2- Quebec	DMP Phone	39 39	14.0 13.4	- 7.1	- 100	- 7.4
North	3- Acadian Peninsula	DMP Phone	101 45	13.7 13.6	7.5 7.6	100 100	- 7.1
Middle	4- Escuminac	DMP Phone	11 22	11.5 13.6	7.6 9.1	100 100	- 6.4
Middle	5- Southeast NB	DMP Phone	3 1	13.3 14.0	8.9 9.0	100 100	- 5.0
South	6- Nova Scotia	DMP Phone	105 27	14.0 15.1	5.7 6.5	100 100	- 6.2
South	7- East P.E.I.	DMP Phone	18 2	13.5 11.5	5.9 6.7	100 100	- 2.0
Middle	8- West P.E.I.	DMP Phone	38 13	12.0 13.0	9.9 8.6	97 100	- 7.4
2021							
Spring fishery							
South	1 - Magdalen Islands	DMP Phone	- 3	- 14.7	- 9.8	- 86	- 4.0
North	2- Quebec	DMP Phone	- 13	- 14.8	- 13.6	- 86	- 6.1
North	3- Acadian Peninsula	DMP Phone	1 9	15.0 13.3	10.7 9.6	86 86	- 6.7
Middle	4- Escuminac	DMP Phone	- 1	- 15.0	- 24.6	- 86	- 5.0
Middle	5- Southeast NB	DMP Phone	9 14	14.8 14.1	10.1 12.0	86 86	- 7.4

Region	Telephone survey area	Source	Number of responses	Net length (fathom)	Number of nets set	% of 2⅝ mesh size	Comparison to previous year
South	6- Nova Scotia	DMP	-	-	-	-	-
		Phone	-	-	-	-	-
South	7- East P.E.I.	DMP	-	-	-	-	-
		Phone	-	-	-	-	-
Middle	8- West P.E.I.	DMP	34	13.9	9.9	86	-
		Phone	15	13.5	10.8	86	5.1
Fall fishery							
South	1 - Magdalen Islands	DMP	1	14.0	-	-	-
		Phone	-	-	-	-	-
North	2- Quebec	DMP	37	14.0	-	-	-
		Phone	36	14.2	7.9	100	5.4
North	3- Acadian Peninsula	DMP	87	14.0	7.8	100	-
		Phone	42	14.0	7.6	100	5.5
Middle	4- Escuminac	DMP	7	15.0	11.6	100	-
		Phone	7	13.6	7.2	100	4.1
Middle	5- Southeast NB	DMP	2	14.0	-	-	-
		Phone	-	-	-	-	-
South	6- Nova Scotia	DMP	102	13.9	5.2	100	-
		Phone	33	15.2	6.5	100	7.5
South	7- East P.E.I.	DMP	26	13.5	7.6	100	-
		Phone	2	13.5	8.0	100	8.5
Middle	8- West P.E.I.	DMP	29	12.6	9.8	98	-
		Phone	10	13.7	9.6	100	5.8

Table 4. Spring spawner catch-at-age (thousands) for fixed gear in the 4T Herring fishery.

	Catch-at-age											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	0	44	6,026	25,253	1,042	2,123	660	243	370	1,561	752	38,072
1979	100	112	7,352	2,544	17,558	540	842	127	127	327	1,421	31,050
1980	0	217	9,420	6,744	2,378	9,068	1,424	807	612	442	720	31,832
1981	3	438	11,843	7,099	1,941	1,399	3,052	415	422	171	882	27,664
1982	11	216	23,577	4,191	988	421	299	315	143	88	618	30,868
1983	0	155	13,547	26,208	2,142	472	76	0	0	8	0	42,608
1984	16	39	3,377	12,083	7,529	409	59	14	7	4	0	23,538
1985	0	39	4,921	12,685	13,742	4,630	614	100	32	71	0	36,833
1986	0	11	2,712	13,905	12,357	10,348	2,783	391	20	233	349	43,109
1987	0	10	1,232	6,164	20,071	11,410	9,674	4,080	947	512	258	54,357
1988	60	549	3,536	6,298	9,353	14,600	6,944	5,246	935	68	269	47,858
1989	0	0	3,941	15,672	4,836	4,912	6,957	4,326	2,598	1,025	279	44,546
1990	0	128	1,925	7,387	4,109	2,178	2,532	3,928	1,827	733	306	25,053
1991	0	0	6,070	11,715	14,140	9,142	3,166	2,897	4,448	1,640	1,097	54,314
1992	0	0	2,160	30,046	11,543	7,579	3,460	1,593	1,956	1,423	2,263	62,023
1993	0	8	231	5,488	40,374	18,381	4,900	2,409	1,375	708	2,724	76,597
1994	0	0	2,061	5,847	24,642	48,553	9,048	3,595	1,221	438	1,032	96,438
1995	0	0	200	13,345	10,782	17,781	28,929	6,408	1,788	1,156	2,271	82,660
1996	0	0	416	1,682	48,104	9,123	14,154	9,414	3,102	590	1,087	87,672
1997	0	2	107	5,440	4,069	37,818	6,961	4,149	3,938	1,015	179	63,678
1998	0	0	785	7,744	15,786	2,264	29,871	3,421	2,449	1,966	875	65,159
1999	0	89	1,724	6,599	9,410	10,297	2,255	16,045	2,583	1,342	1,155	51,499
2000	0	12	2,141	11,977	15,975	15,248	7,568	4,457	11,675	2,912	1,756	73,722
2001	0	0	910	11,316	13,082	9,859	4,920	3,360	1,387	6,593	1,735	53,163
2002	0	1	2,509	7,044	18,352	7,626	3,608	2,075	1,152	1,052	1,214	44,633
2003	0	0	285	10,766	11,071	12,832	3,925	2,483	998	686	759	43,803
2004	0	21	1,607	2,606	15,101	5,400	8,500	3,223	1,164	413	1,005	39,040
2005	0	0	72	3,639	3,209	5,784	2,561	2,023	566	125	174	18,153
2006	0	1	720	1,299	4,653	1,652	528	285	387	28	73	9,626
2007	0	1	864	2,037	1,563	2,323	1,738	803	196	149	110	9,784
2008	0	71	177	2,812	3,111	1,139	1,261	269	52	23	12	8,928
2009	0	23	411	1,060	2,445	3,033	344	349	91	6	14	7,775
2010	0	0	144	1,107	860	1,559	766	366	358	4	13	5,177
2011	0	0	25	116	885	812	1,102	512	782	287	5	4,526
2012	0	0	153	400	400	609	671	340	225	186	84	3,068
2013	0	0	16	303	963	1,157	1,492	1,141	814	50	39	5,974
2014	0	0	1	17	454	773	868	1,080	561	222	67	4,041
2015	0	0	0	103	157	783	1,195	535	396	76	41	3,287
2016	0	0	28	26	649	1,067	1,653	773	338	102	21	4,657
2017	0	6	88	703	746	1,977	1,617	1,207	276	49	3	6,673
2018	0	0	10	57	835	654	929	345	109	3	0	2,944
2019	0	0	13	261	604	1,338	428	539	107	16	0	3,306
2020	0	0	39	255	450	430	508	376	44	38	9	2,148
2021	0	0	0	52	312	448	661	673	108	39	9	2,303

Table 5. *Spring spawner weight-at-age (kg) for fixed gear in the 4T Herring fishery.*

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
1978	-	0.154	0.148	0.187	0.215	0.251	0.283	0.318	0.308	0.337	0.364
1979	0.020	0.161	0.163	0.197	0.226	0.243	0.313	0.335	0.352	0.326	0.360
1980	-	0.184	0.167	0.189	0.231	0.278	0.304	0.334	0.359	0.369	0.379
1981	0.027	0.156	0.178	0.232	0.267	0.318	0.343	0.350	0.374	0.411	0.419
1982	0.038	0.186	0.173	0.207	0.261	0.311	0.370	0.385	0.396	0.416	0.449
1983	-	0.170	0.148	0.206	0.236	0.258	0.343	-	-	0.361	-
1984	0.063	0.104	0.174	0.196	0.217	0.289	0.340	0.404	0.490	0.369	-
1985	-	0.213	0.169	0.198	0.229	0.266	0.315	0.315	0.329	0.432	-
1986	-	0.111	0.183	0.210	0.242	0.261	0.307	0.348	0.336	0.364	0.392
1987	-	0.091	0.192	0.196	0.218	0.249	0.267	0.280	0.317	0.310	0.377
1988	0.040	0.080	0.160	0.197	0.237	0.265	0.290	0.307	0.335	0.369	0.359
1989	-	-	0.165	0.202	0.229	0.257	0.291	0.301	0.314	0.328	0.300
1990	-	0.153	0.169	0.203	0.241	0.273	0.297	0.290	0.311	0.322	0.339
1991	-	-	0.146	0.182	0.219	0.246	0.260	0.292	0.303	0.320	0.319
1992	-	-	0.145	0.172	0.201	0.232	0.255	0.274	0.291	0.299	0.332
1993	-	0.135	0.127	0.164	0.186	0.207	0.244	0.252	0.268	0.294	0.292
1994	-	-	0.141	0.156	0.177	0.200	0.218	0.249	0.314	0.272	0.304
1995	-	0.116	0.182	0.160	0.179	0.202	0.222	0.245	0.271	0.301	0.322
1996	-	-	0.157	0.182	0.173	0.193	0.209	0.233	0.230	0.275	0.277
1997	-	0.133	0.131	0.162	0.183	0.200	0.213	0.233	0.246	0.246	0.303
1998	-	-	0.137	0.161	0.185	0.206	0.221	0.240	0.246	0.257	0.278
1999	-	0.121	0.120	0.149	0.176	0.204	0.220	0.230	0.244	0.254	0.269
2000	-	0.114	0.131	0.158	0.184	0.207	0.225	0.250	0.253	0.262	0.273
2001	-	-	0.135	0.158	0.182	0.198	0.223	0.236	0.257	0.260	0.270
2002	-	0.098	0.141	0.165	0.188	0.205	0.227	0.251	0.270	0.279	0.289
2003	-	-	0.143	0.160	0.184	0.202	0.223	0.233	0.253	0.260	0.280
2004	-	0.130	0.134	0.149	0.178	0.203	0.229	0.238	0.254	0.262	0.288
2005	-	0.075	0.134	0.152	0.172	0.201	0.221	0.252	0.253	0.269	0.308
2006	-	0.120	0.132	0.147	0.169	0.196	0.221	0.246	0.248	0.293	0.242
2007	-	0.108	0.139	0.152	0.169	0.185	0.194	0.212	0.253	0.246	0.234
2008	-	0.137	0.144	0.158	0.164	0.181	0.203	0.237	0.240	0.268	0.298
2009	-	0.118	0.144	0.155	0.165	0.173	0.205	0.209	0.253	0.223	0.206
2010	-	-	0.121	0.148	0.157	0.189	0.202	0.225	0.234	0.248	0.268
2011	-	-	0.112	0.144	0.170	0.179	0.199	0.217	0.229	0.250	0.233
2012	-	-	0.154	0.140	0.143	0.155	0.169	0.186	0.190	0.222	0.220
2013	-	-	0.119	0.134	0.147	0.160	0.181	0.187	0.203	0.217	0.224
2014	-	-	0.114	0.130	0.160	0.170	0.190	0.197	0.208	0.226	0.226
2015	-	-	0.094	0.133	0.144	0.164	0.176	0.188	0.208	0.188	0.231
2016	-	-	0.124	0.129	0.147	0.164	0.17	0.181	0.195	0.211	0.203
2017	-	0.125	0.148	0.138	0.150	0.176	0.177	0.186	0.185	0.198	0.212
2018	-	-	0.138	0.143	0.168	0.178	0.191	0.200	0.201	0.213	0.225
2019	-	-	0.114	0.136	0.140	0.158	0.167	0.187	0.186	0.218	-
2020	-	-	0.116	0.114	0.146	0.164	0.183	0.199	0.206	0.260	0.220
2021	-	-	0.129	0.142	0.153	0.161	0.178	0.182	0.187	0.194	0.210

Table 6. Fall spawner catch-at-age (thousands) for fixed gear in the 4T Herring fishery, by region: a) North, b) Middle, c) South.

Year	Catch-at-age										
	1	2	3	4	5	6	7	8	9	10	11+	total
a) North												
1978	-	0	216	3,414	2,450	510	432	2,709	50	81	1,189	11,049
1979	-	0	168	3,271	1,465	1,260	256	644	531	252	267	8,113
1980	-	26	3,056	1,471	1,648	233	1,154	129	110	147	0	7,974
1981	-	23	3,963	12,839	2,839	593	240	278	53	99	60	20,988
1982	-	0	1,726	5,625	11,797	1,746	331	202	64	40	62	21,593
1983	-	0	98	9,238	3,748	9,002	1,018	413	96	16	102	23,732
1984	-	0	453	7,434	6,808	3,462	3,133	556	113	108	71	22,139
1985	-	0	99	2,878	13,139	8,176	4,901	4,915	1,832	372	6	36,317
1986	-	0	617	9,919	9,734	21,934	15,361	7,286	3,326	447	770	69,394
1987	-	16	7,260	24,247	14,636	13,277	19,804	9,068	5,494	2,412	759	96,973
1988	-	0	152	14,470	24,858	9,543	8,464	7,752	4,121	1,998	1,953	73,312
1989	-	0	283	12,133	19,801	21,160	10,289	4,716	5,928	2,655	2,119	79,083
1990	-	14	2,351	13,755	12,557	19,491	20,685	7,816	5,478	5,759	4,141	92,048
1991	-	0	131	28,732	7,306	5,390	7,996	7,653	2,463	1,539	2,511	63,721
1992	-	0	11	6,153	37,342	10,677	6,225	6,775	5,960	2,872	5,423	81,438
1993	-	0	82	2,051	21,080	24,447	3,430	1,918	1,975	559	712	56,253
1994	-	0	0	6,553	10,534	31,558	47,627	9,076	7,049	3,229	5,405	121,030
1995	-	0	23	3,298	23,949	11,095	26,764	28,406	4,969	3,188	3,483	105,176
1996	-	0	0	12,767	15,443	20,775	4,565	8,681	9,465	1,341	1,561	74,599
1997	-	0	367	8,897	30,662	9,453	8,423	1,621	2,817	2,524	732	65,496
1998	-	0	37	8,752	23,986	22,898	5,734	5,461	787	1,272	2,305	71,232
1999	-	0	175	19,795	23,825	29,632	10,527	2,083	1,327	362	517	88,244
2000	-	0	266	17,183	56,056	14,915	6,279	3,445	668	493	224	99,529
2001	-	0	516	22,863	28,903	29,781	4,552	2,051	561	175	228	89,629
2002	-	1	212	21,279	23,278	16,324	8,777	2,292	683	471	187	73,503
2003	-	0	235	11,578	24,362	16,356	11,533	13,769	3,446	1,512	948	83,741
2004	-	0	1	23,785	17,748	8,619	5,219	4,049	2,776	638	433	63,267
2005	-	0	1	5,034	56,213	22,399	8,627	4,759	2,861	2,025	184	102,102
2006	-	0	5	6,092	37,842	36,714	5,458	1,549	2,922	1,127	602	92,312
2007	-	0	32	5,160	15,268	34,715	23,878	5,096	951	887	561	86,549
2008	-	0	403	18,423	11,717	18,718	15,180	14,670	1,778	598	865	82,352
2009	-	0	532	22,606	38,575	10,619	10,493	6,117	1,701	302	253	91,199
2010	-	0	0	3,120	26,685	23,029	7,969	5,320	4,186	1,708	199	72,217
2011	-	0	0	1,657	6,387	26,763	24,243	2,750	3,140	2,850	773	68,564
2012	-	0	8	156	8,609	17,648	26,305	11,769	2,342	2,749	954	70,540
2013	-	0	0	1,053	9,008	29,030	20,823	10,696	2,295	183	103	73,191
2014	-	0	0	91	4,454	9,817	24,496	11,276	7,629	100	60	57,924
2015	-	0	0	91	2,684	19,072	14,182	17,093	5,314	844	226	59,507
2016	-	0	23	1,288	5,327	14,502	17,954	12,517	4,073	1,913	334	57,931
2017	-	0	0	553	5,261	7,935	14,281	16,572	5,793	2,069	364	52,829
2018	-	0	0	0	849	10,204	12,361	9,637	4,674	1,679	201	39,605
2019	-	0	0	38	503	8,527	15,957	5,548	3,849	1,235	404	36,061
2020	-	0	0	97	612	2,102	9,911	8,130	5,103	1,304	206	27,466
2021	-	0	0	162	2,498	2,571	3,424	8,110	4,140	1,508	261	22,675
b) Middle												
1978	-	0	38	601	749	220	442	2,005	9	59	1,139	5,262
1979	-	0	144	3,673	2,048	831	205	100	209	18	161	7,389

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
1980	-	0	424	964	2,283	579	271	225	282	107	96	5,232
1981	-	0	974	6,224	1,910	1,150	460	629	31	83	238	11,699
1982	-	0	29	1,653	1,559	210	139	116	0	0	31	3,737
1983	-	0	255	3,998	1,482	1,578	351	130	0	0	0	7,794
1984	-	0	41	1,908	2,723	937	1,001	315	77	11	6	7,019
1985	-	0	11	235	1,370	1,010	562	536	200	41	1	3,964
1986	-	0	47	1,600	1,328	2,455	1,120	435	200	27	46	7,257
1987	-	0	298	934	1,761	1,532	3,059	289	267	298	19	8,457
1988	-	0	817	3,091	2,817	2,473	1,135	1,189	886	15	0	12,424
1989	-	0	16	772	1,431	1,274	694	428	378	171	139	5,303
1990	-	0	219	1,923	1,390	1,508	2,655	548	382	298	64	8,987
1991	-	0	17	5,973	1,617	1,332	1,749	2,066	1,271	585	1,335	15,945
1992	-	0	12	3,880	9,415	1,284	534	304	220	106	249	16,004
1993	-	0	0	350	6,612	8,298	1,417	597	415	470	716	18,875
1994	-	0	0	850	1,373	6,909	9,293	1,134	359	439	741	21,099
1995	-	0	0	214	10,009	3,408	12,249	10,646	1,363	243	4,272	42,403
1996	-	0	0	3,414	2,107	12,096	1,046	3,144	3,605	833	869	27,113
1997	-	0	285	4,835	10,979	1,980	4,125	782	938	1,026	639	25,588
1998	-	0	23	5,113	4,301	8,730	1,761	3,286	596	1,293	2,229	27,331
1999	-	0	0	9,710	12,903	5,104	3,222	1,303	2,854	278	1,330	36,703
2000	-	0	13	11,054	21,136	7,789	2,516	1,394	414	369	165	44,850
2001	-	0	383	5,519	13,582	9,633	2,919	630	208	0	293	33,167
2002	-	0	275	9,081	8,110	7,172	6,937	1,245	172	146	217	33,356
2003	-	0	123	5,648	11,842	5,541	3,737	3,739	839	110	156	31,735
2004	-	0	15	5,579	10,122	7,144	5,096	4,523	2,652	920	175	36,227
2005	-	0	0	2,355	14,518	11,757	3,536	3,046	2,099	895	66	38,273
2006	-	0	0	1,697	7,740	13,789	5,094	2,598	1,949	1,544	523	34,935
2007	-	0	193	1,197	3,429	9,509	9,811	3,736	1,509	733	454	30,572
2008	-	0	1,426	12,175	2,575	4,491	5,326	8,515	1,536	1,451	332	37,826
2009	-	0	101	8,185	14,543	3,368	7,438	3,578	1,245	530	245	39,232
2010	-	0	8	1,529	11,467	17,000	4,954	4,333	2,473	1,154	644	43,562
2011	-	0	0	405	2,089	12,157	15,610	2,973	2,237	2,101	631	38,202
2012	-	0	7	147	1,935	8,679	11,646	8,142	925	526	443	32,450
2013	-	0	7	590	1,125	7,042	10,527	6,451	2,488	201	43	28,474
2014	-	0	0	0	3,452	2,161	7,389	8,144	1,536	755	0	23,437
2015	-	0	0	165	1,052	10,058	4,474	7,592	2,987	1,060	0	27,388
2016	-	0	18	279	1,227	7,869	6,459	3,603	1,610	570	0	21,634
2017	-	0	25	128	1,032	3,573	6,651	8,169	4,645	638	23	24,884
2018	-	0	0	76	712	2,951	7,463	5,674	557	302	0	17,736
2019	-	0	0	103	187	1,689	5,691	2,696	3,532	1,081	216	15,194
2020	-	0	0	0	308	236	2,702	2,845	2,170	1,050	669	9,980
2021	-	0	6	80	758	917	1,176	3,145	1,736	437	205	8,460
c) South												
1978	-	41	1,988	1,390	632	154	75	119	22	0	13	4,434
1979	-	16	267	4,634	2,198	773	263	292	175	52	205	8,875
1980	-	38	4,404	1,939	2,352	294	923	129	164	154	77	10,473
1981	-	42	1,158	5,336	2,185	1,049	531	310	88	99	24	10,823
1982	-	0	353	7,029	3,634	3,226	2,345	819	332	81	37	17,856
1983	-	0	467	7,485	5,047	3,237	1,011	1,266	477	47	161	19,198
1984	-	0	397	15,010	5,562	4,586	2,288	703	381	110	23	29,060
1985	-	0	89	3,442	15,465	6,385	3,221	2,234	509	333	29	31,707
1986	-	383	871	20,436	5,745	12,065	3,350	1,635	487	106	164	45,244

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
1987	-	0	1,083	11,141	12,821	6,139	14,100	6,213	4,292	1,851	1,323	58,963
1988	-	0	377	4,361	16,703	9,665	4,750	6,641	3,036	985	665	47,183
1989	-	0	33	1,355	2,076	8,332	4,204	1,803	2,446	622	300	21,171
1990	-	0	875	6,772	6,732	7,712	36,015	9,853	4,322	4,591	2,472	79,345
1991	-	0	11	4,956	1,670	1,339	1,201	3,899	1,365	840	1,190	16,471
1992	-	0	0	1,335	7,461	1,081	631	1,510	3,338	1,241	1,316	17,913
1993	-	0	0	302	3,227	3,902	982	405	586	485	1,123	11,013
1994	-	0	0	1,463	310	10,000	13,800	1,873	2,460	5,256	8,730	43,892
1995	-	0	1	341	7,908	2,733	12,171	10,381	2,759	3,036	7,345	46,675
1996	-	0	4	3,477	2,082	13,644	4,899	11,411	10,891	2,781	8,448	57,637
1997	-	0	454	3,780	22,567	2,027	8,585	1,488	3,105	2,920	2,597	47,521
1998	-	0	0	9,390	4,415	15,711	3,964	8,891	1,751	3,429	4,223	51,773
1999	-	0	89	8,880	32,161	4,365	9,706	1,899	3,102	1,152	1,593	62,949
2000	-	0	77	8,101	31,645	18,887	3,076	3,685	715	1,148	717	68,050
2001	-	0	56	1,816	22,486	21,033	13,536	1,991	1,593	433	824	63,767
2002	-	0	0	17,708	7,514	16,987	14,117	4,249	1,072	926	547	63,120
2003	-	0	61	5,076	41,894	6,513	13,669	8,690	1,700	262	381	78,246
2004	-	0	0	4,823	11,135	24,502	4,842	4,452	2,175	600	312	52,840
2005	-	0	3	424	12,345	20,406	31,839	6,051	6,169	1,732	385	79,354
2006	-	0	51	2,825	7,738	20,291	20,875	15,511	5,119	2,721	760	75,890
2007	-	0	492	206	9,238	13,512	24,751	15,374	4,948	2,939	938	72,397
2008	-	0	292	4,858	1,774	6,585	12,063	15,009	6,873	3,646	2,818	53,919
2009	-	0	411	2,398	20,654	10,345	20,617	6,815	3,615	5,240	2,610	72,705
2010	-	0	0	2,080	8,754	32,103	8,352	10,398	6,809	3,819	2,439	74,754
2011	-	0	1	312	7,530	7,478	25,275	8,102	4,030	2,350	4,185	59,263
2012	-	0	0	24	1,199	12,938	14,639	15,613	1,662	476	1,603	48,156
2013	-	0	15	341	1,025	9,166	19,571	7,271	3,448	110	108	41,054
2014	-	0	0	173	2,842	2,276	8,971	15,942	3,504	1,700	58	35,466
2015	-	0	0	0	1,653	7,979	4,406	12,483	3,358	1,923	208	32,011
2016	-	0	10	305	3,417	10,631	5,826	4,287	1,947	570	39	27,032
2017	-	0	0	368	298	3,692	7,499	2,659	989	208	19	15,732
2018	-	0	0	25	875	4,046	3,838	4,573	856	326	77	14,616
2019	-	0	0	54	80	3,369	8,388	3,536	2,599	826	352	19,205
2020	-	0	0	5	169	487	1,682	1,924	1,082	674	92	6,114
2021	-	0	0	39	477	3,374	2,674	6,285	2,678	341	446	16,314

Table 7. Fall spawner weight-at-age (kg) for fixed gear in the 4T Herring fishery, by region: a) North, b) Middle, c) South.

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
a) North											
1978	-	-	0.200	0.259	0.296	0.339	0.347	0.379	0.416	0.396	0.447
1979	-	-	0.215	0.265	0.307	0.332	0.384	0.401	0.417	0.434	0.452
1980	-	0.212	0.205	0.239	0.296	0.308	0.289	0.319	0.362	0.376	-
1981	-	0.208	0.220	0.255	0.307	0.349	0.404	0.419	0.452	0.466	0.487
1982	-	-	0.226	0.271	0.304	0.344	0.384	0.425	0.425	0.439	0.447
1983	-	-	0.199	0.251	0.292	0.325	0.364	0.404	0.391	0.506	0.460
1984	-	-	0.232	0.255	0.295	0.340	0.356	0.398	0.434	0.391	0.507
1985	-	-	0.224	0.230	0.297	0.343	0.373	0.391	0.414	0.454	0.563
1986	-	-	0.216	0.265	0.303	0.333	0.376	0.396	0.407	0.446	0.452
1987	-	0.174	0.237	0.252	0.289	0.323	0.355	0.380	0.400	0.415	0.437
1988	-	-	0.212	0.260	0.285	0.311	0.341	0.367	0.393	0.389	0.421
1989	-	-	0.223	0.256	0.295	0.327	0.352	0.377	0.391	0.420	0.427
1990	-	0.148	0.198	0.248	0.287	0.325	0.350	0.368	0.389	0.408	0.435
1991	-	-	0.196	0.230	0.263	0.299	0.330	0.349	0.364	0.362	0.398
1992	-	-	0.200	0.229	0.258	0.283	0.312	0.345	0.355	0.363	0.409
1993	-	-	0.172	0.219	0.239	0.265	0.291	0.330	0.346	0.326	0.360
1994	-	-	-	0.209	0.237	0.258	0.288	0.315	0.348	0.353	0.400
1995	-	-	0.187	0.205	0.227	0.247	0.282	0.303	0.333	0.361	0.386
1996	-	-	-	0.221	0.244	0.258	0.281	0.306	0.329	0.376	0.426
1997	-	-	0.191	0.206	0.236	0.260	0.275	0.308	0.337	0.351	0.403
1998	-	-	0.149	0.209	0.232	0.258	0.286	0.293	0.330	0.355	0.362
1999	-	-	0.166	0.212	0.237	0.250	0.279	0.301	0.327	0.370	0.362
2000	-	-	0.177	0.214	0.235	0.260	0.275	0.304	0.317	0.334	0.387
2001	-	-	0.172	0.211	0.237	0.255	0.282	0.305	0.330	0.347	0.371
2002	-	0.031	0.181	0.220	0.240	0.264	0.282	0.296	0.326	0.332	0.362
2003	-	-	0.158	0.209	0.238	0.255	0.278	0.296	0.313	0.333	0.351
2004	-	-	0.149	0.200	0.218	0.252	0.263	0.285	0.308	0.329	0.349
2005	-	-	0.188	0.196	0.225	0.240	0.261	0.285	0.296	0.296	0.313
2006	-	-	0.158	0.202	0.220	0.241	0.258	0.285	0.300	0.303	0.323
2007	-	-	0.156	0.197	0.204	0.225	0.242	0.254	0.290	0.292	0.317
2008	-	-	0.159	0.190	0.214	0.228	0.244	0.259	0.264	0.294	0.319
2009	-	-	0.156	0.190	0.202	0.233	0.251	0.261	0.258	0.282	0.279
2010	-	-	-	0.179	0.206	0.217	0.238	0.250	0.261	0.279	0.295
2011	-	-	-	0.184	0.197	0.216	0.222	0.258	0.263	0.265	0.298
2012	-	-	0.126	0.158	0.183	0.204	0.214	0.225	0.250	0.250	0.290
2013	-	-	-	0.171	0.195	0.205	0.215	0.231	0.242	0.286	0.284
2014	-	0.114	-	0.202	0.213	0.220	0.230	0.241	0.243	0.292	0.301
2015	-	-	-	0.173	0.200	0.212	0.227	0.229	0.241	0.225	0.268
2016	-	-	0.158	0.176	0.198	0.212	0.215	0.223	0.236	0.239	0.243
2017	-	-	-	0.182	0.190	0.205	0.221	0.227	0.238	0.254	0.270
2018	-	-	-	0.111	0.201	0.203	0.210	0.226	0.232	0.247	0.271
2019	-	-	-	0.168	0.198	0.203	0.215	0.222	0.229	0.239	0.258
2020	-	-	-	0.164	0.183	0.205	0.215	0.225	0.229	0.243	0.268
2021	-	-	-	0.196	0.207	0.221	0.229	0.240	0.248	0.250	0.293
b) Middle											
1978	-	-	0.200	0.259	0.261	0.305	0.279	0.363	0.416	0.313	0.410
1979	-	-	0.183	0.224	0.269	0.278	0.315	0.369	0.420	0.419	0.458

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
1980	-	-	0.244	0.249	0.353	0.384	0.354	0.390	0.546	0.504	0.510
1981	-	-	0.221	0.255	0.294	0.344	0.360	0.393	0.501	0.473	0.439
1982	-	-	0.247	0.270	0.305	0.330	0.424	0.449	-	-	0.499
1983	-	-	0.183	0.217	0.263	0.302	0.340	0.430	-	-	-
1984	-	-	0.225	0.227	0.253	0.301	0.344	0.397	0.433	0.484	0.540
1985	-	-	0.224	0.259	0.302	0.331	0.369	0.391	0.414	0.454	0.563
1986	-	-	0.194	0.209	0.244	0.276	0.347	0.397	0.407	0.446	0.453
1987	-	-	0.249	0.230	0.261	0.229	0.326	0.296	0.361	0.249	0.402
1988	-	-	0.234	0.281	0.305	0.357	0.362	0.413	0.439	0.366	0.420
1989	-	-	0.224	0.249	0.278	0.324	0.336	0.335	0.384	0.410	0.419
1990	-	-	0.194	0.236	0.284	0.324	0.342	0.355	0.365	0.404	0.431
1991	-	-	0.185	0.233	0.262	0.272	0.348	0.348	0.364	0.395	0.406
1992	-	-	0.199	0.219	0.242	0.269	0.285	0.328	0.348	0.358	0.412
1993	-	-	-	0.218	0.242	0.263	0.263	0.321	0.341	0.354	0.387
1994	-	-	-	0.213	0.243	0.270	0.294	0.309	0.328	0.399	0.427
1995	-	-	-	0.222	0.244	0.255	0.280	0.286	0.341	0.358	0.385
1996	-	-	-	0.226	0.250	0.261	0.304	0.310	0.318	0.393	0.432
1997	-	-	0.174	0.206	0.235	0.247	0.256	0.295	0.320	0.314	0.387
1998	-	-	0.176	0.219	0.234	0.265	0.286	0.279	0.336	0.343	0.388
1999	-	-	-	0.210	0.237	0.244	0.275	0.296	0.283	0.351	0.362
2000	-	-	0.111	0.214	0.234	0.260	0.273	0.300	0.318	0.311	0.366
2001	-	-	0.168	0.205	0.233	0.254	0.277	0.290	0.303	-	0.308
2002	-	-	0.191	0.219	0.244	0.257	0.288	0.293	0.327	0.327	0.311
2003	-	-	0.170	0.210	0.234	0.260	0.275	0.301	0.312	0.359	0.390
2004	-	-	0.146	0.208	0.229	0.248	0.268	0.286	0.310	0.305	0.362
2005	-	-	-	0.200	0.227	0.240	0.266	0.285	0.303	0.309	0.430
2006	-	-	-	0.197	0.224	0.245	0.260	0.279	0.297	0.310	0.317
2007	-	-	0.155	0.196	0.211	0.228	0.244	0.257	0.275	0.281	0.310
2008	-	-	0.120	0.169	0.206	0.220	0.237	0.242	0.252	0.272	0.300
2009	-	-	0.157	0.180	0.201	0.234	0.239	0.260	0.270	0.268	0.287
2010	-	-	0.139	0.176	0.202	0.213	0.228	0.246	0.255	0.274	0.269
2011	-	-	0.104	0.175	0.197	0.215	0.226	0.231	0.264	0.266	0.283
2012	-	-	0.115	0.153	0.181	0.199	0.212	0.218	0.241	0.262	0.280
2013	-	-	0.131	0.156	0.194	0.198	0.213	0.227	0.232	0.251	0.284
2014	-	-	-	-	0.189	0.209	0.212	0.228	0.231	0.242	0.244
2015	-	-	-	0.195	0.216	0.211	0.227	0.229	0.245	0.247	-
2016	-	-	0.129	0.182	0.22	0.226	0.232	0.24	0.247	0.259	-
2017	-	-	0.134	0.174	0.2	0.212	0.213	0.225	0.234	0.251	-
2018	-	-	-	0.178	0.190	0.209	0.222	0.227	0.226	0.232	-
2019	-	-	-	0.172	0.179	0.201	0.209	0.222	0.225	0.238	0.248
2020	-	-	-	-	0.203	0.198	0.221	0.235	0.242	0.251	0.262
2021	-	-	0.159	0.166	0.199	0.210	0.219	0.229	0.234	0.251	0.261
c) South											
1978	-	0.077	0.133	0.192	0.228	0.236	0.295	0.318	0.331	-	0.338
1979	0.023	0.132	0.186	0.243	0.277	0.314	0.357	0.387	0.417	0.430	0.358
1980	-	0.212	0.205	0.245	0.297	0.315	0.324	0.340	0.358	0.396	0.351
1981	-	0.156	0.220	0.271	0.329	0.381	0.416	0.422	0.448	0.469	0.488
1982	-	-	0.210	0.263	0.297	0.330	0.371	0.360	0.391	0.357	0.404
1983	-	-	0.195	0.245	0.278	0.299	0.333	0.359	0.368	0.398	0.418
1984	-	-	0.212	0.242	0.282	0.304	0.339	0.400	0.405	0.406	0.496
1985	-	-	0.197	0.248	0.281	0.314	0.346	0.368	0.404	0.417	0.445
1986	-	0.175	0.189	0.240	0.277	0.311	0.343	0.361	0.385	0.427	0.348

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
1987	-	-	0.230	0.241	0.276	0.312	0.333	0.361	0.378	0.385	0.429
1988	-	-	0.226	0.246	0.287	0.322	0.352	0.381	0.403	0.416	0.446
1989	-	-	0.171	0.234	0.262	0.312	0.331	0.373	0.390	0.391	0.440
1990	-	-	0.192	0.240	0.277	0.325	0.347	0.372	0.398	0.410	0.428
1991	-	-	0.176	0.234	0.262	0.292	0.335	0.356	0.369	0.392	0.420
1992	-	-	-	0.215	0.252	0.280	0.287	0.338	0.344	0.368	0.388
1993	-	-	-	0.224	0.245	0.262	0.268	0.323	0.357	0.366	0.411
1994	-	-	-	0.213	0.222	0.258	0.284	0.322	0.331	0.360	0.376
1995	-	0.103	0.135	0.215	0.227	0.258	0.275	0.298	0.335	0.356	0.383
1996	-	-	0.172	0.217	0.244	0.254	0.278	0.306	0.322	0.347	0.386
1997	-	-	0.165	0.203	0.232	0.271	0.279	0.320	0.323	0.342	0.399
1998	-	-	-	0.211	0.237	0.257	0.283	0.296	0.319	0.331	0.369
1999	-	-	0.161	0.209	0.236	0.253	0.269	0.300	0.306	0.344	0.346
2000	-	-	0.150	0.203	0.227	0.256	0.281	0.300	0.326	0.329	0.360
2001	-	-	0.160	0.209	0.230	0.248	0.270	0.291	0.306	0.336	0.301
2002	-	-	-	0.216	0.233	0.249	0.271	0.288	0.306	0.308	0.337
2003	-	-	0.169	0.203	0.227	0.247	0.259	0.278	0.302	0.306	0.327
2004	-	-	-	0.206	0.224	0.237	0.254	0.282	0.282	0.303	0.308
2005	-	-	0.188	0.194	0.219	0.234	0.245	0.257	0.272	0.286	0.307
2006	-	-	0.169	0.190	0.215	0.231	0.249	0.257	0.276	0.279	0.299
2007	-	-	0.146	0.163	0.200	0.218	0.234	0.242	0.250	0.258	0.265
2008	-	0.093	0.138	0.160	0.206	0.214	0.227	0.237	0.248	0.257	0.271
2009	-	-	0.143	0.186	0.201	0.228	0.246	0.260	0.274	0.268	0.267
2010	-	-	0.107	0.161	0.205	0.214	0.241	0.257	0.264	0.281	0.296
2011	-	-	0.111	0.146	0.176	0.204	0.217	0.249	0.257	0.258	0.269
2012	-	-	-	0.150	0.170	0.193	0.216	0.221	0.239	0.270	0.265
2013	-	-	0.137	0.146	0.179	0.194	0.210	0.220	0.226	0.253	0.259
2014	-	-	-	0.157	0.175	0.200	0.201	0.213	0.237	0.231	0.272
2015	-	-	0.151	0.165	0.188	0.193	0.194	0.210	0.232	0.218	0.256
2016	-	-	0.12	0.161	0.208	0.206	0.214	0.22	0.237	0.235	0.260
2017	-	-	0.127	0.168	0.169	0.201	0.207	0.213	0.224	0.248	0.240
2018	-	-	-	0.129	0.156	0.171	0.189	0.199	0.216	0.229	0.246
2019	-	-	-	0.164	0.171	0.189	0.196	0.205	0.210	0.220	0.225
2020	-	-	-	0.152	0.180	0.198	0.208	0.218	0.232	0.239	0.254
2021	-	-	-	0.160	0.188	0.207	0.215	0.222	0.235	0.250	0.244

Table 8. Spring spawner catch-at-age (thousands) for mobile gear in the 4T Herring fishery.

Year	Catch-at-age										
	1	2	3	4	5	6	7	8	9	10	11+	total
1978	1,390	14,933	3,664	24,366	3,053	4,619	1,293	734	565	2,877	599	58,093
1979	11,644	14,535	4,553	4,800	25,927	4,014	6,971	2,139	1,638	1,501	12,300	90,021
1980	737	11,101	10,404	1,790	1,878	11,154	8,852	4,207	2,229	751	286	53,389
1981	0	362	1,105	939	9	881	347	699	264	417	7	5,031
1982	0	2,343	3,816	400	53	10	89	165	210	2	19	7,109
1983	0	1,349	8,017	3,838	449	1	65	71	89	0	0	13,878
1984	0	619	1,831	4,190	2,901	291	0	71	41	0	0	9,943
1985	601	1,132	4,581	2,451	3,085	1,153	77	0	0	0	294	13,373
1986	0	4,194	3,982	9,551	7,647	7,410	3,070	212	514	0	60	36,640
1987	0	1,476	1,977	2,945	10,495	7,260	7,060	3,696	0	0	93	35,002
1988	2,710	6,291	2,125	1,546	2,730	11,772	9,514	5,399	2,434	0	2,155	46,676
1989	374	425	2,982	4,949	1,644	4,682	10,289	4,223	2,285	430	118	32,401
1990	46	5,182	6,250	7,301	4,236	2,645	1,504	5,841	2,964	737	318	37,024
1991	32	1,825	9,393	3,064	2,640	1,271	654	1,000	890	653	1,307	22,730
1992	5	860	2,808	7,350	3,461	2,489	707	448	790	527	453	19,896
1993	35	3,093	2,374	6,696	5,403	2,662	1,577	974	1,309	902	2,289	27,315
1994	0	52	4,057	2,255	3,477	5,930	2,435	1,349	647	166	1,251	21,620
1995	0	1,418	1,588	17,081	5,809	4,899	7,749	1,675	1,024	280	1,708	43,231
1996	6	385	2,942	919	11,291	3,589	2,107	1,965	370	388	138	24,100
1997	83	419	1,405	3,457	1,246	7,719	911	1,610	1,444	146	466	18,906
1998	5	298	796	1,930	1,524	213	1,767	461	337	374	254	7,959
1999	267	1,771	2,841	4,854	3,057	1,516	933	2,949	987	480	579	20,234
2000	294	1,314	3,254	3,739	1,485	891	354	305	491	70	92	12,290
2001	557	4,259	3,721	4,852	2,521	1,130	1,157	448	195	288	148	19,276
2002	55	744	3,135	1,060	729	195	554	109	42	7	42	6,670
2003	26	209	654	869	327	279	270	9	5	40	22	2,709
2004	103	487	825	433	360	135	234	17	10	1	17	2,621
2005	372	1,816	1,864	2,571	259	336	52	0	71	0	0	7,340
2006	61	236	898	521	1,825	620	138	24	6	5	0	4,333
2007	524	3,651	3,605	2,396	1,786	2,368	700	256	15	0	113	15,414
2008	268	3,474	1,888	765	1,209	587	774	137	93	16	28	9,239
2009	7	441	1,670	227	171	172	441	17	0	173	38	3,358
2010	0	116	406	941	506	713	634	74	8	0	1	3,398
2011	19	629	814	669	682	577	576	73	106	356	23	4,525
2012	0	17	404	454	279	237	169	9	33	0	21	1,624
2013	1	124	282	831	1,120	703	621	442	41	0	18	4,185
2014	0	489	191	714	309	656	372	213	0	37	82	3,063
2015	0	564	560	206	270	554	864	457	190	22	17	3,704
2016	0	271	495	138	91	41	114	38	86	0	0	1,274
2017	2	102	101	140	18	2	5	1	0	0	0	369
2018	0	0	58	325	660	128	176	268	101	0	0	1,715
2019	0	0	43	687	542	1,469	258	100	49	0	0	3,147
2020	6	11	316	359	256	178	361	48	6	5	4	1,550
2021	-	-	-	-	-	-	-	-	-	-	-	-

Table 9. Spring spawner weight-at-age (kg) for mobile gear in the 4T Herring fishery.

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
1978	0.078	0.131	0.182	0.262	0.248	0.281	0.301	0.308	0.352	0.381	0.389
1979	0.107	0.173	0.193	0.212	0.261	0.259	0.303	0.305	0.340	0.342	0.364
1980	0.114	0.158	0.165	0.217	0.262	0.273	0.258	0.264	0.275	0.364	0.341
1981	0.027	0.158	0.203	0.274	0.272	0.425	0.306	0.284	0.290	0.316	0.417
1982	0.038	0.133	0.225	0.266	0.253	0.315	0.463	0.308	0.339	0.436	0.451
1983	-	0.145	0.188	0.231	0.278	0.270	0.315	0.243	0.411	-	-
1984	0.063	0.121	0.192	0.229	0.262	0.291	0.300	0.380	0.351	0.376	-
1985	0.083	0.137	0.221	0.244	0.297	0.313	0.384	-	-	-	0.384
1986	-	0.144	0.196	0.249	0.283	0.315	0.339	0.349	0.315	-	0.392
1987	-	0.156	0.189	0.251	0.304	0.332	0.358	0.375	-	-	0.527
1988	0.082	0.115	0.176	0.251	0.301	0.337	0.339	0.393	0.412	-	0.442
1989	0.090	0.142	0.212	0.258	0.270	0.313	0.343	0.363	0.385	0.411	0.466
1990	0.078	0.173	0.197	0.246	0.280	0.294	0.333	0.342	0.352	0.409	0.363
1991	0.082	0.143	0.181	0.215	0.248	0.264	0.322	0.334	0.357	0.349	0.401
1992	0.056	0.117	0.148	0.200	0.241	0.272	0.292	0.323	0.327	0.338	0.385
1993	0.070	0.109	0.152	0.179	0.195	0.235	0.252	0.290	0.281	0.311	0.347
1994	-	0.145	0.156	0.188	0.207	0.234	0.258	0.269	0.274	0.316	0.330
1995	-	0.105	0.146	0.182	0.202	0.226	0.247	0.278	0.303	0.314	0.315
1996	0.073	0.116	0.169	0.205	0.224	0.233	0.246	0.276	0.324	0.300	0.378
1997	0.068	0.124	0.155	0.192	0.209	0.249	0.271	0.287	0.308	0.329	0.326
1998	0.076	0.109	0.145	0.171	0.217	0.203	0.248	0.263	0.279	0.296	0.402
1999	0.063	0.118	0.156	0.187	0.232	0.265	0.277	0.294	0.309	0.317	0.319
2000	0.068	0.131	0.159	0.186	0.218	0.247	0.277	0.293	0.294	0.284	0.332
2001	0.062	0.118	0.149	0.190	0.209	0.242	0.256	0.296	0.327	0.330	0.323
2002	0.061	0.106	0.149	0.176	0.206	0.213	0.251	0.281	0.288	0.288	0.329
2003	0.078	0.099	0.141	0.177	0.199	0.238	0.251	0.282	0.291	0.296	0.330
2004	0.068	0.110	0.146	0.162	0.209	0.231	0.251	0.300	0.314	0.290	0.367
2005	0.079	0.120	0.145	0.163	0.188	0.210	0.197	-	0.261	-	-
2006	0.063	0.110	0.145	0.171	0.179	0.203	0.234	0.300	0.350	0.286	-
2007	0.060	0.118	0.145	0.177	0.181	0.197	0.191	0.213	0.300	-	0.198
2008	0.076	0.128	0.141	0.182	0.199	0.207	0.222	0.245	0.230	0.350	0.253
2009	0.033	0.116	0.139	0.191	0.195	0.210	0.172	0.236	-	0.201	0.212
2010	-	0.109	0.134	0.162	0.167	0.200	0.211	0.241	0.255	-	0.269
2011	0.058	0.083	0.122	0.124	0.174	0.169	0.199	0.210	0.191	0.164	0.192
2012	-	0.083	0.123	0.151	0.177	0.184	0.219	0.242	0.216	-	0.236
2013	0.060	0.100	0.127	0.149	0.170	0.183	0.206	0.209	0.227	-	0.287
2014	-	0.099	0.129	0.145	0.176	0.180	0.179	0.212	-	0.194	0.206
2015	-	0.105	0.116	0.140	0.158	0.183	0.194	0.188	0.249	0.268	0.281
2016	-	0.104	0.123	0.142	0.156	0.160	0.185	0.211	0.195	-	-
2017	0.104	0.108	0.126	0.131	0.137	0.178	0.151	0.194	0.240	-	-
2018	-	-	0.125	0.128	0.153	0.154	0.176	0.167	0.170	-	-
2019	-	-	0.135	0.140	0.154	0.174	0.183	0.197	0.230	-	-
2020	-	0.105	0.131	0.132	0.158	0.177	0.193	0.192	0.228	0.256	0.242
2021	-	-	-	-	-	-	-	-	-	-	-

Table 10. Fall spawner catch-at-age (thousands) for mobile gear in the 4T Herring fishery, by region: a) North, b) Middle, c) South.

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
a) North												
1978	0	78	4,003	12,990	16,826	2,873	2,860	10,286	1,055	512	11,617	62,963
1979	154	2,747	7,471	6,113	4,061	3,067	1,093	720	1,800	277	2,683	31,183
1980	0	2,174	17,021	4,658	1,969	730	870	402	482	402	235	29,477
1981	0	234	2,726	3,429	258	44	65	4	36	0	0	6,151
1982	0	0	8,115	2,280	5,593	494	67	84	63	21	202	15,713
1983	0	0	428	1,645	610	1,918	238	30	30	4	30	5,651
1984	0	0	682	2,731	3,196	1,560	1,122	205	36	6	29	9,497
1985	0	0	1,582	2,076	5,969	5,434	2,505	1,910	1,743	522	0	21,863
1986	0	85	1,372	1,723	2,781	5,476	3,343	1,485	1,548	198	211	18,550
1987	0	1,627	3,113	1,979	910	1,293	3,518	3,706	811	825	345	17,441
1988	0	0	2,187	2,615	3,030	1,430	3,033	2,609	995	1,326	1,558	22,622
1989	0	0	1,053	2,159	4,305	4,358	1,819	2,159	2,593	1,511	1,156	21,897
1990	0	71	4,018	2,950	3,203	1,815	1,576	1,271	1,782	846	261	17,319
1991	0	0	4,974	17,006	3,587	1,000	1,679	1,078	275	477	1,335	31,408
1992	0	0	579	4,637	11,898	2,348	1,564	1,074	1,084	914	3,912	27,750
1993	0	0	4,383	2,596	4,064	6,268	1,737	1,416	1,354	1,497	1,681	26,404
1994	0	0	0	6,300	2,312	5,250	6,666	1,029	706	463	871	24,063
1995	0	0	1,891	3,504	17,824	5,557	7,296	7,799	1,505	527	905	46,876
1996	0	0	1,257	9,473	3,269	7,600	2,168	1,610	1,196	318	271	26,671
1997	0	0	2,290	4,317	5,437	1,413	2,302	423	742	413	254	18,378
1998	0	0	1,481	2,817	2,842	1,690	468	1,778	108	455	144	11,826
1999	0	690	7,217	10,835	5,770	2,761	1,239	767	490	183	112	30,065
2000	0	793	4,875	8,784	10,216	2,650	1,369	582	223	272	136	29,899
2001	144	1,194	6,603	4,579	5,105	4,098	705	490	228	0	21	23,166
2002	0	76	1,363	7,505	6,378	4,178	4,009	975	321	346	217	25,367
2003	0	0	4,531	9,687	5,600	3,695	3,219	3,961	960	549	318	32,520
2004	0	71	2,533	8,511	3,204	1,537	741	344	333	40	0	17,314
2005	0	802	3,145	9,147	7,649	1,800	240	100	159	42	38	23,122
2006	0	800	1,966	3,218	7,747	5,366	1,417	493	315	239	54	21,616
2007	0	1,491	14,991	4,688	2,787	2,987	1,571	390	81	3	12	29,000
2008	0	1,385	8,080	5,566	1,678	834	607	771	3	24	0	18,948
2009	0	179	4,648	5,917	2,313	295	211	51	5	0	0	13,618
2010	0	0	1,811	6,543	10,381	6,966	1,272	690	204	90	0	27,845
2011	0	0	749	2,101	2,304	2,477	1,015	368	8	59	6	10,263
2012	0	0	379	333	1,085	827	485	119	26	13	2	3,301
2013	17	0	447	3,702	3,534	4,630	3,414	1,446	762	93	45	18,700
2014	0	36	0	769	3,890	2,468	2,904	1,572	1,052	104	0	14,697
2015	0	0	1,252	502	557	3,262	965	1,214	737	329	28	9,098
2016	0	0	1,168	2,045	1,658	656	806	344	148	60	16	7,264
2017	0	0	102	114	143	82	17	6	8	0	0	692
2018	0	0	0	313	463	1,649	1,762	736	456	586	1	5,950
2019	0	0	0	483	502	1,293	1,039	337	89	24	9	4,245
2020	0	0	0	652	729	184	186	266	48	58	16	2,254
2021	-	-	-	-	-	-	-	-	-	-	-	-
b) Middle												
1978	0	20	933	4,614	2,041	574	723	1,891	197	63	2,166	13,288
1979	0	0	500	182	64	3,072	734	2,022	1,721	1,297	7,114	17,742
1980	0	117	1,096	419	333	239	90	251	665	149	551	3,448

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
1981	0	2	653	1,608	166	80	117	8	20	0	0	3,274
1982	0	0	73	252	415	22	4	9	0	0	28	1,108
1983	0	0	3,828	3,921	1,248	1,521	249	47	57	14	14	10,683
1984	0	0	51	323	653	239	223	60	10	1	2	1,566
1985	0	0	35	26	118	153	67	57	26	6	0	489
1986	0	0	51	60	62	82	45	17	19	2	1	401
1987	0	1	55	25	15	8	25	11	4	6	1	240
1988	0	0	194	50	27	23	33	28	15	1	0	292
1989	0	0	7	15	35	24	11	18	15	10	8	147
1990	0	0	89	90	77	33	28	15	25	9	1	320
1991	0	0	98	619	207	94	156	130	52	96	501	1,888
1992	0	0	9	371	548	130	79	33	30	23	150	1,946
1993	0	0	0	52	352	847	322	272	171	433	624	2,948
1994	0	0	0	157	85	311	383	49	22	44	81	1,293
1995	0	0	0	30	792	332	784	663	155	19	549	3,398
1996	0	0	11	1,366	305	676	197	225	169	89	60	3,505
1997	0	0	913	870	948	134	306	95	96	72	97	3,191
1998	0	0	68	303	564	1,690	151	140	141	360	427	3,839
1999	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	320	464	288	464	190	64	0	0	3	1,795
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	154	1,321	8,673	7,234	3,128	988	583	515	229	116	22,941
2006	0	1	28	192	574	85	30	15	0	0	0	926
2007	0	0	176	238	37	322	118	87	19	31	8	1,036
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	61	211	126	81	9	4	1	0	0	438
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	18	35	91	33	76	10	1	1	261
2013	0	0	0	447	212	543	1,060	571	565	82	17	3,307
2014	0	0	0	0	930	256	398	454	120	78	0	2,107
2015	0	0	0	231	108	906	253	261	185	49	0	1,810
2016	0	0	633	207	231	0	0	0	0	0	0	1,172
2017	0	0	98	7	18	33	7	2	6	0	0	155
2018	0	0	0	0	137	174	755	396	53	104	0	1,639
2019	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0
c) South												
1978	0	1,253	16,471	5,727	2,628	890	1,469	2,846	592	693	4,007	36,647
1979	3	3,204	994	778	821	1,094	250	499	329	86	2,092	8,117
1980	0	653	23,220	10,725	19,568	9,324	3,900	1,139	1,437	1,194	1,064	72,306
1981	0	882	6,631	6,750	651	173	265	19	132	0	0	15,546
1982	0	0	700	1,053	954	324	65	63	41	5	33	5,157
1983	0	0	1,452	1,298	785	701	233	89	138	12	47	4,476
1984	0	0	343	1,770	1,140	950	449	121	43	4	7	5,290
1985	0	0	287	386	1,327	969	383	237	67	46	0	3,911
1986	0	262	1,101	836	272	408	138	63	47	8	5	2,750
1987	0	5	205	286	111	36	120	178	56	39	28	1,661

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
1988	0	0	117	101	193	106	173	185	64	75	71	1,374
1989	0	0	14	27	51	159	68	76	98	36	18	586
1990	0	0	356	318	373	170	377	263	277	134	34	2,823
1991	0	0	66	514	214	95	107	245	55	138	447	1,950
1992	0	0	74	400	907	523	400	335	581	392	806	4,150
1993	0	0	0	45	172	398	223	185	241	447	980	1,720
1994	0	0	0	2,036	1,272	4,691	6,226	618	1,076	858	1,777	18,229
1995	0	22	474	263	1,789	537	1,712	1,884	370	398	1,032	8,340
1996	0	0	1,444	2,400	2,169	2,433	1,720	1,383	729	424	751	13,927
1997	0	0	1,675	1,125	3,477	887	2,007	381	542	303	564	10,943
1998	0	0	3	77	122	353	118	490	91	273	697	2,240
1999	0	23	846	2,005	3,480	2,109	4,730	2,132	1,738	460	1,233	18,756
2000	0	236	1,926	3,738	1,875	1,020	371	459	83	47	118	9,875
2001	2	831	6,223	2,837	4,609	4,693	1,956	1,337	836	250	310	23,885
2002	0	954	2,799	6,060	4,530	4,663	3,411	870	232	455	174	24,148
2003	0	201	4,034	5,966	6,382	3,697	4,609	3,633	1,543	303	357	30,726
2004	0	448	2,059	6,792	3,471	2,984	2,191	1,801	1,445	467	333	21,992
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	240	360	260	420	381	129	10	15	3	0	1,817
2007	0	0	70	95	15	128	47	34	8	12	3	411
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	3	287	96	152	15	11	3	0	0	751
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	3	22	136	41	146	19	1	4	387
2013	0	0	0	258	193	707	1,970	644	783	45	42	4,768
2014	0	0	0	324	765	270	483	889	274	175	0	3,189
2015	0	0	61	0	170	719	250	430	209	89	26	2,115
2016	0	0	345	227	644	0	0	0	0	0	0	1,465
2017	0	0	1	20	5	34	8	1	1	0	0	98
2018	0	0	0	0	168	239	388	319	82	112	0	1,350
2019	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0

Table 11. Fall spawner weight-at-age (kg) for mobile gear in the 4T Herring fishery.

	Weight-at-age										
Year	1	2	3	4	5	6	7	8	9	10	11
1978	-	0.100	0.149	0.214	0.253	0.278	0.293	0.331	0.332	0.316	0.388
1979	0.067	0.123	0.180	0.232	0.266	0.293	0.291	0.340	0.365	0.355	0.380
1980	0.033	0.108	0.139	0.174	0.224	0.245	0.290	0.338	0.379	0.388	0.423
1981	0.080	0.111	0.181	0.226	0.256	0.314	0.366	0.234	0.261	0.470	-
1982	-	0.095	0.168	0.221	0.259	0.279	0.374	0.334	0.355	0.455	0.434
1983	-	0.103	0.170	0.213	0.246	0.283	0.316	0.375	0.349	0.222	0.456
1984	-	0.095	0.146	0.208	0.248	0.279	0.305	0.329	0.373	0.392	0.433
1985	-	0.090	0.190	0.215	0.258	0.281	0.311	0.326	0.382	0.419	-
1986	-	0.116	0.158	0.207	0.252	0.276	0.306	0.328	0.335	0.362	0.404
1987	-	0.111	0.172	0.218	0.250	0.284	0.319	0.341	0.351	0.391	0.393
1988	0.074	0.095	0.157	0.220	0.261	0.307	0.327	0.341	0.342	0.414	0.382
1989	-	0.099	0.159	0.213	0.250	0.279	0.319	0.323	0.327	0.360	0.377
1990	-	0.105	0.171	0.213	0.236	0.288	0.310	0.323	0.329	0.338	0.386
1991	-	-	0.149	0.191	0.221	0.263	0.279	0.307	0.310	0.327	0.380
1992	-	0.072	0.128	0.171	0.211	0.237	0.261	0.282	0.290	0.301	0.335
1993	-	0.076	0.128	0.156	0.199	0.225	0.258	0.279	0.310	0.323	0.354
1994	-	0.086	0.134	0.159	0.174	0.204	0.222	0.262	0.274	0.302	0.336
1995	-	0.072	0.118	0.163	0.177	0.198	0.224	0.239	0.271	0.310	0.341
1996	-	0.089	0.133	0.165	0.183	0.209	0.222	0.248	0.269	0.291	0.331
1997	-	0.082	0.141	0.165	0.191	0.224	0.226	0.241	0.262	0.296	0.339
1998	-	0.076	0.126	0.165	0.187	0.224	0.248	0.244	0.303	0.300	0.387
1999	-	0.072	0.128	0.155	0.189	0.214	0.248	0.271	0.289	0.317	0.356
2000	-	0.077	0.131	0.162	0.185	0.208	0.231	0.262	0.263	0.275	0.318
2001	0.023	0.078	0.127	0.156	0.184	0.200	0.215	0.240	0.251	0.237	0.295
2002	-	0.084	0.148	0.188	0.222	0.245	0.272	0.290	0.321	0.329	0.360
2003	-	0.081	0.138	0.169	0.197	0.219	0.240	0.260	0.276	0.318	0.310
2004	-	0.080	0.131	0.160	0.181	0.204	0.224	0.248	0.265	0.278	0.290
2005	-	0.078	0.125	0.151	0.177	0.202	0.228	0.282	0.284	0.301	0.349
2006	-	0.079	0.132	0.164	0.181	0.206	0.215	0.228	0.264	0.301	0.345
2007	-	0.086	0.127	0.152	0.165	0.184	0.202	0.215	0.226	0.258	0.205
2008	-	0.093	0.133	0.153	0.159	0.179	0.184	0.197	0.210	0.218	-
2009	-	0.092	0.123	0.146	0.166	0.179	0.195	0.220	0.231	-	-
2010	0.044	0.094	0.118	0.137	0.155	0.166	0.176	0.198	0.194	0.205	0.309
2011	-	0.069	0.104	0.123	0.141	0.153	0.168	0.179	0.200	0.186	0.234
2012	-	0.076	0.107	0.125	0.142	0.162	0.163	0.206	0.228	0.219	0.245
2013	0.033	0.078	0.112	0.130	0.150	0.169	0.184	0.209	0.218	0.234	0.254
2014	-	0.065	0.109	0.134	0.150	0.167	0.182	0.200	0.222	0.224	-
2015	-	0.102	0.102	0.125	0.148	0.164	0.190	0.194	0.205	0.214	0.231
2016	-	0.096	0.115	0.125	0.167	0.165	0.171	0.186	0.195	0.186	0.196
2017	-	0.071	0.103	0.128	0.172	0.197	0.220	0.254	0.250	-	-
2018	-	0.097	0.097	0.107	0.131	0.151	0.168	0.198	0.191	0.224	0.233
2019	-	-	0.107	0.115	0.135	0.159	0.173	0.178	0.200	0.241	0.234
2020	-	0.084	0.099	0.127	0.139	0.163	0.181	0.178	0.179	0.196	0.220
2021	-	-	-	-	-	-	-	-	-	-	-

Table 12. *Percent of fishing days with no gillnet catch derived from the telephone survey for main fishing areas in the spring and fall fishery.*

Year	Spring fishing season (%)	Fall fishing season (%)
2006	46.7	16.7
2007	40.0	28.8
2008	49.4	28.8
2009	23.2	17.5
2010	34.1	19.9
2011	26.2	27.3
2012	43.1	24.2
2013	36.3	22.8
2014	29.6	31.5
2015	16.2	40.9
2016	27.8	23.9
2017	39.8	40.5
2018	37.2	40.7
2019	25.5	30.3
2020	24.3	37.3
2021	24.3	37.3

Table 13. Results of the multiplicative general linear model applied to the fishery catch-per-unit-effort data for each region (NAFO 4T).

Area	R^2	F_{year}	P_{year}	F_{week}	P_{week}	F_{area}	P_{area}
Spring spawner (SS)							
4T	0.40	19.4	<0.0001	11.7	<0.0001	52.4	<0.0001
Fall spawner (FS)							
North region	0.57	2.8	<0.0001	19.2	<0.0001	-	-
Middle region	0.69	2.3	0.0002	14.2	<0.0001	-	-
South region	0.51	4.3	<0.0001	12.7	<0.0001	-	-

Table 14. Spring spawner fixed gear catch-per-unit-effort values (number per net-haul) for NAFO area 4T.

Year	Age							
	4	5	6	7	8	9	10	11
1990	113.7	63.3	33.5	39.0	60.5	28.1	11.3	4.7
1991	176.6	213.1	137.8	47.7	43.7	67.0	24.7	16.5
1992	530.6	203.9	133.9	61.1	28.1	34.5	25.1	40.0
1993	58.2	428.2	195.0	52.0	25.6	14.6	7.5	28.9
1994	44.2	186.5	367.4	68.5	27.2	9.2	3.3	7.8
1995	123.5	99.8	164.6	267.7	59.3	16.5	10.7	21.0
1996	14.2	405.7	76.9	119.4	79.4	26.2	5.0	9.2
1997	70.8	53.0	492.5	90.6	54.0	51.3	13.2	2.3
1998	75.2	153.3	22.0	290.0	33.2	23.8	19.1	8.5
1999	69.6	99.2	108.6	23.8	169.2	27.2	14.2	12.2
2000	101.8	135.8	129.7	64.4	37.9	99.3	24.8	14.9
2001	107.4	124.2	93.6	46.7	31.9	13.2	62.6	16.5
2002	67.8	176.6	73.4	34.7	20.0	11.1	10.1	11.7
2003	129.9	133.6	154.9	47.4	30.0	12.0	8.3	9.2
2004	23.6	136.7	48.9	77.0	29.2	10.5	3.7	9.1
2005	65.4	57.6	103.9	46.0	36.3	10.2	2.3	3.1
2006	60.5	216.7	76.9	24.6	13.3	18.0	1.3	3.4
2007	94.8	72.7	108.1	80.9	37.4	9.1	6.9	5.1
2008	145.4	160.9	58.9	65.2	13.9	2.7	1.2	0.6
2009	86.0	198.3	246.1	27.9	28.3	7.4	0.5	1.1
2010	56.4	43.8	79.4	39.0	18.6	18.3	0.2	0.7
2011	7.8	59.9	55.0	74.7	34.7	53.0	19.5	0.3
2012	51.6	51.5	78.5	86.6	43.8	29.0	24.0	10.8
2013	38.0	120.6	144.9	186.9	142.9	101.9	6.2	4.8
2014	2.5	65.1	110.9	124.5	154.9	80.4	31.8	9.6
2015	14.6	22.2	110.9	169.2	75.8	56.1	10.8	5.8
2016	1.9	46.8	77.0	119.2	55.8	24.4	7.3	1.5
2017	81.6	86.6	229.6	187.7	140.1	32.0	5.7	0.4
2018	5.6	82.3	64.4	91.5	34.0	10.7	0.3	0.0
2019	28.1	65.0	143.8	46.0	58.0	11.5	1.7	0.0
2020	60.3	106.3	101.6	119.9	88.7	10.3	8.9	2.1
2021	16.7	100.1	143.8	212.2	215.9	34.6	12.7	2.8

Table 15. Fall spawner fixed gear catch-per-unit-effort values (number per net-haul) by region: a) North, b) Middle, and c) South.

Year	Age							
	4	5	6	7	8	9	10	11
a) North								
1986	104.7	102.8	231.6	162.2	76.9	35.1	4.7	8.1
1987	191.8	115.8	105.0	156.7	71.7	43.5	19.1	6.0
1988	111.2	191.0	73.3	65.0	59.6	31.7	15.3	15.0
1989	185.6	302.9	323.7	157.4	72.1	90.7	40.6	32.4
1990	68.5	62.5	97.0	103.0	38.9	27.3	28.7	20.6
1991	482.6	122.7	90.5	134.3	128.5	41.4	25.8	42.2
1992	73.6	446.8	127.8	74.5	81.1	71.3	34.4	64.9
1993	30.3	311.2	360.9	50.6	28.3	29.1	8.3	10.5
1994	40.5	65.0	194.8	294.1	56.0	43.5	19.9	33.4
1995	17.7	128.6	59.6	143.7	152.5	26.7	17.1	18.7
1996	82.9	100.2	134.8	29.6	56.3	61.4	8.7	10.1
1997	90.7	312.5	96.3	85.8	16.5	28.7	25.7	7.5
1998	56.4	154.7	147.6	37.0	35.2	5.1	8.2	14.9
1999	121.9	146.7	182.4	64.8	12.8	8.2	2.2	3.2
2000	152.4	497.1	132.3	55.7	30.5	5.9	4.4	2.0
2001	146.5	185.3	190.9	29.2	13.1	3.6	1.1	1.5
2002	185.7	203.1	142.4	76.6	20.0	6.0	4.1	1.6
2003	85.8	180.6	121.2	85.5	102.1	25.5	11.2	7.0
2004	212.6	158.7	77.1	46.7	36.2	24.8	5.7	3.9
2005	48.2	537.7	214.3	82.5	45.5	27.4	19.4	1.8
2006	16.5	102.5	99.5	14.8	4.2	7.9	3.1	1.6
2007	35.6	105.5	239.8	165.0	35.2	6.6	6.1	3.9
2008	65.4	41.6	66.4	53.9	52.1	6.3	2.1	3.1
2009	120.1	204.9	56.4	55.7	32.5	9.0	1.6	1.3
2010	18.1	154.8	133.6	46.2	30.9	24.3	9.9	1.2
2011	8.2	31.7	132.9	120.4	13.7	15.6	14.2	3.8
2012	1.1	62.2	127.6	190.2	85.1	16.9	19.9	6.9
2013	9.1	77.9	250.9	180.0	92.5	19.8	1.6	0.9
2014	1.7	81.0	178.6	445.7	205.2	138.8	1.8	1.1
2015	2.4	70.2	498.9	371.0	447.1	139.0	22.1	5.9
2016	19.5	80.7	219.7	272.0	189.6	61.7	29.0	5.1
2017	7.8	74.7	112.6	202.7	235.2	82.2	29.4	5.2
2018	0.0	19.3	232.4	281.5	219.5	106.4	38.2	4.6
2019	1.3	17.6	297.4	556.6	193.5	134.3	43.1	14.1
2020	4.9	30.7	105.4	496.9	407.6	255.8	65.4	10.3
2021	5.5	85.2	87.7	116.7	276.5	141.1	51.4	8.9
b) Middle								
1986	131.9	109.5	202.5	92.3	35.8	16.5	2.2	3.8
1987	79.5	149.8	130.3	260.3	24.6	22.7	25.4	1.6
1988	68.4	62.3	54.7	25.1	26.3	19.6	0.3	0.0
1989	23.6	43.8	39.0	21.2	13.1	11.6	5.2	4.2
1990	46.9	33.9	36.8	64.7	13.4	9.3	7.3	1.6
1991	154.2	41.8	34.4	45.2	53.3	32.8	15.1	34.5
1992	103.2	250.4	34.1	14.2	8.1	5.8	2.8	6.6
1993	9.6	180.8	226.9	38.7	16.3	11.4	12.8	19.6
1994	14.1	22.8	114.5	154.0	18.8	5.9	7.3	12.3
1995	2.7	125.4	42.7	153.4	133.3	17.1	3.0	53.5
1996	61.5	38.0	217.9	18.8	56.6	64.9	15.0	15.7
1997	125.0	283.8	51.2	106.6	20.2	24.2	26.5	16.5
1998	53.5	45.0	91.3	18.4	34.4	6.2	13.5	23.3

Year	Age							
	4	5	6	7	8	9	10	11
1999	118.2	157.1	62.1	39.2	15.9	34.8	3.4	16.2
2000	201.1	384.5	141.7	45.8	25.4	7.5	6.7	3.0
2001	108.7	267.4	189.7	57.5	12.4	4.1	0.0	5.8
2002	145.9	130.3	115.2	111.4	20.0	2.8	2.3	3.5
2003	84.8	177.8	83.2	56.1	56.2	12.6	1.7	2.3
2004	126.3	229.2	161.7	115.4	102.4	60.0	20.8	4.0
2005	54.2	333.8	270.3	81.3	70.0	48.3	20.6	1.5
2006	47.3	215.5	383.9	141.8	72.3	54.3	43.0	14.6
2007	50.8	145.6	403.8	416.6	158.6	64.1	31.1	19.3
2008	316.9	67.0	116.9	138.6	221.6	40.0	37.8	8.6
2009	154.0	273.6	63.4	140.0	67.3	23.4	10.0	4.6
2010	12.7	95.3	141.3	41.2	36.0	20.6	9.6	5.4
2011	4.4	22.6	131.8	169.2	32.2	24.3	22.8	6.8
2012	2.3	30.5	136.9	183.7	128.4	14.6	8.3	7.0
2013	16.9	32.2	201.4	301.0	184.5	71.1	5.8	1.2
2014	0.0	48.0	30.0	102.7	113.1	21.3	10.5	0.0
2015	6.9	44.2	422.8	188.1	319.1	125.5	44.6	0.0
2016	18.1	79.7	511.1	419.5	234.0	104.6	37.0	0.0
2017	2.1	17.2	59.7	111.1	136.4	77.6	10.7	0.4
2018	4.0	37.2	154.2	389.9	296.4	29.1	15.8	0.0
2019	4.5	8.1	73.7	248.1	117.5	154.0	47.1	9.4
2020	0.0	22.3	17.1	195.7	206.1	157.2	76.1	48.5
2021	8.7	82.3	99.5	127.6	341.4	188.4	47.4	22.3
c) South								
1986	486.6	136.8	287.3	79.8	38.9	11.6	2.5	3.9
1987	133.2	153.3	73.4	168.5	74.3	51.3	22.1	15.8
1988	62.4	239.1	138.4	68.0	95.1	43.5	14.1	9.5
1989	106.8	163.6	656.5	331.2	142.1	192.7	49.0	23.6
1990	110.9	110.2	126.3	589.7	161.3	70.8	75.2	40.5
1991	356.2	120.0	96.2	86.3	280.2	98.1	60.3	85.5
1992	101.1	565.0	81.9	47.8	114.4	252.8	94.0	99.6
1993	30.3	323.0	390.6	98.3	40.5	58.7	48.5	112.5
1994	35.6	7.5	243.5	336.0	45.6	59.9	128.0	212.6
1995	4.1	96.0	33.2	147.7	126.0	33.5	36.8	89.2
1996	44.9	26.9	176.1	63.2	147.3	140.6	35.9	109.0
1997	124.8	745.0	66.9	283.4	49.1	102.5	96.4	85.7
1998	125.8	59.1	210.4	53.1	119.1	23.4	45.9	56.6
1999	155.9	564.6	76.6	170.4	33.3	54.5	20.2	28.0
2000	119.8	468.0	279.3	45.5	54.5	10.6	17.0	10.6
2001	39.8	493.2	461.3	296.9	43.7	34.9	9.5	18.1
2002	386.6	164.1	370.9	308.2	92.8	23.4	20.2	11.9
2003	102.1	843.1	131.1	275.1	174.9	34.2	5.3	7.7
2004	112.9	260.6	573.5	113.3	104.2	50.9	14.0	7.3
2005	10.0	292.3	483.1	753.8	143.3	146.0	41.0	9.1
2006	78.9	216.0	566.3	582.6	432.9	142.9	75.9	21.2
2007	8.0	360.0	526.6	964.6	599.1	192.8	114.6	36.6
2008	133.0	48.6	180.3	330.2	410.9	188.2	99.8	77.1
2009	55.0	473.6	237.2	472.8	156.3	82.9	120.2	59.9
2010	49.1	206.9	758.6	197.4	245.7	160.9	90.3	57.6
2011	7.7	186.3	185.1	625.5	200.5	99.7	58.2	103.6
2012	0.3	13.1	140.9	159.4	170.0	18.1	5.2	17.5
2013	8.9	26.6	238.3	508.8	189.0	89.6	2.9	2.8
2014	5.7	94.6	75.8	298.6	530.6	116.6	56.6	1.9
2015	0.0	60.4	291.4	160.9	455.8	122.6	70.2	7.6

Year	Age							
	4	5	6	7	8	9	10	11
2016	2.6	28.8	89.5	49.1	36.1	16.4	4.8	0.3
2017	9.7	7.9	97.5	198.0	70.2	26.1	5.5	0.5
2018	0.5	17.8	82.6	78.3	93.3	17.5	6.7	1.6
2019	5.6	8.2	346.0	861.4	363.1	266.9	84.9	36.2
2020	0.6	19.4	56.0	193.5	221.2	124.4	77.5	10.6
2021	2.2	26.6	188.0	149.0	350.1	149.2	19.0	24.9

Table 16. Spring spawner and fall spawner catch-at-age from the fishery-independent acoustic survey in NAFO area 4Tmno.

Year	Catch-at-age								
	2	3	4	5	6	7	8	9	10
Spring spawner									
1994	2,548	231,972	100,087	109,649	104,274	28,059	6,389	7,213	1,020
1995	46,535	7,724	76,887	21,389	24,905	20,645	4,959	736	74
1996	278,013	139,355	16,008	159,956	40,479	26,474	29,966	5,851	3,603
1997	101,589	68,210	70,032	9,970	84,978	5,522	12,833	14,800	2,648
1998	151,583	28,563	31,795	19,716	5,616	37,904	6,423	5,438	3,585
1999	238,373	107,078	47,912	19,836	6,278	3,667	18,015	2,748	1,380
2000	20,037	29,123	24,640	6,843	5,361	1,647	4,821	2,155	448
2001	27,425	4,997	6,963	4,343	1,605	1,844	119	500	440
2002	88,655	13,609	2,289	8,815	3,494	847	1,684	271	123
2003	220,566	29,059	29,526	18,176	17,349	1,461	1,878	3,586	2,843
2004	231,086	52,413	1,258	1,328	556	0	0	0	0
2005	15,262	34,282	31,252	1,542	2,852	588	249	0	0
2006	56,579	15,674	20,989	18,519	1,770	885	0	257	0
2007	37,678	31,964	6,481	11,994	8,039	1,050	1,456	0	0
2008	47,260	19,560	7,599	6,554	5,760	3,091	2,294	532	0
2009	36,674	35,845	16,153	7,076	2,438	1,224	1,773	0	0
2010	29,739	38,543	39,988	8,137	8,469	3,930	2,433	1,517	0
2011	20,724	39,960	14,878	16,259	10,973	4,135	106	3,538	104
2012	3,665	113,586	29,857	9,938	6,969	2,494	1,243	260	379
2013	604	8,850	21,554	21,927	13,612	4,517	1,456	0	0
2014	23,417	17,322	13,489	7,512	6,430	7,003	666	0	872
2015	57,318	66,883	30,346	26,148	8,971	22,890	16,166	1,244	1,713
2016	6,910	45,251	12,587	7,921	6,040	2,515	1,261	2,222	0
2017	977	21,840	45,750	9,669	7,939	15,161	900	0	0
2018	517	2,932	11,722	20,933	4,215	5,128	3,246	4,076	286
2019	121	5,732	11,452	8,947	11,240	5,954	1,975	1,027	12
2020	98	9,066	7,900	10,749	5,941	13,652	6,531	2,279	209
2021	69	4,464	29,305	6,824	6,205	14,225	11,506	4,038	3,026
Fall spawner									
1994	2,157	4,442	201,387	61,956	33,090	17,255	2,309	0	12
1995	12,349	22,326	11,645	50,030	9,306	15,773	23,592	1,762	767
1996	225,769	241,001	163,904	21,951	72,902	16,442	9,671	4,046	961
1997	66,808	306,768	200,366	69,384	8,383	32,111	9,572	8,225	3,820
1998	66,600	190,598	74,419	45,341	27,959	5,228	22,791	3,178	5,052
1999	59,703	308,283	191,388	63,421	32,461	15,972	2,502	4,774	4,719
2000	55,502	127,954	188,246	137,871	40,048	13,236	6,624	2,368	3,731
2001	96,857	32,803	12,930	10,047	8,640	1,367	817	214	125
2002	258,715	44,258	31,652	20,948	28,715	16,128	4,708	689	93
2003	50,838	333,738	98,553	41,490	9,442	11,315	18,169	4,074	1,247
2004	29,536	69,977	53,648	10,918	2,238	63	278	0	734
2005	29,090	62,910	254,830	139,139	31,887	10,935	4,141	4,135	1,762
2006	220,870	75,320	43,319	75,695	51,402	7,406	1,436	806	543
2007	99,281	178,232	49,782	21,208	13,262	7,885	649	712	571
2008	71,833	114,412	60,903	9,288	6,846	5,522	5,750	520	322
2009	71,658	112,022	80,911	39,829	5,644	1,569	833	134	37
2010	35,034	108,389	114,470	94,716	25,242	4,023	1,296	213	213
2011	29,046	42,618	88,110	68,688	51,739	22,620	4,808	2,908	1,077
2012	306	251,515	124,155	109,611	54,470	18,041	1,794	2,958	190
2013	4,292	19,527	173,674	70,662	99,164	41,757	10,859	7,683	11,321
2014	141,469	73,572	23,157	100,959	52,157	49,191	29,077	8,924	2,203

Year	Catch-at-age								
	2	3	4	5	6	7	8	9	10
2015	9,286	475,926	140,251	51,569	218,421	46,386	28,011	15,334	1,606
2016	30,862	45,012	186,762	49,395	64,463	59,739	27,586	6,224	0
2017	20,893	41,153	64,922	148,495	61,293	18,118	30,772	1,595	641
2018	25,983	19,013	19,434	9,203	34,144	19,067	3,854	1,349	1,945
2019	1,740	25,633	23,656	7,543	11,635	16,264	5,022	308	749
2020	34,495	52,083	43,603	29,954	5,786	7,494	17,243	2,715	2,381
2021	46,093	58,462	23,208	28,346	12,510	6,955	14,632	12,364	2,232

Table 17. Relative selectivity-at-age for 2⅝” and 2¾” mesh calculated from the experimental netting survey and commercial gillnet fishery.

Year	Age													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2 ⅝"														
1986	0.164	0.347	0.611	0.840	0.947	0.931	0.918	0.836	0.528	0.771	0.540	0.464	0.458	0.448
1987	0.393	0.483	0.596	0.813	0.943	0.947	0.894	0.833	0.771	0.675	0.562	0.393	0.393	0.393
1988	0.185	0.347	0.657	0.834	0.927	0.946	0.903	0.877	0.781	0.728	0.667	0.492	0.444	0.416
1989	0.283	0.399	0.647	0.882	0.963	0.961	0.856	0.831	0.739	0.776	0.561	0.574	0.514	0.406
1990	0.017	0.306	0.604	0.824	0.936	0.935	0.856	0.754	0.760	0.700	0.651	0.586	0.526	0.419
1991	0.212	0.372	0.510	0.751	0.909	0.935	0.925	0.899	0.788	0.745	0.670	0.527	0.426	0.413
1992	0.233	0.251	0.464	0.709	0.931	0.883	0.916	0.861	0.810	0.763	0.683	0.549	0.425	0.393
1993	0.153	0.153	0.436	0.630	0.832	0.936	0.912	0.867	0.832	0.772	0.707	0.716	0.635	0.393
1994	0.041	0.057	0.327	0.622	0.781	0.917	0.954	0.919	0.853	0.809	0.675	0.543	0.728	0.490
1995	0.116	0.420	0.402	0.529	0.676	0.857	0.938	0.915	0.863	0.808	0.837	0.693	0.580	0.436
1996	0.072	0.192	0.398	0.608	0.688	0.811	0.916	0.956	0.863	0.776	0.710	0.748	0.575	0.645
1997	0.028	0.096	0.312	0.555	0.727	0.859	0.936	0.953	0.960	0.834	0.690	0.631	0.706	0.472
1998	0.033	0.135	0.364	0.522	0.718	0.864	0.933	0.947	0.941	0.930	0.754	0.736	0.687	0.573
1999	0.064	0.083	0.319	0.533	0.628	0.811	0.896	0.952	0.930	0.921	0.758	0.603	0.687	0.444
2000	0.008	0.098	0.327	0.496	0.685	0.815	0.915	0.953	0.958	0.902	0.835	0.802	0.713	0.470
2001	0.008	0.067	0.294	0.475	0.626	0.786	0.888	0.956	0.944	0.952	0.898	0.799	0.577	0.503
2002	0.001	0.128	0.282	0.446	0.584	0.727	0.852	0.936	0.946	0.936	0.945	0.877	0.752	0.726
2003	0.048	0.213	0.287	0.429	0.586	0.724	0.826	0.907	0.934	0.960	0.914	0.926	0.696	0.393
2004	0.006	0.097	0.272	0.420	0.575	0.697	0.837	0.907	0.941	0.937	0.900	0.840	0.580	0.513
2005	0.000	0.058	0.236	0.425	0.537	0.639	0.794	0.869	0.913	0.919	0.932	0.852	0.590	0.512
2006	0.012	0.123	0.245	0.395	0.556	0.654	0.765	0.888	0.923	0.958	0.913	0.730	0.917	0.724
2007	0.021	0.048	0.280	0.394	0.553	0.683	0.762	0.835	0.907	0.893	0.902	0.969	0.661	0.369
2008	0.015	0.034	0.182	0.378	0.523	0.650	0.744	0.793	0.877	0.904	0.932	0.954	0.808	0.802
2009	0.023	0.079	0.212	0.314	0.511	0.649	0.752	0.829	0.853	0.882	0.944	0.943	0.951	0.814
2010	0.001	0.027	0.147	0.321	0.384	0.586	0.652	0.738	0.809	0.803	0.896	0.957	0.970	0.774
2011	0.001	0.022	0.097	0.271	0.426	0.467	0.667	0.725	0.804	0.862	0.848	0.927	0.905	0.757
2012	0.000	0.056	0.090	0.209	0.342	0.484	0.536	0.707	0.815	0.891	0.934	0.869	0.658	0.612
2013	0.012	0.031	0.093	0.253	0.338	0.439	0.546	0.597	0.751	0.911	0.850	0.970	0.959	0.950
2014	0.012	0.050	0.170	0.256	0.352	0.395	0.484	0.576	0.623	0.980	0.965	0.942	0.895	0.829
2015	0.007	0.068	0.145	0.293	0.337	0.460	0.512	0.601	0.660	0.793	0.791	0.735	0.702	0.684
2016	0.002	0.056	0.184	0.349	0.438	0.513	0.581	0.650	0.720	0.902	0.917	0.821	0.597	0.580
2017	0.047	0.264	0.207	0.307	0.441	0.521	0.593	0.666	0.771	0.782	0.823	0.751	0.652	0.559
2018	0.012	0.028	0.126	0.305	0.402	0.503	0.566	0.619	0.699	0.819	0.852	0.912	0.900	0.893
2019	0.002	0.019	0.090	0.160	0.327	0.409	0.504	0.555	0.629	0.694	0.829	0.911	0.877	0.794
2020	0.001	0.035	0.099	0.215	0.393	0.469	0.558	0.622	0.693	0.757	0.962	0.897	0.892	0.889
2021	0.005	0.034	0.095	0.206	0.293	0.428	0.539	0.616	0.740	0.775	0.815	0.836	0.831	0.826
2 3/4"														
1986	0.067	0.173	0.371	0.625	0.803	0.938	0.967	0.951	0.804	0.959	0.815	0.747	0.740	0.730
1987	0.027	0.262	0.359	0.579	0.806	0.898	0.962	0.942	0.902	0.895	0.823	0.673	0.673	0.673
1988	0.077	0.173	0.415	0.609	0.770	0.897	0.923	0.985	0.929	0.940	0.903	0.768	0.723	0.696
1989	0.129	0.203	0.408	0.689	0.818	0.942	0.966	0.958	0.927	0.951	0.826	0.823	0.777	0.693
1990	0.005	0.160	0.366	0.592	0.852	0.946	0.960	0.935	0.942	0.907	0.873	0.826	0.784	0.701
1991	0.090	0.188	0.288	0.504	0.710	0.931	0.957	0.962	0.956	0.929	0.891	0.796	0.707	0.694
1992	0.103	0.113	0.249	0.460	0.724	0.728	0.950	0.964	0.959	0.946	0.897	0.814	0.706	0.673
1993	0.061	0.061	0.229	0.387	0.597	0.770	0.875	0.969	0.962	0.922	0.906	0.918	0.881	0.673
1994	0.013	0.020	0.159	0.382	0.535	0.727	0.897	0.959	0.959	0.949	0.906	0.813	0.906	0.767
1995	0.058	0.218	0.209	0.302	0.448	0.647	0.772	0.903	0.967	0.949	0.970	0.901	0.844	0.718
1996	0.025	0.081	0.209	0.367	0.443	0.584	0.759	0.876	0.957	0.929	0.911	0.919	0.816	0.897
1997	0.009	0.036	0.152	0.326	0.476	0.636	0.763	0.852	0.929	0.934	0.901	0.872	0.927	0.755
1998	0.010	0.055	0.183	0.297	0.473	0.652	0.766	0.866	0.934	0.948	0.922	0.905	0.915	0.838
1999	0.022	0.030	0.156	0.305	0.392	0.580	0.682	0.875	0.914	0.945	0.938	0.855	0.877	0.726
2000	0.002	0.038	0.162	0.277	0.438	0.582	0.729	0.824	0.916	0.947	0.976	0.956	0.908	0.747
2001	0.002	0.024	0.141	0.261	0.382	0.545	0.678	0.813	0.910	0.910	0.945	0.937	0.825	0.767
2002	0.000	0.056	0.133	0.239	0.347	0.482	0.629	0.763	0.792	0.943	0.933	0.977	0.955	0.941

Year	Age													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2003	0.016	0.102	0.137	0.228	0.350	0.478	0.599	0.719	0.821	0.915	0.974	0.975	0.898	0.673
2004	0.002	0.038	0.127	0.222	0.342	0.456	0.612	0.719	0.815	0.897	0.938	0.899	0.846	0.785
2005	0.000	0.021	0.109	0.226	0.311	0.398	0.564	0.666	0.742	0.844	0.906	0.814	0.830	0.773
2006	0.027	0.049	0.113	0.206	0.328	0.414	0.529	0.694	0.758	0.830	0.868	0.949	0.967	0.944
2007	0.006	0.017	0.132	0.204	0.325	0.441	0.524	0.624	0.732	0.765	0.799	0.931	0.902	0.825
2008	0.005	0.012	0.078	0.196	0.303	0.412	0.505	0.560	0.674	0.731	0.822	0.934	0.957	0.950
2009	0.007	0.030	0.095	0.154	0.295	0.414	0.515	0.615	0.638	0.680	0.845	0.860	0.942	0.985
2010	0.000	0.009	0.063	0.158	0.198	0.359	0.423	0.507	0.588	0.598	0.757	0.880	0.923	0.968
2011	0.000	0.007	0.038	0.132	0.230	0.258	0.441	0.494	0.583	0.685	0.707	0.872	0.946	0.957
2012	0.000	0.021	0.034	0.092	0.172	0.270	0.309	0.473	0.590	0.712	0.843	0.805	0.892	0.861
2013	0.027	0.010	0.037	0.119	0.169	0.236	0.314	0.356	0.512	0.698	0.608	0.956	0.972	0.983
2014	0.027	0.017	0.071	0.120	0.177	0.205	0.268	0.339	0.379	0.931	0.829	0.940	0.947	0.951
2015	0.002	0.024	0.059	0.140	0.167	0.253	0.289	0.361	0.414	0.579	0.950	0.937	0.926	0.918
2016	0.001	0.020	0.081	0.175	0.237	0.293	0.346	0.405	0.474	0.686	0.736	0.611	0.858	0.847
2017	0.015	0.127	0.098	0.151	0.241	0.299	0.356	0.422	0.539	0.593	0.954	0.919	0.864	0.809
2018	0.027	0.009	0.049	0.151	0.211	0.283	0.330	0.375	0.449	0.582	0.637	0.986	0.993	0.996
2019	0.000	0.006	0.035	0.069	0.162	0.215	0.284	0.323	0.386	0.447	0.583	0.677	0.982	0.939
2020	0.000	0.011	0.038	0.096	0.206	0.256	0.326	0.381	0.445	0.516	0.800	0.995	0.997	0.998
2021	0.001	0.011	0.037	0.091	0.142	0.235	0.317	0.383	0.500	0.545	0.602	0.989	0.988	0.987

Table 18. Multi-species bottom trawl survey fall spawning Herring stratified mean numbers per tow at age.

Year	Age										
	1	2	3	4	5	6	7	8	9	10	11+
1994	0.43	1.46	3.89	48.32	12.34	17.06	17.80	4.69	2.93	8.36	6.67
1995	2.69	3.17	27.91	15.75	51.73	11.28	18.52	14.96	2.19	3.18	7.79
1996	4.44	1.12	0.60	2.06	0.72	3.37	1.44	2.18	1.27	0.48	1.36
1997	10.84	10.57	8.20	8.55	28.58	11.46	22.60	6.04	5.60	2.78	4.36
1998	2.40	4.17	2.55	15.72	5.85	9.14	3.36	5.97	1.38	1.63	2.62
1999	42.60	60.15	12.94	8.52	5.53	1.71	2.21	1.27	1.06	0.65	0.89
2000	14.21	12.43	17.18	32.82	20.53	8.25	1.56	3.12	0.98	0.74	0.18
2001	0.53	8.69	41.15	22.70	22.64	16.55	7.62	3.18	2.44	0.98	1.90
2002	1.82	36.29	39.48	102.42	26.97	21.96	15.86	4.12	2.41	0.61	0.63
2003	5.68	2.32	6.43	25.38	33.44	8.37	4.48	3.14	0.47	0.19	0.26
2004	6.51	4.57	16.84	26.49	17.57	17.97	12.22	8.09	4.03	0.90	0.82
2005	7.06	1.18	6.61	32.64	48.92	22.29	9.75	7.79	4.14	3.45	1.54
2006	37.10	11.55	2.23	7.79	6.02	9.66	4.73	2.61	0.24	0.11	0.27
2007	31.69	146.87	110.27	10.97	18.69	12.61	14.99	5.95	3.58	1.08	1.07
2008	23.84	15.63	24.81	18.50	3.37	6.36	6.54	4.09	3.09	1.10	1.11
2009	2.26	16.36	25.53	25.27	20.78	5.18	2.96	1.56	1.62	0.06	0.44
2010	3.16	38.96	46.17	71.07	50.75	49.98	6.44	6.53	4.77	3.50	2.83
2011	3.89	70.08	10.82	58.62	66.92	34.08	17.12	8.01	5.01	1.69	1.43
2012	0.16	50.47	243.65	59.90	159.89	131.15	63.86	29.16	5.07	1.37	0.38
2013	1.54	5.61	15.38	66.46	23.06	24.28	16.18	8.30	1.01	0.31	0.21
2014	4.14	21.58	10.55	20.35	87.41	15.48	11.74	7.77	0.39	0.09	0.01
2015	4.07	29.33	68.04	20.07	16.37	33.13	11.28	14.45	5.81	1.43	0.22
2016	7.58	8.87	13.64	21.29	10.41	20.79	11.18	2.07	1.42	0.30	0.08
2017	2.13	15.30	12.18	14.45	9.81	6.30	10.11	2.20	0.50	0.03	0.00
2018	2.34	23.91	6.36	3.59	5.42	8.26	3.11	2.29	0.70	0.49	0.02
2019	4.38	3.26	2.60	2.05	0.68	0.81	0.75	0.38	0.10	0.06	0.00
2020	0.06	6.71	0.58	0.51	0.26	0.18	0.19	0.23	0.08	0.02	0.03
2021	3.80	16.03	8.99	8.60	12.84	10.07	2.75	6.06	2.88	1.26	0.11

Table 19. *Maximum likelihood estimates (MLEs) of January 1 spring spawner biomass (t).*

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	16,656	12,556	50,187	13,105	12,749	6,074	2,938	2,972	3,135	8,075	99,235
1979	30,237	14,574	9,529	29,504	7,312	7,423	3,648	1,861	1,741	6,408	67,427
1980	30,097	18,496	9,309	5,048	13,490	3,150	3,387	1,647	915	3,639	40,585
1981	69,204	21,974	11,299	4,884	2,701	6,382	1,503	1,562	759	2,197	31,287
1982	80,770	54,736	16,141	8,360	3,586	1,979	4,315	1,042	1,137	1,862	38,422
1983	66,544	68,527	43,024	12,181	5,608	2,562	1,013	2,956	701	2,000	70,045
1984	51,240	59,790	58,495	32,379	9,420	4,229	1,740	604	1,833	1,624	110,324
1985	28,533	62,245	52,093	51,346	26,679	7,782	2,979	1,110	514	2,125	144,629
1986	20,428	29,718	63,326	44,992	43,434	22,763	5,278	1,777	669	1,765	184,003
1987	32,741	20,757	27,025	50,262	36,639	33,954	14,385	3,039	1,025	1,409	167,738
1988	26,036	27,039	18,066	21,143	38,747	27,332	20,578	8,603	1,702	1,373	137,545
1989	51,332	33,299	22,744	13,378	15,808	28,566	15,442	11,420	4,665	1,633	113,656
1990	171,404	53,273	33,819	19,058	10,309	11,534	16,022	8,563	6,293	3,253	108,851
1991	66,565	128,900	46,978	26,917	13,586	6,934	6,402	8,460	4,570	5,259	119,108
1992	32,360	51,966	98,437	35,092	18,048	8,335	3,731	3,380	4,449	5,048	176,520
1993	92,287	31,533	42,806	74,766	24,637	12,059	4,830	2,113	1,902	5,176	168,290
1994	18,383	97,435	28,218	34,115	52,900	16,124	6,682	2,787	1,136	3,820	145,783
1995	20,836	14,620	92,182	22,481	24,338	35,985	8,992	3,646	1,522	2,500	191,645
1996	23,113	25,480	12,639	71,809	15,979	15,965	18,512	4,370	1,819	1,860	142,953
1997	28,226	23,263	24,472	10,008	50,797	10,549	8,271	9,413	2,081	1,809	117,401
1998	24,235	23,751	20,135	17,899	6,601	33,867	5,671	4,394	4,833	1,977	95,376
1999	36,452	22,481	19,148	14,715	11,776	4,169	17,903	3,040	2,254	3,422	76,427
2000	20,254	30,757	18,212	13,494	9,036	6,556	2,220	9,171	1,509	2,760	62,958
2001	22,884	14,724	23,150	11,700	6,923	4,133	2,800	931	3,792	1,681	55,109
2002	10,762	18,293	10,343	14,365	5,848	3,070	1,724	1,153	369	2,178	39,050
2003	21,882	9,230	13,305	6,466	7,347	2,695	1,311	718	473	1,025	33,340
2004	17,742	19,278	6,705	7,855	3,078	3,086	1,042	491	260	531	23,049
2005	27,809	14,690	14,700	3,852	3,530	1,173	1,082	346	164	260	25,108
2006	29,298	20,479	10,752	9,645	2,304	1,715	436	341	110	111	25,413
2007	32,636	24,413	15,237	7,308	6,232	1,303	792	201	141	87	31,302
2008	48,636	24,650	18,471	10,226	4,512	3,393	589	310	82	86	37,668
2009	29,240	32,503	17,601	11,887	5,992	2,462	1,758	319	140	73	40,232
2010	28,655	19,468	21,065	10,984	7,342	3,564	1,524	1,026	177	118	45,799
2011	12,954	19,431	12,339	14,062	6,757	4,600	2,289	951	567	152	41,717
2012	10,860	13,219	14,411	8,618	9,024	4,338	2,486	1,192	502	372	40,943
2013	12,129	11,147	11,760	11,078	6,608	6,197	2,447	1,341	634	493	40,559
2014	13,329	10,879	10,226	9,137	8,204	4,730	3,228	1,221	669	516	37,931
2015	26,910	11,222	9,113	7,985	6,960	6,030	2,199	1,523	547	557	34,913
2016	12,555	23,421	9,784	7,129	6,120	4,956	2,361	849	589	386	32,172
2017	14,428	12,352	20,002	8,242	5,895	4,721	1,806	819	299	334	42,118
2018	12,489	12,703	10,394	17,073	6,765	4,773	1,672	619	288	213	41,797
2019	10,336	11,678	10,886	8,136	14,056	5,355	1,644	586	220	172	41,055
2020	4,094	9,543	9,616	8,927	6,890	11,078	2,037	611	243	148	39,550
2021	16,197	3,706	8,344	7,856	7,208	5,623	4,574	831	243	158	34,836

Table 20. Maximum likelihood estimates (MLEs) of January 1 spring spawner abundance (number in thousands).

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	147,395	88,419	235,732	56,609	49,722	20,981	9,894	8,937	8,557	21,837	412,271
1979	170,829	96,578	52,184	125,495	29,484	25,829	12,133	5,721	5,168	17,576	273,590
1980	201,589	109,059	50,508	22,418	51,706	12,087	11,697	5,494	2,591	10,299	166,800
1981	474,324	129,792	56,921	21,431	9,103	20,885	5,261	5,091	2,391	5,610	126,694
1982	642,560	325,614	82,565	33,588	12,446	5,276	12,370	3,116	3,015	4,739	157,117
1983	501,087	458,373	221,543	53,615	21,596	7,993	3,284	7,699	1,940	4,826	322,495
1984	540,509	367,032	320,520	147,985	35,467	14,269	4,889	2,009	4,710	4,139	533,988
1985	238,371	406,828	270,333	231,082	106,208	25,440	9,111	3,122	1,283	5,650	652,229
1986	162,906	181,987	302,129	195,362	166,033	76,257	15,740	5,637	1,932	4,289	767,379
1987	217,545	125,342	133,785	212,345	136,002	115,452	44,344	9,153	3,278	3,617	657,976
1988	298,582	168,360	90,968	91,134	142,715	91,259	62,832	24,133	4,981	3,753	511,775
1989	420,411	231,080	120,212	59,991	59,095	92,356	47,527	32,722	12,568	4,548	429,020
1990	981,131	324,834	165,942	80,312	39,470	38,809	49,865	25,660	17,667	9,241	426,967
1991	469,101	760,026	247,905	120,164	53,384	24,998	20,882	26,757	13,761	14,429	522,279
1992	312,964	358,884	571,976	176,075	77,659	32,712	13,445	11,197	14,338	15,104	912,505
1993	993,399	238,344	269,729	410,353	117,097	49,484	18,423	7,553	6,287	16,530	895,456
1994	129,643	759,429	179,620	193,287	270,867	73,794	26,719	9,921	4,065	12,279	770,552
1995	250,128	99,251	572,202	127,952	125,646	167,218	37,639	13,588	5,042	8,306	1,057,593
1996	229,985	191,864	74,790	405,012	81,776	75,808	79,144	17,756	6,405	6,292	746,982
1997	242,907	174,782	143,445	52,787	260,231	49,832	35,931	37,398	8,385	5,995	594,003
1998	253,509	179,657	127,353	99,162	33,490	157,302	24,550	17,652	18,362	7,060	484,932
1999	344,540	179,989	125,395	83,702	59,087	18,882	77,503	12,057	8,664	12,476	397,766
2000	162,685	232,130	118,721	76,759	45,362	29,896	9,063	37,053	5,760	10,097	332,712
2001	216,297	106,464	146,889	66,740	35,577	18,856	11,913	3,589	14,654	6,269	304,488
2002	117,873	139,853	66,426	80,836	29,929	14,214	7,164	4,496	1,353	7,884	212,302
2003	261,430	75,469	86,789	36,929	37,562	12,569	5,665	2,838	1,779	3,654	187,786
2004	182,912	164,907	45,859	46,236	15,874	14,305	4,508	2,018	1,010	1,932	131,742
2005	249,631	115,940	100,001	23,795	18,606	5,535	4,499	1,406	628	916	155,385
2006	302,975	158,508	72,066	58,847	12,432	8,077	1,860	1,357	404	434	155,476
2007	303,589	193,910	100,441	44,510	34,375	6,658	3,637	796	568	347	191,333
2008	394,135	191,530	120,644	60,295	24,721	16,916	2,733	1,391	295	335	227,331
2009	265,814	242,376	116,798	72,000	34,336	13,087	8,355	1,294	646	290	246,805
2010	276,861	157,894	143,297	68,225	40,969	18,756	7,404	4,616	707	510	284,483
2011	196,280	168,670	95,874	86,269	40,317	23,520	10,839	4,207	2,603	684	264,313
2012	161,122	126,498	108,353	61,078	53,974	24,523	12,867	5,833	2,248	1,751	270,626
2013	137,046	108,641	85,159	72,646	40,587	35,373	13,168	6,854	3,096	2,119	259,002
2014	145,516	95,678	75,584	58,720	49,128	26,630	16,658	6,093	3,146	2,386	238,344
2015	279,728	104,391	68,465	53,735	41,159	33,686	11,746	7,253	2,638	2,389	221,071
2016	138,878	206,167	76,738	49,990	38,663	28,946	12,893	4,436	2,723	1,882	216,270
2017	143,420	103,888	153,859	56,920	36,592	27,725	10,116	4,452	1,524	1,578	292,766
2018	131,183	108,110	78,090	114,814	41,811	26,227	9,230	3,320	1,452	1,009	275,950
2019	107,558	99,638	81,974	58,954	85,864	30,811	8,719	3,042	1,090	807	271,263
2020	42,072	81,637	75,476	61,780	43,942	62,906	10,999	3,082	1,070	666	259,922
2021	168,364	31,842	61,714	56,887	46,264	32,576	24,845	4,319	1,207	679	228,491

Table 21. Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of spring spawners by age. $F_{6\text{-}8}$ is the January 1 abundance-weighted average F for ages 6 to 8 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F6-8
1978	0.026	0.130	0.233	0.255	0.258	0.258	0.258	0.258	0.258	0.258	0.258
1979	0.049	0.248	0.445	0.487	0.492	0.492	0.492	0.492	0.492	0.492	0.492
1980	0.051	0.261	0.468	0.512	0.518	0.518	0.518	0.518	0.518	0.518	0.518
1981	0.019	0.095	0.170	0.186	0.188	0.188	0.188	0.188	0.188	0.188	0.188
1982	0.012	0.059	0.106	0.115	0.117	0.117	0.117	0.117	0.117	0.117	0.117
1983	0.011	0.058	0.104	0.113	0.114	0.115	0.115	0.115	0.115	0.115	0.115
1984	0.005	0.027	0.048	0.053	0.053	0.054	0.054	0.054	0.054	0.054	0.053
1985	0.007	0.034	0.062	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.068
1986	0.011	0.057	0.102	0.111	0.112	0.113	0.113	0.113	0.113	0.113	0.112
1987	0.016	0.080	0.143	0.157	0.158	0.159	0.159	0.159	0.159	0.159	0.159
1988	0.020	0.100	0.180	0.197	0.199	0.199	0.199	0.199	0.199	0.199	0.199
1989	0.018	0.091	0.163	0.179	0.181	0.181	0.181	0.181	0.181	0.181	0.181
1990	0.004	0.019	0.071	0.157	0.205	0.219	0.221	0.222	0.222	0.222	0.215
1991	0.004	0.021	0.079	0.173	0.226	0.241	0.244	0.245	0.245	0.245	0.237
1992	0.004	0.017	0.063	0.139	0.182	0.194	0.196	0.196	0.197	0.197	0.190
1993	0.004	0.018	0.068	0.151	0.197	0.210	0.212	0.213	0.213	0.213	0.206
1994	0.004	0.020	0.076	0.168	0.219	0.234	0.237	0.237	0.237	0.237	0.230
1995	0.005	0.023	0.085	0.187	0.245	0.261	0.264	0.265	0.265	0.265	0.256
1996	0.004	0.021	0.078	0.172	0.225	0.240	0.243	0.243	0.243	0.243	0.236
1997	0.004	0.019	0.072	0.157	0.206	0.219	0.222	0.222	0.222	0.222	0.215
1998	0.005	0.022	0.082	0.180	0.235	0.250	0.253	0.254	0.254	0.254	0.246
1999	0.006	0.027	0.102	0.223	0.292	0.311	0.315	0.316	0.316	0.316	0.306
2000	0.009	0.043	0.161	0.354	0.463	0.493	0.499	0.500	0.500	0.500	0.485
2001	0.010	0.045	0.171	0.375	0.491	0.522	0.529	0.530	0.531	0.531	0.514
2002	0.008	0.040	0.150	0.329	0.430	0.458	0.464	0.465	0.465	0.465	0.450
2003	0.010	0.047	0.179	0.393	0.515	0.548	0.555	0.556	0.556	0.556	0.539
2004	0.012	0.056	0.212	0.466	0.610	0.649	0.657	0.659	0.659	0.659	0.638
2005	0.012	0.033	0.088	0.207	0.392	0.571	0.678	0.726	0.745	0.751	0.547
2006	0.006	0.016	0.041	0.097	0.184	0.267	0.318	0.340	0.349	0.352	0.256
2007	0.008	0.022	0.058	0.135	0.256	0.373	0.443	0.474	0.487	0.491	0.357
2008	0.005	0.013	0.035	0.082	0.155	0.225	0.267	0.286	0.293	0.296	0.216
2009	0.003	0.007	0.019	0.046	0.086	0.126	0.150	0.160	0.164	0.166	0.121
2010	0.002	0.005	0.014	0.032	0.061	0.089	0.106	0.113	0.116	0.117	0.085
2011	0.002	0.005	0.013	0.031	0.060	0.087	0.103	0.110	0.113	0.114	0.083
2012	0.001	0.002	0.007	0.015	0.029	0.043	0.051	0.054	0.056	0.056	0.041
2013	0.002	0.005	0.014	0.034	0.064	0.093	0.111	0.119	0.122	0.123	0.089
2014	0.001	0.004	0.010	0.025	0.047	0.068	0.081	0.086	0.089	0.089	0.065
2015	0.001	0.004	0.011	0.026	0.048	0.070	0.084	0.090	0.092	0.093	0.067
2016	0.001	0.004	0.010	0.023	0.044	0.063	0.075	0.081	0.083	0.084	0.061
2017	0.002	0.004	0.012	0.027	0.052	0.076	0.090	0.096	0.099	0.100	0.073
2018	0.001	0.003	0.007	0.016	0.031	0.045	0.054	0.058	0.059	0.060	0.043
2019	0.001	0.003	0.008	0.019	0.036	0.053	0.063	0.068	0.069	0.070	0.051
2020	0.001	0.002	0.005	0.011	0.021	0.031	0.037	0.040	0.041	0.041	0.030
2021	0.000	0.001	0.003	0.008	0.015	0.022	0.026	0.028	0.029	0.029	0.021

Table 22. Risk analysis table of annual catch options (between 0 and 1,250 t) for 2022 and 2024 and subsequent years until 2027, with predicted resulting SSB (kt) in 2023, 2024 and 2027, resulting probabilities (%) of SSB being greater than the LRP, resulting probabilities of increases in SSB by 5%, and resulting abundance weighted fishing mortality rate ($F_{6\text{-}8}$) for the spring spawner component of Atlantic Herring from the southern Gulf of St. Lawrence.

		Catch options (t)			
	Year	0	250	500	1,250
SSB (kt)	2023	35.2	35.0	34.8	34.2
	2024	35.3	34.9	34.6	33.6
	2027	35.4	34.9	34.3	32.5
SSB > LRP (%)	2023	21.7	21.4	20.9	19.8
	2024	20.8	20.2	19.4	17.8
	2027	20.3	19.2	18.3	15.8
5% increase in SSB (%)	2023	68.5	67.8	67.0	64.5
	2024	44.3	43.7	43.4	42.3
$F_{6\text{-}8}$	2022	0	0.02	0.03	0.09
	2023	0	0.02	0.03	0.08

Table 23. SCA maximum likelihood estimates of August 1 biomass (t) of fall spawners in the North region of the southern Gulf of St. Lawrence.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	4+
1978	11,615	6,584	7,907	5,734	3,556	2,513	2,930	880	697	2,094	26,311
1979	11,697	8,053	4,470	2,373	1,414	762	675	710	232	627	11,264
1980	9,849	13,528	4,783	1,693	755	420	244	214	220	283	8,611
1981	24,953	16,295	12,402	2,651	786	350	208	125	102	233	16,857
1982	14,656	21,778	19,785	9,308	1,709	466	218	129	78	198	31,891
1983	12,108	22,894	20,497	14,137	5,841	1,025	296	127	83	163	42,169
1984	14,881	19,551	29,316	17,886	10,503	4,173	778	220	88	192	63,157
1985	14,779	21,715	23,072	26,633	14,052	8,017	3,325	604	168	213	76,084
1986	16,858	24,594	26,429	18,536	18,857	9,780	5,733	2,306	416	244	82,301
1987	17,231	28,097	31,581	19,654	12,110	11,298	6,088	3,509	1,395	386	86,022
1988	9,527	19,232	33,335	22,364	10,781	6,432	6,240	3,262	1,863	940	85,217
1989	23,753	14,378	22,181	23,444	13,976	6,506	3,895	3,670	1,932	1,615	77,219
1990	27,499	36,471	18,186	17,304	13,621	7,923	3,673	2,147	2,019	1,937	66,810
1991	8,729	30,665	42,615	12,009	8,682	6,598	3,766	1,707	973	1,793	78,143
1992	9,884	11,089	33,621	32,566	7,559	5,332	3,883	2,166	969	1,552	87,648
1993	6,870	15,318	12,353	26,927	20,465	4,588	3,027	2,168	1,153	1,334	72,014
1994	9,426	10,809	22,116	11,819	19,452	14,116	2,925	1,925	1,316	1,540	75,208
1995	8,524	13,352	14,322	15,399	6,017	9,371	6,094	1,268	826	1,195	54,491
1996	9,015	11,716	16,565	7,366	4,866	1,827	2,553	1,632	346	541	35,696
1997	11,154	13,059	14,280	9,888	2,927	1,830	598	808	513	262	31,105
1998	9,921	17,810	15,555	9,157	4,248	1,212	638	214	278	257	31,559
1999	8,477	15,125	24,207	9,720	4,171	1,845	429	232	75	181	40,861
2000	6,932	14,610	20,186	16,444	4,401	1,784	657	147	81	85	43,784
2001	6,131	10,841	20,490	13,639	7,488	1,894	632	223	53	56	44,475
2002	12,864	11,252	15,434	15,291	7,297	3,813	772	262	89	45	43,004
2003	15,353	19,556	15,332	11,901	8,162	3,783	1,572	315	107	53	41,223
2004	13,406	21,728	23,630	8,437	4,522	2,969	1,069	444	90	44	41,205
2005	7,624	17,713	25,824	18,653	5,291	2,671	1,335	466	189	55	54,484
2006	14,489	11,924	22,685	19,590	10,654	2,894	1,025	521	176	91	57,636
2007	36,066	21,676	16,020	19,859	12,163	5,739	1,058	380	187	97	55,502
2008	30,132	35,829	31,272	12,346	9,930	5,700	1,947	317	140	99	61,751
2009	36,169	53,767	75,051	30,659	11,772	9,527	3,353	895	180	88	131,525
2010	28,703	43,863	53,481	57,158	22,399	7,762	3,733	1,313	385	113	146,346
2011	22,949	30,015	52,305	55,809	49,643	18,740	3,627	1,726	595	237	182,680
2012	13,568	33,571	33,921	57,759	55,496	44,674	8,305	1,602	739	363	202,859
2013	12,263	18,836	45,150	41,299	58,559	52,160	17,419	3,231	636	417	218,869
2014	14,429	16,438	24,352	54,135	44,818	56,600	19,595	6,431	1,196	400	207,527
2015	16,126	21,544	20,438	29,268	57,600	43,004	19,873	6,857	2,083	538	179,661
2016	6,037	17,172	31,235	24,595	30,782	52,769	13,981	6,446	2,191	816	162,815
2017	1,769	7,495	21,327	38,338	26,241	28,130	18,191	4,730	2,248	1,066	140,270
2018	3,735	2,591	8,523	23,678	37,639	23,454	10,359	6,729	1,772	1,251	113,403
2019	2,804	4,579	3,103	9,636	21,766	34,255	8,842	3,835	2,517	1,110	85,065
2020	4,859	3,645	5,260	3,274	10,627	20,466	13,304	3,393	1,449	1,388	59,161
2021	10,066	6,415	5,071	6,464	3,698	10,226	8,268	5,274	1,329	1,139	41,468

Table 24. SCA maximum likelihood estimates of January 1 abundance (number in thousands) of fall spawners in the North region of the southern Gulf of St. Lawrence.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	4+
1978	54,186	38,369	36,479	23,416	12,100	8,977	8,681	2,765	2,369	5,220	100,005
1979	114,450	42,136	20,298	9,110	5,055	2,585	2,054	1,986	633	1,736	43,457
1980	136,719	89,622	24,123	6,312	2,517	1,385	758	603	583	695	36,975
1981	153,453	108,136	57,433	10,258	2,479	983	579	317	252	534	72,835
1982	217,833	123,530	83,181	33,914	5,337	1,277	542	320	175	434	125,181
1983	168,985	175,430	95,706	51,451	18,833	2,940	754	320	189	359	170,551
1984	186,202	136,244	138,564	67,077	34,054	12,412	2,075	532	226	387	255,326
1985	233,883	150,169	108,149	100,291	46,450	23,504	9,177	1,534	393	453	289,952
1986	223,935	188,486	117,719	72,179	61,971	28,536	15,466	6,038	1,010	557	303,476
1987	172,242	180,327	145,791	72,043	39,488	33,617	16,578	8,985	3,508	910	320,921
1988	136,015	140,134	139,500	84,125	36,127	19,592	17,580	8,669	4,699	2,310	312,602
1989	326,855	111,821	110,551	86,572	46,540	19,814	11,159	10,012	4,937	3,992	293,577
1990	275,872	271,501	88,402	65,551	44,729	23,797	10,343	5,825	5,226	4,661	248,533
1991	114,101	231,748	214,327	48,610	30,315	20,417	10,864	4,722	2,659	4,514	336,427
1992	185,374	97,176	189,919	140,412	28,609	17,698	11,656	6,202	2,696	4,095	401,286
1993	121,806	159,742	80,268	122,633	80,582	16,273	9,604	6,325	3,366	3,685	322,735
1994	443,385	183,783	379,337	106,752	198,388	51,670	9,734	5,744	3,783	4,217	759,625
1995	272,479	351,412	145,112	251,743	57,104	35,416	21,059	3,967	2,341	3,260	520,002
1996	472,563	223,702	271,901	77,447	124,996	7,263	8,918	5,302	999	1,410	498,235
1997	607,871	383,796	177,124	171,500	35,643	7,100	2,092	2,569	1,527	694	398,249
1998	596,155	505,193	307,499	110,691	90,977	4,502	2,339	689	846	732	518,275
1999	432,639	498,865	411,224	210,665	54,229	6,984	1,525	792	233	535	686,188
2000	808,889	369,903	410,446	272,562	106,289	6,955	2,303	503	261	253	799,573
2001	672,339	688,651	308,022	287,369	144,649	7,217	2,265	750	164	168	750,603
2002	802,143	579,536	584,384	218,449	174,601	14,395	2,706	849	281	124	995,790
2003	579,066	699,641	496,592	460,164	133,921	13,993	5,455	1,026	322	154	1,111,626
2004	535,480	512,351	599,386	383,533	313,255	11,544	3,803	1,483	279	129	1,313,412
2005	342,341	477,751	448,302	485,781	291,906	10,579	4,910	1,618	631	174	1,243,899
2006	1,280,720	308,023	419,881	342,425	352,735	11,949	3,868	1,795	591	294	1,133,538
2007	1,124,710	1,153,810	275,896	344,974	258,599	24,089	4,230	1,369	635	313	910,106
2008	1,123,320	1,026,540	1,040,450	226,806	265,390	28,921	8,244	1,447	468	325	1,572,051
2009	857,413	1,032,220	933,838	912,839	180,200	33,735	11,296	3,220	565	310	2,076,002
2010	531,574	794,270	947,942	819,555	781,008	33,716	15,127	5,065	1,444	392	2,604,248
2011	782,414	495,710	735,650	849,654	702,968	88,224	15,187	6,813	2,281	827	2,401,605
2012	558,076	731,387	462,676	669,126	753,357	211,114	37,325	6,425	2,882	1,315	2,144,220
2013	399,576	521,901	684,356	423,458	596,367	251,824	78,915	13,952	2,402	1,569	2,052,842
2014	551,115	375,227	488,155	626,146	373,218	264,721	87,398	27,387	4,842	1,378	1,873,245
2015	419,249	518,701	352,133	449,971	557,983	195,161	87,454	28,872	9,048	2,055	1,682,677
2016	164,457	394,114	487,325	323,537	401,591	250,377	62,272	27,904	9,212	3,542	1,565,761
2017	179,637	155,036	369,770	446,999	287,776	130,517	82,659	20,558	9,212	4,211	1,351,702
2018	175,487	168,206	145,747	340,590	398,375	113,809	46,393	29,381	7,307	4,771	1,086,373
2019	157,729	164,818	157,357	133,831	305,739	167,416	41,461	16,901	10,703	4,400	837,808
2020	310,008	148,026	154,497	145,646	117,870	99,401	61,123	15,137	6,170	5,514	605,358
2021	141,488	67,681	138,642	142,055	132,352	47,506	36,441	22,407	5,549	4,283	529,235

Table 25. SCA maximum likelihood estimates of August 1 biomass (t) of fall spawners in the Middle region of the southern Gulf of St. Lawrence.

Year	Age										
	2	3	4	5	6	7	8	9	10	11+	4+
1978	2,728	7,343	4,501	2,238	942	1,716	1,803	722	327	2,810	15,059
1979	8,062	4,272	4,490	3,124	1,124	346	853	808	287	1,108	12,140
1980	3,493	9,565	3,732	3,274	741	127	44	125	103	179	8,325
1981	3,655	5,514	8,517	2,533	1,414	218	44	16	43	94	12,878
1982	6,417	10,647	5,761	5,562	679	245	47	9	4	27	12,333
1983	4,019	10,321	5,599	3,381	3,125	350	167	27	4	18	12,673
1984	2,411	6,279	8,765	3,777	1,038	722	105	46	8	5	14,465
1985	3,735	12,396	6,832	7,139	2,087	486	412	58	24	9	17,046
1986	7,068	10,761	5,596	4,084	4,477	1,321	387	310	43	22	16,239
1987	2,497	10,158	7,388	4,403	2,040	2,294	790	241	156	40	17,351
1988	3,026	7,215	8,684	6,221	3,035	1,209	1,715	543	142	114	21,662
1989	16,391	10,992	4,732	5,381	3,626	1,520	809	1,030	353	162	17,612
1990	13,982	30,570	7,428	3,539	3,403	2,163	1,056	566	710	365	19,230
1991	2,487	20,649	29,182	5,460	2,049	1,953	1,385	679	379	668	41,756
1992	6,888	5,276	18,402	20,191	2,918	908	1,010	717	350	548	45,044
1993	3,085	14,016	4,855	14,348	13,169	1,693	648	657	475	569	36,415
1994	7,497	1,599	12,308	3,314	9,462	8,032	1,125	433	446	699	35,818
1995	2,569	5,372	4,014	12,913	2,179	5,718	5,035	769	274	702	31,605
1996	5,242	4,140	10,810	3,204	7,444	1,018	2,534	2,175	354	418	27,957
1997	9,811	10,956	6,044	8,230	1,638	3,109	451	1,117	938	326	21,853
1998	8,588	10,199	12,348	4,950	4,230	696	1,268	188	460	525	24,664
1999	6,514	7,634	17,360	9,643	2,106	1,376	223	389	60	296	31,452
2000	4,690	4,513	15,970	14,161	4,355	737	451	72	126	112	35,983
2001	5,686	12,185	10,648	13,086	7,138	1,740	275	162	24	78	33,153
2002	8,012	12,198	15,577	9,934	8,319	4,053	865	142	80	52	39,021
2003	5,190	19,533	16,420	13,470	6,696	4,760	2,089	434	75	69	44,014
2004	7,100	14,399	23,858	14,717	9,439	4,178	2,631	1,130	231	77	56,261
2005	3,360	6,639	12,475	20,638	10,460	6,081	2,271	1,431	595	174	54,125
2006	13,105	6,496	13,069	13,646	14,002	6,146	2,901	1,075	671	341	51,851
2007	21,816	31,445	10,521	12,354	12,804	9,496	2,898	1,329	473	451	50,326
2008	10,940	19,075	31,939	7,404	9,672	7,609	3,594	1,247	595	420	62,480
2009	11,190	24,883	34,421	37,181	9,122	8,677	4,987	2,409	616	449	97,862
2010	8,288	15,372	25,369	34,707	33,756	5,928	3,663	1,944	951	456	106,773
2011	8,294	8,367	19,409	25,906	32,939	27,338	2,654	1,723	880	647	111,495
2012	6,878	12,646	9,859	20,313	24,546	27,505	12,088	1,187	772	675	96,945
2013	5,114	10,987	17,560	12,454	19,400	21,316	11,584	4,998	504	601	88,417
2014	4,267	7,218	14,173	20,889	13,082	17,402	9,093	4,802	2,085	417	81,943
2015	3,494	8,502	9,320	16,536	21,980	11,847	7,710	3,989	2,051	1,136	74,570
2016	1,444	5,732	11,290	13,526	18,956	20,073	5,300	3,454	1,762	1,397	75,757
2017	2,529	2,388	8,295	14,864	12,822	16,000	9,228	2,386	1,605	1,497	66,697
2018	3,352	4,426	3,599	9,380	14,385	10,644	7,244	4,100	1,055	1,428	51,834
2019	2,334	5,638	6,327	3,879	9,166	12,434	5,430	3,692	2,092	1,176	44,195
2020	4,315	3,956	8,240	7,534	3,735	8,425	7,002	3,001	2,052	1,835	41,825
2021	4,374	7,373	5,799	9,338	7,628	3,586	4,986	4,085	1,763	2,257	39,441

Table 26. SCA maximum likelihood estimates of January 1 abundance (number in thousands) of fall spawners in the Middle region of the southern Gulf of St. Lawrence.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	4+
1978	42,612	39,118	22,030	9,720	3,445	6,571	5,519	2,014	1,113	6,808	57,219
1979	88,533	27,666	25,037	12,728	3,995	1,122	2,632	2,199	802	3,153	51,668
1980	49,358	57,283	17,209	11,733	2,327	383	123	283	236	425	32,720
1981	67,544	32,023	36,451	9,526	4,087	590	118	37	86	202	51,098
1982	106,463	43,913	20,619	19,952	2,180	641	116	23	7	56	43,594
1983	60,614	69,247	28,506	12,950	10,493	1,061	399	72	14	40	53,535
1984	70,996	39,413	44,692	16,238	3,771	2,284	291	109	20	15	67,419
1985	87,633	46,174	25,543	27,298	7,214	1,459	1,125	143	54	17	62,853
1986	71,642	57,002	29,996	16,246	15,494	3,897	1,010	778	99	49	67,569
1987	46,714	46,598	37,006	18,870	8,628	7,646	2,459	637	491	93	75,830
1988	74,827	30,776	30,636	23,499	9,943	4,193	4,675	1,503	389	357	75,196
1989	276,541	49,359	20,246	19,250	11,540	4,388	2,321	2,587	832	413	61,575
1990	182,607	185,599	33,087	13,302	11,356	6,497	3,057	1,617	1,802	867	71,585
1991	42,321	125,383	127,184	21,930	7,372	5,823	4,015	1,889	999	1,649	170,861
1992	161,394	29,954	88,460	85,044	10,994	3,261	2,989	2,060	969	1,358	195,135
1993	33,980	116,993	21,680	62,408	52,293	6,368	2,144	1,964	1,354	1,529	149,740
1994	84,288	25,200	86,612	15,590	38,380	30,049	4,038	1,359	1,245	1,827	179,101
1995	51,137	64,006	19,097	63,410	9,483	21,544	18,047	2,424	816	1,845	136,666
1996	95,565	39,656	49,401	13,616	29,536	3,672	8,613	7,210	968	1,063	114,079
1997	137,530	75,224	31,075	35,906	6,606	12,025	1,514	3,549	2,971	837	94,483
1998	119,214	109,363	59,534	22,712	17,116	2,616	4,754	598	1,402	1,504	110,236
1999	83,852	95,962	87,442	42,534	8,865	5,139	765	1,389	175	849	147,159
2000	108,318	68,558	77,961	63,865	17,535	2,852	1,570	234	424	312	164,752
2001	115,979	89,788	56,517	58,609	29,260	6,480	979	538	80	253	152,717
2002	162,181	97,183	74,986	44,632	34,273	15,019	3,048	460	253	156	172,828
2003	115,349	137,278	81,996	59,938	26,685	18,065	7,114	1,443	218	194	195,651
2004	92,039	98,742	117,220	67,145	39,199	15,829	9,395	3,698	750	214	253,450
2005	63,783	79,734	85,338	97,361	45,049	23,972	8,205	4,868	1,916	500	267,209
2006	273,414	55,875	69,628	70,697	60,775	24,871	10,783	3,689	2,189	1,086	243,718
2007	251,161	242,161	49,435	60,968	57,005	38,860	11,242	4,804	1,641	1,457	225,412
2008	186,840	224,626	216,392	43,807	50,550	39,199	18,406	5,263	2,246	1,448	377,310
2009	149,564	168,495	202,382	193,190	36,370	34,215	17,304	8,022	2,291	1,608	495,382
2010	92,739	135,890	152,964	182,256	163,199	25,665	15,101	7,552	3,497	1,699	551,933
2011	153,794	84,892	124,319	139,139	158,398	124,773	11,575	6,756	3,376	2,322	570,658
2012	118,572	141,782	78,230	114,114	123,794	129,090	54,490	5,027	2,933	2,473	510,150
2013	80,877	109,925	131,398	72,259	102,655	103,381	52,883	22,218	2,049	2,203	489,046
2014	95,898	75,267	102,261	121,787	65,042	85,093	41,197	20,965	8,804	1,685	446,833
2015	63,244	89,487	70,210	95,058	110,114	54,395	35,039	16,881	8,586	4,295	394,578
2016	26,588	59,126	83,627	65,350	85,714	90,807	22,697	14,539	7,001	5,342	375,077
2017	49,234	24,890	55,332	78,017	59,480	72,779	40,450	10,067	6,445	5,471	328,041
2018	62,483	46,122	23,307	51,607	70,498	49,168	32,916	18,193	4,525	5,356	255,570
2019	43,942	58,543	43,199	21,758	46,919	59,497	24,500	16,325	9,019	4,898	226,114
2020	81,875	41,170	54,833	40,341	19,841	40,018	31,575	12,947	8,624	7,351	215,529
2021	82,295	76,705	38,561	51,232	36,962	17,207	22,155	17,420	7,141	8,810	199,487

Table 27. SCA maximum likelihood estimates of August 1 biomass (t) of fall spawners in the South region of the southern Gulf of St. Lawrence.

Year	Age										
	2	3	4	5	6	7	8	9	10	11+	4+
1978	8,251	13,606	7,649	4,814	2,131	1,828	1,401	499	493	1,309	20,124
1979	27,601	9,551	14,805	6,432	2,677	1,021	857	591	196	572	27,151
1980	19,689	17,788	8,051	11,797	4,249	1,499	698	550	373	483	27,701
1981	26,002	20,716	14,464	4,934	4,499	945	291	94	76	112	25,414
1982	36,151	31,750	21,091	14,020	3,196	1,967	487	142	42	81	41,027
1983	19,498	48,458	30,675	16,380	7,942	1,360	1,006	241	72	61	57,736
1984	32,122	26,801	51,294	22,743	9,712	3,977	896	625	152	89	89,489
1985	39,767	44,161	27,595	39,991	14,388	5,193	2,715	603	412	155	91,052
1986	31,741	53,769	46,434	20,412	26,293	8,174	3,762	1,917	413	345	107,750
1987	11,594	33,053	58,481	35,484	13,163	14,494	5,723	2,558	1,274	528	131,705
1988	10,750	15,412	28,619	47,540	22,996	7,077	9,670	3,719	1,646	1,126	122,393
1989	36,357	13,093	15,061	20,184	32,279	13,511	5,232	7,049	2,608	1,981	97,904
1990	30,253	48,358	14,254	11,419	15,062	21,970	11,310	4,333	5,687	3,565	87,601
1991	7,434	32,878	51,292	11,632	6,860	7,390	12,105	6,106	2,270	4,865	102,520
1992	13,644	9,123	31,003	40,445	8,203	4,347	5,669	9,105	4,579	5,151	108,501
1993	4,443	24,864	8,274	25,707	28,579	5,256	3,437	4,389	6,917	7,462	90,021
1994	20,868	4,914	25,091	6,879	19,486	20,117	4,395	2,837	3,594	11,310	93,708
1995	5,123	12,250	5,689	22,302	4,605	11,272	12,522	2,897	1,749	8,868	69,905
1996	17,291	7,576	14,016	5,604	17,121	3,131	7,324	7,920	1,756	6,187	63,056
1997	18,841	23,445	9,745	19,122	3,945	8,962	1,591	3,608	3,900	3,675	54,547
1998	17,531	19,094	28,651	9,649	13,688	2,323	4,653	828	1,783	3,657	65,232
1999	9,871	24,981	24,192	27,067	6,646	7,209	1,111	2,184	390	2,388	71,188
2000	34,621	14,401	32,474	27,507	17,055	3,006	2,799	422	823	1,022	85,109
2001	25,051	48,221	18,937	33,678	19,464	9,307	1,384	1,266	184	746	84,965
2002	31,056	40,938	67,345	20,693	25,888	11,615	4,452	652	578	421	131,643
2003	16,190	40,356	53,023	73,893	16,724	16,383	5,920	2,196	324	484	168,947
2004	13,516	21,559	50,926	53,268	57,713	10,976	8,576	2,964	1,100	387	185,910
2005	9,163	27,964	29,346	58,218	49,682	46,054	6,876	5,280	1,810	914	198,180
2006	45,333	13,768	37,947	33,810	54,955	41,582	27,647	4,181	3,053	1,588	204,762
2007	29,853	73,760	17,755	35,083	31,366	45,320	22,425	14,638	2,191	2,348	171,125
2008	36,686	43,252	95,141	19,995	33,095	26,034	23,198	11,164	7,287	2,217	218,132
2009	22,854	51,294	58,008	102,404	21,158	30,231	13,986	12,225	5,716	4,722	248,449
2010	10,044	23,092	60,491	64,244	104,946	18,311	14,426	6,467	5,697	4,844	279,425
2011	10,211	10,972	26,788	61,693	60,490	90,786	7,917	6,026	2,631	4,232	260,563
2012	12,702	20,499	12,223	31,700	62,668	53,833	34,789	2,951	2,306	2,486	202,956
2013	7,738	21,207	24,313	13,605	32,900	58,927	19,204	12,097	995	1,648	163,690
2014	10,534	12,393	26,660	25,446	14,533	31,045	20,906	6,707	4,141	892	130,329
2015	10,968	11,966	14,166	28,309	27,369	13,543	11,024	7,359	2,242	1,743	105,755
2016	3,170	16,133	17,516	17,008	31,407	26,553	5,213	4,213	2,705	1,430	106,044
2017	5,916	4,454	23,202	23,763	19,649	29,245	11,191	2,184	1,789	1,632	112,655
2018	3,739	7,910	5,983	23,982	22,401	16,402	13,202	5,018	1,009	1,611	89,608
2019	4,301	5,251	11,042	6,468	23,500	21,532	8,044	6,421	2,458	1,197	80,663
2020	9,210	5,947	7,317	13,986	7,379	24,682	12,013	4,424	3,422	1,937	75,159
2021	11,949	12,670	8,197	8,733	14,594	7,581	13,799	6,786	2,515	2,920	65,125

Table 28. SCA maximum likelihood estimates of January 1 abundance (number in thousands) of fall spawners in the South region of the southern Gulf of St. Lawrence.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	4+
1978	110,806	134,303	54,422	23,431	10,151	7,050	4,956	1,724	1,652	3,469	106,856
1979	221,495	71,933	83,472	30,483	10,784	3,648	2,783	1,771	591	1,723	135,255
1980	230,419	145,768	46,388	51,279	17,087	5,386	2,216	1,614	1,008	1,305	126,282
1981	307,573	145,291	83,751	21,342	15,507	3,046	849	283	188	259	125,226
1982	541,346	204,616	95,844	51,812	9,912	5,286	1,280	353	117	186	164,790
1983	272,623	360,256	135,353	60,572	26,706	4,100	2,755	662	182	157	230,487
1984	483,476	181,465	238,734	86,720	33,381	12,510	2,454	1,640	394	202	376,035
1985	631,825	321,826	120,293	153,353	48,400	16,009	7,687	1,501	1,002	364	348,608
1986	270,710	420,626	213,557	77,880	88,935	24,926	10,649	5,093	994	905	422,939
1987	145,671	180,216	279,051	138,005	44,759	45,037	16,273	6,924	3,310	1,234	534,592
1988	151,871	97,879	120,568	180,663	77,167	21,366	27,140	9,755	4,148	2,722	443,529
1989	512,354	102,896	66,119	79,634	107,918	41,358	14,453	18,293	6,573	4,628	338,975
1990	337,460	351,518	70,504	44,858	51,690	66,785	32,219	11,242	14,225	8,710	300,231
1991	96,378	233,722	242,023	46,407	24,154	22,410	34,408	16,481	5,746	11,721	403,350
1992	305,294	67,496	163,443	167,371	30,535	15,061	16,985	26,033	12,467	13,212	445,107
1993	72,202	217,346	47,982	114,901	111,953	19,357	11,319	12,742	19,525	19,259	357,037
1994	213,924	52,478	157,852	34,647	80,856	76,619	15,321	8,951	10,075	30,666	414,987
1995	98,144	160,062	39,112	114,217	21,965	44,446	45,349	9,026	5,270	23,985	303,370
1996	254,281	75,404	122,483	29,029	73,962	12,277	25,643	26,038	5,179	16,786	311,395
1997	260,056	199,552	58,793	90,916	17,297	34,769	5,626	11,660	11,828	9,977	240,867
1998	306,162	207,900	158,583	44,655	56,413	8,629	16,452	2,643	5,473	10,234	303,082
1999	182,932	249,586	168,400	122,349	27,719	27,694	3,860	7,301	1,172	6,963	365,458
2000	579,918	151,959	205,545	129,874	70,385	11,622	9,990	1,378	2,603	2,900	434,297
2001	441,030	489,899	127,563	164,458	83,862	36,062	5,054	4,311	594	2,372	424,276
2002	453,769	377,828	417,309	104,051	110,533	45,737	16,223	2,258	1,924	1,324	699,360
2003	246,686	392,990	325,711	347,307	74,005	66,355	22,216	7,836	1,090	1,568	846,087
2004	258,281	215,653	342,155	274,929	255,290	46,856	33,156	11,046	3,894	1,321	968,647
2005	152,085	227,815	189,846	296,789	223,241	193,040	27,565	19,460	6,481	3,059	959,481
2006	773,466	135,449	202,533	166,503	244,997	172,623	110,309	15,718	11,093	5,439	929,214
2007	439,861	694,667	121,613	181,334	145,672	195,293	91,566	57,744	8,215	8,639	810,076
2008	488,885	397,975	628,327	109,691	159,840	117,037	98,582	45,617	28,724	8,383	1,196,201
2009	260,982	445,143	362,275	570,624	97,717	131,750	57,567	47,958	22,163	18,026	1,308,080
2010	116,617	238,922	407,376	330,492	507,206	78,216	57,326	24,678	20,524	17,196	1,443,015
2011	216,983	107,297	219,771	373,832	297,394	421,750	32,357	23,451	10,082	15,408	1,394,045
2012	223,825	200,556	99,157	202,762	340,251	256,276	158,904	12,097	8,759	9,520	1,087,726
2013	130,442	207,588	185,979	91,817	185,541	296,829	88,359	54,417	4,139	6,254	913,335
2014	178,965	121,246	192,919	172,549	84,030	160,703	100,308	29,627	18,229	3,482	761,847
2015	188,093	166,585	112,833	179,149	157,444	71,435	54,238	33,516	9,888	7,245	625,749
2016	53,887	175,221	155,147	104,852	163,453	133,416	25,237	18,962	11,703	5,982	618,752
2017	100,830	50,214	163,247	144,299	96,166	141,699	52,379	9,829	7,378	6,881	621,879
2018	63,798	93,937	46,776	151,919	133,190	85,876	65,112	23,956	4,493	6,518	517,839
2019	73,267	59,444	87,517	43,536	140,239	118,944	41,685	31,458	11,568	5,316	480,262
2020	157,006	68,295	55,404	81,473	40,140	124,367	58,160	20,270	15,287	8,205	403,306
2021	203,733	146,409	63,683	51,639	75,659	36,730	64,191	29,956	10,438	12,097	344,392

Table 29. SCA maximum likelihood estimates of August 1 total biomass (t) of fall spawners in the southern Gulf of St. Lawrence.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	4+
1978	22,594	27,534	20,057	12,786	6,629	6,056	6,134	2,102	1,517	6,213	61,493
1979	47,359	21,875	23,764	11,930	5,215	2,129	2,385	2,108	716	2,307	50,555
1980	33,031	40,881	16,565	16,764	5,745	2,046	986	889	697	946	44,637
1981	54,610	42,524	35,383	10,118	6,698	1,513	542	235	222	438	55,149
1982	57,223	64,176	46,637	28,890	5,584	2,678	752	280	124	306	85,251
1983	35,625	81,672	56,772	33,898	16,908	2,735	1,469	395	159	242	112,578
1984	49,414	52,631	89,375	44,407	21,253	8,872	1,779	891	248	287	167,112
1985	58,281	78,272	57,499	73,763	30,528	13,695	6,452	1,265	604	376	184,182
1986	55,667	89,123	78,459	43,031	49,627	19,274	9,882	4,534	871	611	206,289
1987	31,322	71,308	97,450	59,541	27,313	28,086	12,601	6,309	2,825	953	235,077
1988	23,302	41,859	70,638	76,125	36,812	14,719	17,625	7,524	3,651	2,180	229,272
1989	76,500	38,462	41,973	49,008	49,881	21,536	9,937	11,749	4,893	3,758	192,735
1990	71,735	115,399	39,869	32,262	32,086	32,055	16,039	7,047	8,415	5,867	173,641
1991	18,649	84,192	123,089	29,101	17,591	15,941	17,256	8,492	3,623	7,326	222,419
1992	30,416	25,488	83,027	93,202	18,680	10,587	10,562	11,987	5,898	7,251	241,194
1993	14,397	54,198	25,481	66,982	62,213	11,537	7,112	7,214	8,546	9,365	198,450
1994	37,791	17,322	59,515	22,012	48,400	42,266	8,444	5,195	5,356	13,548	204,734
1995	16,216	30,974	24,025	50,615	12,800	26,362	23,651	4,934	2,849	10,765	156,000
1996	31,548	23,432	41,391	16,174	29,430	5,975	12,411	11,727	2,456	7,146	126,709
1997	39,806	47,459	30,069	37,239	8,509	13,901	2,640	5,533	5,351	4,263	107,505
1998	36,040	47,103	56,554	23,755	22,166	4,231	6,559	1,230	2,521	4,439	121,455
1999	24,862	47,740	65,759	46,430	12,923	10,430	1,763	2,805	525	2,865	143,500
2000	46,243	33,524	68,630	58,112	25,811	5,527	3,907	640	1,029	1,220	164,876
2001	36,868	71,247	50,075	60,403	34,089	12,941	2,291	1,651	262	880	162,593
2002	51,932	64,388	98,356	45,918	41,505	19,481	6,088	1,056	747	518	213,668
2003	36,732	79,445	84,774	99,264	31,583	24,926	9,580	2,945	505	606	254,184
2004	34,021	57,685	98,414	76,422	71,675	18,123	12,276	4,538	1,421	509	283,377
2005	20,147	52,317	67,645	97,509	65,433	54,806	10,482	7,177	2,594	1,143	306,790
2006	72,927	32,189	73,701	67,046	79,612	50,622	31,572	5,777	3,900	2,020	314,250
2007	87,735	126,881	44,296	67,295	56,333	60,555	26,380	16,347	2,851	2,896	276,953
2008	77,758	98,157	158,353	39,744	52,697	39,343	28,740	12,728	8,022	2,736	342,362
2009	70,214	129,944	167,479	170,244	42,051	48,435	22,326	15,529	6,511	5,259	477,836
2010	47,035	82,326	139,342	156,109	161,101	32,000	21,822	9,724	7,033	5,413	532,544
2011	41,454	49,354	98,501	143,408	143,072	136,864	14,198	9,475	4,105	5,115	554,738
2012	33,149	66,715	56,003	109,772	142,709	126,013	55,181	5,740	3,817	3,524	502,759
2013	25,115	51,031	87,023	67,358	110,859	132,403	48,207	20,327	2,135	2,666	470,976
2014	29,230	36,049	65,184	100,470	72,433	105,047	49,595	17,939	7,422	1,710	419,800
2015	30,588	42,011	43,924	74,114	106,948	68,394	38,607	18,205	6,377	3,417	359,986
2016	10,651	39,037	60,041	55,129	81,145	99,395	24,493	14,112	6,658	3,643	344,616
2017	10,213	14,338	52,825	76,965	58,711	73,375	38,610	9,300	5,641	4,195	319,622
2018	10,825	14,927	18,105	57,040	74,425	50,500	30,804	15,846	3,836	4,290	254,845
2019	9,439	15,467	20,472	19,983	54,431	68,221	22,317	13,949	7,068	3,483	209,923
2020	18,383	13,548	20,816	24,794	21,742	53,573	32,319	10,819	6,923	5,159	176,145
2021	26,388	26,458	19,067	24,535	25,920	21,392	27,053	16,146	5,606	6,316	146,035

Table 30. SCA maximum likelihood estimates of January 1 total abundance (number in thousands) of fall spawners in the southern Gulf of St. Lawrence.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	4+
1978	207,605	211,790	112,930	56,567	25,696	22,598	19,155	6,503	5,134	15,496	264,080
1979	424,478	141,734	128,807	52,321	19,833	7,355	7,469	5,956	2,026	6,612	230,380
1980	416,496	292,674	87,720	69,325	21,930	7,154	3,097	2,500	1,827	2,425	195,977
1981	528,570	285,450	177,635	41,127	22,074	4,619	1,546	637	527	995	249,159
1982	865,642	372,059	199,643	105,679	17,429	7,204	1,938	696	300	676	333,565
1983	502,222	604,933	259,565	124,972	56,032	8,102	3,907	1,054	385	556	454,573
1984	740,674	357,122	421,990	170,035	71,206	27,205	4,821	2,281	640	603	698,780
1985	953,341	518,169	253,985	280,942	102,065	40,971	17,988	3,178	1,449	834	701,413
1986	566,287	666,114	361,272	166,304	166,400	57,359	27,125	11,910	2,103	1,511	793,984
1987	364,627	407,141	461,848	228,918	92,874	86,300	35,311	16,546	7,309	2,237	931,343
1988	362,713	268,788	290,704	288,287	123,237	45,152	49,394	19,928	9,236	5,389	831,327
1989	1,115,750	264,076	196,915	185,455	165,998	65,559	27,933	30,892	12,342	9,033	694,127
1990	795,939	808,618	191,993	123,711	107,774	97,078	45,619	18,683	21,254	14,238	620,349
1991	252,799	590,853	583,534	116,948	61,841	48,649	49,287	23,092	9,404	17,884	910,638
1992	652,062	194,626	441,822	392,827	70,137	36,020	31,629	34,295	16,131	18,665	1,041,528
1993	227,988	494,081	149,930	299,942	244,828	41,998	23,066	21,031	24,244	24,473	829,512
1994	741,597	261,461	623,801	156,989	317,624	158,339	29,093	16,054	15,103	36,710	1,353,712
1995	421,759	575,480	203,321	429,370	88,552	101,406	84,455	15,417	8,427	29,090	960,037
1996	822,409	338,761	443,785	120,092	228,493	23,212	43,173	38,549	7,146	19,259	923,709
1997	1,005,457	658,572	266,992	298,322	59,546	53,894	9,233	17,778	16,326	11,508	733,598
1998	1,021,531	822,456	525,616	178,058	164,506	15,747	23,544	3,930	7,721	12,469	931,592
1999	699,423	844,413	667,066	375,548	90,813	39,818	6,150	9,483	1,580	8,347	1,198,805
2000	1,497,125	590,420	693,952	466,301	194,209	21,429	13,863	2,114	3,288	3,466	1,398,623
2001	1,229,348	1,268,338	492,102	510,436	257,771	49,760	8,297	5,599	838	2,792	1,327,595
2002	1,418,093	1,054,547	1,076,679	367,132	319,407	75,152	21,978	3,567	2,459	1,605	1,867,978
2003	941,101	1,229,909	904,299	867,409	234,610	98,412	34,784	10,305	1,629	1,915	2,153,364
2004	885,800	826,746	1,058,761	725,607	607,744	74,229	46,355	16,227	4,923	1,664	2,535,509
2005	558,209	785,300	723,486	879,931	560,196	227,592	40,680	25,946	9,028	3,733	2,470,590
2006	2,327,600	499,347	692,042	579,625	658,507	209,443	124,960	21,202	13,873	6,819	2,306,471
2007	1,815,732	2,090,638	446,944	587,276	461,276	258,242	107,038	63,916	10,492	10,409	1,945,594
2008	1,799,045	1,649,141	1,885,169	380,304	475,780	185,156	125,232	52,327	31,438	10,155	3,145,562
2009	1,267,959	1,645,858	1,498,495	1,676,653	314,287	199,700	86,167	59,199	25,019	19,943	3,879,464
2010	740,930	1,169,082	1,508,282	1,332,303	1,451,413	137,598	87,554	37,295	25,464	19,287	4,599,196
2011	1,153,191	687,899	1,079,740	1,362,625	1,158,760	634,747	59,119	37,020	15,739	18,557	4,366,307
2012	900,473	1,073,725	640,062	986,002	1,217,402	596,480	250,718	23,549	14,574	13,308	3,742,096
2013	610,895	839,414	1,001,733	587,534	884,563	652,034	220,157	90,586	8,590	10,026	3,455,224
2014	825,978	571,740	783,335	920,482	522,290	510,517	228,903	77,979	31,875	6,544	3,081,925
2015	670,586	774,773	535,176	724,178	825,541	320,991	176,731	79,270	27,522	13,595	2,703,004
2016	244,932	628,461	726,099	493,739	650,758	474,600	110,207	61,405	27,916	14,866	2,559,590
2017	329,701	230,140	588,349	669,315	443,422	344,995	175,488	40,454	23,036	16,563	2,301,621
2018	301,768	308,266	215,830	544,116	602,063	248,852	144,421	71,529	16,325	16,645	1,859,782
2019	274,937	282,805	288,074	199,125	492,897	345,857	107,645	64,683	31,289	14,614	1,544,184
2020	548,889	257,491	264,734	267,460	177,851	263,786	150,858	48,355	30,081	21,070	1,224,193
2021	427,516	290,795	240,885	244,925	244,974	101,443	122,786	69,783	23,128	25,190	1,073,113

Table 31. SCA maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of fall spawners in the North region of the southern Gulf of St. Lawrence. F5-10 is the January 1 abundance-weighted average F for ages 5 to 10 years.

Year	Age										
	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.037	0.423	1.173	1.319	1.329	1.330	1.330	1.330	1.330	1.330	1.325
1979	0.030	0.344	0.954	1.072	1.081	1.081	1.081	1.081	1.081	1.081	1.077
1980	0.020	0.231	0.641	0.721	0.726	0.727	0.727	0.727	0.727	0.727	0.723
1981	0.003	0.048	0.313	0.439	0.449	0.449	0.449	0.449	0.449	0.449	0.442
1982	0.002	0.041	0.266	0.374	0.382	0.383	0.383	0.383	0.383	0.383	0.376
1983	0.001	0.022	0.141	0.199	0.203	0.203	0.203	0.203	0.203	0.203	0.200
1984	0.001	0.017	0.109	0.153	0.157	0.157	0.157	0.157	0.157	0.157	0.155
1985	0.002	0.029	0.190	0.267	0.273	0.273	0.273	0.273	0.273	0.273	0.270
1986	0.003	0.043	0.277	0.389	0.398	0.398	0.398	0.398	0.398	0.398	0.394
1987	0.003	0.054	0.347	0.487	0.498	0.498	0.498	0.498	0.498	0.498	0.494
1988	0.003	0.044	0.284	0.399	0.407	0.408	0.408	0.408	0.408	0.408	0.403
1989	0.003	0.053	0.340	0.478	0.488	0.489	0.489	0.489	0.489	0.489	0.483
1990	0.004	0.066	0.428	0.601	0.614	0.615	0.615	0.615	0.615	0.615	0.609
1991	0.002	0.041	0.265	0.372	0.380	0.380	0.381	0.381	0.381	0.381	0.377
1992	0.003	0.045	0.291	0.409	0.418	0.419	0.419	0.419	0.419	0.419	0.412
1993	0.002	0.033	0.215	0.302	0.308	0.309	0.309	0.309	0.309	0.309	0.305
1994	0.004	0.073	0.472	0.663	0.677	0.678	0.678	0.678	0.678	0.678	0.674
1995	0.007	0.123	0.797	1.119	1.143	1.145	1.145	1.145	1.145	1.145	1.133
1996	0.006	0.107	0.694	0.975	0.996	0.997	0.997	0.997	0.997	0.997	0.987
1997	0.005	0.092	0.593	0.833	0.851	0.852	0.852	0.852	0.852	0.852	0.840
1998	0.005	0.087	0.566	0.796	0.813	0.814	0.814	0.814	0.814	0.814	0.802
1999	0.005	0.089	0.579	0.814	0.832	0.833	0.833	0.833	0.833	0.833	0.821
2000	0.005	0.090	0.584	0.820	0.838	0.839	0.839	0.839	0.839	0.839	0.825
2001	0.004	0.074	0.481	0.675	0.690	0.691	0.691	0.691	0.691	0.691	0.681
2002	0.004	0.072	0.463	0.651	0.665	0.666	0.666	0.666	0.666	0.666	0.657
2003	0.006	0.105	0.677	0.951	0.971	0.973	0.973	0.973	0.973	0.973	0.961
2004	0.003	0.053	0.343	0.482	0.492	0.493	0.493	0.493	0.493	0.493	0.487
2005	0.004	0.065	0.421	0.592	0.605	0.605	0.605	0.605	0.605	0.605	0.596
2006	0.002	0.035	0.291	0.560	0.595	0.598	0.598	0.598	0.598	0.598	0.574
2007	0.002	0.034	0.289	0.555	0.591	0.593	0.593	0.593	0.593	0.593	0.572
2008	0.002	0.025	0.207	0.398	0.423	0.425	0.425	0.425	0.425	0.425	0.413
2009	0.001	0.015	0.123	0.236	0.251	0.252	0.252	0.252	0.252	0.252	0.242
2010	0.001	0.010	0.082	0.157	0.167	0.168	0.168	0.168	0.168	0.168	0.161
2011	0.000	0.006	0.050	0.096	0.102	0.102	0.102	0.102	0.102	0.102	0.099
2012	0.000	0.005	0.042	0.080	0.085	0.086	0.086	0.086	0.086	0.086	0.083
2013	0.000	0.006	0.049	0.094	0.100	0.101	0.101	0.101	0.101	0.101	0.099
2014	0.000	0.005	0.043	0.083	0.088	0.089	0.089	0.089	0.089	0.089	0.087
2015	0.000	0.006	0.048	0.093	0.099	0.099	0.099	0.099	0.099	0.099	0.098
2016	0.000	0.006	0.052	0.100	0.106	0.107	0.107	0.107	0.107	0.107	0.105
2017	0.000	0.006	0.049	0.094	0.100	0.101	0.101	0.101	0.101	0.101	0.098
2018	0.000	0.006	0.050	0.096	0.102	0.102	0.102	0.102	0.102	0.102	0.100
2019	0.001	0.007	0.062	0.120	0.127	0.128	0.128	0.128	0.128	0.128	0.126
2020	0.001	0.009	0.073	0.140	0.149	0.149	0.149	0.149	0.149	0.149	0.148
2021	0.001	0.010	0.081	0.156	0.166	0.167	0.167	0.167	0.167	0.167	0.164

Table 32. SCA maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of fall spawners in the Middle region of the southern Gulf of St. Lawrence. F5-10 is the January 1 abundance-weighted average F for ages 5 to 10 years.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.002	0.016	0.119	0.459	0.692	0.736	0.741	0.742	0.742	0.742	0.638
1979	0.005	0.045	0.328	1.269	1.914	2.035	2.050	2.052	2.052	2.052	1.603
1980	0.003	0.022	0.161	0.625	0.942	1.001	1.009	1.009	1.010	1.010	0.699
1981	0.001	0.010	0.173	1.045	1.423	1.451	1.452	1.452	1.452	1.452	1.175
1982	0.000	0.002	0.035	0.213	0.290	0.295	0.296	0.296	0.296	0.296	0.223
1983	0.000	0.008	0.133	0.804	1.095	1.116	1.117	1.117	1.117	1.117	0.945
1984	0.000	0.004	0.063	0.381	0.519	0.529	0.530	0.530	0.530	0.530	0.422
1985	0.000	0.001	0.023	0.136	0.186	0.189	0.190	0.190	0.190	0.190	0.150
1986	0.000	0.002	0.034	0.203	0.276	0.282	0.282	0.282	0.282	0.282	0.245
1987	0.000	0.002	0.037	0.223	0.304	0.310	0.311	0.311	0.311	0.311	0.267
1988	0.000	0.003	0.049	0.295	0.402	0.410	0.410	0.411	0.411	0.411	0.347
1989	0.000	0.001	0.021	0.129	0.176	0.179	0.179	0.179	0.179	0.179	0.155
1990	0.000	0.002	0.035	0.214	0.292	0.298	0.298	0.298	0.298	0.298	0.267
1991	0.000	0.003	0.057	0.345	0.470	0.479	0.480	0.480	0.480	0.480	0.408
1992	0.000	0.002	0.027	0.165	0.224	0.229	0.229	0.229	0.229	0.229	0.177
1993	0.000	0.002	0.031	0.187	0.255	0.260	0.260	0.260	0.260	0.260	0.222
1994	0.000	0.002	0.037	0.222	0.302	0.308	0.308	0.308	0.308	0.308	0.291
1995	0.000	0.005	0.084	0.510	0.695	0.708	0.709	0.709	0.709	0.709	0.599
1996	0.000	0.005	0.080	0.484	0.659	0.672	0.673	0.673	0.673	0.673	0.626
1997	0.000	0.005	0.085	0.512	0.697	0.711	0.712	0.712	0.712	0.712	0.595
1998	0.000	0.007	0.120	0.724	0.987	1.006	1.007	1.007	1.007	1.007	0.869
1999	0.000	0.007	0.113	0.685	0.933	0.951	0.952	0.952	0.952	0.952	0.756
2000	0.000	0.006	0.098	0.593	0.808	0.824	0.825	0.825	0.825	0.825	0.650
2001	0.000	0.004	0.059	0.360	0.490	0.500	0.500	0.500	0.500	0.500	0.411
2002	0.000	0.003	0.057	0.348	0.474	0.483	0.484	0.484	0.484	0.484	0.418
2003	0.000	0.003	0.045	0.269	0.367	0.374	0.374	0.374	0.374	0.374	0.317
2004	0.000	0.003	0.042	0.256	0.348	0.355	0.356	0.356	0.356	0.356	0.304
2005	0.000	0.003	0.056	0.339	0.462	0.471	0.471	0.471	0.471	0.471	0.398
2006	0.000	0.001	0.012	0.094	0.326	0.432	0.447	0.448	0.449	0.449	0.258
2007	0.000	0.001	0.009	0.076	0.263	0.349	0.360	0.362	0.362	0.362	0.227
2008	0.000	0.001	0.010	0.083	0.287	0.381	0.394	0.395	0.395	0.395	0.271
2009	0.000	0.001	0.009	0.073	0.253	0.335	0.347	0.348	0.348	0.348	0.152
2010	0.000	0.001	0.006	0.052	0.180	0.239	0.247	0.248	0.248	0.248	0.130
2011	0.000	0.000	0.004	0.036	0.123	0.164	0.169	0.170	0.170	0.170	0.109
2012	0.000	0.000	0.004	0.030	0.105	0.139	0.143	0.144	0.144	0.144	0.101
2013	0.000	0.000	0.004	0.033	0.116	0.154	0.159	0.159	0.159	0.159	0.119
2014	0.000	0.000	0.004	0.032	0.110	0.145	0.150	0.151	0.151	0.151	0.099
2015	0.000	0.000	0.004	0.036	0.126	0.166	0.172	0.173	0.173	0.173	0.115
2016	0.000	0.000	0.003	0.028	0.098	0.129	0.134	0.134	0.134	0.134	0.097
2017	0.000	0.000	0.004	0.036	0.125	0.166	0.172	0.172	0.172	0.172	0.120
2018	0.000	0.000	0.004	0.030	0.105	0.139	0.143	0.144	0.144	0.144	0.105
2019	0.000	0.000	0.003	0.027	0.094	0.125	0.129	0.129	0.129	0.129	0.106
2020	0.000	0.000	0.003	0.022	0.077	0.102	0.106	0.106	0.106	0.106	0.079
2021	0.000	0.000	0.002	0.020	0.068	0.090	0.094	0.094	0.094	0.094	0.062

Table 33. SCA maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of fall spawners in the South region of the southern Gulf of St. Lawrence. F5-10 is the January 1 abundance-weighted average F for ages 5 to 10 years.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.026	0.069	0.173	0.370	0.617	0.808	0.908	0.949	0.964	0.970	0.579
1979	0.012	0.032	0.081	0.172	0.288	0.377	0.423	0.443	0.450	0.453	0.239
1980	0.055	0.148	0.370	0.790	1.318	1.726	1.939	2.027	2.060	2.072	1.043
1981	0.001	0.010	0.074	0.361	0.670	0.746	0.756	0.757	0.758	0.758	0.518
1982	0.001	0.007	0.052	0.256	0.476	0.530	0.538	0.539	0.539	0.539	0.316
1983	0.001	0.005	0.039	0.189	0.352	0.392	0.397	0.398	0.398	0.398	0.252
1984	0.001	0.005	0.036	0.177	0.328	0.366	0.371	0.371	0.371	0.371	0.237
1985	0.000	0.004	0.028	0.138	0.257	0.286	0.290	0.291	0.291	0.291	0.181
1986	0.000	0.004	0.030	0.147	0.274	0.305	0.309	0.310	0.310	0.310	0.233
1987	0.001	0.005	0.038	0.184	0.342	0.381	0.387	0.387	0.387	0.387	0.268
1988	0.000	0.003	0.026	0.126	0.235	0.261	0.265	0.265	0.266	0.266	0.179
1989	0.000	0.001	0.011	0.056	0.103	0.115	0.117	0.117	0.117	0.117	0.093
1990	0.001	0.007	0.052	0.253	0.469	0.523	0.530	0.531	0.531	0.531	0.457
1991	0.000	0.002	0.013	0.063	0.116	0.130	0.131	0.132	0.132	0.132	0.107
1992	0.000	0.002	0.013	0.063	0.116	0.129	0.131	0.131	0.131	0.131	0.087
1993	0.000	0.001	0.007	0.032	0.060	0.067	0.068	0.068	0.068	0.068	0.051
1994	0.001	0.004	0.034	0.166	0.309	0.344	0.349	0.349	0.349	0.349	0.305
1995	0.001	0.005	0.035	0.172	0.319	0.355	0.360	0.360	0.360	0.360	0.266
1996	0.001	0.007	0.057	0.276	0.513	0.572	0.579	0.580	0.581	0.581	0.500
1997	0.001	0.007	0.052	0.254	0.472	0.526	0.533	0.534	0.534	0.534	0.378
1998	0.001	0.007	0.056	0.273	0.508	0.566	0.574	0.574	0.575	0.575	0.446
1999	0.001	0.010	0.075	0.369	0.685	0.763	0.773	0.774	0.775	0.775	0.498
2000	0.001	0.007	0.055	0.270	0.501	0.558	0.565	0.566	0.566	0.566	0.375
2001	0.001	0.006	0.050	0.243	0.452	0.504	0.511	0.511	0.512	0.512	0.344
2002	0.001	0.005	0.040	0.198	0.367	0.409	0.414	0.415	0.415	0.415	0.315
2003	0.001	0.005	0.036	0.174	0.323	0.360	0.365	0.365	0.365	0.365	0.230
2004	0.000	0.002	0.017	0.083	0.154	0.172	0.174	0.174	0.174	0.174	0.126
2005	0.000	0.002	0.016	0.076	0.142	0.158	0.160	0.160	0.160	0.160	0.122
2006	0.000	0.000	0.003	0.026	0.119	0.192	0.205	0.206	0.207	0.207	0.131
2007	0.000	0.000	0.003	0.026	0.119	0.191	0.204	0.206	0.206	0.206	0.135
2008	0.000	0.000	0.003	0.022	0.100	0.160	0.171	0.172	0.172	0.172	0.119
2009	0.000	0.000	0.004	0.030	0.134	0.216	0.231	0.232	0.233	0.233	0.095
2010	0.000	0.000	0.003	0.022	0.101	0.163	0.174	0.175	0.175	0.175	0.088
2011	0.000	0.000	0.002	0.015	0.070	0.113	0.120	0.121	0.121	0.121	0.071
2012	0.000	0.000	0.002	0.013	0.061	0.098	0.105	0.106	0.106	0.106	0.069
2013	0.000	0.000	0.002	0.016	0.071	0.113	0.121	0.122	0.122	0.122	0.092
2014	0.000	0.000	0.002	0.020	0.091	0.146	0.156	0.157	0.157	0.157	0.102
2015	0.000	0.000	0.003	0.021	0.095	0.152	0.163	0.164	0.164	0.164	0.090
2016	0.000	0.000	0.002	0.016	0.072	0.116	0.124	0.125	0.125	0.125	0.078
2017	0.000	0.000	0.001	0.009	0.042	0.068	0.073	0.073	0.073	0.073	0.045
2018	0.000	0.000	0.001	0.009	0.042	0.068	0.073	0.073	0.073	0.073	0.043
2019	0.000	0.000	0.001	0.011	0.050	0.080	0.086	0.086	0.086	0.086	0.063
2020	0.000	0.000	0.000	0.004	0.019	0.030	0.032	0.033	0.033	0.033	0.023
2021	0.000	0.000	0.002	0.013	0.061	0.098	0.105	0.105	0.105	0.105	0.074

Table 34. SCA maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of fall spawners in the southern Gulf of St. Lawrence. F5-10 is the January 1 abundance-weighted average F for ages 5 to 10 years.

Year	Age									
	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.005	0.026	0.055	0.044	0.025	0.022	0.020	0.007	0.006	0.015	0.912
1979	0.007	0.018	0.034	0.031	0.016	0.006	0.009	0.007	0.003	0.009	0.765
1980	0.016	0.043	0.035	0.052	0.027	0.011	0.005	0.004	0.003	0.004	0.957
1981	0.001	0.007	0.030	0.022	0.017	0.004	0.001	0.000	0.000	0.001	0.637
1982	0.001	0.007	0.028	0.030	0.007	0.003	0.001	0.000	0.000	0.000	0.319
1983	0.000	0.006	0.023	0.032	0.025	0.003	0.002	0.000	0.000	0.000	0.321
1984	0.000	0.003	0.027	0.032	0.018	0.008	0.001	0.001	0.000	0.000	0.218
1985	0.001	0.006	0.025	0.052	0.026	0.011	0.005	0.001	0.000	0.000	0.214
1986	0.001	0.010	0.040	0.043	0.053	0.020	0.010	0.004	0.001	0.001	0.304
1987	0.001	0.011	0.062	0.065	0.038	0.036	0.015	0.007	0.003	0.001	0.352
1988	0.000	0.007	0.044	0.063	0.037	0.015	0.016	0.007	0.003	0.002	0.265
1989	0.001	0.006	0.039	0.048	0.036	0.015	0.008	0.007	0.003	0.003	0.241
1990	0.001	0.021	0.043	0.054	0.055	0.051	0.024	0.010	0.011	0.008	0.497
1991	0.000	0.010	0.067	0.029	0.018	0.013	0.011	0.005	0.002	0.004	0.251
1992	0.001	0.005	0.060	0.082	0.018	0.010	0.008	0.006	0.003	0.004	0.219
1993	0.000	0.006	0.018	0.052	0.045	0.008	0.004	0.003	0.003	0.003	0.177
1994	0.002	0.014	0.188	0.080	0.171	0.071	0.013	0.007	0.006	0.014	0.503
1995	0.002	0.044	0.119	0.334	0.079	0.072	0.053	0.010	0.005	0.014	0.759
1996	0.003	0.025	0.200	0.090	0.182	0.017	0.030	0.025	0.005	0.012	0.756
1997	0.004	0.037	0.111	0.184	0.043	0.033	0.006	0.011	0.010	0.007	0.631
1998	0.003	0.046	0.190	0.117	0.119	0.011	0.016	0.003	0.005	0.008	0.690
1999	0.003	0.048	0.261	0.246	0.072	0.032	0.005	0.008	0.001	0.007	0.695
2000	0.005	0.035	0.258	0.296	0.138	0.015	0.009	0.001	0.002	0.002	0.659
2001	0.003	0.055	0.158	0.255	0.152	0.026	0.005	0.003	0.000	0.001	0.530
2002	0.004	0.044	0.292	0.178	0.173	0.036	0.010	0.002	0.001	0.001	0.506
2003	0.004	0.075	0.351	0.514	0.164	0.044	0.016	0.004	0.001	0.001	0.596
2004	0.002	0.028	0.216	0.225	0.207	0.019	0.011	0.004	0.001	0.000	0.317
2005	0.001	0.032	0.197	0.343	0.229	0.048	0.011	0.006	0.002	0.001	0.367
2006	0.003	0.011	0.124	0.203	0.259	0.051	0.030	0.006	0.004	0.002	0.343
2007	0.003	0.040	0.081	0.201	0.185	0.065	0.025	0.014	0.003	0.002	0.332
2008	0.002	0.026	0.220	0.096	0.143	0.046	0.028	0.011	0.006	0.002	0.263
2009	0.001	0.015	0.118	0.246	0.068	0.048	0.022	0.015	0.006	0.005	0.172
2010	0.000	0.008	0.080	0.146	0.211	0.025	0.016	0.007	0.005	0.004	0.133
2011	0.000	0.003	0.038	0.092	0.112	0.077	0.007	0.005	0.002	0.002	0.090
2012	0.000	0.004	0.020	0.060	0.098	0.061	0.028	0.003	0.002	0.001	0.081
2013	0.000	0.003	0.035	0.044	0.085	0.075	0.027	0.012	0.001	0.001	0.100
2014	0.000	0.002	0.022	0.059	0.048	0.059	0.030	0.010	0.005	0.001	0.092
2015	0.000	0.003	0.018	0.049	0.084	0.039	0.024	0.011	0.004	0.002	0.098
2016	0.000	0.002	0.026	0.036	0.063	0.054	0.013	0.007	0.003	0.002	0.097
2017	0.000	0.001	0.019	0.046	0.040	0.035	0.019	0.005	0.003	0.002	0.087
2018	0.000	0.001	0.007	0.036	0.054	0.024	0.014	0.007	0.002	0.002	0.084
2019	0.000	0.001	0.010	0.017	0.050	0.038	0.012	0.007	0.004	0.002	0.103
2020	0.000	0.001	0.011	0.022	0.020	0.023	0.014	0.004	0.002	0.002	0.091
2021	0.000	0.001	0.011	0.024	0.029	0.013	0.015	0.009	0.003	0.003	0.114

Table 35. Risk analysis table from the SCA model of annual catch options (between 2,000 and 18,000 t) for 2022 and 2023 and subsequent years until 2027, with predicted resulting SSB (kt) in 2023, 2024 and 2027, resulting probabilities (%) of SSB being lower than the LRP, resulting probabilities of increases in SSB by 5%, and resulting fully-recruited fishing mortality rate ($F_{5\text{-}10}$) for the fall spawner component of Atlantic Herring from the southern Gulf of St. Lawrence.

Catch option (tons)	2023 SSB (kt)	2024 SSB (kt)	SSB < LRP in 2023 (%)	SSB < LRP in 2024 (%)	SSB < LRP 2027 (%)	SSB > USR in 2023 (%)	SSB > USR in 2024 (%)	SSB > USR in 2027 (%)	SSB 2023 > 2022 (%)	SSB 2024 >2022 (%)	5% increase SSB 2022 to 2023 (%)	5% increase SSB 2023 to 2024 (%)	Average $F_{5\text{-}10}$ in 2022	Average $F_{5\text{-}10}$ in 2023
2,000	186.3008	184.0275	0	0	0	0	2	1	63	59	54	40	0.01	0.01
4,000	185.5242	182.1457	0	0	0	0	1	1	63	58	53	39	0.03	0.03
6,000	184.3327	179.9804	0	0	0	0	1	1	61	56	52	38	0.04	0.04
8,000	183.2936	178.7745	0	0	0	0	1	1	60	54	51	38	0.06	0.06
10,000	181.7065	176.7426	0	0	0	0	1	1	58	52	50	38	0.07	0.07
12,000	181.0641	175.1833	0	0	0	0	1	1	58	52	49	37	0.09	0.09
14,000	179.7282	172.7570	0	0	0	0	1	1	56	49	47	36	0.10	0.11
16,000	178.2872	171.0207	0	0	0	0	1	1	55	48	45	36	0.12	0.12
18,000	177.6406	169.0473	0	0	0	0	1	1	54	47	46	35	0.13	0.14

FIGURES

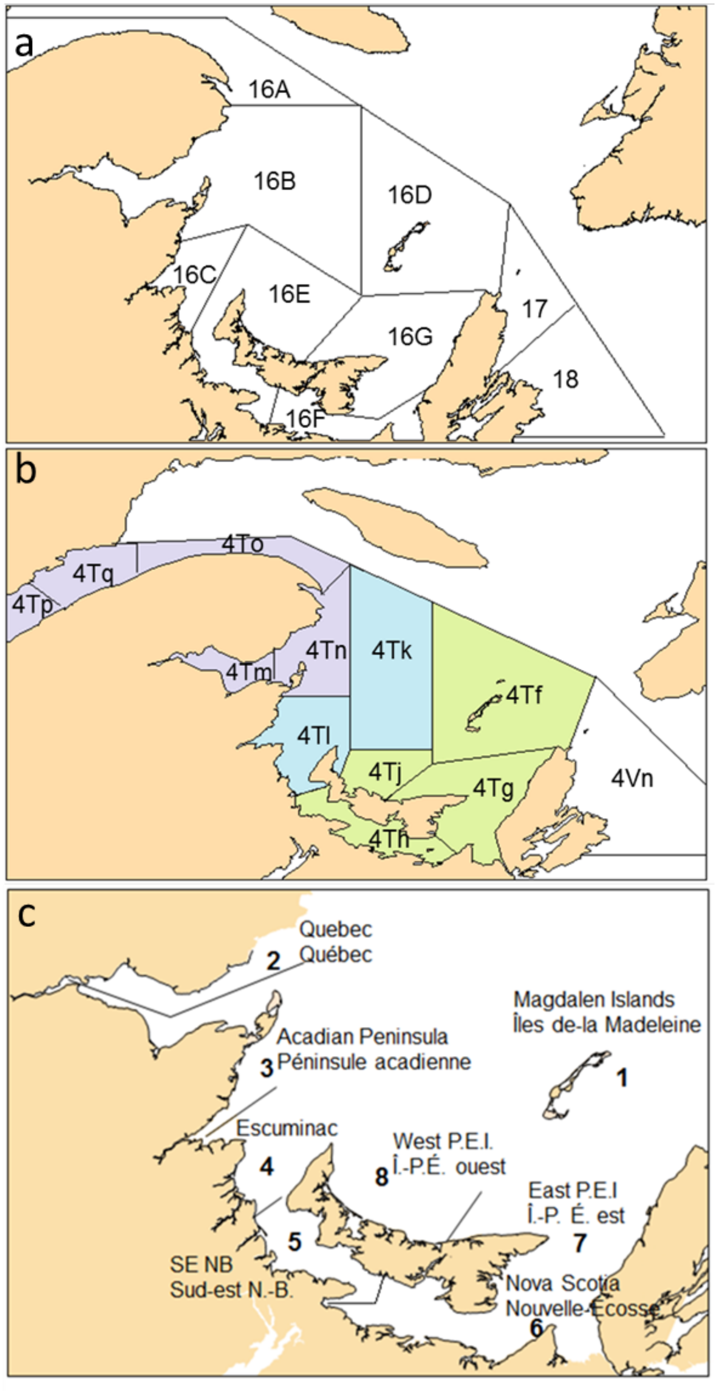


Figure 1. Southern Gulf of St. Lawrence Herring fishery management zones (upper panel, a), Northwest Atlantic Fisheries Organization (NAFO) Divisions 4T and 4Vn, where purple represents the North region, blue = Middle region, and green = South region (middle panel, b), and geographic areas used in the telephone survey of the Herring gillnet fishery (lower panel, c).

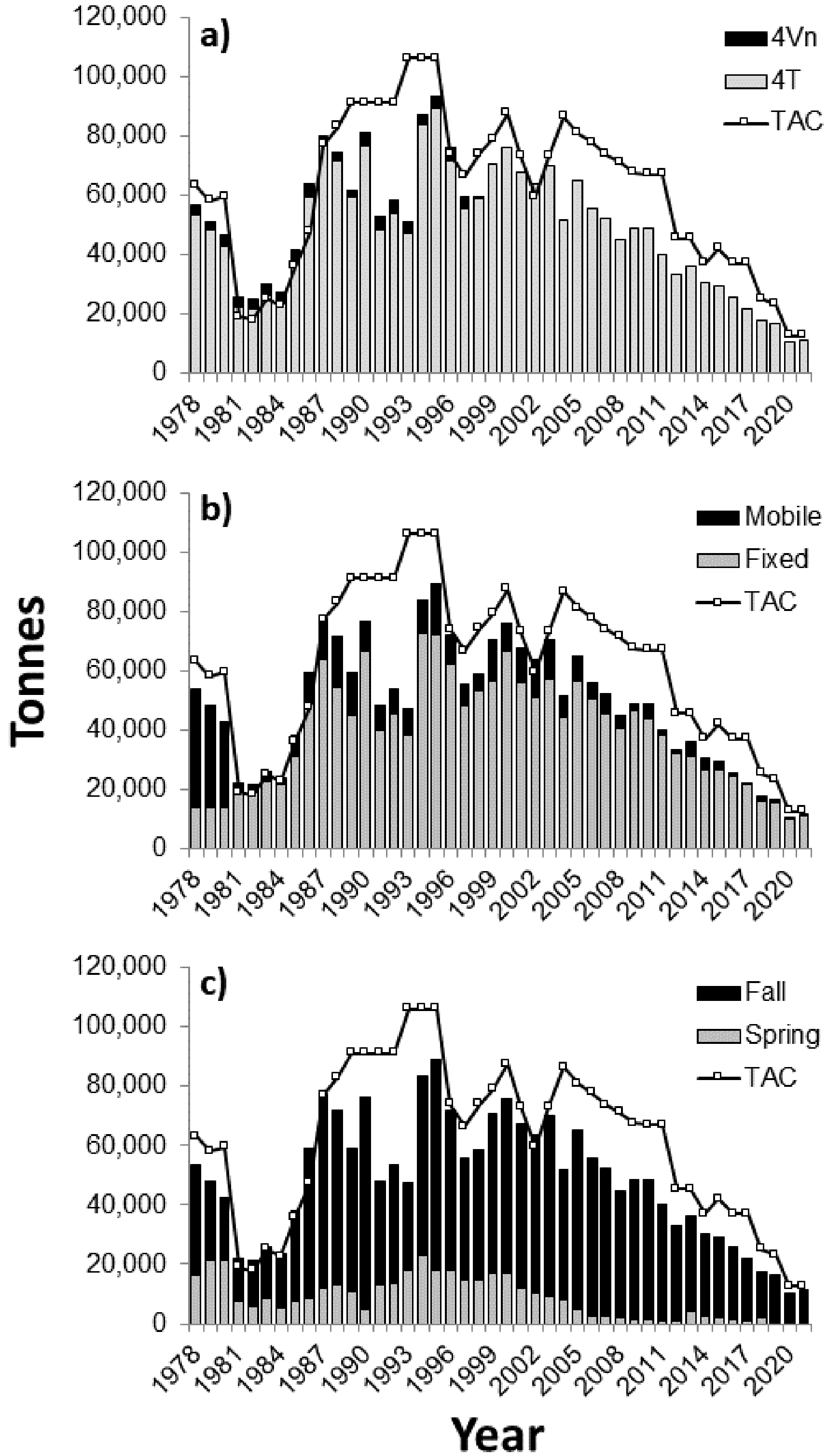


Figure 2. Reported landings (tonnes) of southern Gulf of St. Lawrence Atlantic Herring (spring and fall spawners combined) by NAFO Division (upper panel, a), by gear fleet (middle panel, b), and by fishing season (lower panel, c), 1978 to 2021. In all panels, the corresponding annual TAC (tonnes) is shown. For landings by season, the landings in Div. 4Vn were attributed to the fall fishing season. Data for 2020 and 2021 are preliminary.

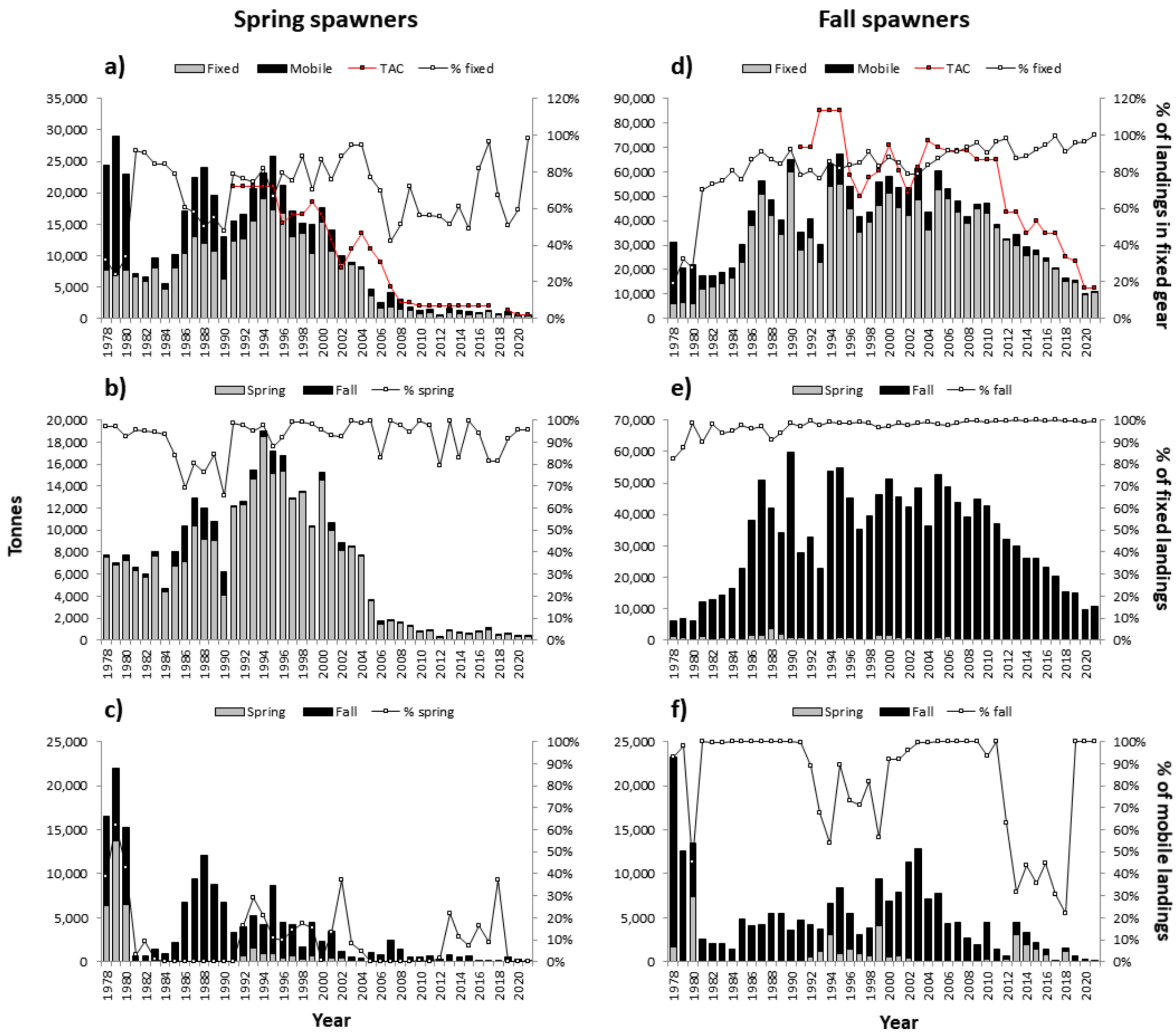


Figure 3. Estimated landings (tonnes) of the spring spawner component (left) and fall spawner component (right) of Atlantic Herring from the southern Gulf of St. Lawrence, 1978 to 2021. Panel a and d shows the estimated landings by gear type and the proportion of the landings attributed to the fixed gear fleet and the TAC for the spawner component (red symbols) for 1991 to 2021. Panels b and e shows the estimated landings of Herring in the fixed gear fleet that occurred in the spring fishery season and the fall fishery season as well as the proportion of Herring landed in the matching fishing season. Panels c and f shows the estimated landings of Herring in the mobile gear fleet that occurred in the spring fishery season and the fall fishery season as well as the proportion of Herring landed in the matching fishing season. For landings by season, the landings in NAFO Division 4Vn were attributed to the fall fishing season. Data for 2018 and 2021 are preliminary.

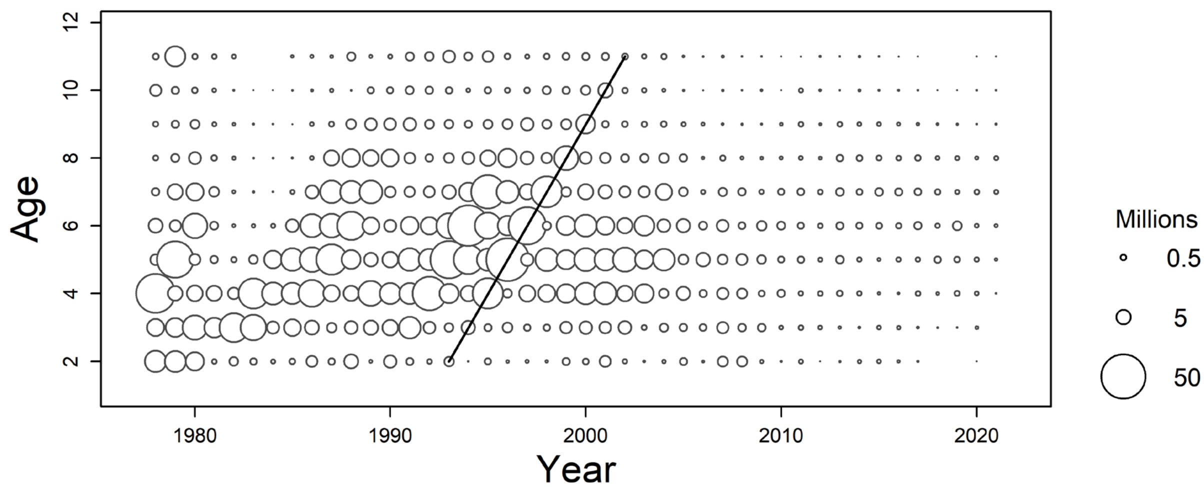


Figure 4. Catch-at-age of the spring spawner component from the fishery, all gears combined, 1978 to 2021. Size of the bubble is proportional to the catch numbers by age and year. The diagonal line represents the most recent strong year-class (1991). The values indicated at age 11 represent catches for ages 11 years and older.

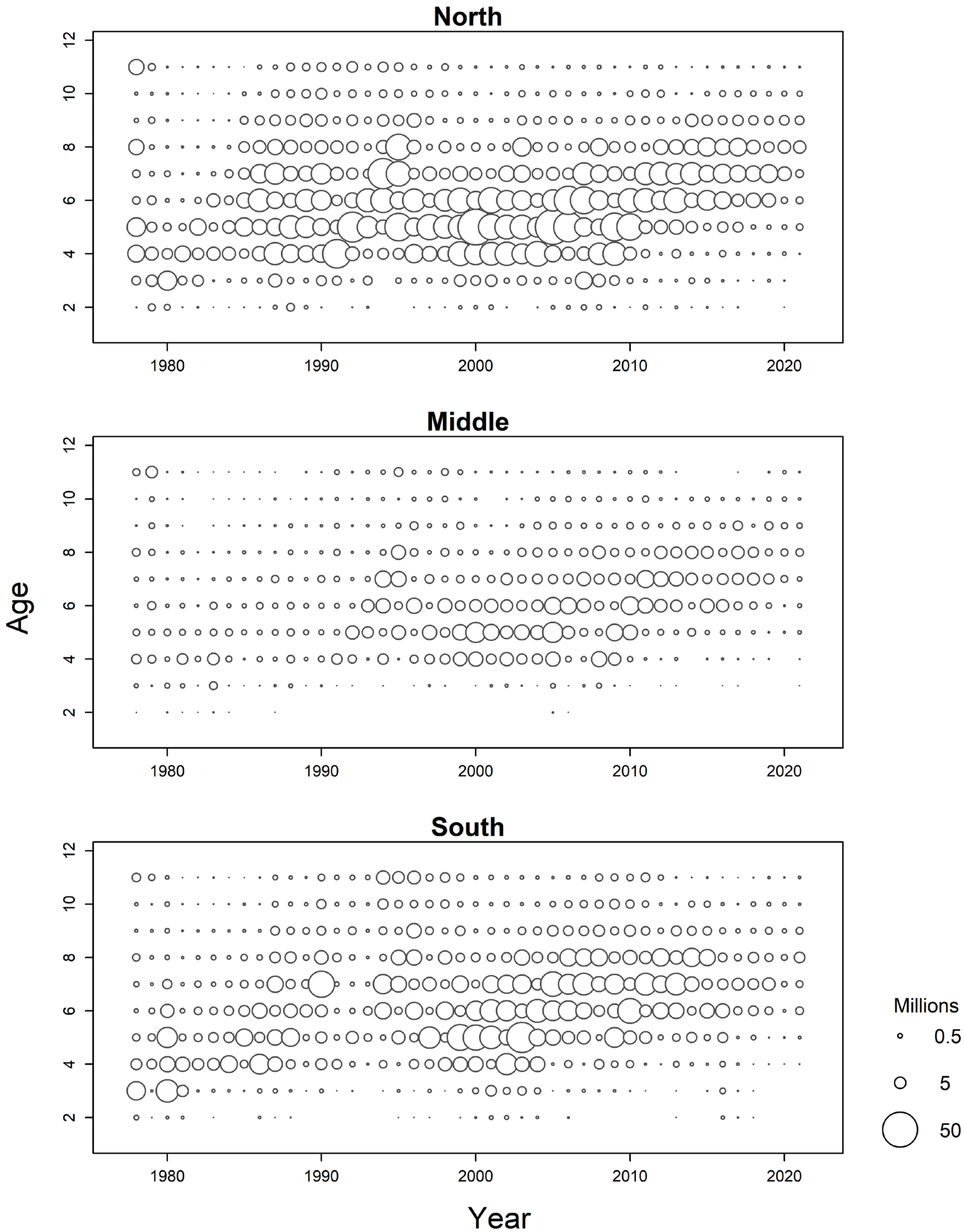


Figure 5. Bubble plots of fishery catch-at-age (number) by region for both mobile and fixed gear combined, 1978 to 2021. The size of the bubble is proportional to the number of fish in the catch by age and year. The values indicated at age 11 represent catches for ages 11 years and older.

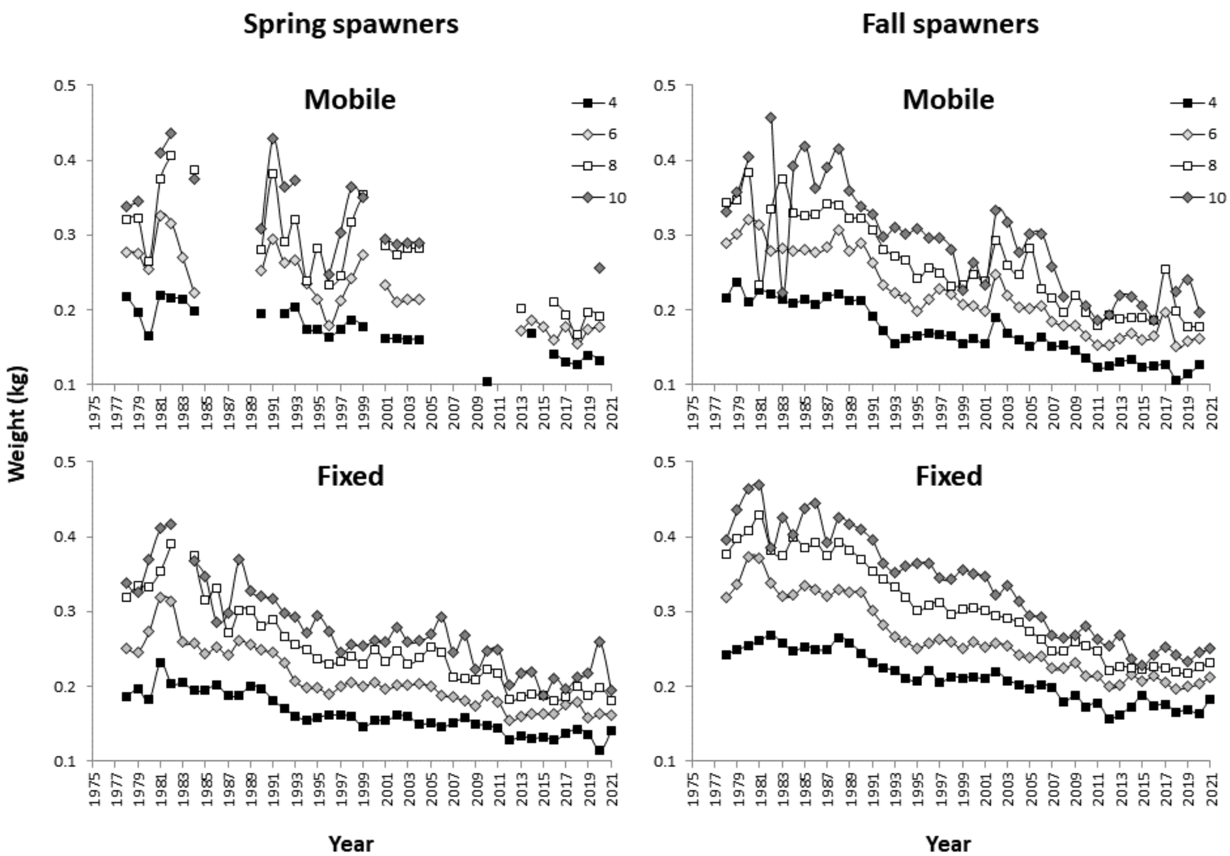


Figure 6. Mean weight (kg) of Atlantic Herring for ages 4, 6, 8, and 10 of spring spawners (left panels) sampled from catches in the spring season and fall spawners (right panels) sampled from catches in the fall season from mobile (upper panels) and fixed (lower panels) commercial gears, in NAFO Div. 4T for 1978 to 2021.

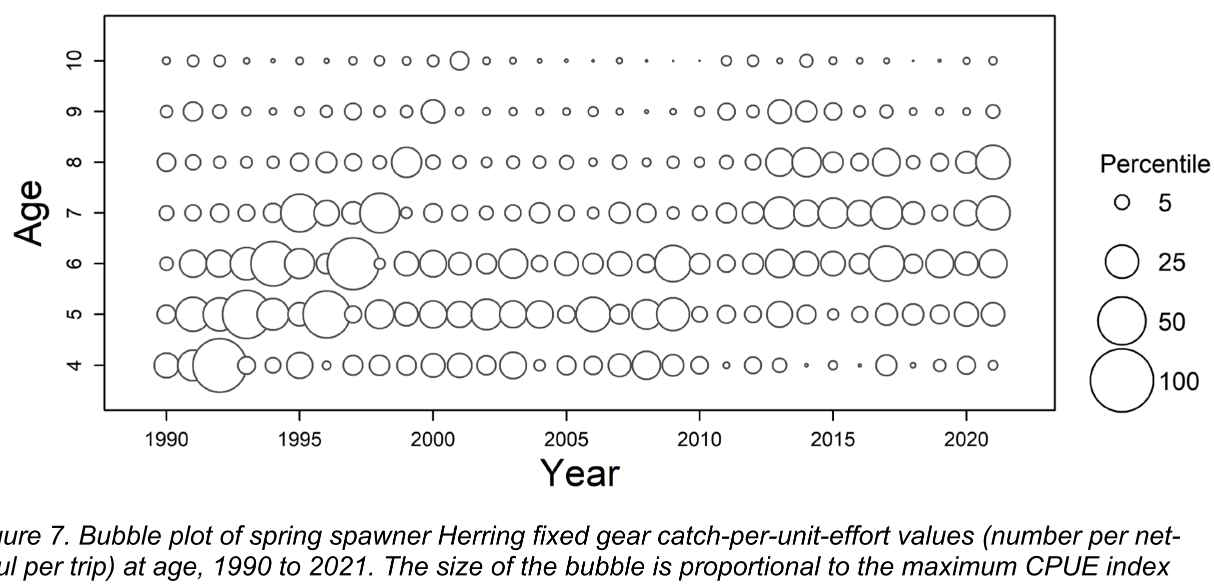


Figure 7. Bubble plot of spring spawner Herring fixed gear catch-per-unit-effort values (number per net-haul per trip) at age, 1990 to 2021. The size of the bubble is proportional to the maximum CPUE index value.

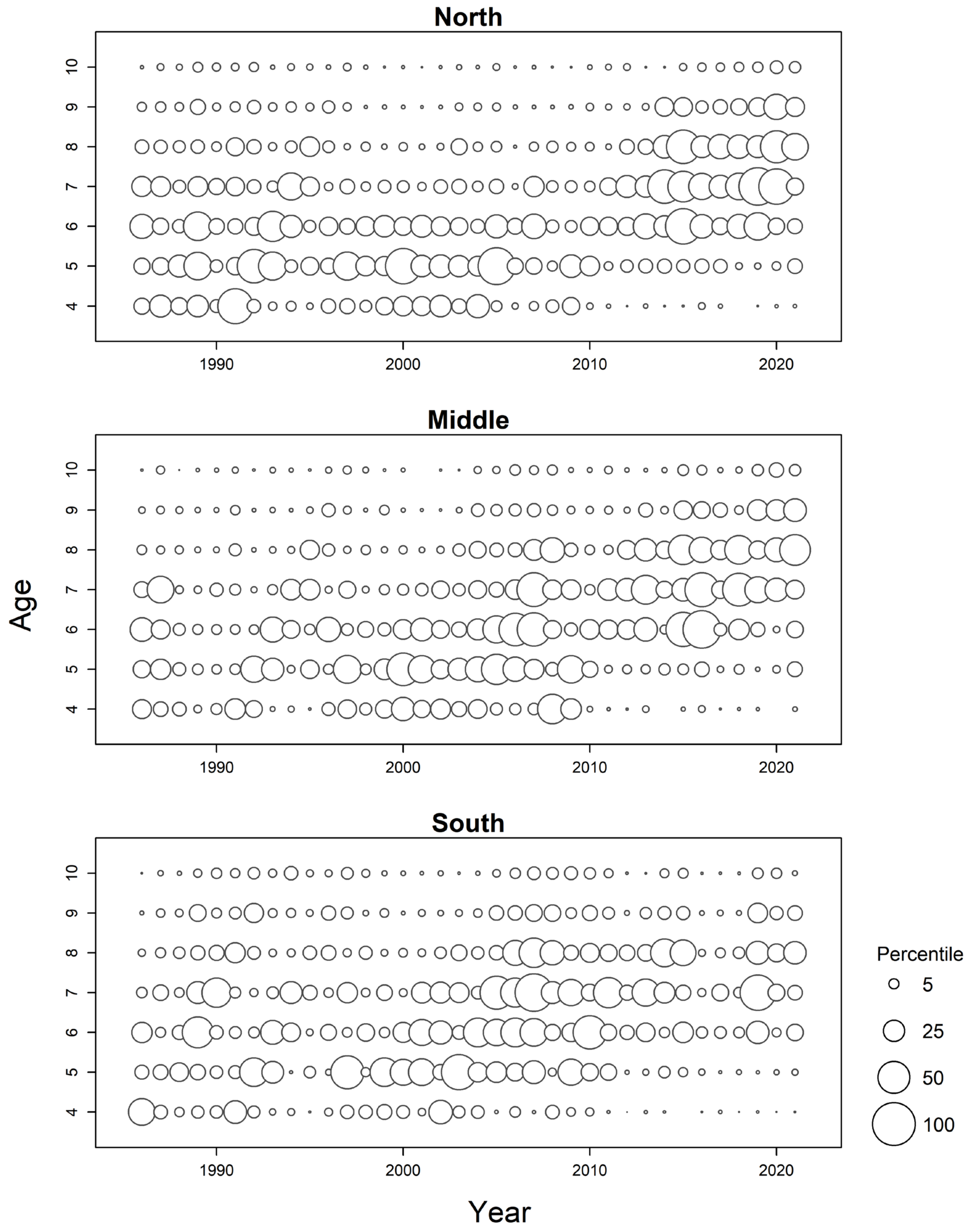
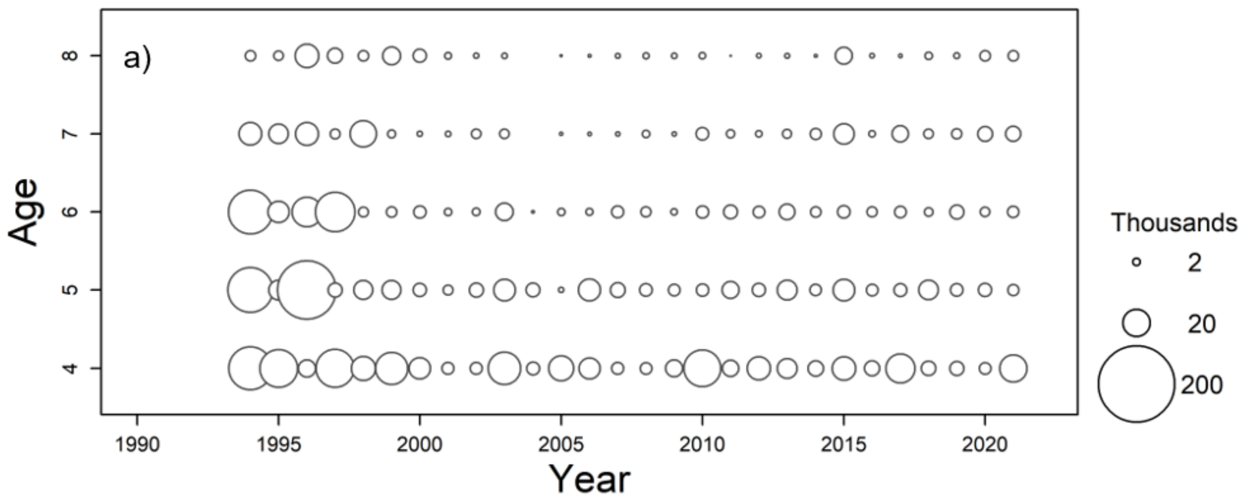


Figure 8. Fall spawner (FS) fixed gear age-disaggregated catch-per-unit-effort values (number per net-haul per trip) by region (upper panel North, middle panel Middle, and lower panel South), 1986 to 2021. The size of the bubble is proportional to the CPUE index value.



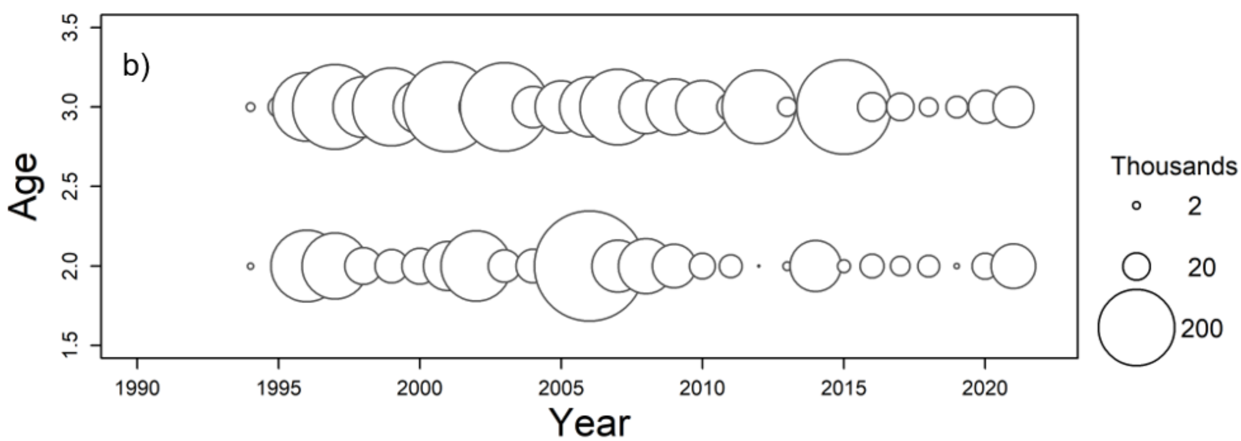


Figure 9. Bubble plot of abundance-at-age (number) from the fisheries-independent acoustic survey for spring spawners (upper panel a); ages 4 to 8) and fall spawners (lower panel b); ages 2 to 3) from 1994 to 2021.

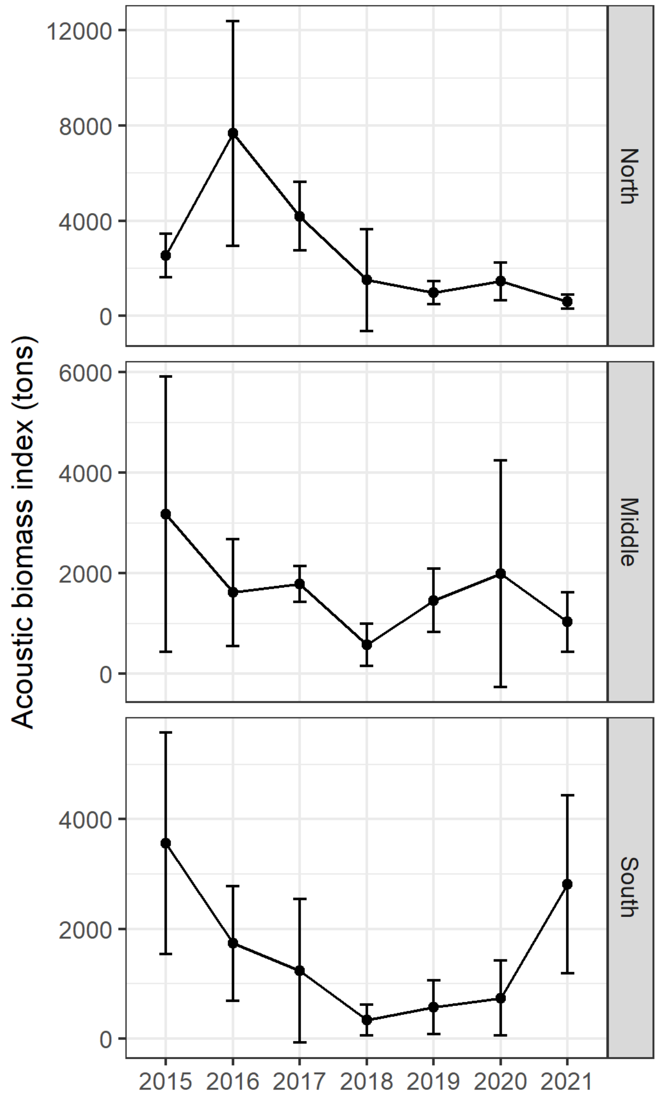


Figure 10. FSCP acoustic biomass indices of NAFO Division 4T fall spawning Atlantic herring in the North, Middle and South regions between 2015 and 2021. Points are average and vertical lines are 95% confidence intervals.

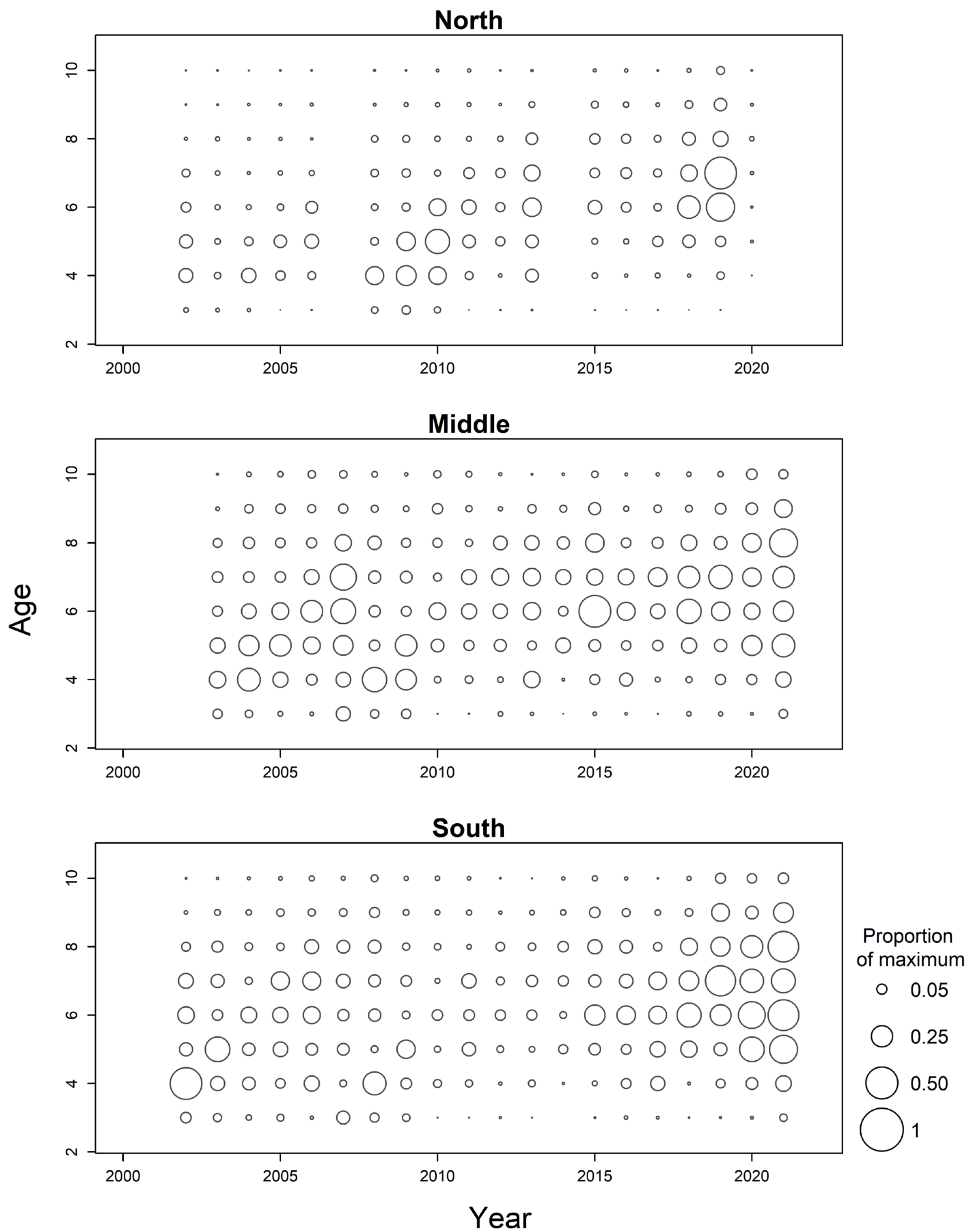


Figure 11. Bubble plots of catch-at-age indices (number) of fall spawners from the experimental netting survey by region (upper panel North, middle panel Middle, and lower panel South) from 2002 to 2021. The size of the bubble is proportional to the index value.

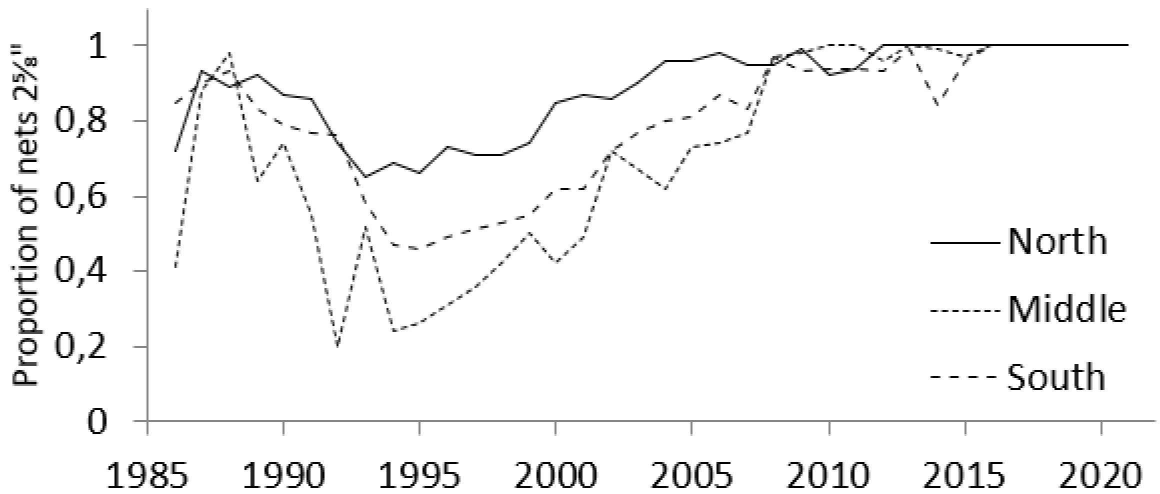


Figure 12. Variations in the proportions of gillnets with mesh sizes 2 ⅝ inches by region, 1986 to 2021. It is assumed that all other nets used were of mesh size 2 ¾.

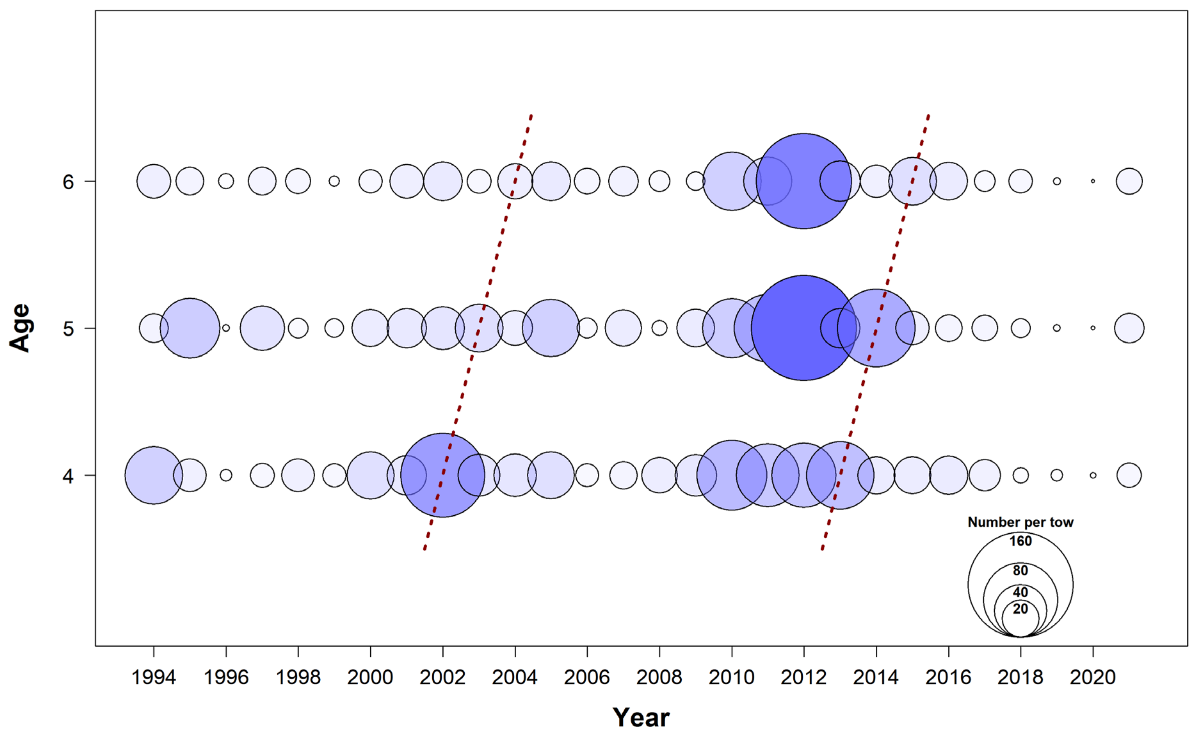


Figure 13. Multispecies bottom trawl survey abundance index (number of fish per standardized tow) for fall spawning Herring ages 4 to 6 years, 1994 to 2021.

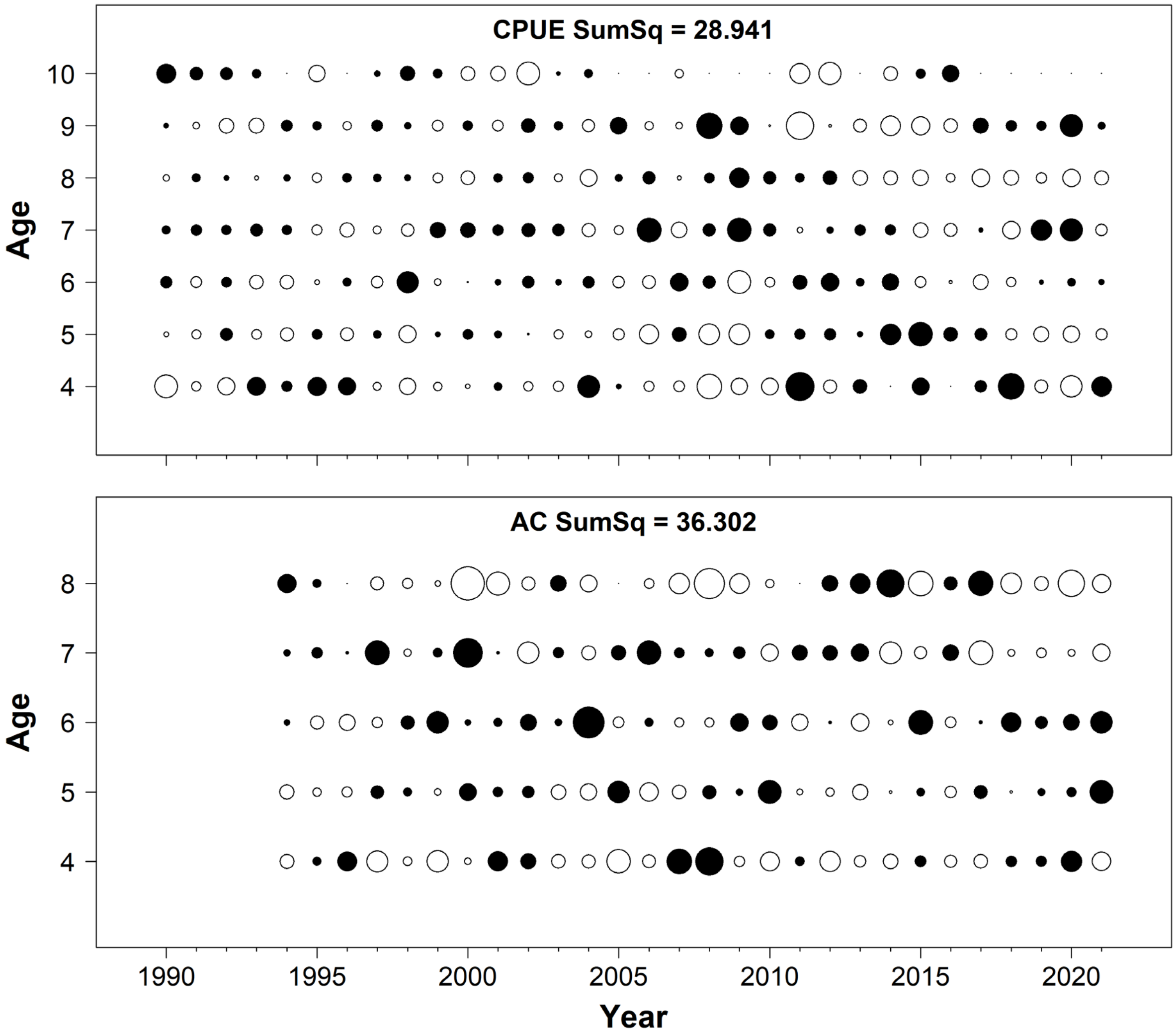


Figure 14. Residuals in PAA (observed – predicted indices) for the population model of spring spawners in the southern Gulf of St. Lawrence. The upper panel shows residuals for the CPUE index and the bottom panel shows residuals for the acoustic index. Rows are for ages and columns for years. Circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

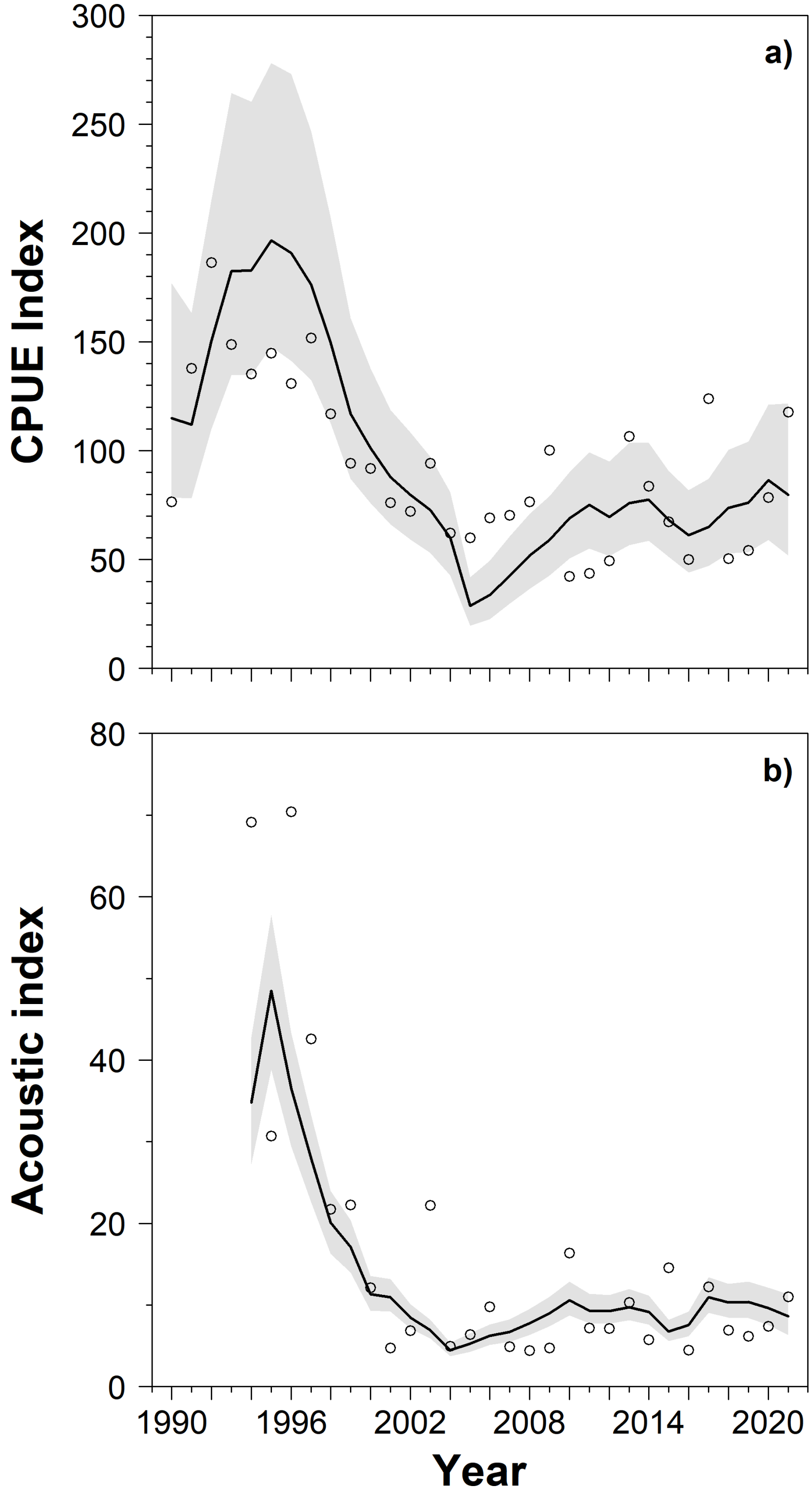


Figure 15. Observed (circles) and predicted (lines and shading) age-aggregated CPUE (upper panels) and acoustic (lower panels) indices (kg) for the population model of spring spawners in the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

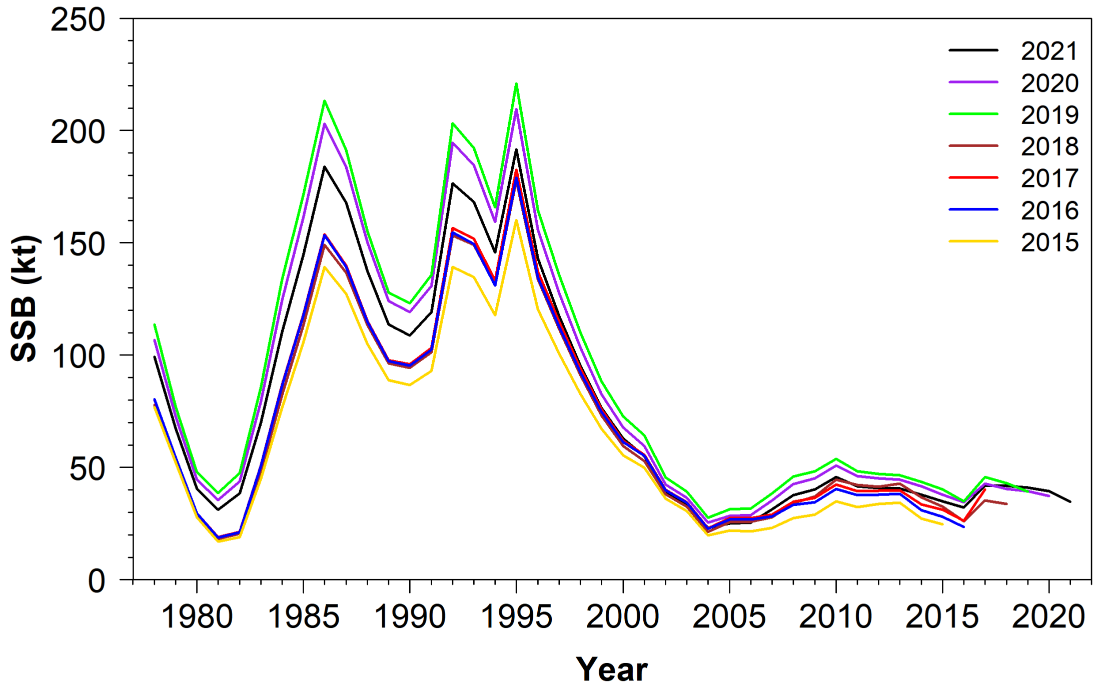


Figure 16. Retrospective patterns in estimated spawning stock biomass (SSB) of ages 4 to 10 and years 2021 to 2015 for spring spawners in the southern Gulf of St. Lawrence. Lined colors correspond to peels between years 2015 and 2021.

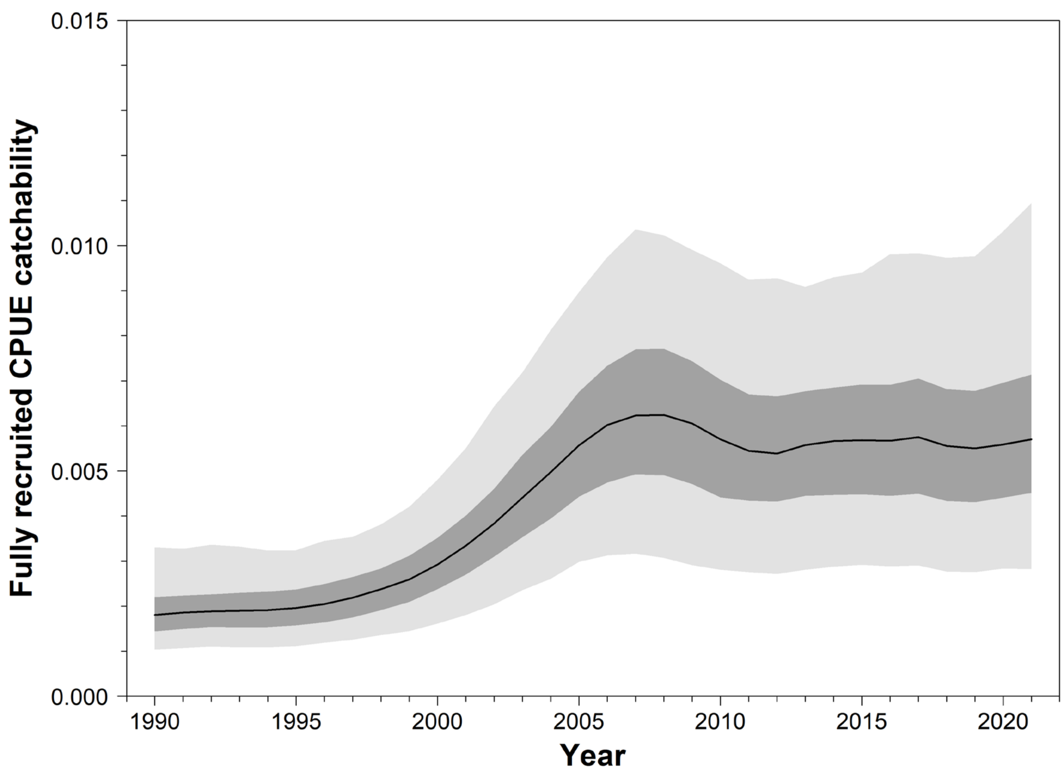


Figure 17. Estimated fully-recruited catchability to the CPUE index (q) from the spring spawners population model. Lines show the median estimates and shading their 50% (dark shading) and 95% (light shading) confidence interval based on MCMC sampling.

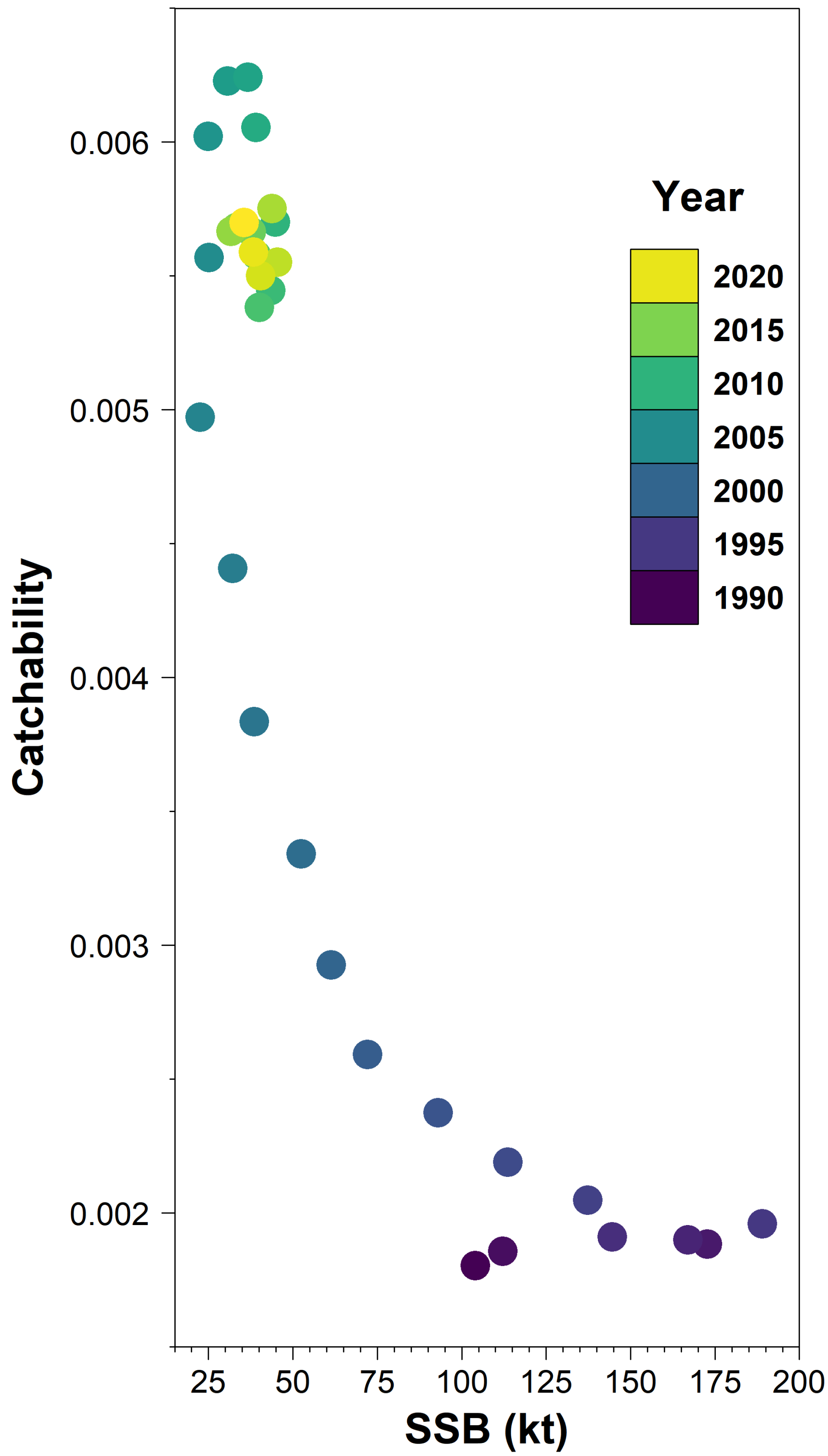


Figure 18. Fully-recruited catchability to the CPUE gillnet fishery (q) in function of SSB (kilotons) for spring spawning Herring between 1990 and 2021.

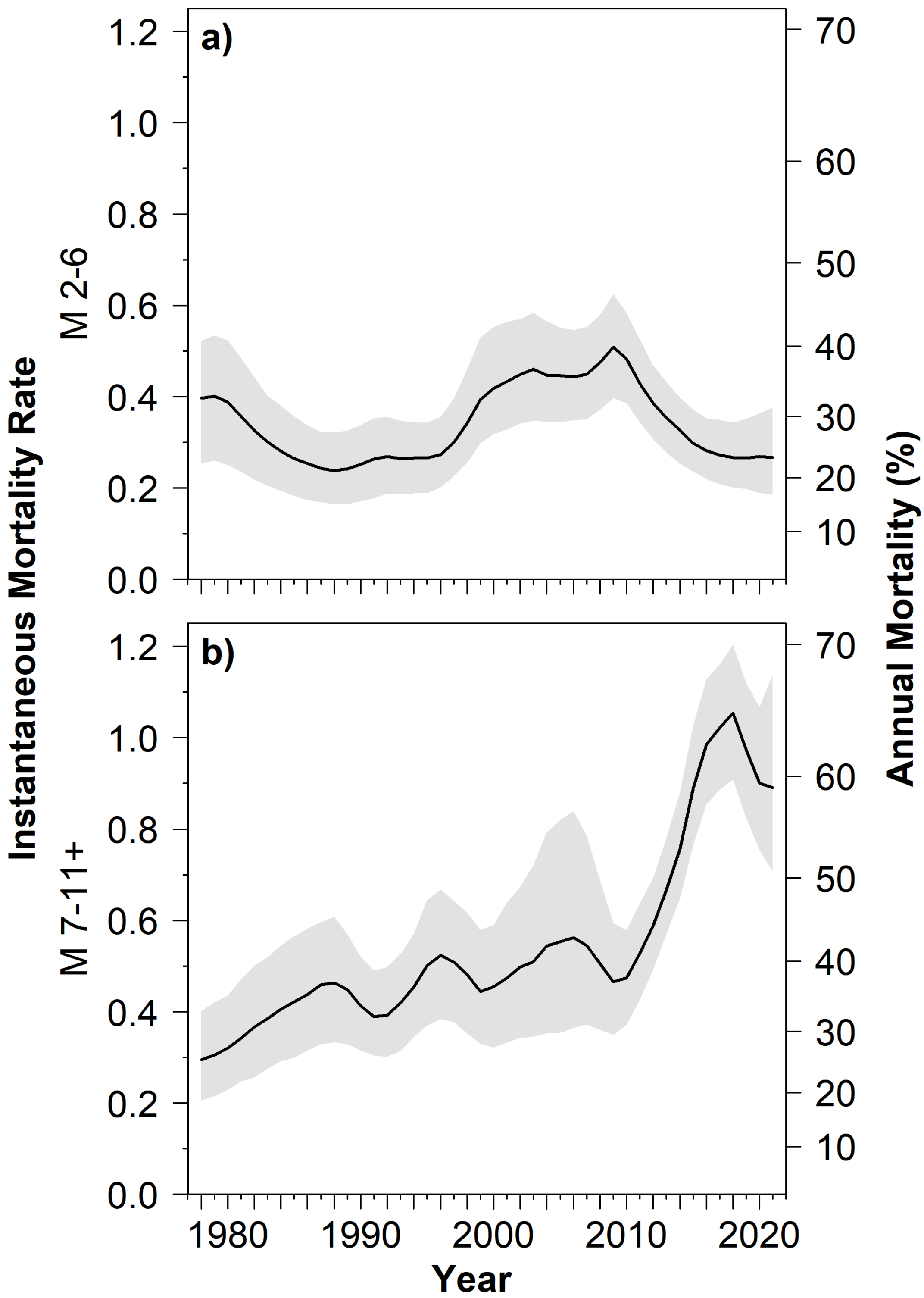


Figure 19. Estimated instantaneous natural mortality rate (left axis) and annual mortality (%, right axis) of spring spawning Atlantic Herring from the population model, for ages 2 to 6 (upper panel) and 7 to 11+ (lower panel). Lines show the median estimates and shading their 95% confidence interval based on MCMC sampling.

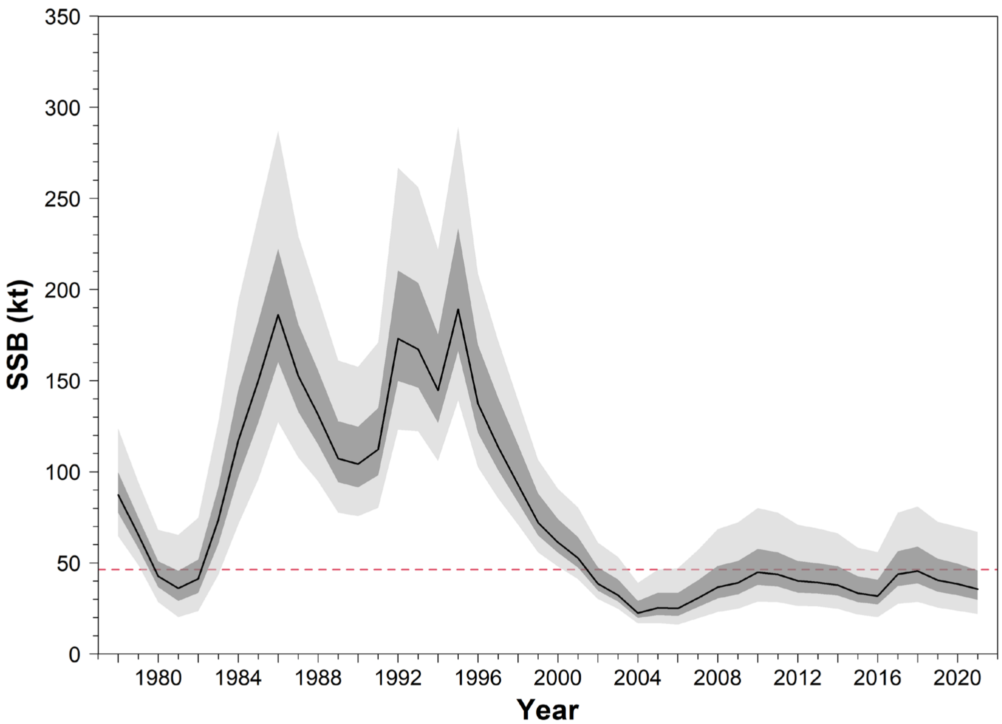


Figure 20. Estimated beginning of the fishing season (April 1) SSB of the spring spawner component of Atlantic Herring in the southern Gulf of St. Lawrence, 1978 to 2021. The solid line is the median MCMC estimate and shading its 50% (dark shading) and 95% (light shading) confidence intervals. The red dashed horizontal line is the Limit Reference Point (LRP) (46,340 t of SSB).

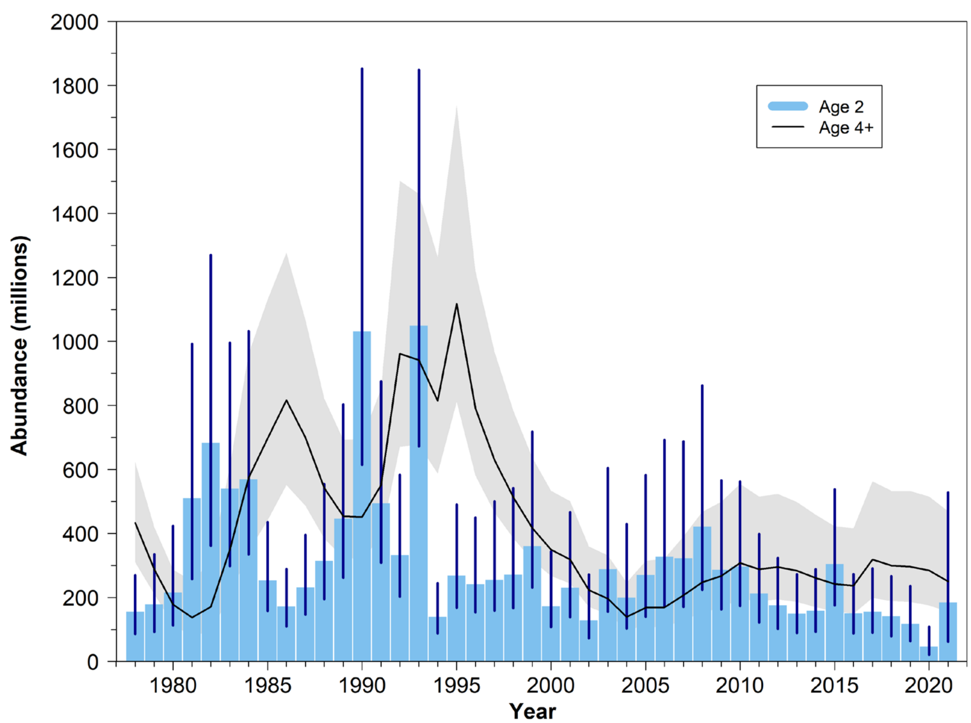


Figure 21. Estimated January 1 abundance of 2 year old Herring (blue bars), and Herring 4 years and older (black line) of the spring spawner component in the southern Gulf of St. Lawrence. Black line show the median MCMC estimate and vertical lines and shading show 95% confidence interval.

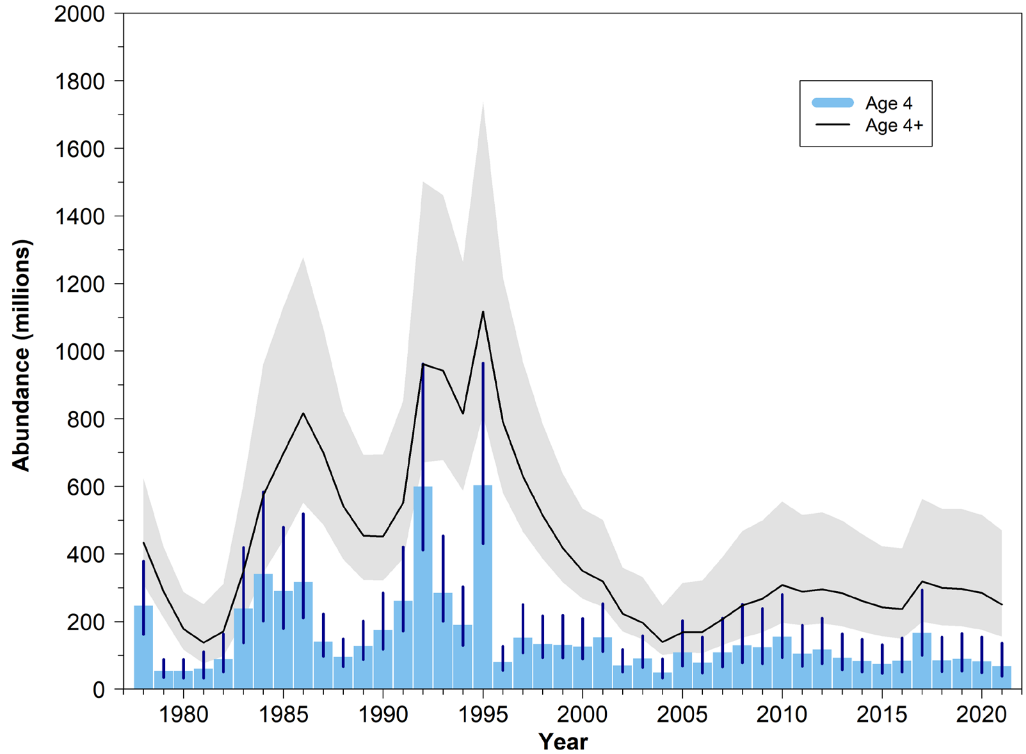


Figure 22. Estimated January 1 abundance of 4 year old Herring (blue bars), and Herring 4 years and older (black line) of the spring spawner component in the southern Gulf of St. Lawrence. Black line show the median MCMC estimate and vertical lines and shading show 95% confidence interval.

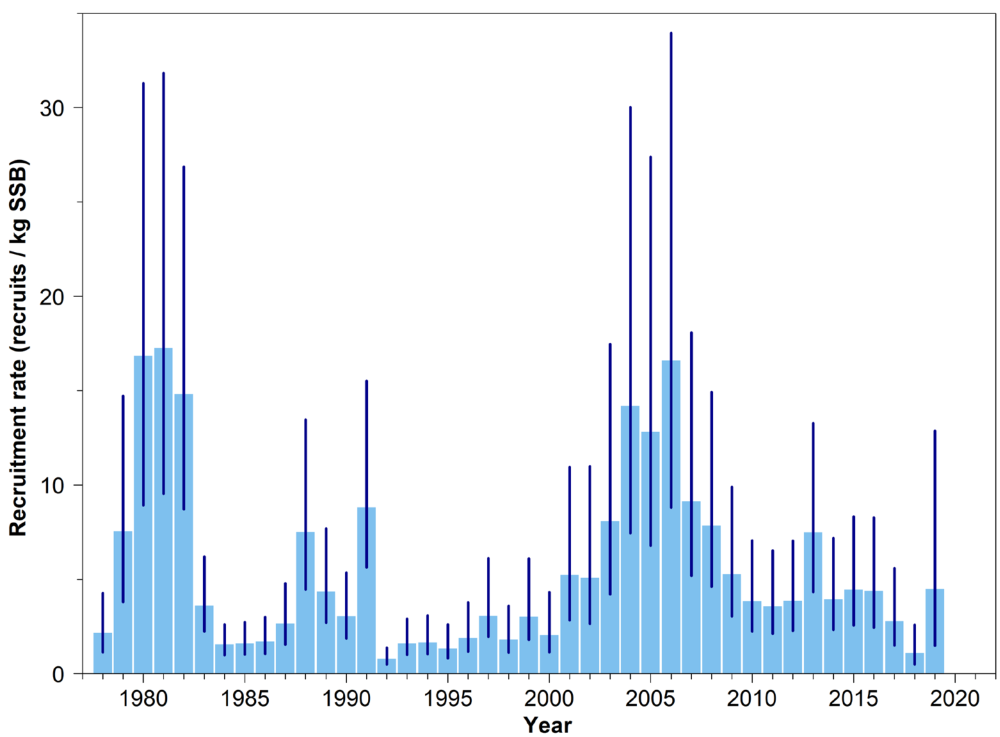


Figure 23. Recruitment rates for age 2 recruits for the 1978 to 2019 cohorts of spring spawning Atlantic Herring in NAFO Div. 4T. Vertical lines indicate 95% confidence intervals.

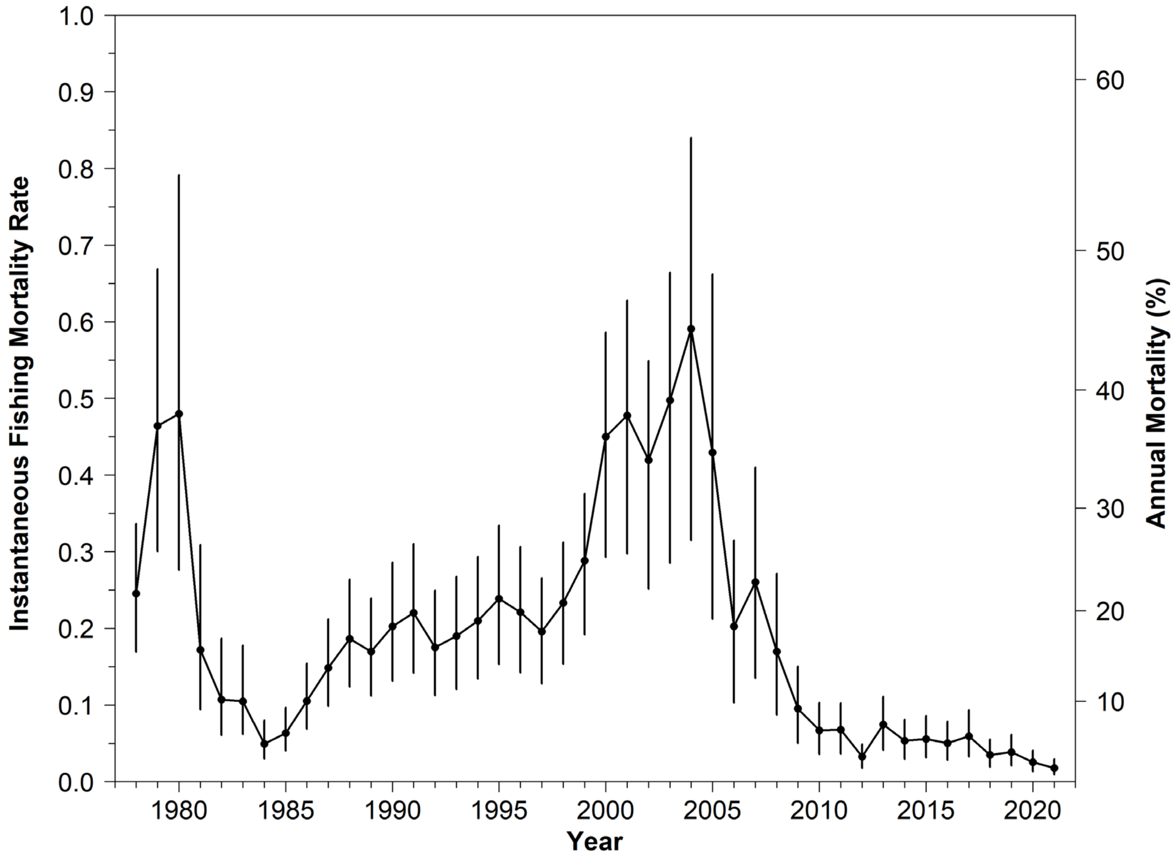


Figure 24. Estimated January 1 abundance weighted age 6 to 8 fishing mortality (F6-8, left axis; annual exploitation rate, right axis) of spring spawning Herring in the southern Gulf of St. Lawrence. Circles are the median estimates and vertical lines their 95% confidence intervals.

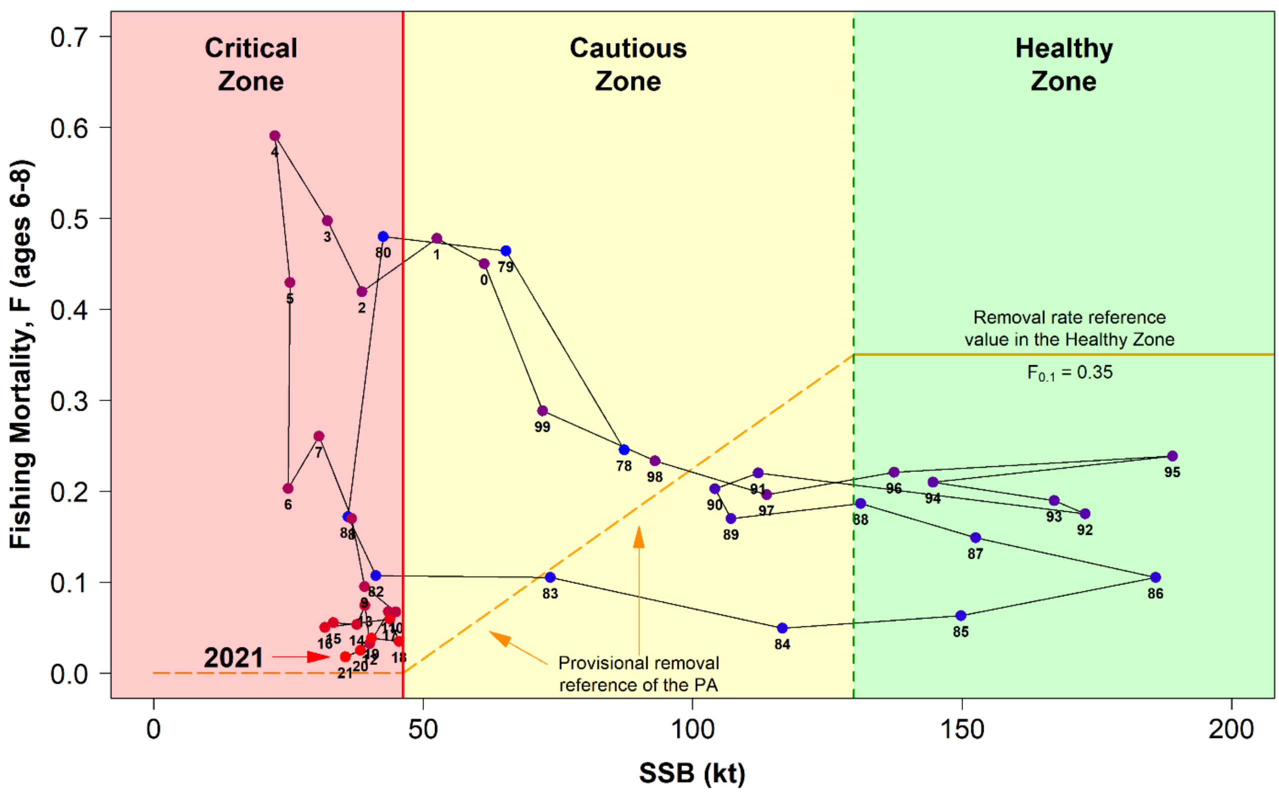


Figure 25. The southern Gulf of St. Lawrence Atlantic Herring spring spawner component trajectory in relation to SSB (kt = thousand t) and abundance weighted fishing mortality rates for ages 6 to 8 years. The red vertical line is the LRP and the green dashed vertical line is the Upper Stock Reference (USR). The orange solid horizontal line is the removal rate reference value ($F_{0.1}$ = 0.35) in the Healthy Zone and orange dashed line is the provisional harvest decision rule of the Precautionary Approach Framework in the Cautious and Critical Zones. Point labels are years (83 = 1983, 0 = 2000).

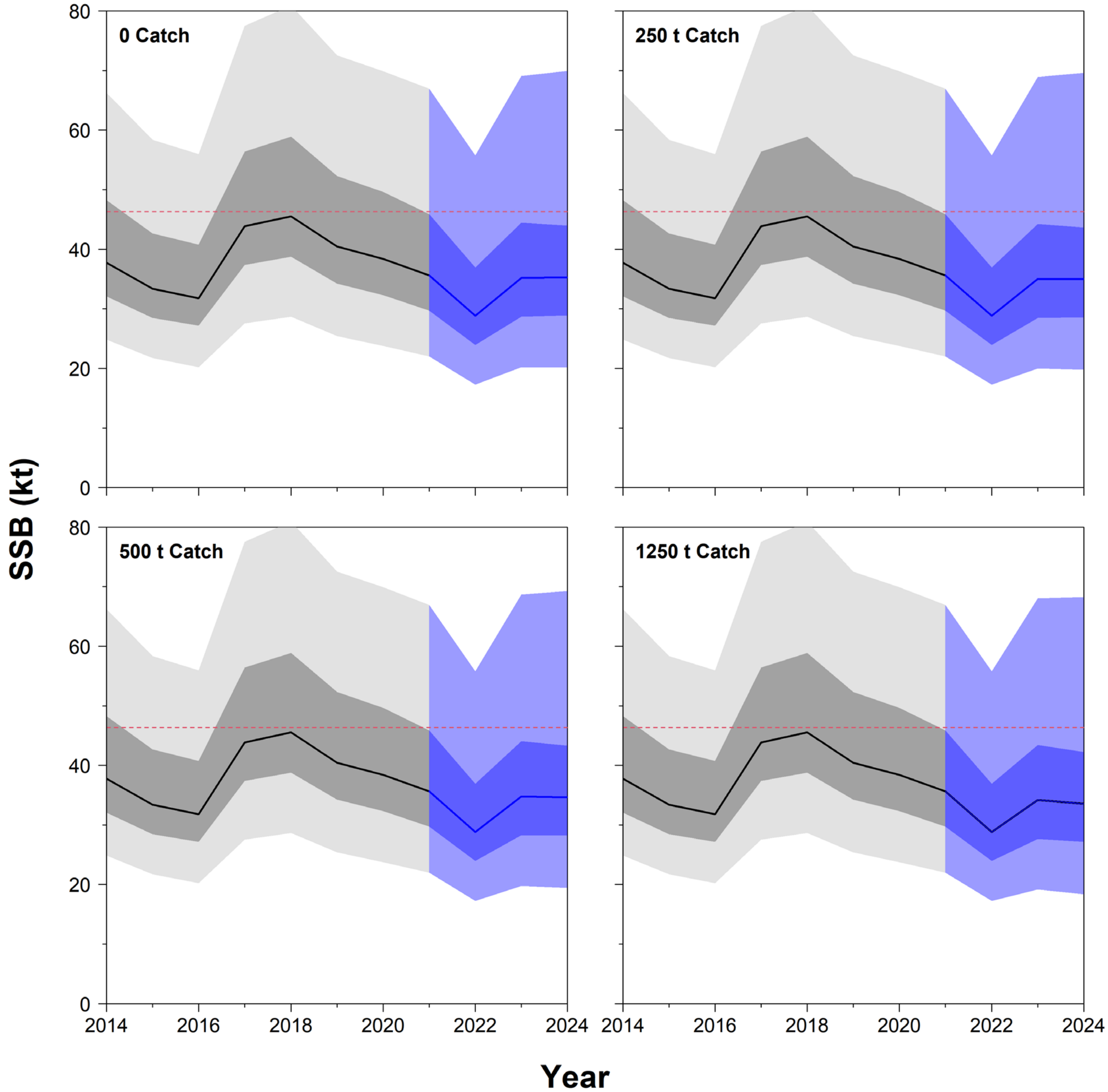


Figure 26. Projected April 1 SSB (in kt) of spring spawning Atlantic Herring from the southern Gulf of St. Lawrence under a recent 5 years average recruitment level and 2 years average natural mortality level at various catch levels in 2022 and 2023. Lines show the median estimates of the April 1 SSB, dark shading the 75% confidence interval and light shading the 95% confidence intervals of these estimates (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period. The red horizontal line is the LRP.

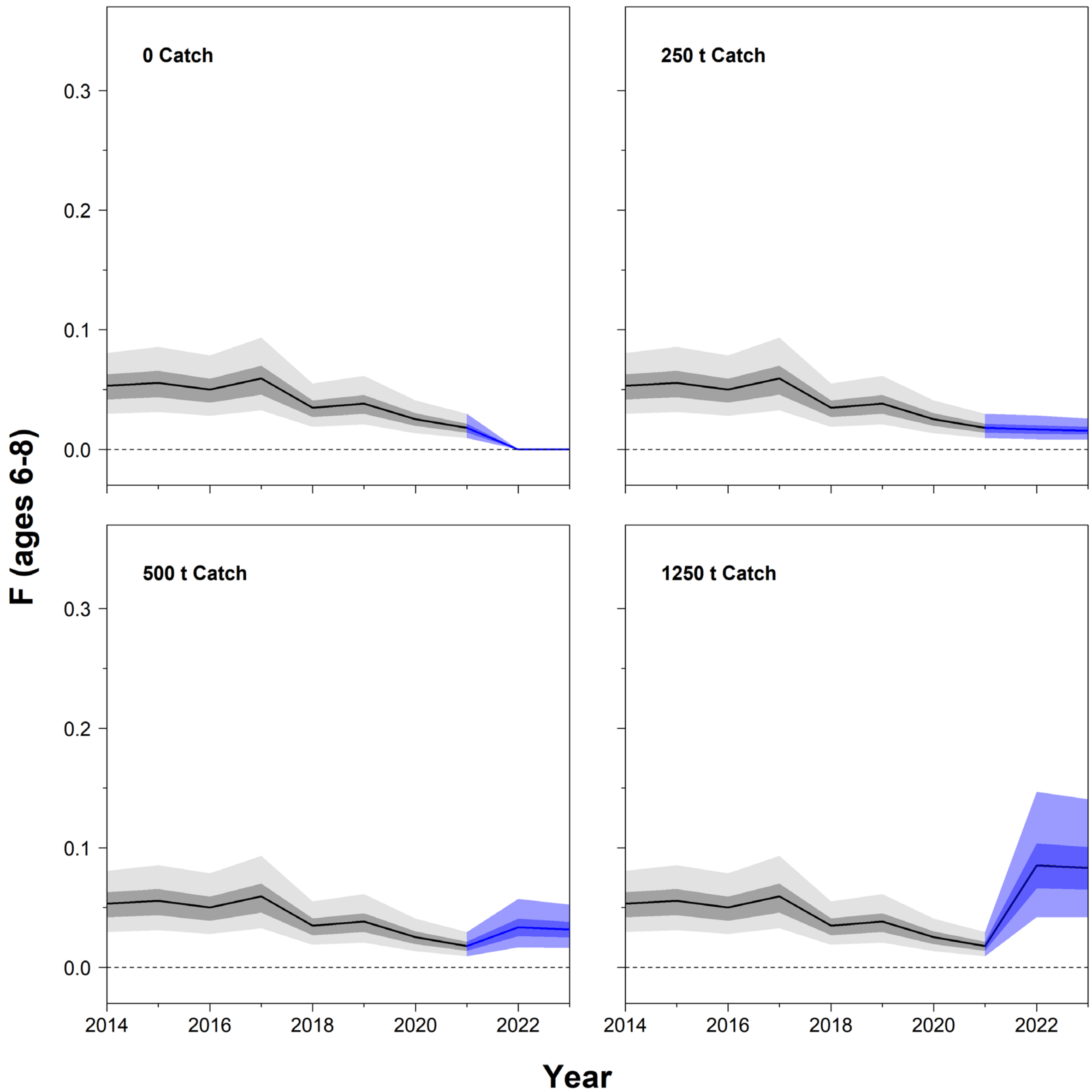


Figure 27. Projected ages 6 to 8 fishing mortality rate (F) of spring spawner Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels in 2022 and 2023. Lines show the median estimates of fishing mortality, dark shading the 75% confidence interval and light shading the 95% confidence intervals of these estimates (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period.

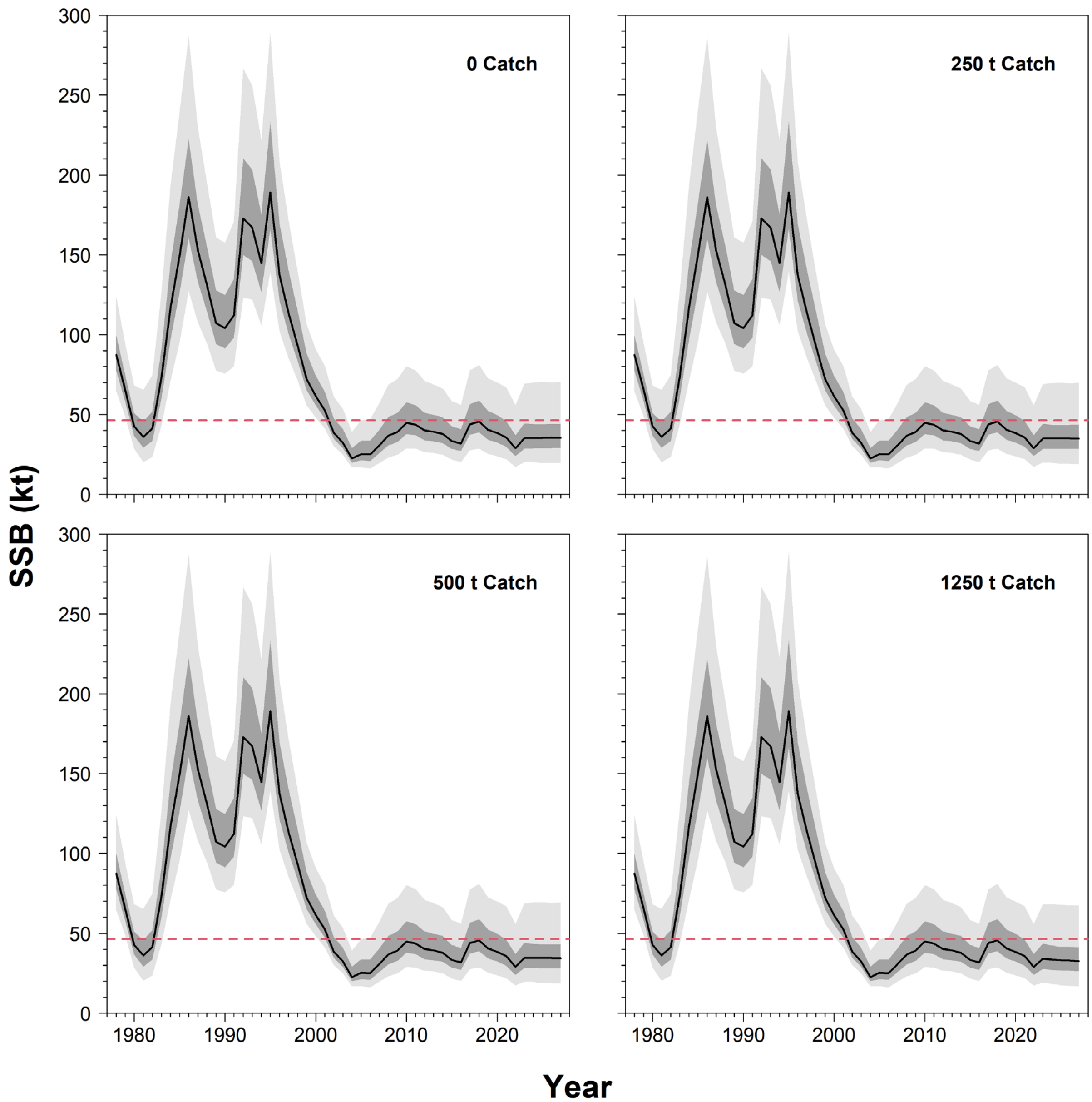


Figure 28. Projected April 1 SSB (in kt) of spring spawner Atlantic Herring from the southern Gulf of St. Lawrence under a recent 5 years average recruitment level and 2 years average natural mortality level at various catch levels in all years between 2022 and 2027. Lines show the median estimates of the April 1 SSB, dark shading the 75% confidence interval and light shading the 95% confidence intervals of these estimates (based on MCMC sampling). The red horizontal line is the LRP.

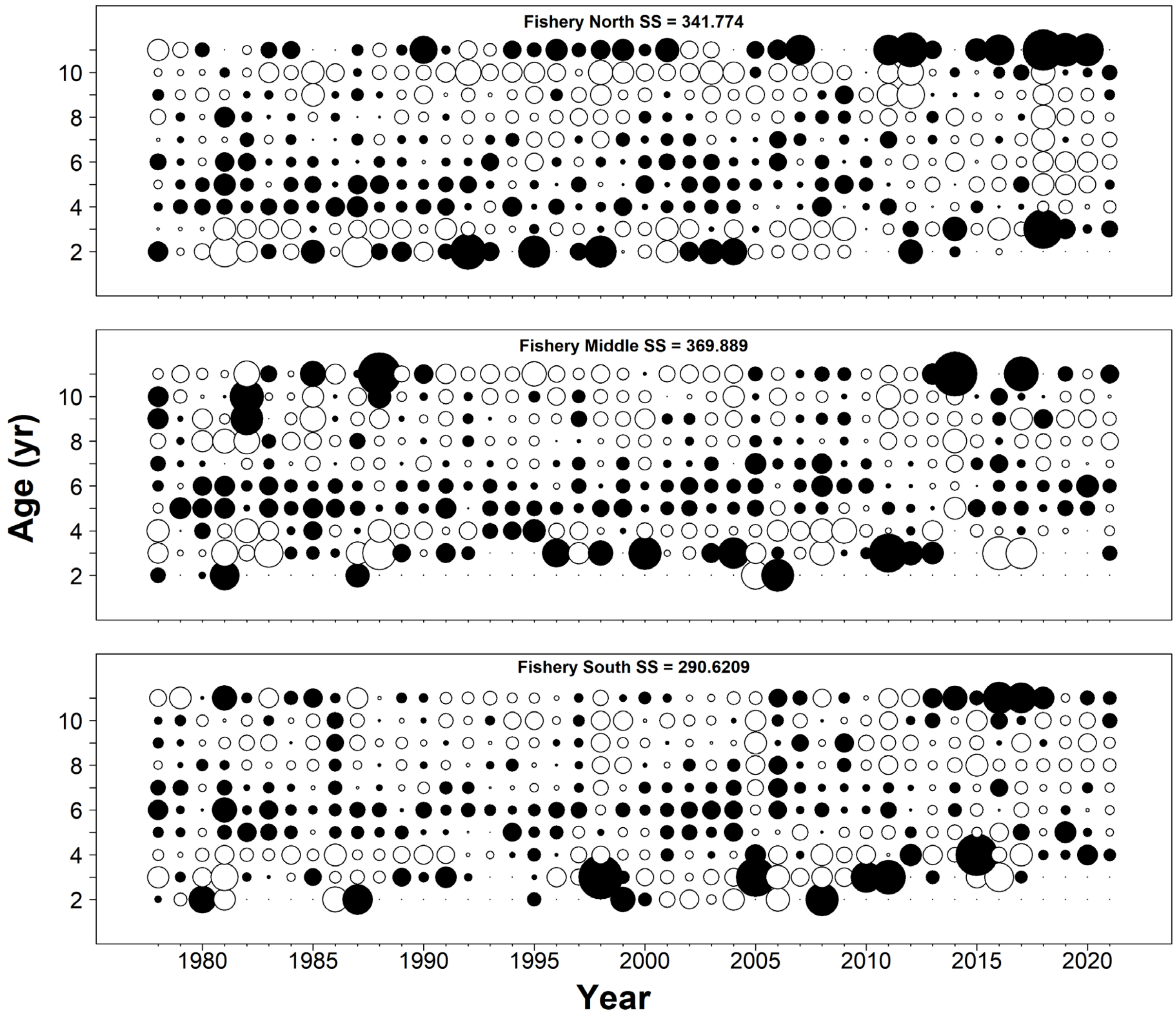


Figure 29. Fishery catch PAA residuals by region (North, Middle and South) from the SCA population model of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

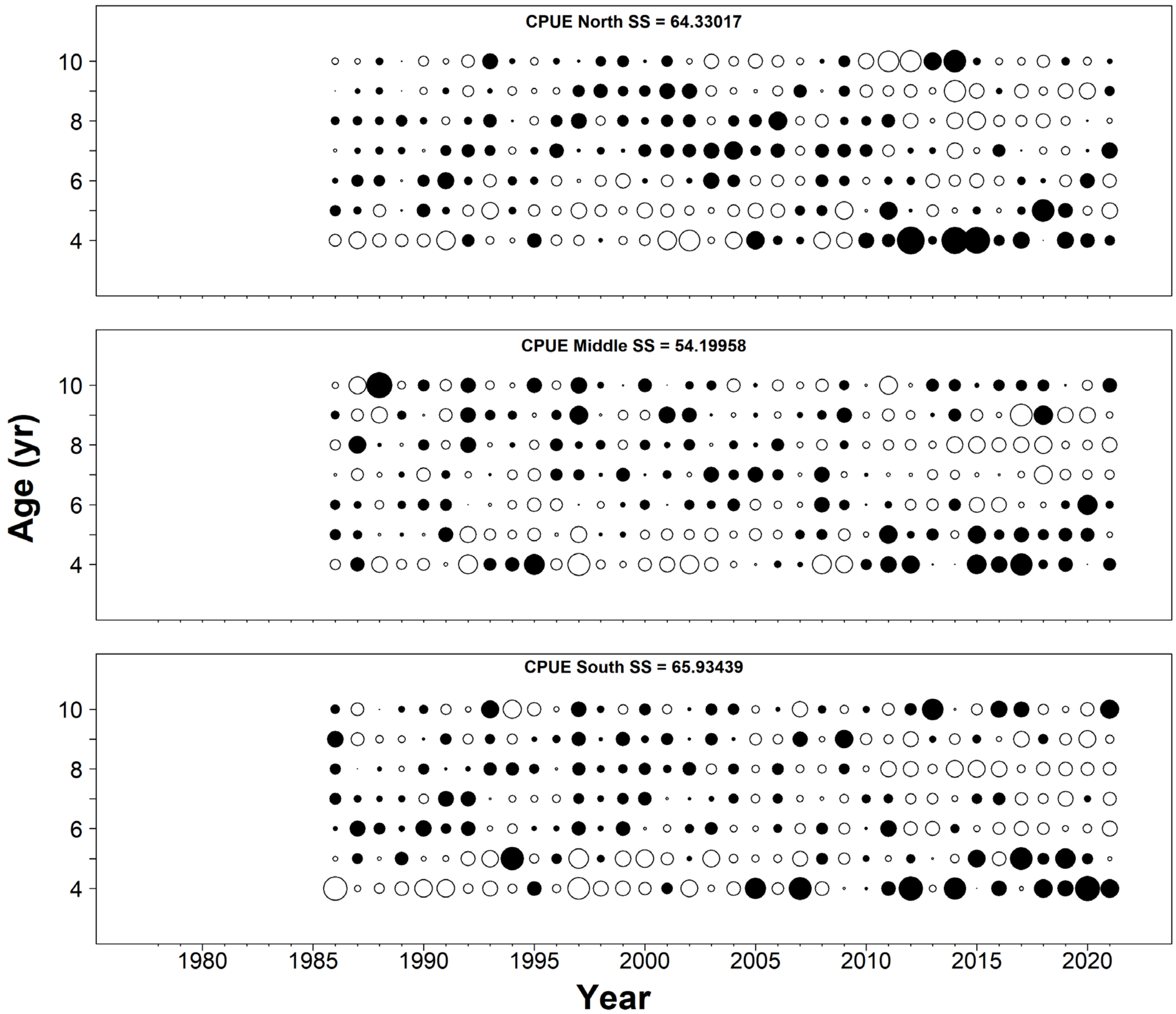


Figure 30. CPUE index PAA residuals by region (North, Middle and South) from the SCA population model of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

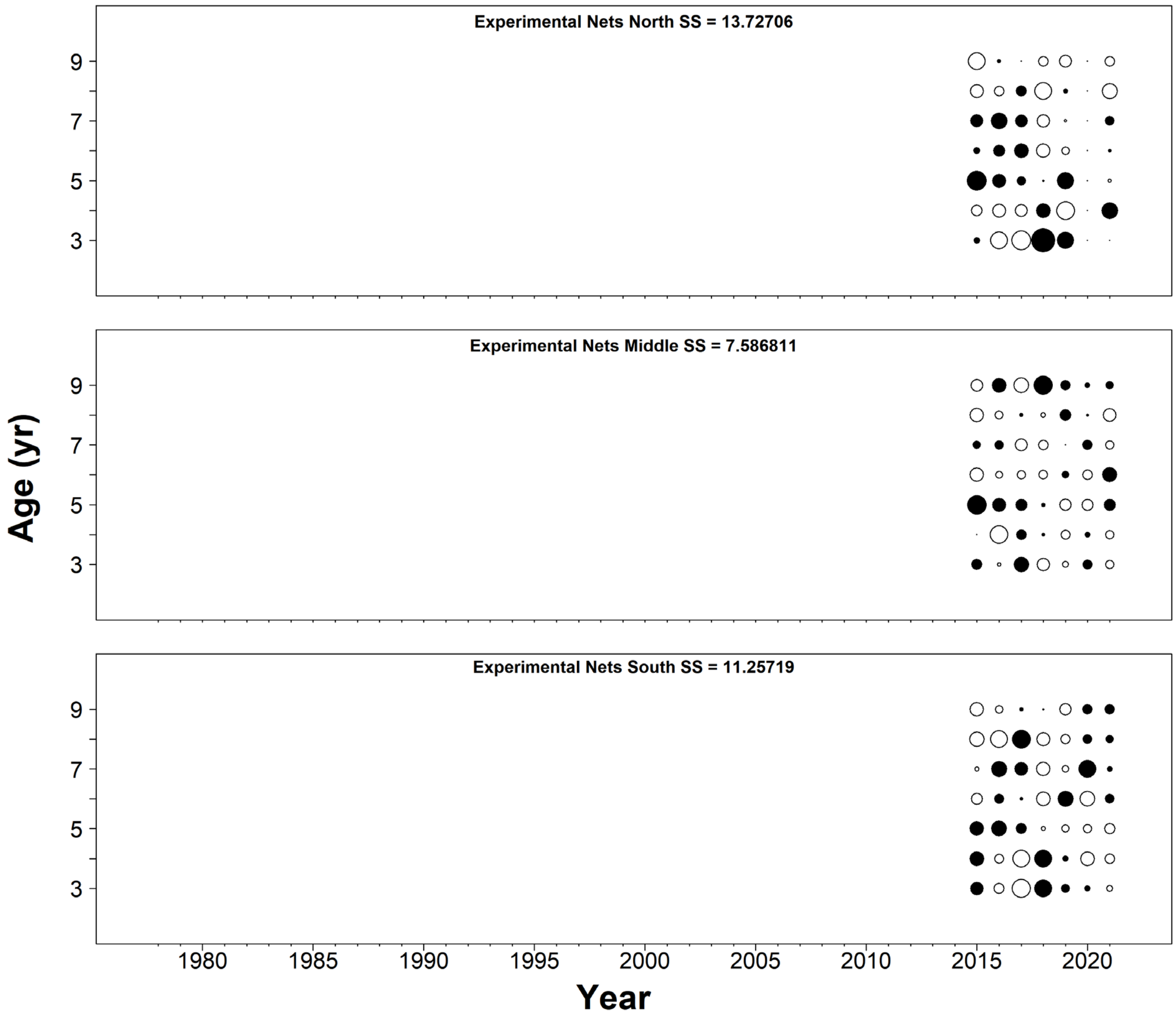


Figure 31. Experimental nets index PAA residuals by region (North, Middle and South) from the SCA population model of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted). Results are only provided for the years during which the acoustic survey was conducted.

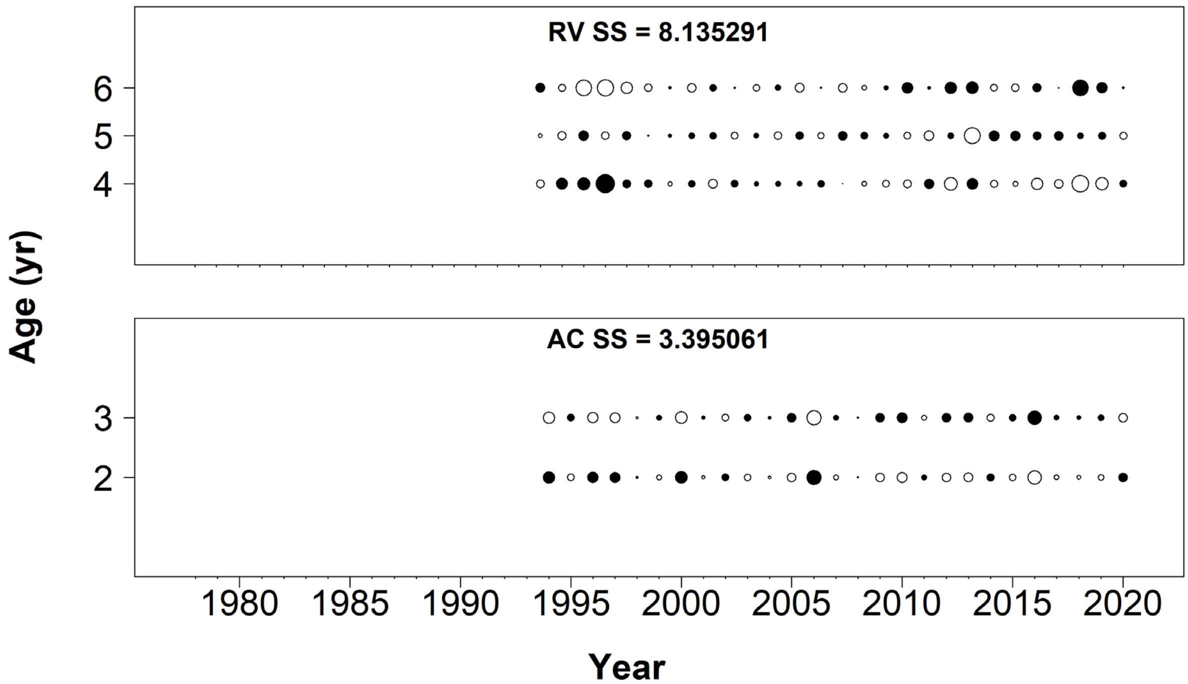


Figure 32. RV survey index (top) and Acoustic survey index (AC, bottom) PAA residuals from the SCA population model of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

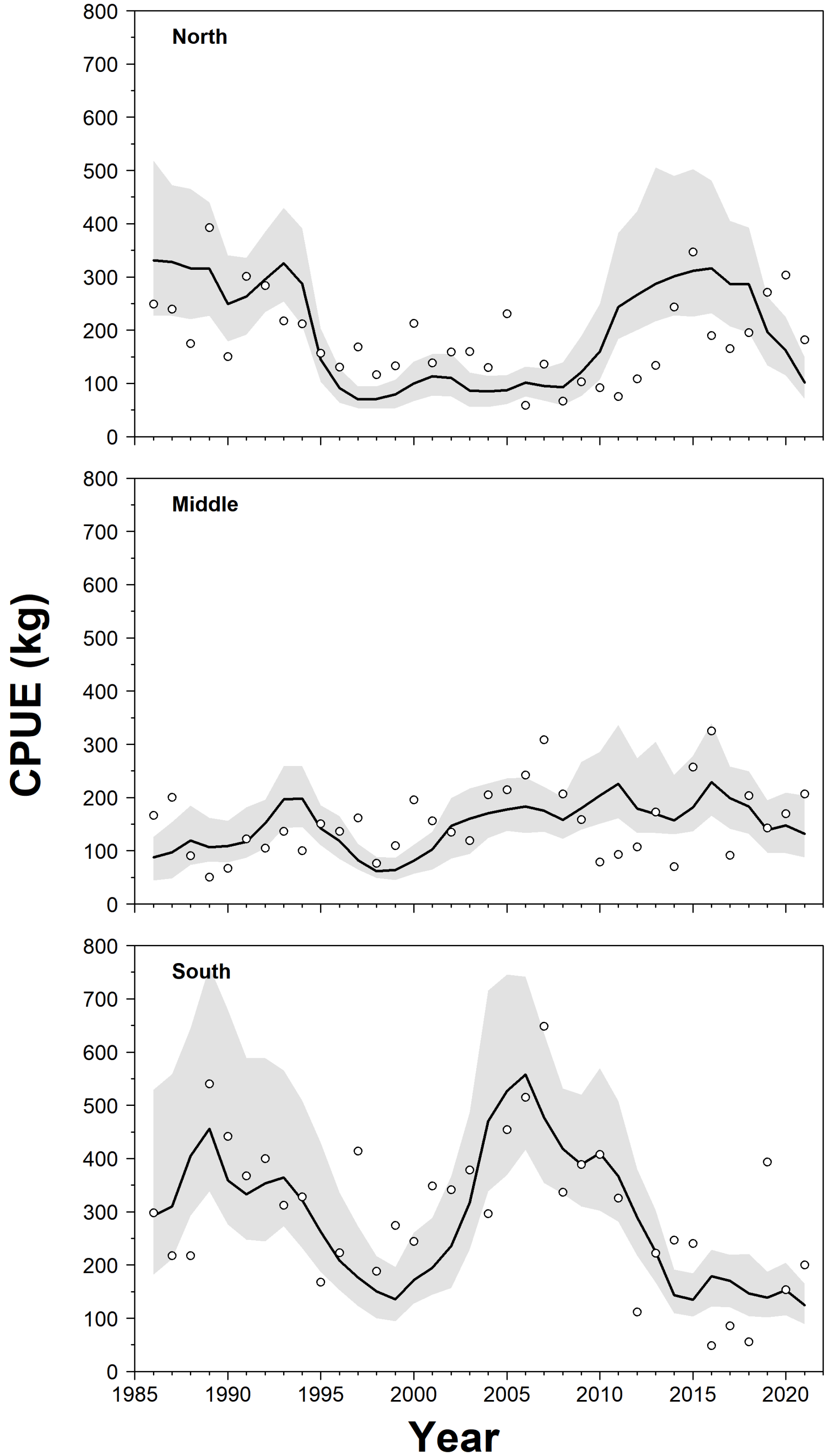


Figure 33. Observed (circles) and predicted (lines and shading) age-aggregated commercial gillnet CPUE indices by region (CPUE North, CPUE Middle, CPUE South) from the SCA population model for fall spawners from the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

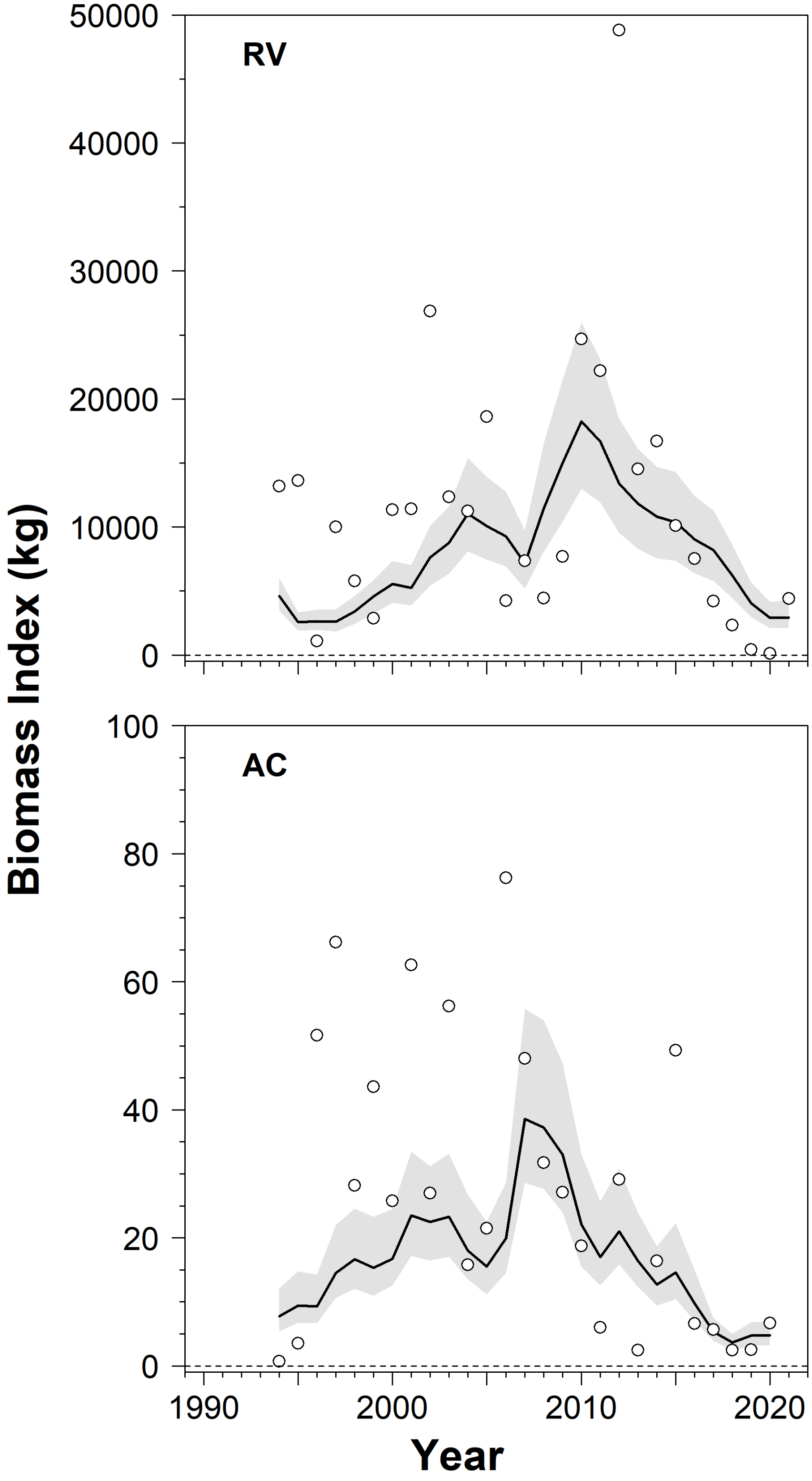


Figure 34. Observed (circles) and predicted (lines and shading) age-aggregated RV indices (RV, all regions combined) and acoustic indices (AC, all regions combined) from the SCA population model for fall spawners from the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

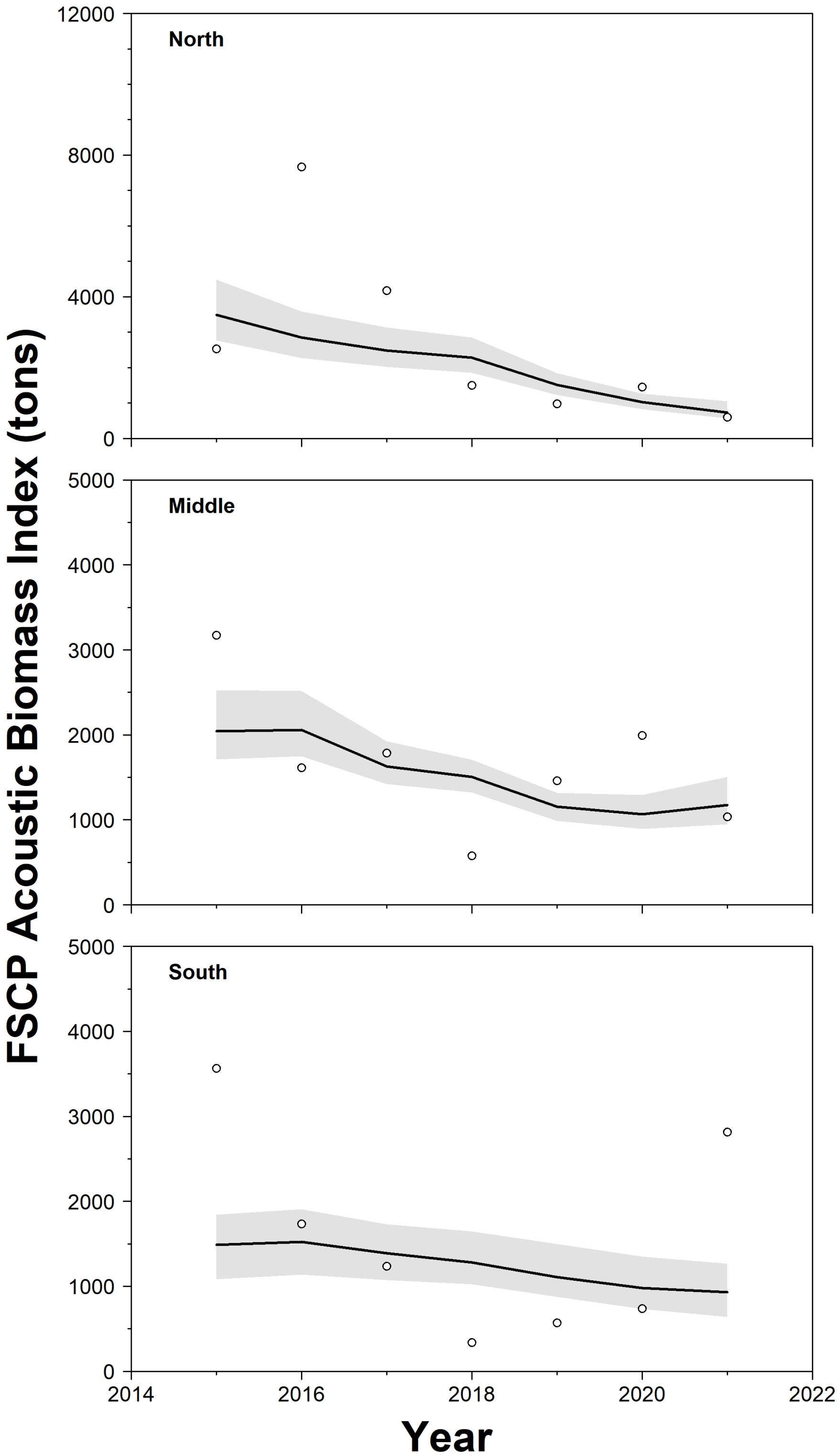


Figure 35. Observed (circles) and predicted (lines and shading) age-aggregated FSCP Acoustic Biomass Index from the SCA population model for fall spawners from the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

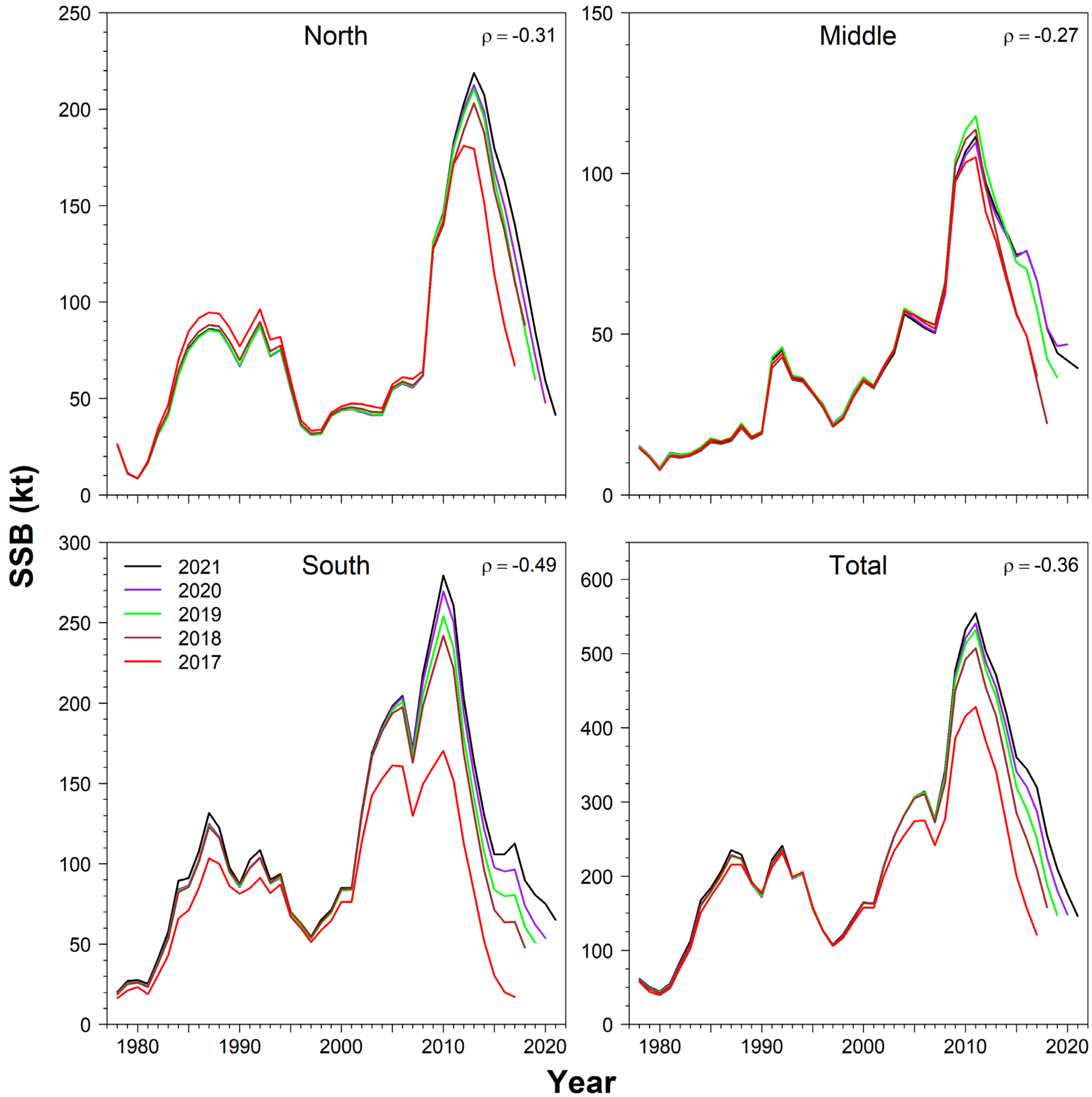


Figure 36. Retrospective patterns in SSB and Mohn's rho of fall spawners within the three regions (North, Middle, South) for the SCA population model of Atlantic Herring of the southern Gulf of St. Lawrence. Colored lines shows retrospective peels between 2017 and 2021.

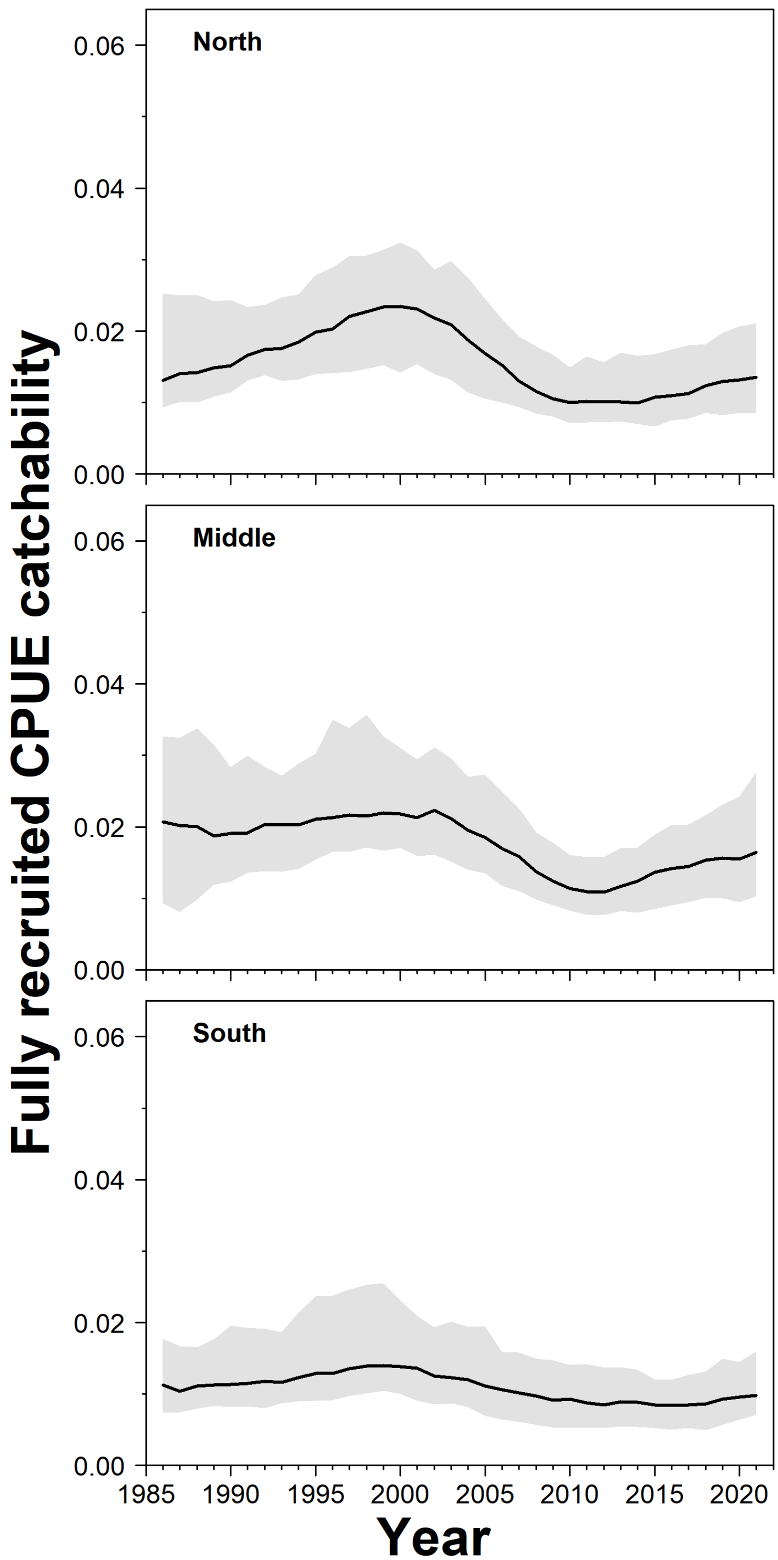


Figure 37. Estimated fully-recruited catchability for the commercial gillnet CPUE index by region (North, Middle, South), from the SCA population model of fall spawning Atlantic Herring in the southern Gulf of St. Lawrence. Lines show the median estimates and shading their 95% confidence intervals based on MCMC sampling.

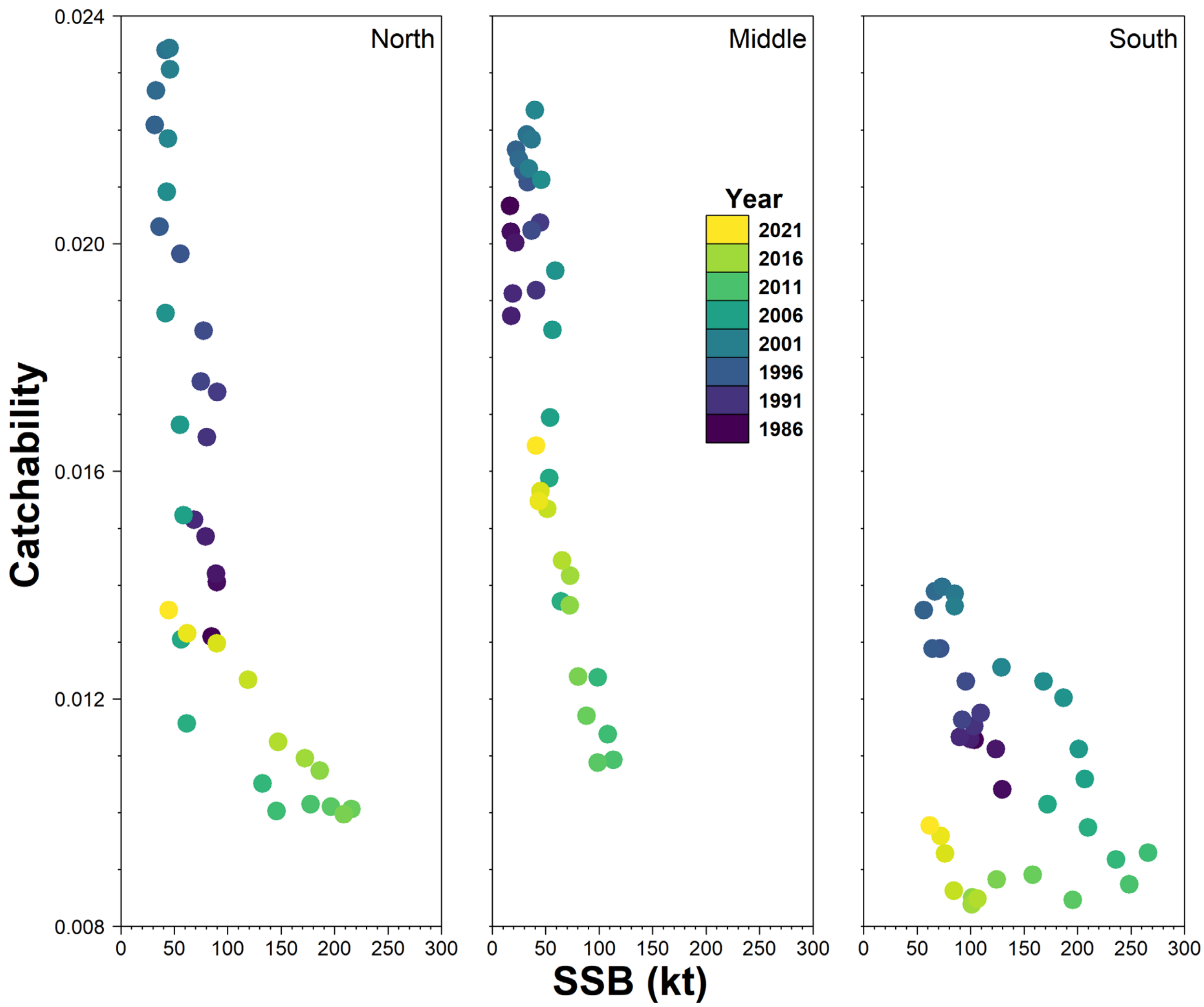


Figure 38. Estimated fully-recruited catchability for the commercial gillnet CPUE index in relation to SSB by region (North, Middle, South), from the SCA population model of fall spawning Atlantic Herring in the southern Gulf of St. Lawrence.

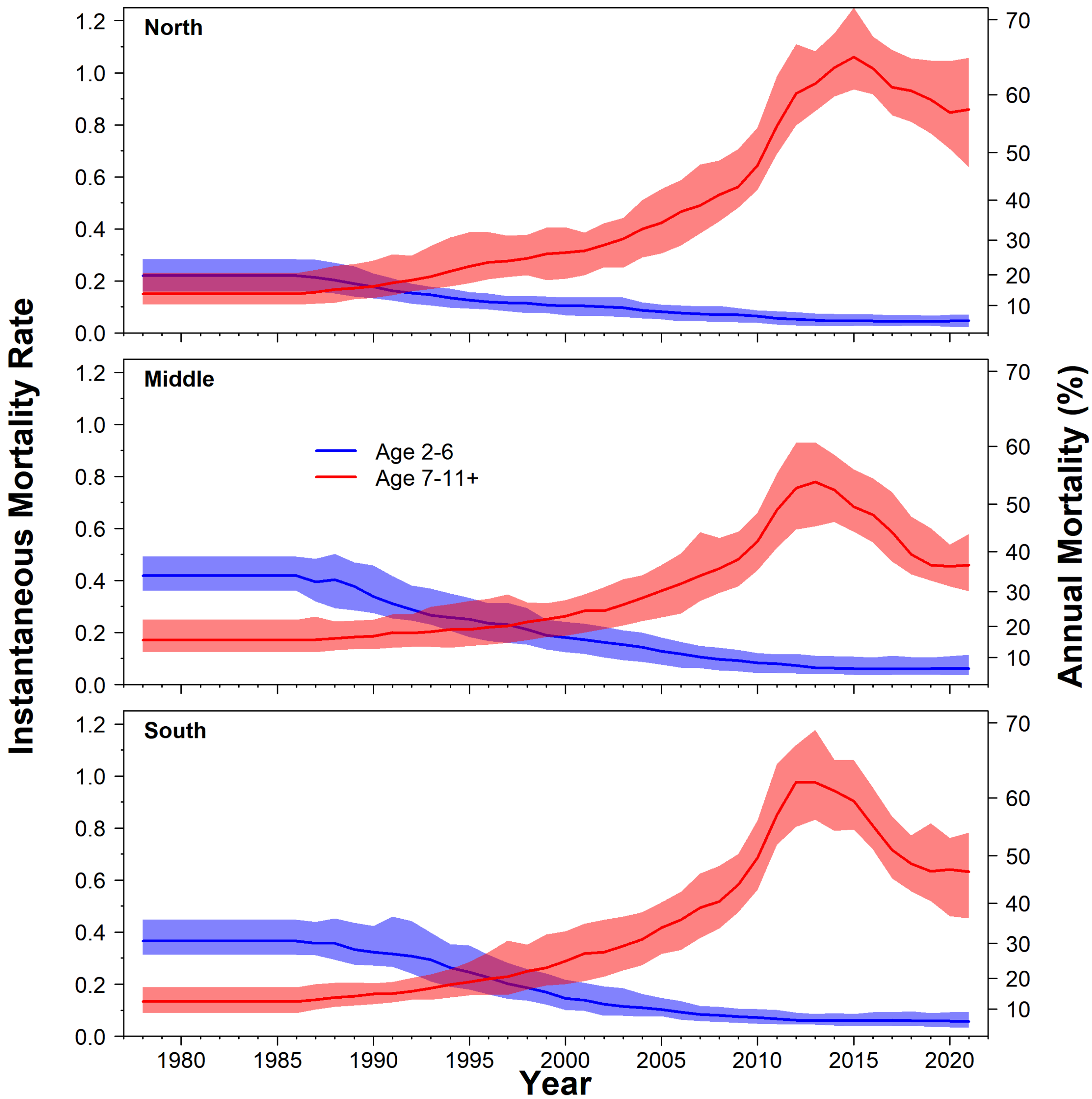


Figure 39. Estimated instantaneous natural mortality rate (left axis) and annual mortality (%, right axis) of fall spawning Atlantic Herring for three regions of the sGSL (North, Middle, South) from the SCA population model, for ages 2 to 6 (blue) and 7 to 11+ (red). Lines show the median estimates and shading their 95% confidence interval based on MCMC sampling.

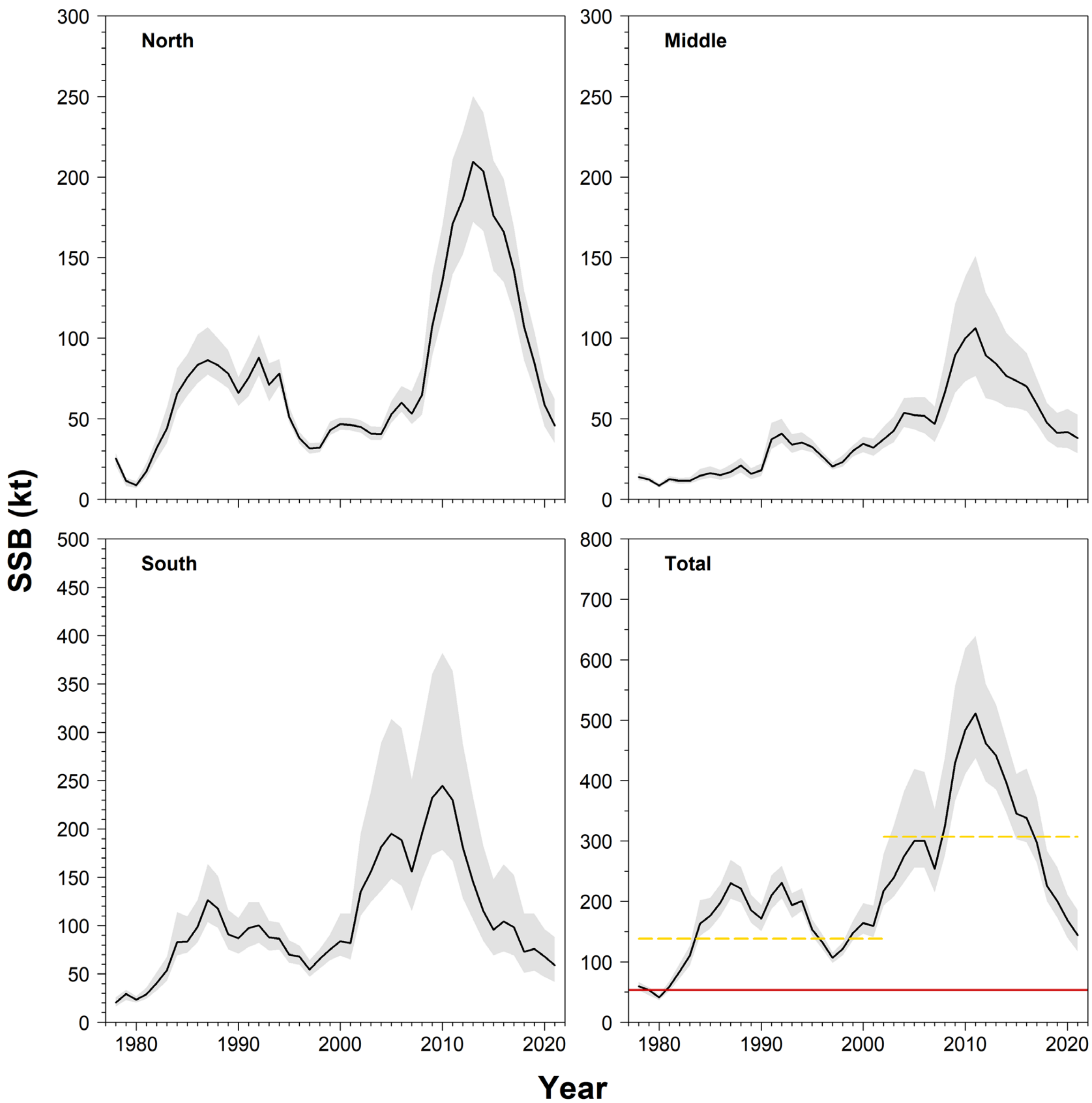


Figure 40. Estimated beginning of fishing season (August 1) SSB of fall spawning Herring by region and overall (Total) for the southern Gulf of St. Lawrence from the SCA population model. The black line shows the median estimates of the MCMC sampling and the shading their 95% confidence intervals. In the bottom right panel for Total, the solid and dashed yellow horizontal lines represent the USR level and the red horizontal line is the LRP. SSB, USR and LRP values are adjusted to August 1st using natural mortality estimates at age for 7 months.

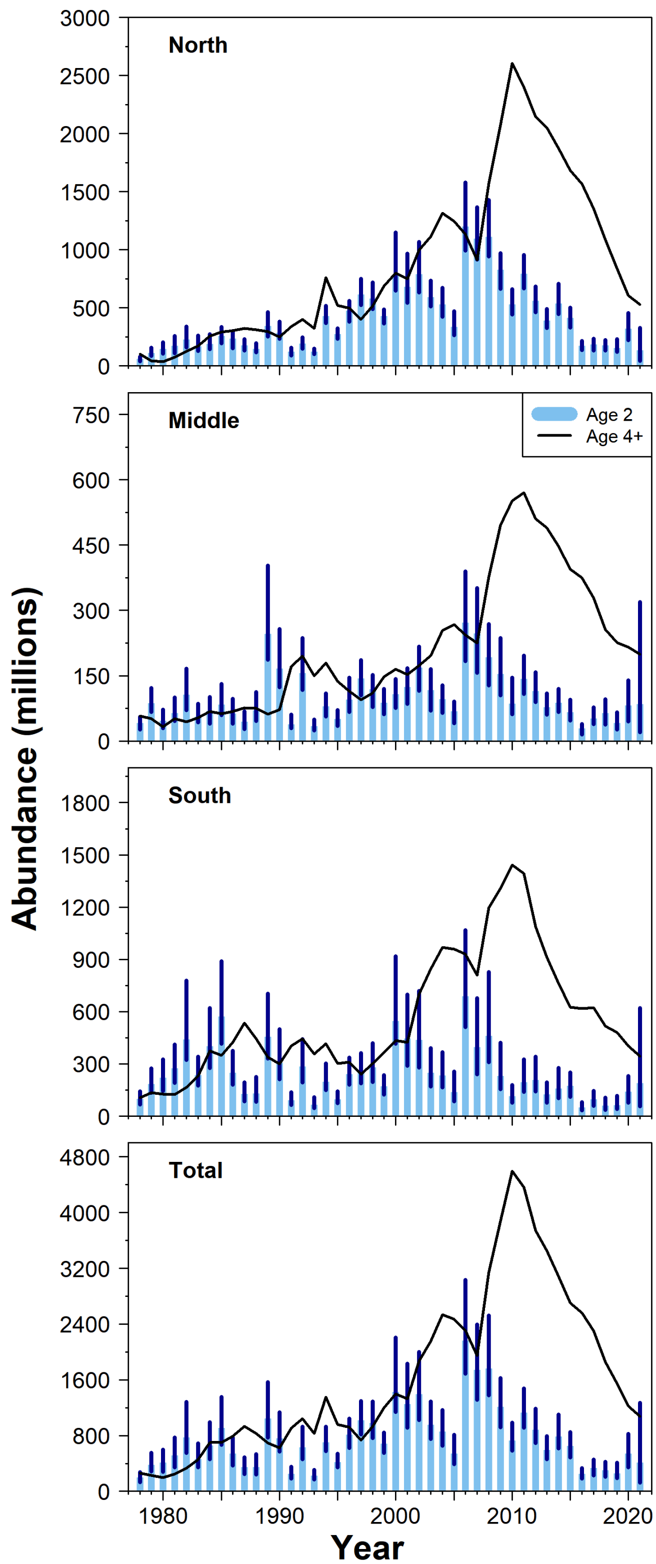


Figure 41. Estimated January 1 abundance of 2 year old Herring (blue bars), and Herring 4 years and older (black line) of the fall spawner component in three regions (North, Middle, South) in the southern Gulf of St. Lawrence from the SCA population model. Black line show the median MCMC estimate and vertical lines show 95% confidence interval.

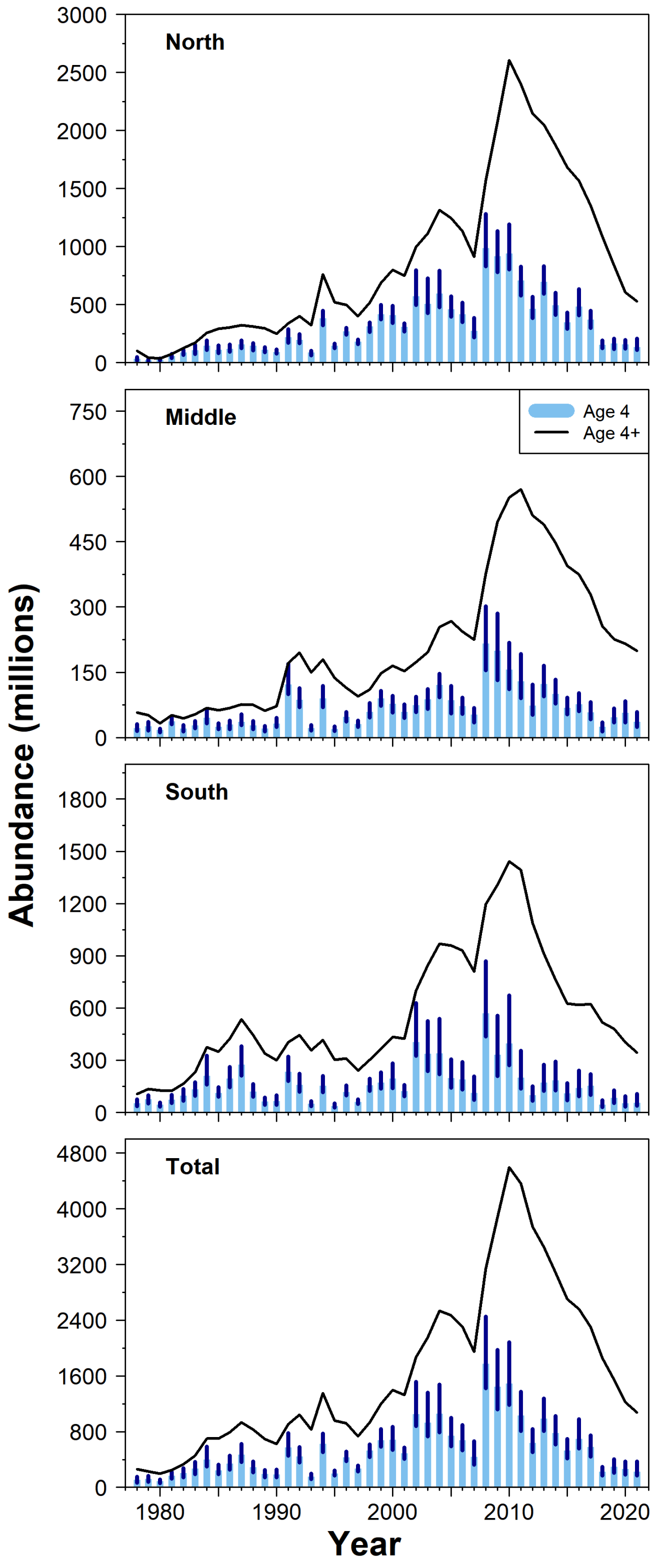


Figure 42. Estimated January 1 abundance of 4 year old Herring (blue bars), and Herring 4 years and older (black line) of the fall spawner component in three regions (North, Middle, South) in the southern Gulf of St. Lawrence from the SCA population model. Black line show the median MCMC estimate and vertical lines show 95% confidence interval.

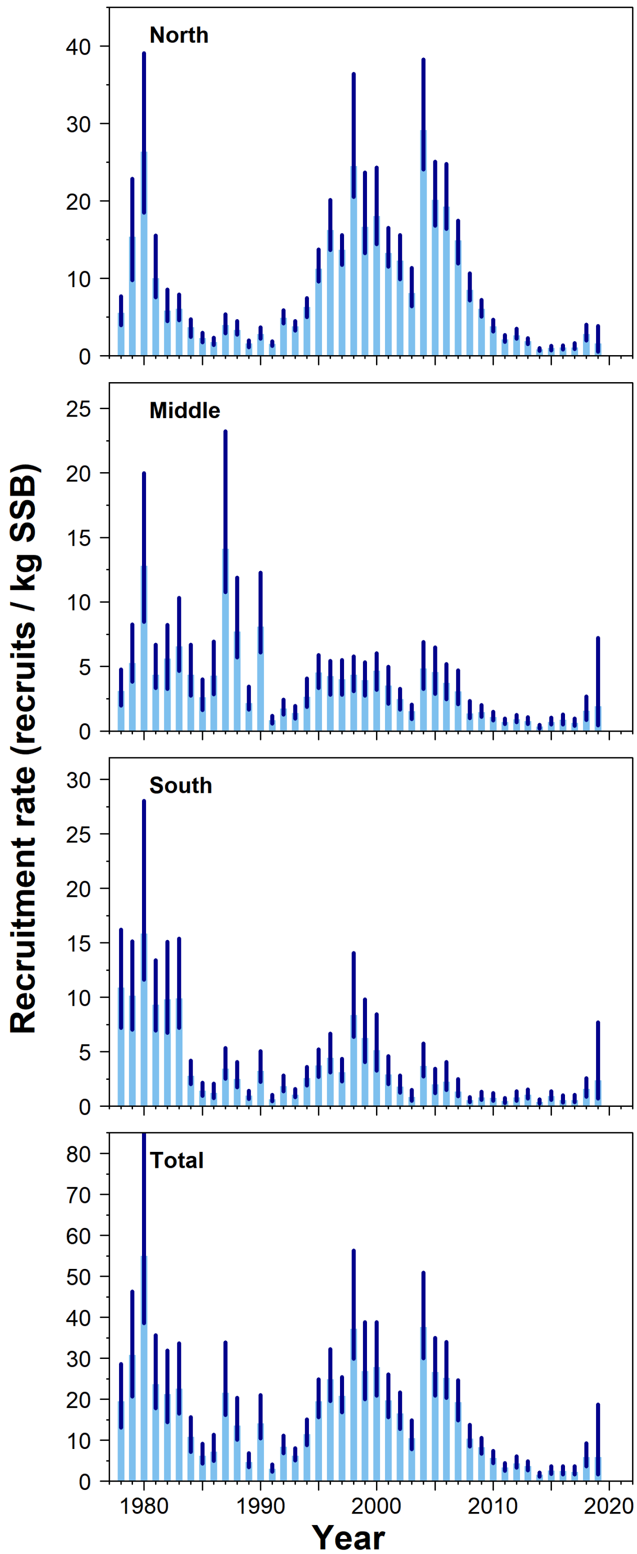


Figure 43. Estimated recruitment rate (recruits per kg of SSB) at age 2 (circles) of fall spawners in the three regions (North, Middle, South) and summed over regions (Total) of the southern Gulf of St. Lawrence, from the SCA population model. Bars show the median estimates and vertical lines show the 95% confidence intervals.

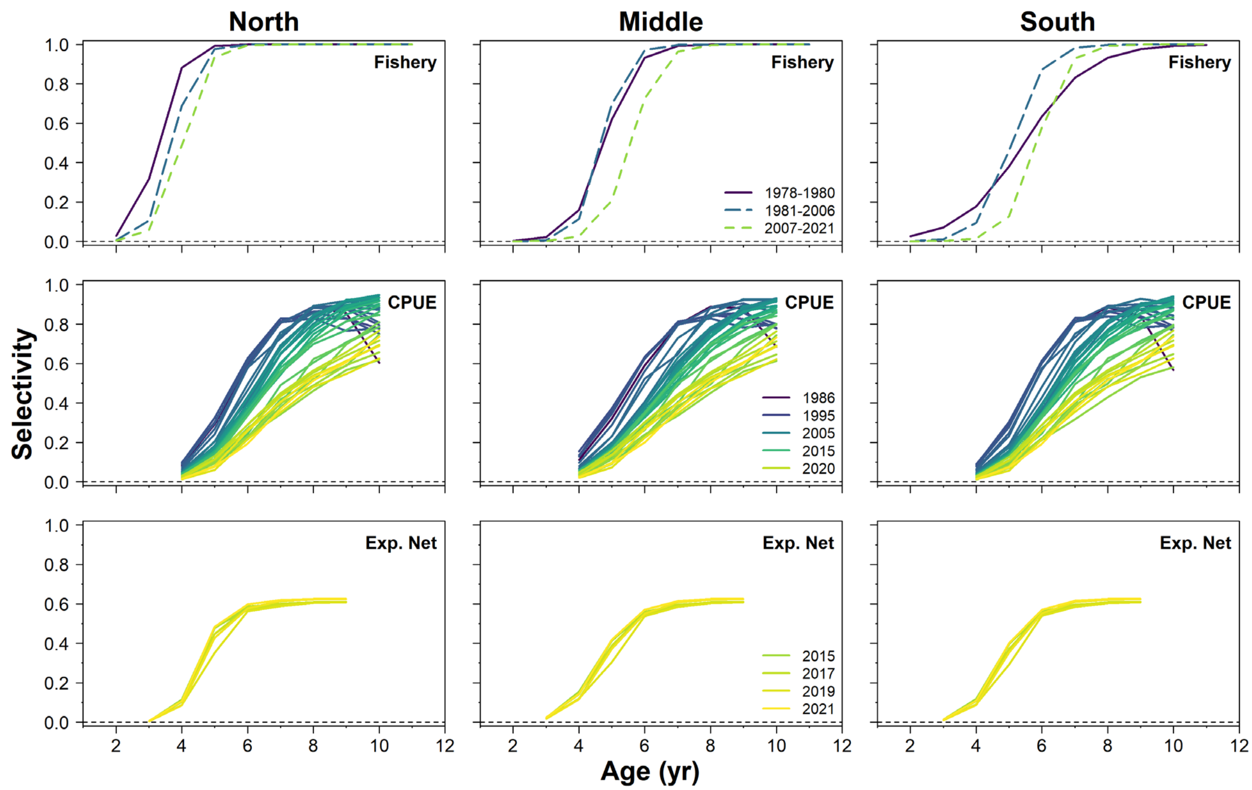


Figure 44. Estimated fishery (top row), CPUE (Middle row) and experimental nets (bottom row) selectivity for three populations of the southern Gulf of St. Lawrence (North in the left column, Middle in the Middle column and South in the right column), from the SCA population model. Lines show the maximum likelihood estimates for years or time-periods identified in respective Figure legends.

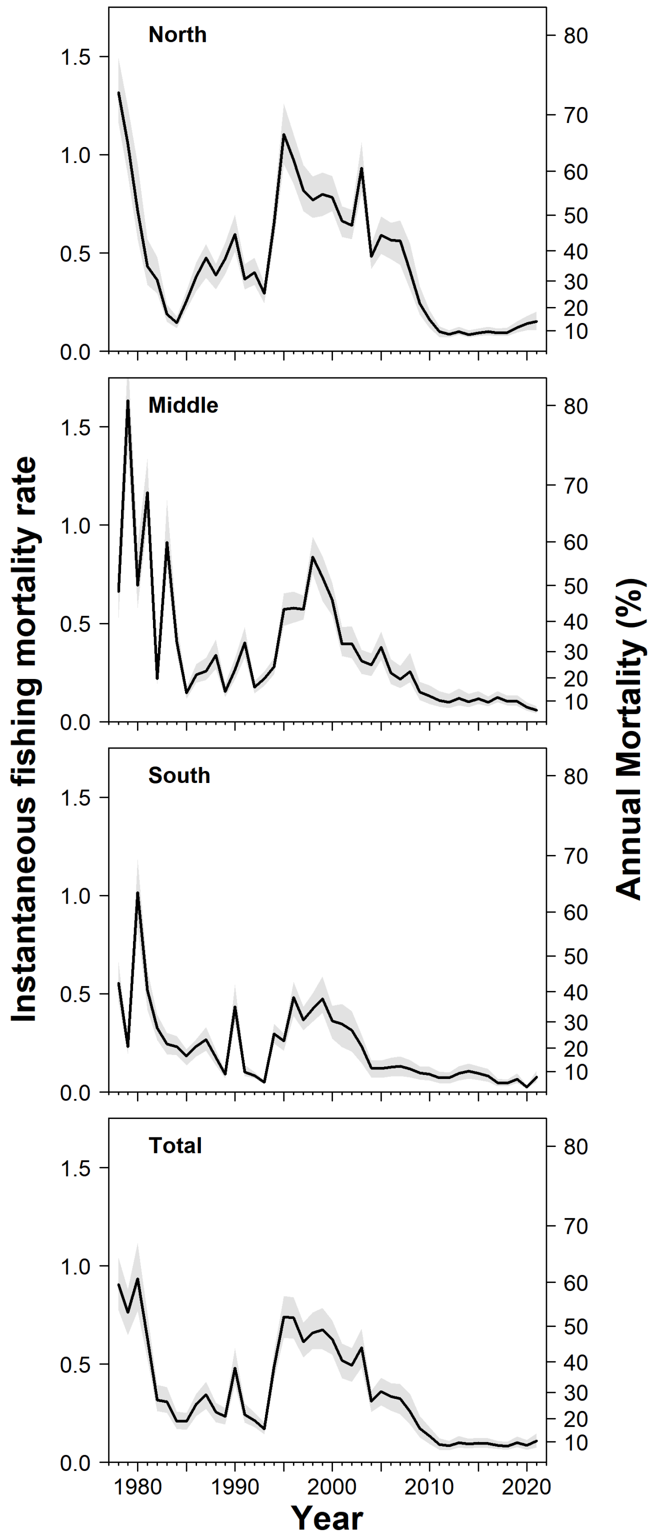


Figure 45. Estimated beginning-of-the-year abundance averaged age 5 to 10 fishing mortality (F5-10, left axis; annual exploitation rate, right axis) of fall spawning Herring by region and averaged over regions (weighted by region-specific abundance at ages 5-10 years) in the southern Gulf of St Lawrence from the SCA model. Lines show the median estimates and shading their 95% confidence intervals.

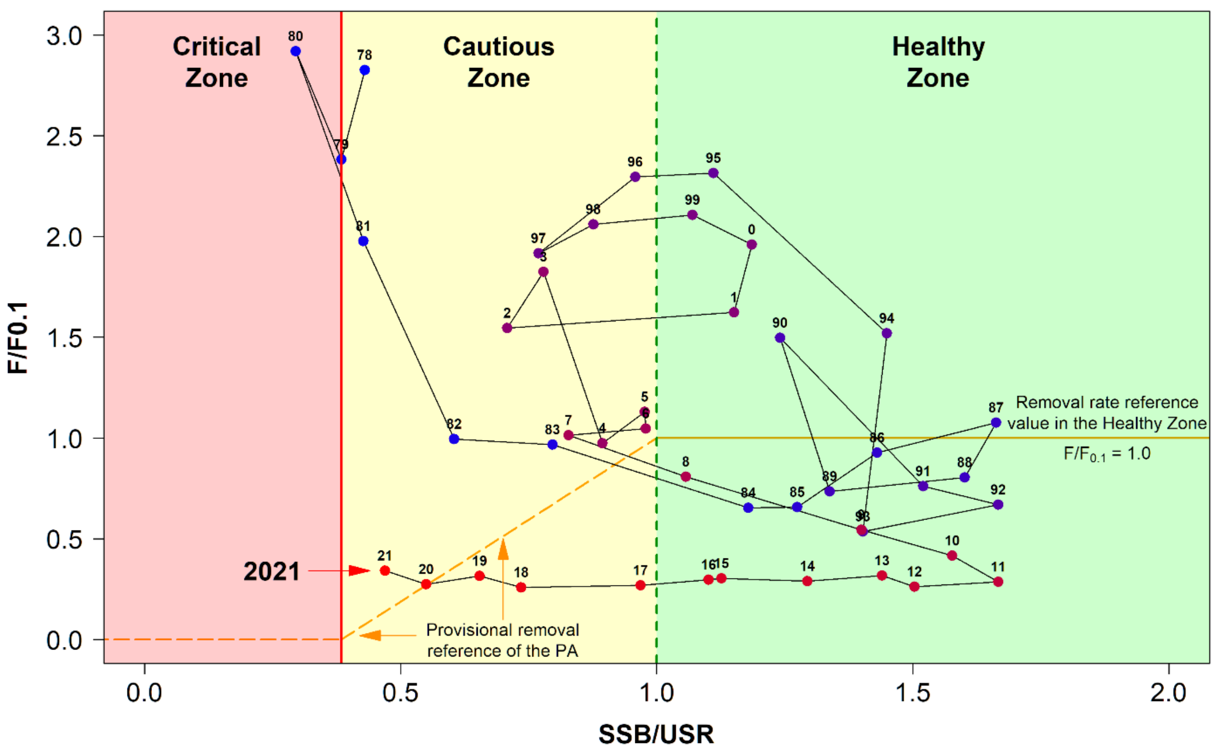


Figure 46. Southern Gulf of St. Lawrence Atlantic Herring fall spawner component trajectory in relation to SSB/USB and fishing mortality rates for ages 5 to 10 years from the SCA population model. The red vertical line is the LRP and the green vertical line is the USR. The orange dashed line is the provisional removal reference of the Precautionary Approach Framework.

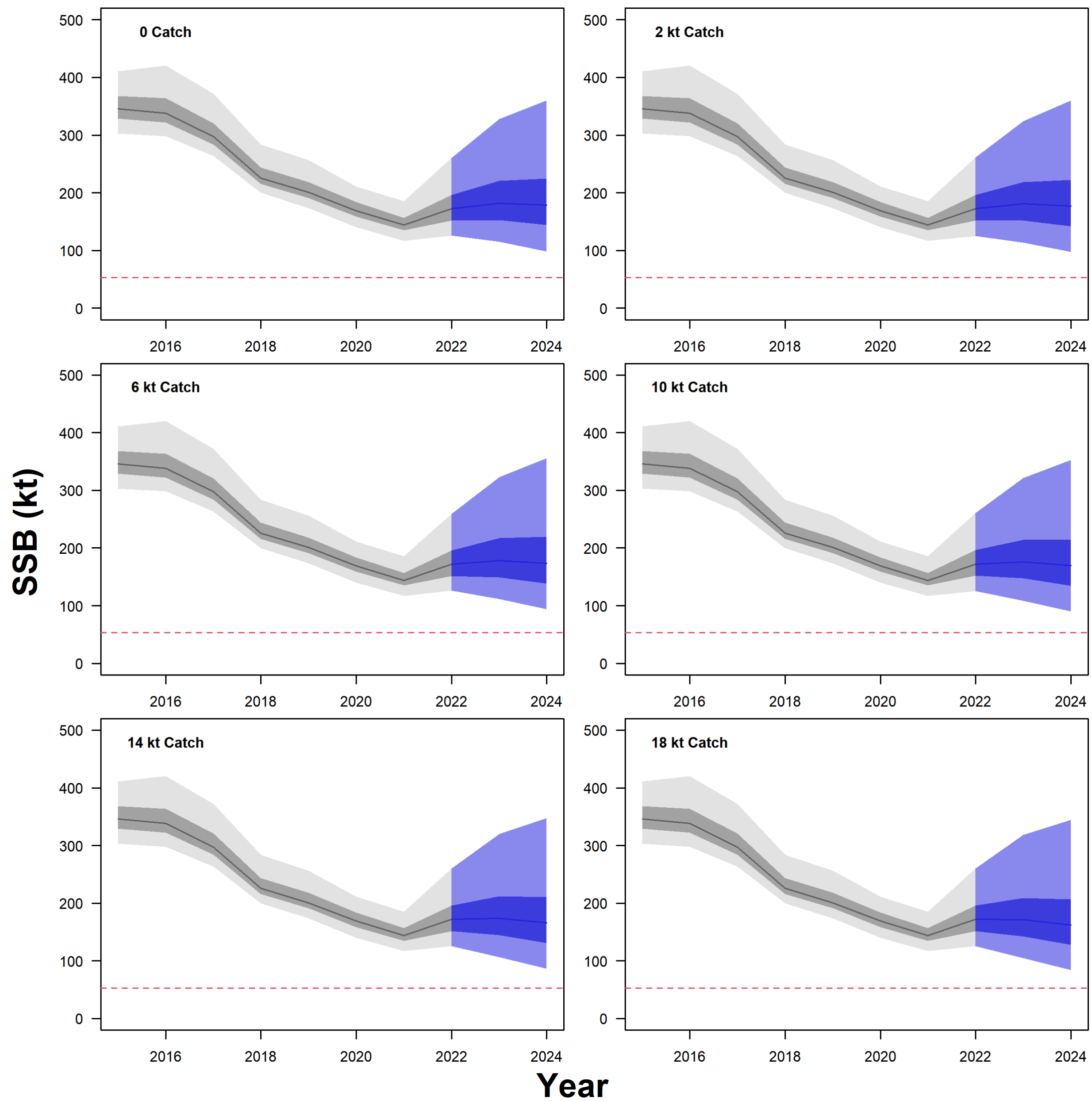


Figure 47. Projected SSB (in kt) of fall spawning Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels in 2022 and 2023, under a 5 recent years average recruitment and 2 recent years average natural mortality scenario. Lines show the median estimates of August 1 SSB, dark shading the 95% confidence intervals and light shading the 50% confidence interval (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period. The red horizontal line is the LRP.

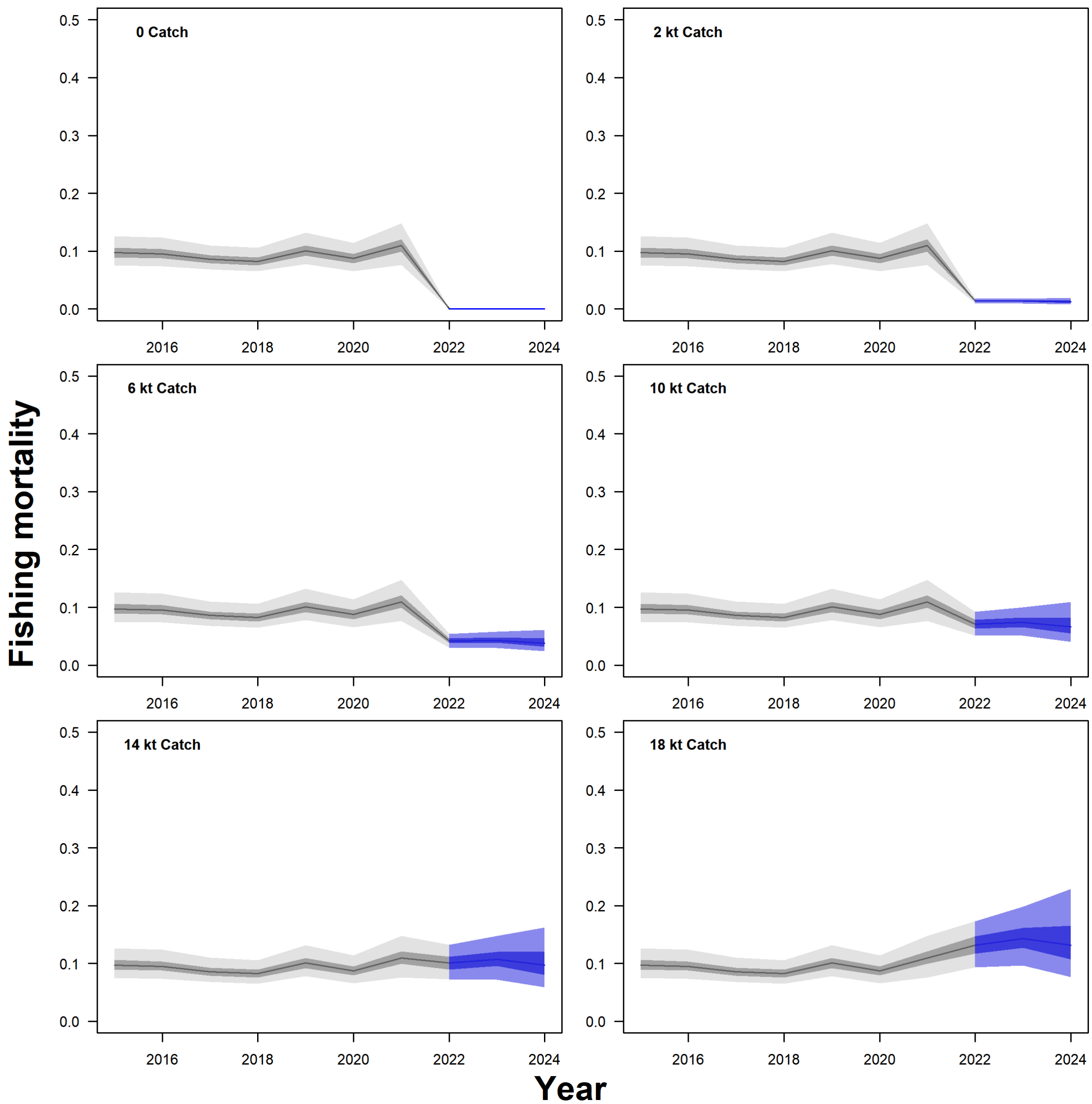


Figure 48. Projected average fishing mortality ($F_{5\text{-}10}$) of fall spawning Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels in 2022 and 2023, under a 5 recent years average recruitment and 2 recent years average natural mortality scenario. Lines show the median estimates of fishing mortality, dark shading the 95% confidence intervals and light shading the 50% confidence interval (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period.

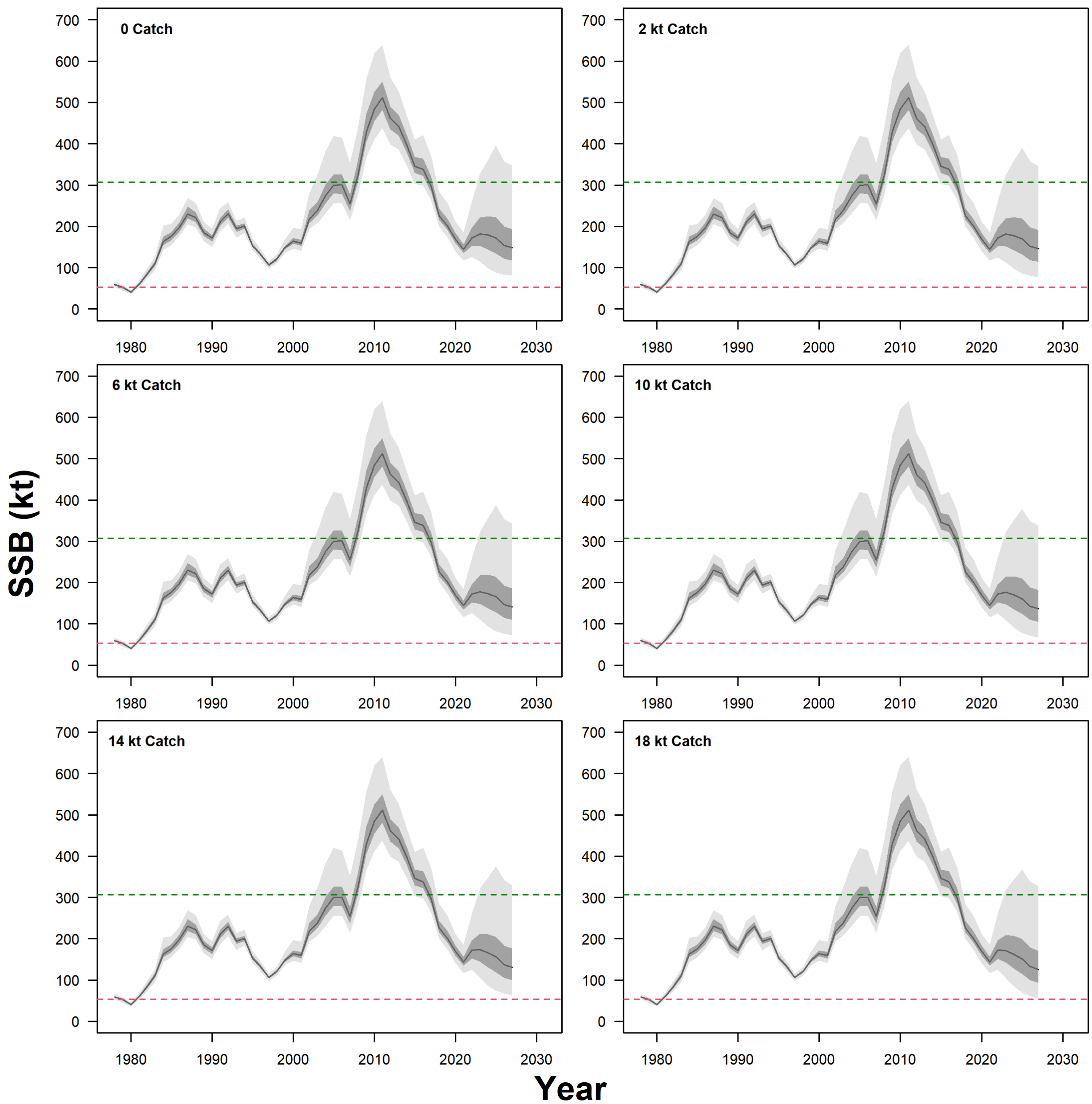


Figure 49. Six years projections of SSB (in kt) of fall spawning Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels from the SCA population model, under a 5 recent years average recruitment and 2 recent years average natural mortality scenario. Lines show the median estimates of August 1 SSB, light shading shows the 95% and dark shading shows the 50% confidence intervals (based on MCMC sampling). The green and red horizontal lines are the USR and LRP, respectively.

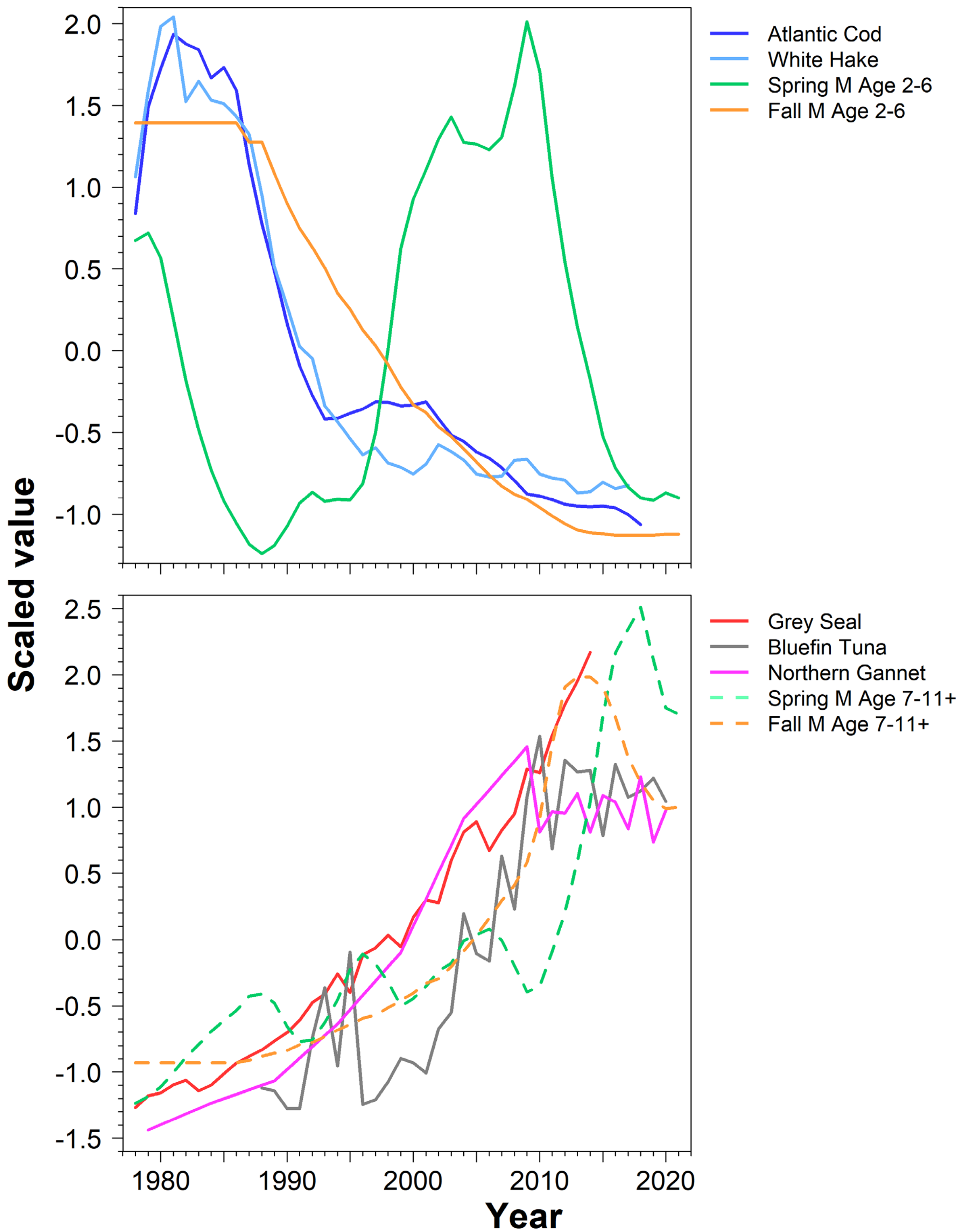


Figure 50. Scaled relative abundance indices for Herring major predators (Atlantic cod, White Hake, Grey seal, Atlantic Bluefin Tuna, Northern Gannet) between 1970-2021 alongside with natural mortality (M) estimates for age groups 2-6 (M2-6) and 7-11+ (M7-11) from the SCA spring and fall herring stock models.

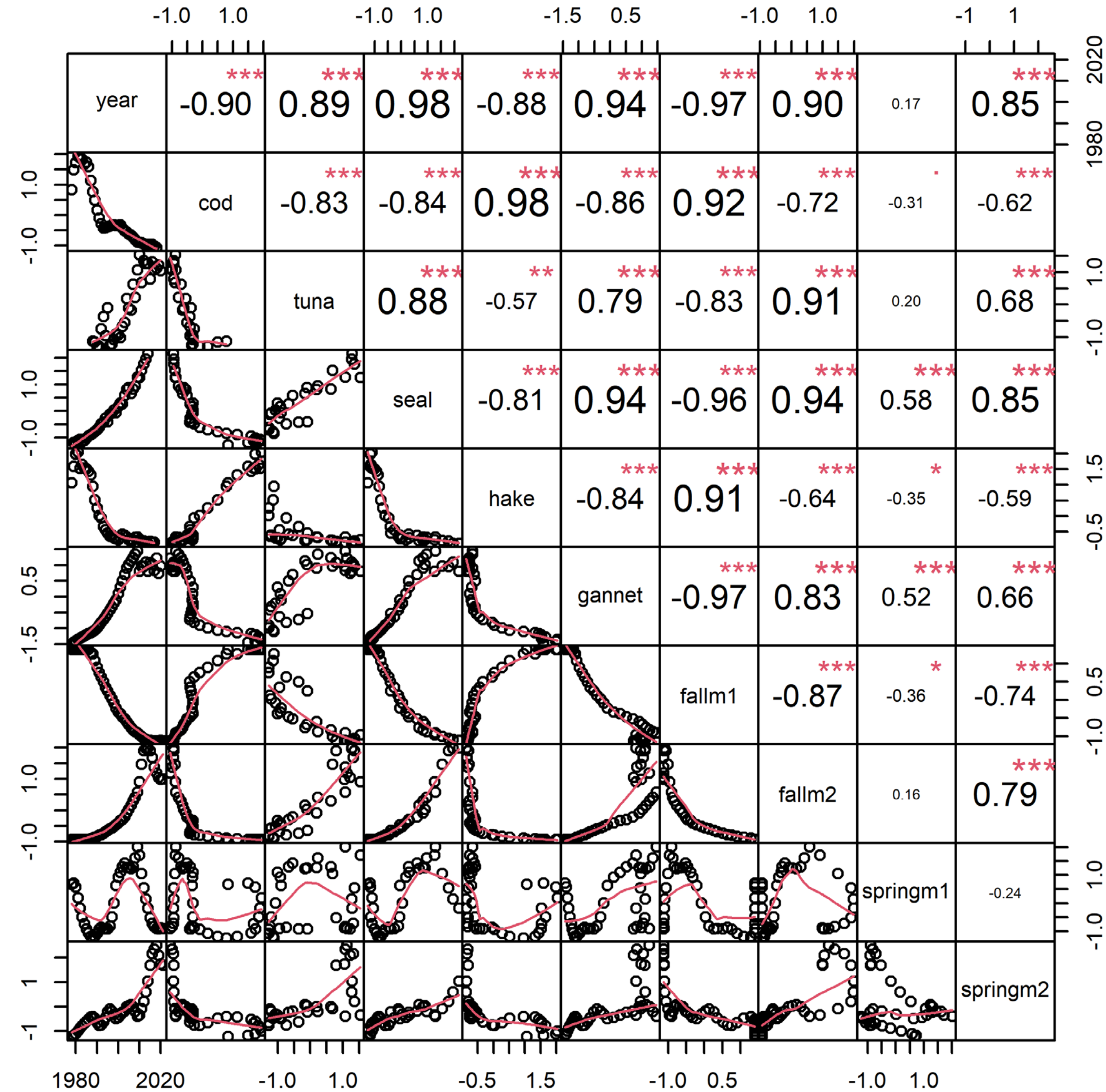


Figure 51. Correlation matrix between the scaled relative abundance indices for Herring major predators (Atlantic cod, White Hake, Grey seal, Atlantic Bluefin Tuna, Northern Gannet) between 1970-2021 alongside with natural mortality estimates for age groups 2-6 (m1) and 7-11+ (m2) from the spring and fall herring stock models.

APPENDIX A. AGE READING CONSISTENCY TEST

Yearly age reading consistency tests are done in order to evaluate and ensure the consistency of age reading over time. A sub-sample of pairs of Herring otoliths from years 1993, 1994, 1996 and 2003 was re-aged, and the new ages were compared to the reference ages. Otolith samples were randomly selected for age-groups 1 to 11+ and from years between 1993 and 2003, gear types used and type of sample (commercial and research). In total, a final set of over 200 otoliths was used. All aging was done by the primary reader in 2020 and 2021.

The results show an overall agreement of 86.7% (mean coefficient of variation of 0.48) in 2020, and an agreement of 86.2% (mean coefficient of variation of 0.41) in 2021 (Figure A1). The CV is considered to be a more robust measure of the precision of age determination (Campana et al. 1995). There was no bias present from ages 1 to 9. For older Herring (9+), the primary reader tend to slightly underestimate the age with more variation among samples.

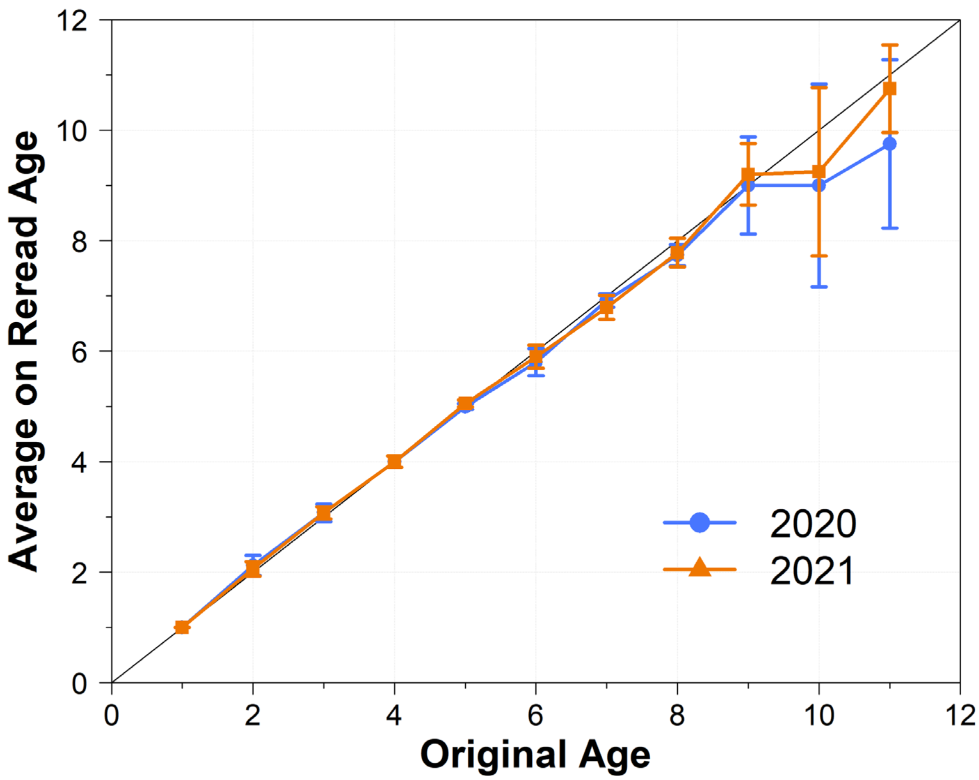


Figure A1. Comparison of ages obtained during the validation test in 2020 and 2021 with the original ages assigned. Bars indicate the coefficient of variation. Straight line indicates original ages.

APPENDIX B. FISHERY-INDEPENDENT ACOUSTIC SURVEY RESULTS

The 2020-2021 acoustic surveys were carried out between September 13 and October 10 in the 4Tmno areas (i.e., Chaleurs-Miscou; Figures B1 and B2) and the biomass of Herring were estimated to be 30,082 and 37,953 t, respectively. The distribution of Herring in the area can be seen in Figures B1-B2 and Tables B1-B2. The 2020 and 2021 acoustic biomass indices of the Chaleurs-Miscou area for the combined spring and fall spawner groups has increased by 59.8 and 101.6%, respectively, compared to the lowest in the history of the survey that was recorded in 2019 (Figure B3).

Midwater trawl samples were collected where Herring densities were found by the hydroacoustic vessel. The catch (length frequency) by set was weighted by the sum of acoustic Herring densities recorded in the stratum or group of strata defined in the catch-at-age parameters as representing the biomass in that area. Using the Herring densities recorded as the weighting factor is considered a better method as it does not depend on an estimated standardized amount of Herring caught in a set of one nautical mile.

Table B1. Herring biomass densities and estimates by stratum and area from the fishery-independent acoustic surveys conducted in 2020.

Stratum	Average TS (dB/kg)	Stratum Area (km^2)	Mean Sa ($/m^2$)	Density (kg/m2)	Biomass (tons)	SE (tons)	SE (%)
Gaspé							
Rivière au Renard	-	124.6	0.00	0.0000	0.0	0.0	0.0
Cap Bon Ami	-	69.0	0.00	0.0000	0.0	0.0	0.0
Malbaie	-	95.6	0.00	0.0000	0.0	0.0	0.0
Anse à Beaufils	-	96.0	0.00	0.0000	0.0	0.0	0.0
Chaleur							
Grande Rivière	-34.95	106.4	-52.90	0.0160	1,707.4	385.8	22.6
Newport	-34.95	124.9	-51.41	0.0226	2,822.2	1,658.0	58.7
Shigawake	-34.80	265.6	-53.35	0.0140	3,709.0	1,593.0	43.0
New Carlisle	-34.80	169.0	-57.20	0.0058	972.9	615.4	63.2
New Richmond	-	111.6	0.00	0.0000	0.0	0.0	0.0
Belledune	-34.40	266.0	-54.75	0.0092	2,455.7	1,191.9	48.5
Nepisiguit	-35.11	211.3	-49.80	0.0339	7,167.2	3,064.3	42.8
Maisonnette	-35.11	145.0	-54.75	0.0109	1,576.1	616.3	39.1
Miscou							
West Miscou	-35.17	330.5	-58.57	0.0046	1,509.7	567.1	37.6
North Miscou	-35.30	295.7	-55.79	0.0089	2,640.6	1,709.1	64.7
Miscou NW	-35.30	444.0	-58.56	0.0047	2,096.3	1,337.3	63.8
Miscou NE	-34.80	352.8	-69.49	0.0003	119.9	121.5	101.3
Miscou SW	-34.08	552.2	-58.15	0.0039	2,163.1	1,041.8	48.2
Miscou SE	-34.80	521.3	-61.40	0.0022	1,141.9	900.2	78.8
Total					**30,081.8**		

Table B2. Herring biomass densities and estimates by stratum and area from the fishery-independent acoustic surveys conducted in 2021.

Stratum	Average TS (dB/kg)	Stratum Area (km^2)	Mean Sa (/m^2)	Density (kg/m2)	Biomass (tons)	SE (tons)	SE (%)
Gaspé							
Rivière au Renard	-35.06	124.6	-65.74	0.0009	106.6	124.3	116.6
Cap Bon Ami	-	69.0	0.00	0.0000	0.0	0.0	0.0
Malbaie	-35.06	95.6	-101.43	<0.0001	<0.0	<0.0	83.1
Anse à Beaufils	-35.06	96.0	-62.29	0.0019	181.8	139.2	76.6
Chaleur							
Grande Rivière	-35.70	106.4	-70.12	0.0004	38.5	22.0	57.3
Newport	-35.70	124.9	-58.42	0.0054	668.4	583.5	87.3
Shigawake	-35.70	265.6	-59.38	0.0043	1,138.5	430.6	37.8
New Carlisle	-34.54	169.0	-47.28	0.0533	9,004.6	6,081.7	67.5
New Richmond	-34.54	111.6	-49.87	0.0294	3,276.9	790.4	24.1
Belledune	-32.39	266.0	-54.16	0.0067	1,773.0	297.4	16.8
Nepisiguit	-34.93	211.3	-56.47	0.0070	1,482.8	596.7	40.2
Maisonnette	-35.56	145.0	-55.41	0.0103	1,500.5	805.9	53.7
Miscou							
West Miscou	-35.32	330.5	-57.19	0.0065	2,147.7	843.1	39.3
North Miscou	-	295.7	0.00	0.0000	0.0	0.0	0.0
Miscou NW	-35.35	444.0	-51.39	0.0249	11,049.3	10,168.6	92.0
Miscou NE	-35.35	352.8	-58.69	0.0046	1,631.7	738.9	45.3
Miscou SW	-35.35	552.2	-62.08	0.0021	1,172.0	232.2	19.8
Miscou SE	-35.35	521.3	-58.07	0.0053	2,780.7	1,015.3	36.5
Total					**37,953.1**		

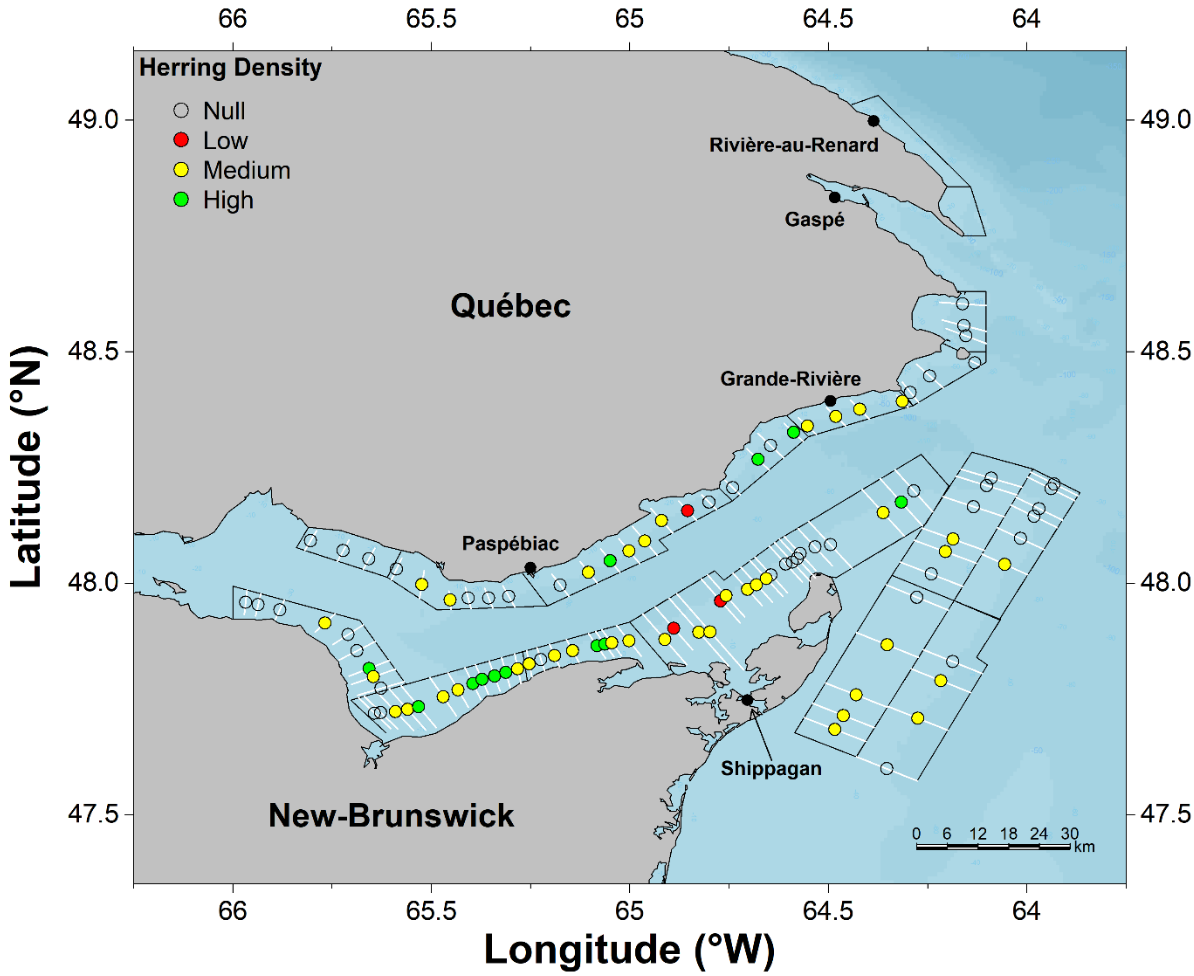


Figure B1. Surveyed transects covered during the 2020 acoustic surveys (whites lines) and Herring biomass density (colored circles, kg/m², Low, Medium or High, by transect).

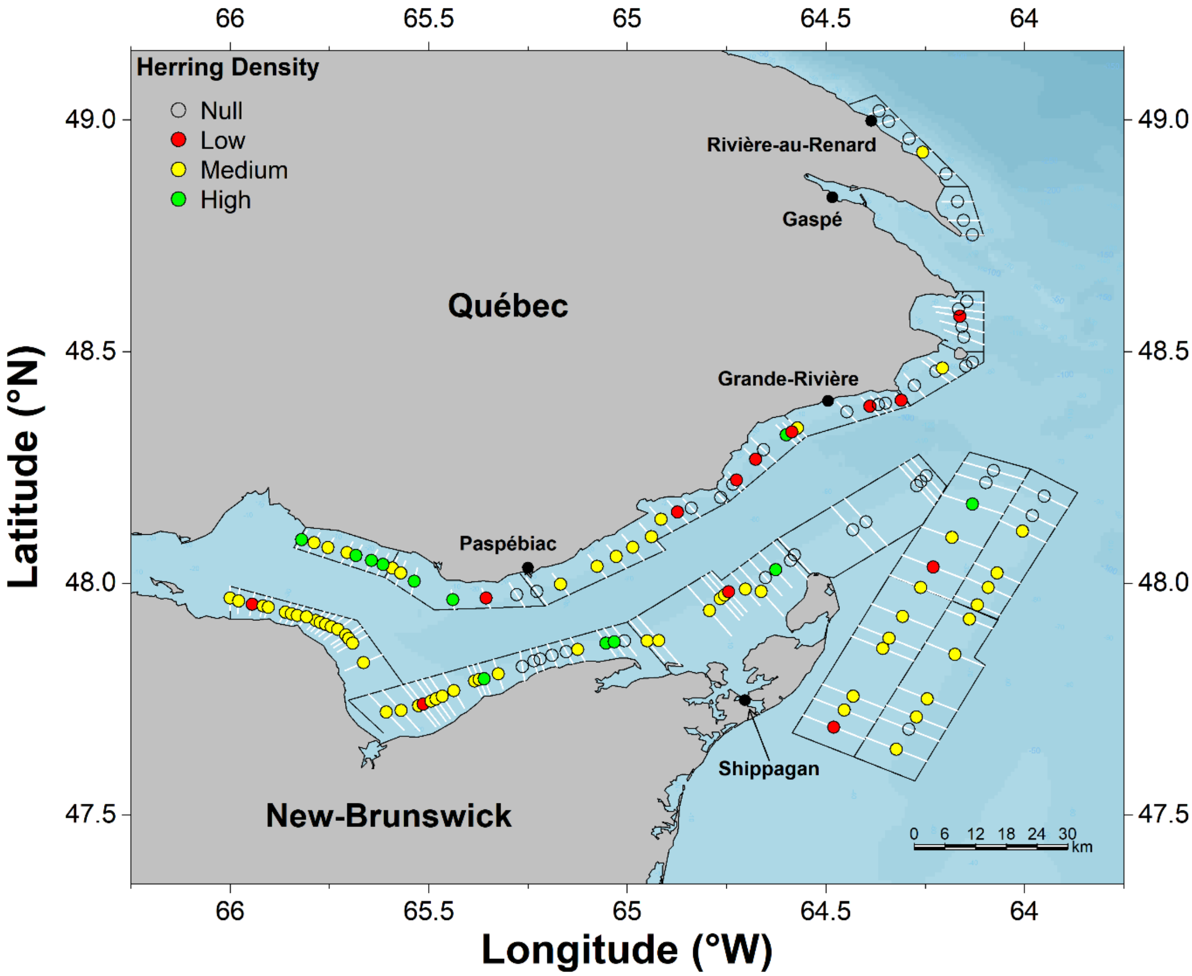


Figure B2. Surveyed transects covered during the 2021 acoustic surveys (whites lines) and Herring biomass density (colored circles, kg/m², Low Medium or High, by transect).

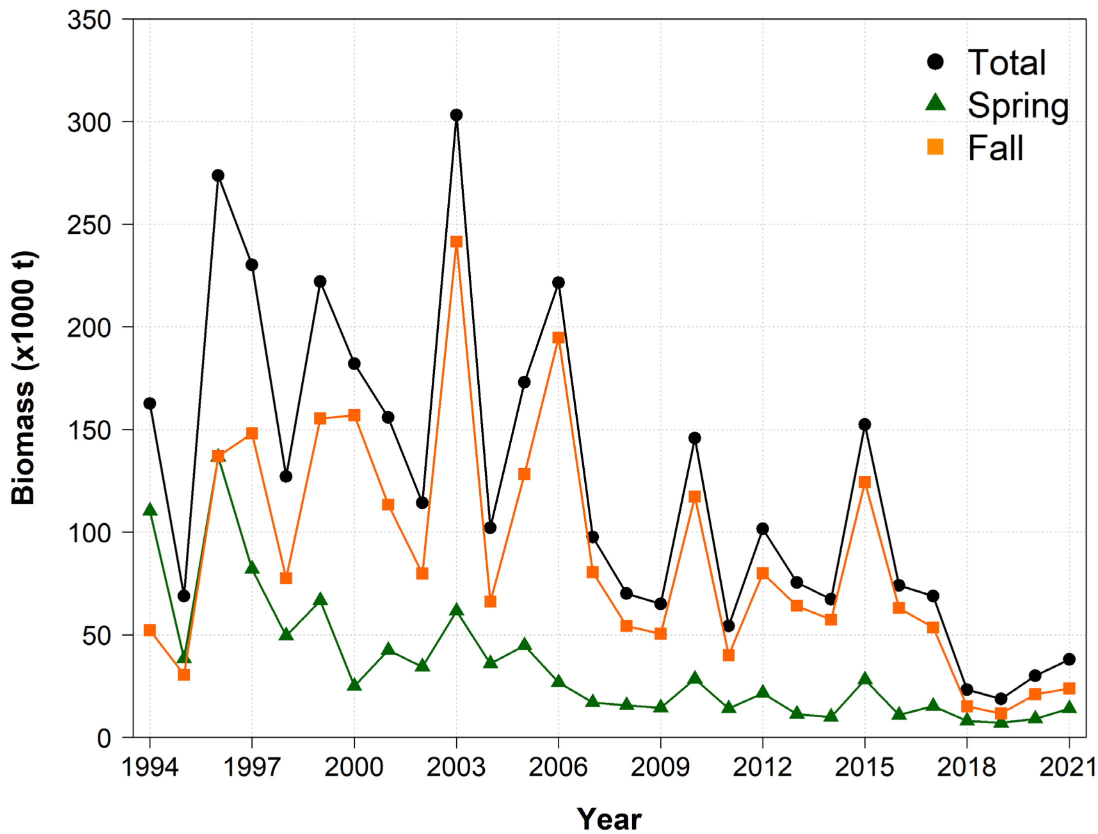


Figure B3. Acoustic survey total biomass (black) of spring (green) and fall (orange) spawners between 1994 and 2021.

APPENDIX C. SPAWNING GROUND ACOUSTIC SURVEY RESULTS

The spawning ground acoustic survey began in 2015, and has been conducted each year since. It follows a stratified random design with a protocol consistent with the fishery-independent acoustic survey. Six spawning grounds were identified: Gaspé, Miscou, Escuminac/Richibucto, West PEI, East PEI (Fisherman's Bank/North Lake), and Pictou (Figure C1). Strata were defined for each spawning ground using the acoustic information collected in previous industry partnership studies. Strata were designed to be large enough to encompass the historical spawning grounds in each region. Transects were randomly generated each year within strata at a minimum of 400 m apart (Figure C2).

Each fishing association selected one or two fish harvesters to conduct acoustic surveys to quantify the biomass of fish schools using a hull or side-mounted 120 kHz single beam transducer. Acoustic data from fishing vessels has been used to analyse school morphology characteristics, spatial patterns, relative changes in school density (Shen et al. 2008) and to develop estimates of abundance (Melvin et al. 2002; Honkalehto et al. 2011). In the sGSL, fishery acoustic data collected on Atlantic herring spawning aggregations can be used to obtain relative nightly biomass estimates (Claytor and Allard 2001; Claytor and Clay 2001). For each region, the goal of the analysis is to estimate the relative spawning biomass from a set of nightly acoustic observations. Surveys were to be conducted once each before and after the fishing season as well as during each weekend fishing closure, where possible. West PEI and Escuminac/Richibucto regions did not have weekend fishing closures until 2018; sampling in these regions was thus only possible before and after the fishing season until the implementation of weekend closures. Fish size and age frequency data used to convert the acoustic data into biomass estimates were obtained from the experimental gillnet surveys. Nightly acoustic data were processed and analysed for each region in order to obtain a nightly estimate of biomass (Tables C1 to C3), as described in Claytor and Clay 2001.

Figure C3 shows the mean nightly biomass per spawning ground for each year. Some regions/years show great variations in nightly fish biomass (i.e. Miscou and Gaspé 2016, Escuminac 2015). In general, there is a decreasing trend in biomass in most regions over time. Due to weather and other logistical constraints, there are missing sampling trips for some regions and years; the presence or absence of samples, especially at the beginning or end of a fishing season, can have a great impact on the mean nightly biomass of fish observed in an area. Escuminac/Richibucto and West PEI regions are especially sensitive to missing samples prior to 2018 when weekend fishing closures were implemented, as only two trips (one before and one after the fishing season) were able to be completed each year before this time. The proportion of the strata covered and the frequency of survey coverage varied among year and regions from complete strata coverage on a weekly basis to a complete absence of surveys for East PEI in 2015 and 2021 and Escuminac in 2018 (Tables C1 to C6 for details). Gaspé (except for 2017), Miscou and Pictou regions show good coverage over the sampling season with five samples almost every year (Table C4).

Gaspe and Miscou regions show the highest mean nightly biomass in 2016, with intermediate values for 2015 and 2017. Gaspe biomass was lowest in 2018, closely followed by 2020 and 2021. Miscou shows a decreasing trend in biomass from 2017 to 2019, with an increase in biomass in 2020 to a value similar to that of 2018. The biomass decreased again in 2021, with 2019 and 2021 having the lowest biomass values in Miscou. Escuminac/Richibucto had one observation of a high total nightly biomass of 15,238 t in 2015 for a high mean nightly biomass, with decreasing mean biomass ever since. The lowest biomass estimates for the Escuminac/Richibucto region were observed in 2019, 2020, and 2021; however, sampling effort in this region was low in all years up until 2020. Similarly, due to lack of weekend fishing closures in West PEI until 2018, it is difficult to say that the spawning biomass is accurately estimated in 2015-2017. The mean nightly biomass for West PEI in 2019 and 2020 were the highest mean nightly biomass estimates of all six sampling regions in those years. Pictou shows a general decreasing trend in biomass from 2015-2020, with the highest biomass level observed in 2015. The biomass estimate in Pictou in 2021, however, shows a substantial increase, and is the second highest biomass estimate for the Pictou region, behind 2015. This 2021 value in Pictou represents the highest nightly estimated biomass in all regions in 2021.

Figure C4 shows the mean nightly biomass per geographic region, where North represents Gaspé and Miscou, Middle represents Escuminac/Richibucto and West PEI, and South represents East PEI and Pictou. Overall, the highest biomass for each geographic region is seen in 2015 (Middle and South regions), or 2016 (North), and the lowest biomass per night of acoustics per region in 2021, 2018, and 2018, for the North, Middle, and South regions, respectively (Figure C4). The results show a general decrease in average nightly biomass in all geographic regions over time, with the exception of an increase in the South region in 2021. The North region had higher biomasses than the Middle and South regions in 2016 and 2017, however, the biomass observed in all three regions has become more similar beginning in 2018, with the exception of the South biomass value in 2021.

For this index to be included in future assessments, surveys need to be consistent across regions and conscientiously carried out. Weekend closures in West PEI and Escuminac that began in 2018 and remain for future years will allow harvesters to acquire more samples from these spawning beds. In some cases, the first sampling date shows the highest biomass of the season, which could indicate inadequate capture of the spawner biomass estimate for the spawning grounds. Starting the acoustic surveys earlier in the year could help better capture the spawning biomass over the entire spawning season; however, this survey is currently aligned with dates of the fishing season.

Table C1. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2020.

Herring Fishing Area	Region	Area	Date	Mean Target Strength (dB kg^{-1})	Area (km²)	Mean Backscatter (dB m^{-2})	Biomass Density (kg m^{-2})	Biomass Estimate (t)	Biomass Estimate Standard Error (t)
16B	North	Gaspé	2020-08-22	-35.45	38.6	-20.88	6.36E-04	16	15
16B	North	Gaspé	2020-08-29	-35.45	38.6	-60.67	4.76E-03	222	199
16B	North	Gaspé	2020-09-04	-35.45	38.6	-55.59	3.93E-02	1951	1207
16B	North	Gaspé	2020-09-11	-35.45	38.6	-22.71	1.80E-04	7	6
16B	North	Gaspé	2020-09-18	-35.45	38.6	-63.83	3.03E-03	111	47
16B	North	Miscou	2020-08-19	-35.60	386.9	-61.11	4.74E-03	936	899
16B	North	Miscou	2020-09-04	-35.60	386.9	-27.81	4.98E-03	920	722
16B	North	Miscou	2020-09-11	-35.60	386.9	-33.18	7.21E-04	268	137
16B	North	Miscou	2020-09-17	-35.60	386.9	-41.49	1.37E-02	4286	2646
16B	North	Miscou	2020-09-20	-35.60	386.9	-61.42	8.83E-03	3152	1523
16B	North	Miscou	2020-10-02	-35.60	386.9	-50.57	3.19E-02	3150	NA**
16C	Middle	Escuminac	2020-08-21	-35.75	145.5	-46.46	1.97E-03	328	128
16C	Middle	Escuminac	2020-08-29	-35.75	145.5	0.00	0.00E+00	0	0
16C	Middle	Escuminac	2020-09-04	-35.75	145.5	-32.96	6.00E-04	147	104
16C	Middle	Escuminac	2020-09-12	-35.75	145.5	-56.07	9.31E-03	244	161
16C	Middle	Escuminac	2020-09-20	-35.75	145.5	-30.67	1.76E-03	196	174
16C	Middle	Escuminac	2020-10-02	-35.75	145.5	-16.09	3.43E-04	10	9**
16E	Middle	West PEI	2020-08-24	-35.60	111.3	-33.05	3.50E-02	7877	7112
16E	Middle	West PEI	2020-09-04	-35.60	111.3	-44.29	6.48E-04	52	45
16E	Middle	West PEI	2020-09-12	-35.60	111.3	-18.17	4.28E-03	1135	1030
16E	Middle	West PEI	2020-09-19	-35.60	111.3	-14.00	7.62E-02	1737	1664
16E	Middle	West PEI	2020-09-25	-35.60	111.3	-47.38	8.78E-02	13836	8359
16E	Middle	West PEI	2020-10-03	-35.60	111.3	-51.41	2.62E-02	66	14**
16E	Middle	West PEI	2020-10-04	-35.60	111.3	-38.90	4.31E-03	323	271**
16F	South	Pictou	2020-09-01	-35.63	127.2	-13.02	2.26E-04	37	35
16F	South	Pictou	2020-09-12	-35.63	127.2	-51.32	2.46E-03	145	103
16F	South	Pictou	2020-09-19	-35.63	127.2	-69.61	4.00E-04	13	11
16F	South	Pictou	2020-09-25	-35.63	127.2	-36.67	5.21E-03	1873	1586
16F	South	Pictou	2020-10-02	-35.63	127.2	-25.04	9.06E-04	110	48
16G	South	East PEI	2020-09-13	-35.90	56.1	-48.97	6.62E-02	3817	2130
16G	South	East PEI	2020-10-03	-35.90	56.1	-54.35	1.52E-02	802	446
16G	South	East PEI	2020-10-28	-35.90	56.1	0.00	0.00E+00	0	0

**These nightly biomass estimates were conducted after the regular time-sampling grid and are not included in figures C3 and C4, below.

Table C2. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2021.

Herring Fishing Area	Region	Area	Date	Mean Target Strength (dB kg^{-1})	Total Area (km^2)	Mean Backscatter (dB m^{-2})	Mean Biomass Density (kg m-2)	Total Biomass Estimate (t)	Biomass Estimate Standard Error (t)
16B	North	Gaspé	2021-08-28	-35.54	38.6	-20.89	6.46E-04	26	14
16B	North	Gaspé	2021-09-11	-35.54	38.6	-20.80	6.84E-04	28	27
16B	North	Gaspé	2021-09-18	-35.54	38.6	-56.25	4.56E-02	1341	659
16B	North	Gaspé	2021-09-25	-35.54	38.6	-54.32	1.73E-02	538	327
16B	North	Gaspé	2021-10-01	-35.54	38.6	-36.47	3.16E-02	792	655
16B	North	Miscou	2021-08-23	-35.88	386.9	-51.03	2.91E-03	1165	516
16B	North	Miscou	2021-09-11	-35.88	386.9	-60.76	3.56E-03	557	223
16B	North	Miscou	2021-09-18	-35.88	386.9	-78.08	1.58E-04	15	20
16B	North	Miscou	2021-10-01	-35.88	386.9	-58.90	3.95E-04	187	283
16C	Middle	Escuminac	2021-09-11	-35.59	145.5	-55.06	1.99E-02	338	179
16C	Middle	Escuminac	2021-10-01	-35.59	145.5	-56.46	1.21E-02	219	188
16C	Middle	Escuminac	2021-10-09	-35.59	145.5	0.00	0.00E+00	0	0
16E	Middle	West PEI	2021-09-11	-35.88	111.3	-39.84	1.21E-01	3875	2247
16E	Middle	West PEI	2021-09-17	-35.88	111.3	-44.42	4.26E-03	914	894
16E	Middle	West PEI	2021-09-24	-35.88	111.3	0.00	0.00E+00	0	0
16E	Middle	West PEI	2021-10-01	-35.88	111.3	-41.04	1.35E-02	840	651
16F	South	Pictou	2021-09-08	-35.55	127.2	-28.23	1.26E-04	13	8
16F	South	Pictou	2021-09-17	-35.55	127.2	-55.30	2.24E-03	33	28
16F	South	Pictou	2021-09-23	-35.55	127.2	-33.25	6.21E-03	1198	1156
16F	South	Pictou	2021-10-01	-35.55	127.2	-44.37	2.97E-02	7400	6048
16F	South	Pictou	2021-10-06	-35.55	127.2	-31.30	2.14E-02	6616	6315

Table C3. Number of individual acoustic sampling trips per year and region from the spawning ground acoustic surveys.

Region	2015	2016	2017	2018	2019	2020	2021
Gaspe	5	5	1	5	7	5	5
Miscou	5	5	4	5	7	6	4
Escuminac	2	2	1	0	1	6	3
West PEI	2	1	2	6	4	7	4
Pictou	5	5	4	5	5	5	5
East PEI	0	3	5	2	2	3	0
Total	19	21	17	23	26	32	21

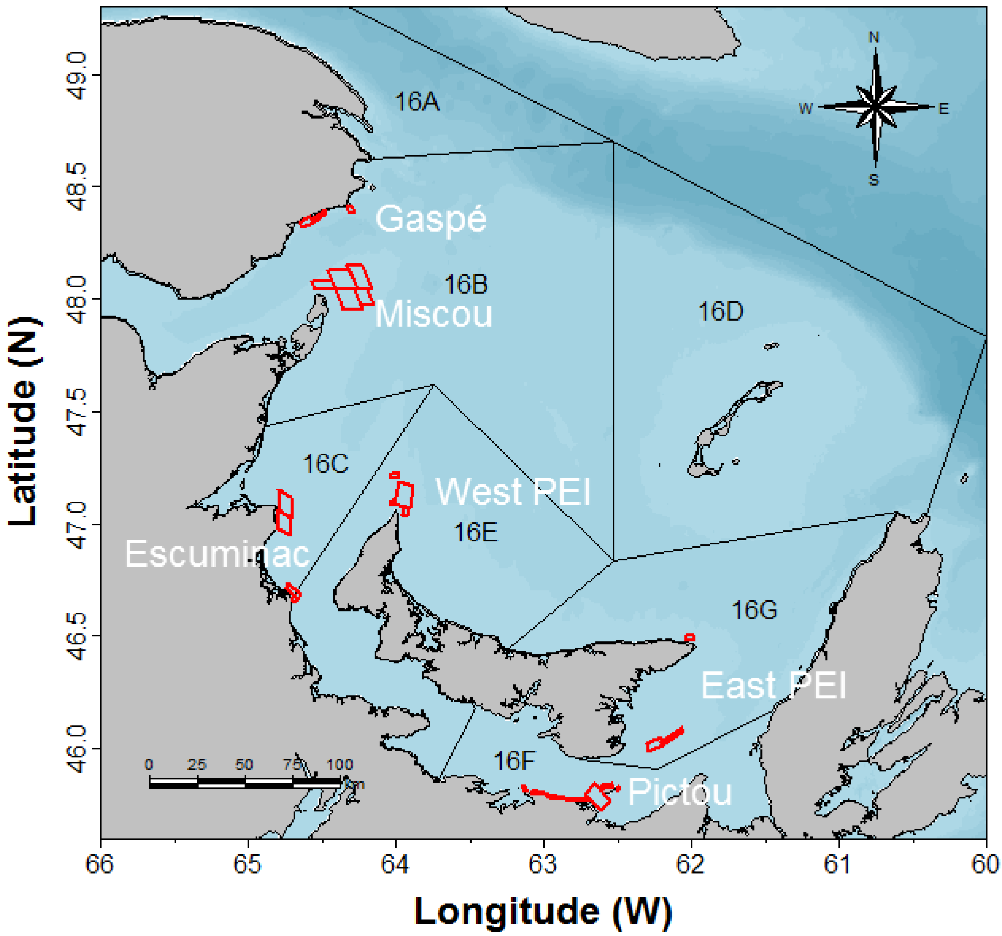


Figure C1. Spawning grounds surveyed during the spawning ground acoustic surveys.

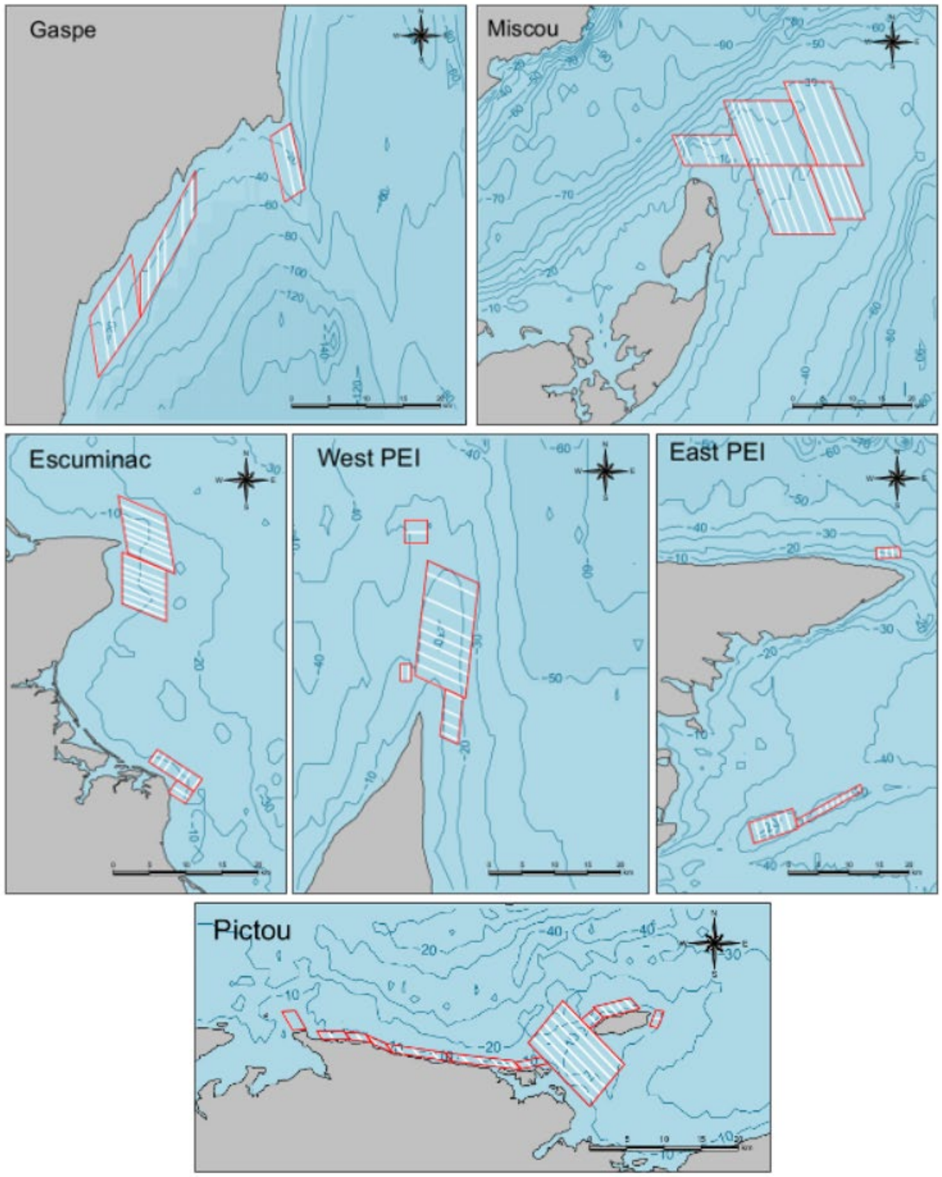


Figure C2. Strata (red boxes) and transects (white lines) surveyed during the spawning ground acoustic surveys.

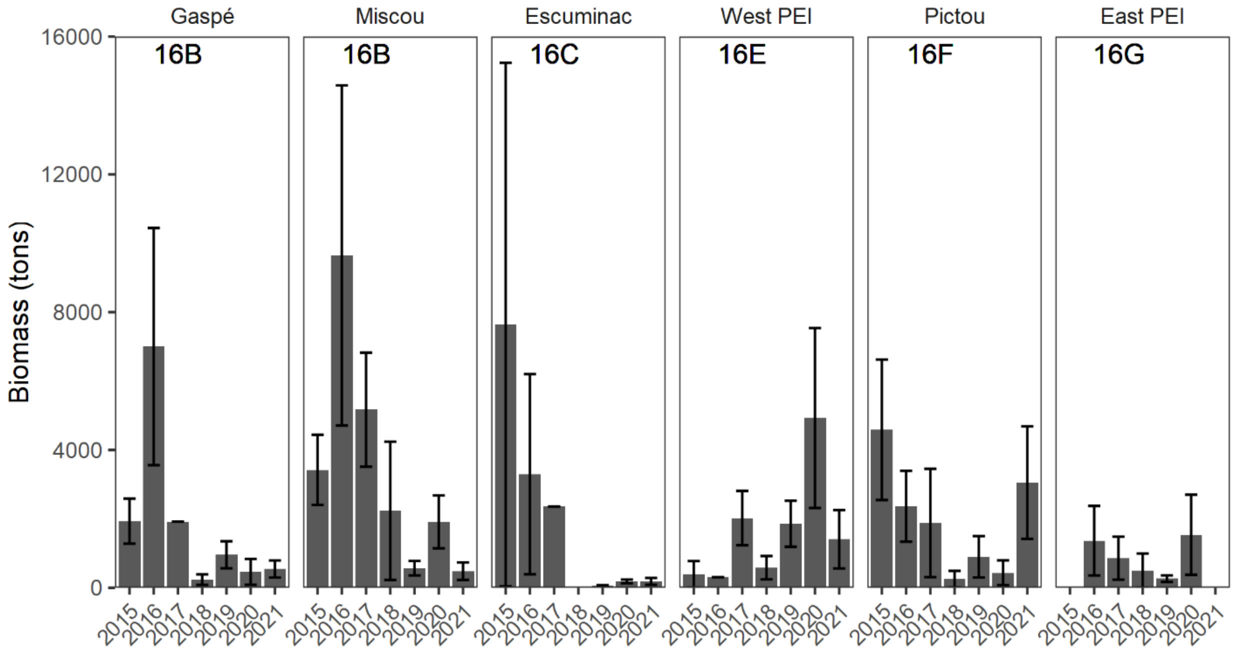


Figure C3. Nightly Atlantic herring biomass estimates (tons; mean ± one standard error bar) by spawning ground from the spawning ground acoustic surveys for years 2015 to 2021.

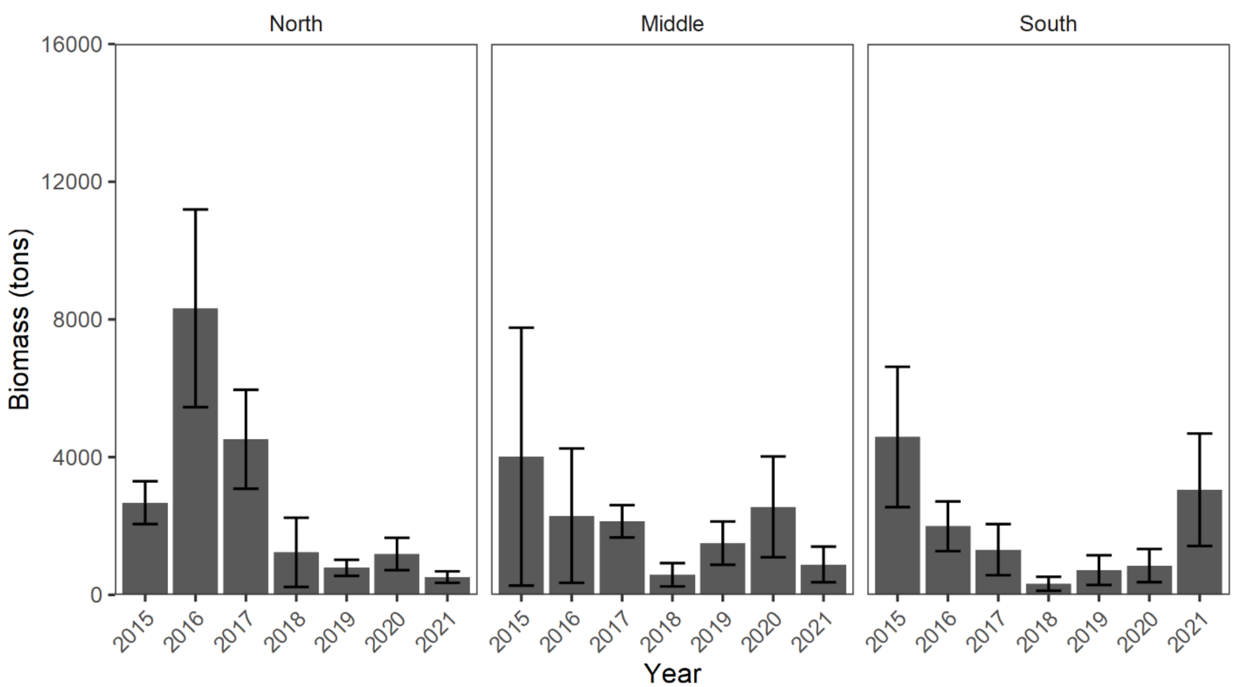


Figure C4. Nightly Atlantic herring biomass estimates (tons; mean ± one standard error bar) by geographic region (North, Middle, South) from the spawning ground acoustic surveys for years 2015 to 2021.

APPENDIX D. MULTISPECIES BOTTOM-TRAWL SURVEY RESULTS

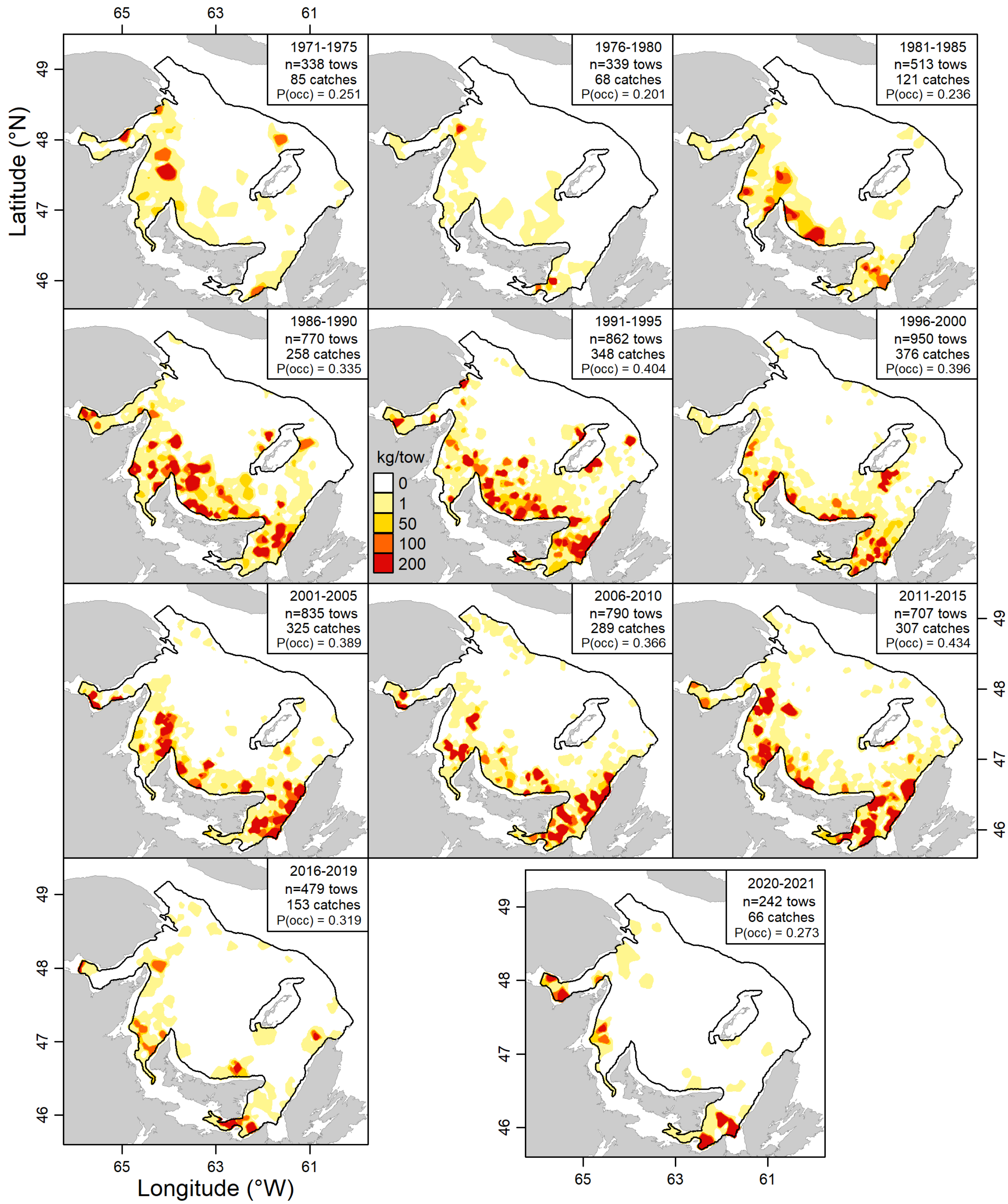


Figure D1. Spatial distribution of Herring catches by block of years in the southern Gulf of St. Lawrence bottom trawl research vessel survey from 1971 to 2021. P(occ) indicates probability of occurrence (the number of tows catching Herring divided by the total number of tows).

APPENDIX E. COMPARISON OF CPUE ESTIMATIONS FROM FORMER SAS CODE AND NEWLY TRANSLATED AND UPDATED R CODE

The objective of this work was to translate historical codes used to estimate CPUE from the SAS (Statistical Analysis Software) to the R (R Foundation for Statistical Computing Platform) programming language in order to update and improve access and understanding of the calculation methods. Ultimately this work will improve the year to year repeatability of the CPUE estimations used by the population model.

This work has allowed us to:

1. Automate and standardize all procedures related to data importation, selection and calculations.
2. Standardize the definitions of the different spatial aggregation levels, allowing access to the smallest possible aggregation level for the estimations for both spawning groups.
3. Use raw data instead of archived data which provides better documentation of corrections and the methodological modifications through time.

Moreover, this work has improved accessibility and transferability of this knowledge.

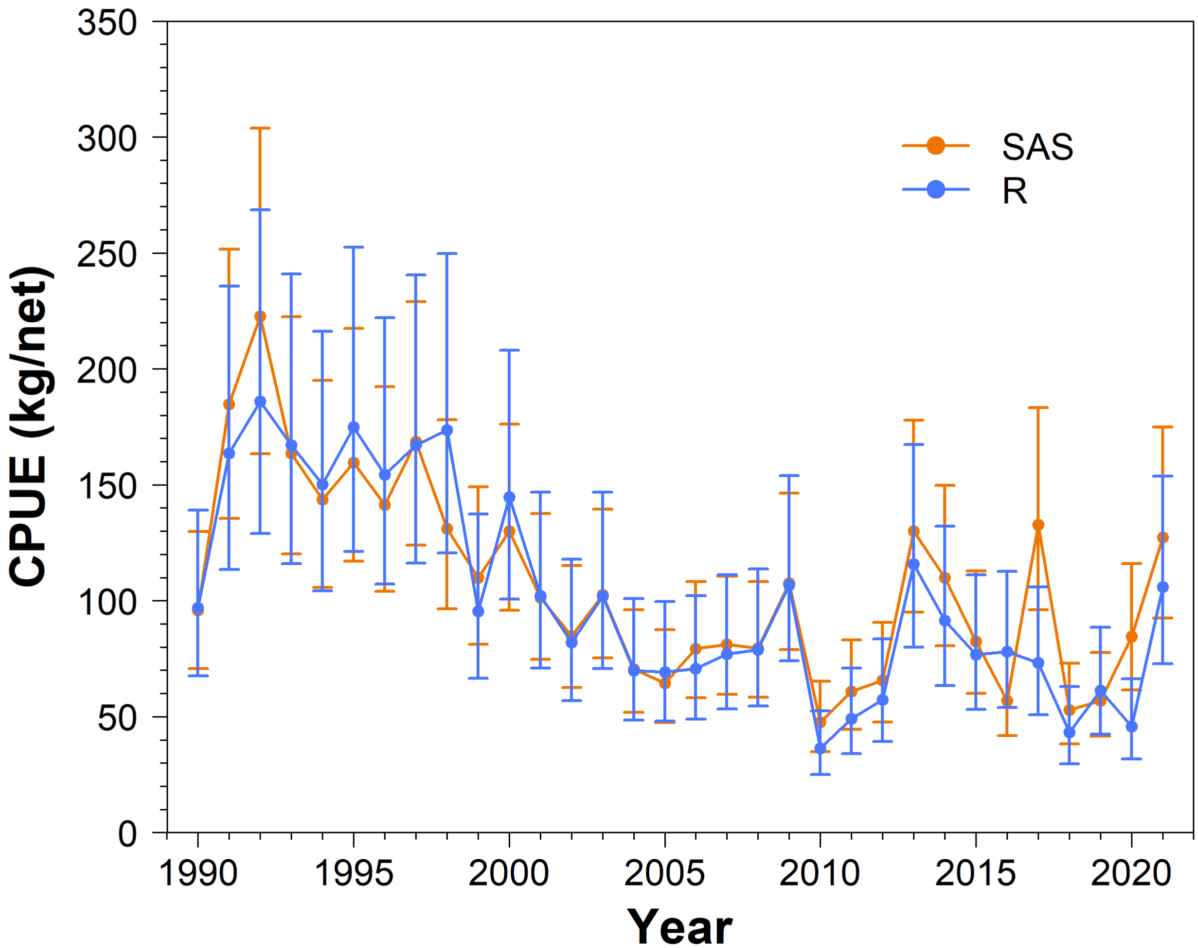


Figure E1. CPUE estimations of spring spawning Atlantic Herring from the southern Gulf of St. Lawrence using former SAS methodology which has been translated and updated into R.

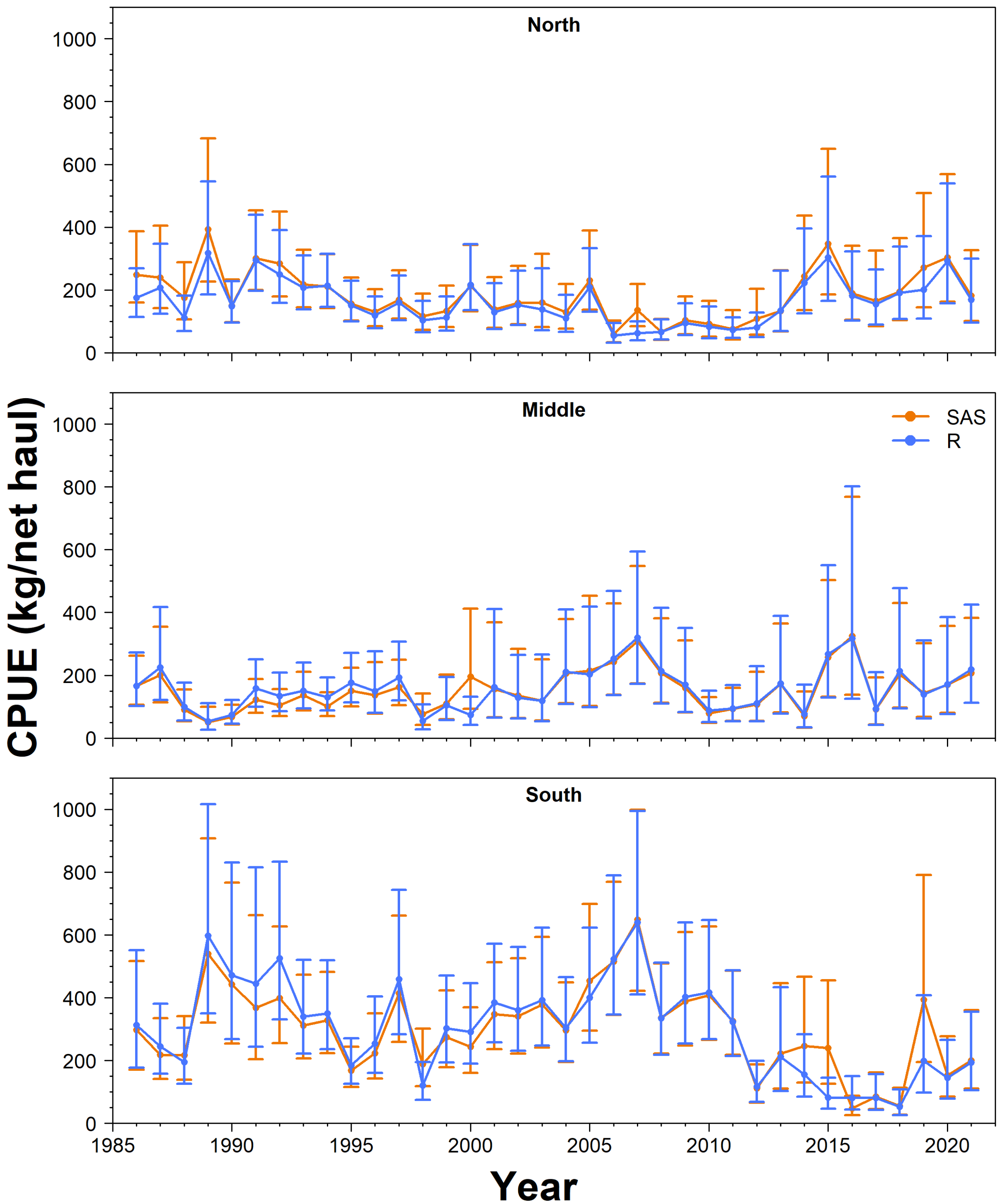


Figure E2. CPUE estimations of fall spawning Atlantic Herring by region in the southern Gulf of St. Lawrence using former SAS methodology which has been translated and updated into R.