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Gulf Region

Assessment of the NAFO Division 4TVn southern Gulf of St. Lawrence Atlantic Herring (*Clupea harengus*) in 2018-2019

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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 in 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, and catches in the multi-species bottom trawl survey of the sGSL. The data and indices are reported for the whole-area 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 2020 is estimated to be approximately 26,000 t; 55 % of the limit reference point (LRP = 47,250 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 only slightly reduces the probabilities of SSB decline in projections. By 2029, the probability of exceeding the LRP was 0 % at all catch levels, with SSB values ranging between 160 and 1,198 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 2019 (16,000 t), the probabilities of a 5 % increase in SSB by 2022 are 29 %. Long-term projections show a continuous decline, with SSB in the Critical Zone by 2025. 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. The catch level offering the greatest probabilities of increasing SSB in the short and long term was 2,000 t.

1. 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). Age at first spawning is typically four years of age.

Herring in the sGSL are managed across seven Herring Fishing Areas (HFA) in area 16 (A-G; Figure 1a). These HFAs cover the same region as NAFO Division 4T (Figure 1). 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. The spring and fall spawners of 4T Herring are considered distinct stocks and are assessed separately. Recent genetic studies have confirmed genetic differentiation between these stocks (Lamichhaney et al. 2017). Herring also show high spawning site fidelity (Wheeler and Winters 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 consists of five large southern Gulf vessels (> 19.8 m). 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 1). 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 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 2019, with projections for 2020, 2021, and 2029.

2. DATA SOURCES

For the spring spawning Herring assessment, the population model was fit to 4T data. For the fall spawning Herring assessment, the regionally-disaggregated models for the three regions (North, Middle, South) cover the entire 4T area. The regions are defined on the basis of traditional Herring spawning beds and fishing areas: North (Gaspé and Miscou; 4Tmnopq), Middle (Escuminac-Richibucto and west Prince Edward Island; 4Tkl) and South (east Prince Edward Island and Pictou; 4Tfghj) (Figure 1). 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) and inputs that are common to the entire area (e.g., acoustic survey index, RV survey index).

2.1. LANDINGS

Catch data were taken 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 TAC for the spring and fall spawners components is set for the 4T stock unit. In 2018, an interim TAC of 500 t was allocated for spring spawners, however no official TAC was set, and a TAC of 25,200 t was set for the fall spawners. For 2019, the TAC was distributed between the spring spawners at 1,250 t and fall spawners at 22,250 t for a total of 23,500 t. (Table 1; Figure 2). Seventy-seven percent of the TAC 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 season fisheries were 798 t and 1,047 t for 2018 and 2019, 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 2019 period. In 2018 and 2019, the fixed gear fleet was estimated to have landed 67 % and 51 %, respectively, of the total harvests of spring spawning Herring (Table 1; Figure 3a). More than 80 % of the spring spawning Herring landed by the fixed gear fleet is landed during the spring fishing season, whereas most (> 80 %) of the spring spawning Herring landed by the mobile fleet is landed in the fall season (Figure 3b,c).

The preliminary landings of fall spawners in 2018 and 2019 were 16,742 t and 15,544 t, respectively (Table 1; Figure 3d). Over the 1978 to 2019 period, most of the fall spawning Herring have been landed in the fixed gear fleet. In 2018 and 2019, the fixed gear fleet was estimated to have landed 91 % and 93 %, 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, 22 % were landed in the fall fishing season in 2018, compared to 100 % in 2019 (Figure 3f).

The recent 2015 to 2019 mean proportion of the total catch caught by fixed gear was 69 % of the spring spawners and 94 % of the fall spawners (Table 1). The majority of the 2018-2019 spring fishery fixed gear catches occurred in Herring areas 4Th (South) and 4Tmn (North; Table 2). Meanwhile, the majority of the 2018-2019 fall fishery fixed gear catches occurred in Herring area 4Tmn (North; Figure 1; Table 2). The mobile gear (Edge) spring fishery landed 1,246 t and 0 t in 2018 and 2019, respectively. The fall fishery 2018 and 2019 mobile gear catches were all from 4Tmn (533 t and 1,163 t; North; Figure 1; Table 2).

In 2018, 160 % of the spring spawners interim TAC was attained, whereas 84 % of the TAC was attained in 2019. However, due to historical shares considerations, the TAC is not an accurate representation of the fishery objectives set each year. The target catch in 2019 was 500 t, while 1,047 t were captured (209 % of the target catch; Table 1).

In 2018, 66 % of the fall spawners TAC was attained, while 105 % of the target catch was captured. In 2019, 70 % of the TAC was attained, while 97 % of the target catch was captured (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: (i) fishing closure on some spawning areas in all HFA except 16A and 16F, (ii) weekly landing limits of 10,206 kg in all HFA except 16A, 16D, and 16F, where no restrictions apply, and (iii) 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 (DFO, 2010, 2012, 2014).

2.1.1. 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.

2.2. 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 2018 fixed gear telephone survey contacted 265 fishermen randomly selected out of approximately 505 active commercial licence holders in both seasons combined. A total of 44 fishermen responded to the spring fishing season survey and 149 fishermen responded to the fall fishing season survey for a total of 193. The 2019 fixed gear telephone survey contacted 270 fishermen randomly selected out of approximately 526 active commercial licence holders in both seasons combined. A total of 67 fishermen responded to the spring fishery survey and 170 fishermen responded to the fall fishery survey for a total of 237. 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 2019 spring fishery were similar to those in 2018 and to those in the previous years. For the fall fishery there was a sense that the 2018 abundance in the North region had declined slightly, increased slightly in the Middle region, and decreased in the South. When comparing 2019 to 2018 in the fall fishing season, the North region respondents indicated a decline, the Middle region a slight increase and an 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 2018 and 2019 was 100 % (Table 3).

2.3. 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).

2.4. 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 4T Herring 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 in 2018 covered a total transect distance of 1259 km within the 4Tmno areas. Due to mechanical issues in 2019, the survey covered 822 km (Appendix B Figure B1). All strata were covered, but the density of transects surveyed was reduced. 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 (methods described in LeBlanc and Dale 1996; LeBlanc et al. 2015).

2.5. EXPERIMENTAL NETS

In this 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.

2.6. SPAWNING GROUND ACOUSTIC SURVEYS

In 2015, a spawning ground acoustic survey project that follows the design of the fishery-independent acoustic survey (Section 2.4) was initiated. The survey design uses random parallel transects within predefined strata that cover the same spawning grounds as the experimental nets (Section 2.5, Appendix C). The survey is an industry partnership between DFO and fishery associations. 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 acoustic survey (Section 2.4). The catches from the experimental nets (Section 2.5) are used to calibrate the target strength for the acoustics in order to obtain the nightly estimates of spawning biomass.

This biomass index is not currently incorporated into the assessment models. The results of the first five years of data are available in Appendix C. While the results are not used in this assessment model, the goal is to include the index in later assessments when a longer time series is available.

2.7. MULTISPECIES BOTTOM-TRAWL SURVEY

The annual multi-species bottom trawl survey, conducted each September since 1971, provides information on the abundance and distribution of 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).

2.8. 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 2017. As predator data was in different units, abundance indices for each predator and natural mortality estimates were rescaled between 0 and 1 to be comparable between data sources, allowing to compare the timing and direction of changes in values.

3. INPUTS AND INDICES

3.1. 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). 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. Catch-at-age and weights-at-age are presented for fixed gear (spring spawners: Tables 4-5, fall spawners: Tables 6-7) and mobile gear (spring spawners: Tables 8-9, fall spawners: Tables 10-11).

The dominant age in the 2018 spring spawners catch was age 5 belonging to the 2013 year-class. In 2019 the dominant age was the same year-class, now age 6 (Tables 4, 8; Figure 4). For fall spawners, the dominant age was 6 in both years in the North (2012-2013 cohorts), age 7 in the Middle in both years (2011-2012 cohorts), ages 6 to 8 in 2018 (2010 to 2012 cohorts) and age 7 in 2019 (2012 cohort) in the South (Tables 6, 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 (Tables 5, 8; Figure 6). The average weight-at-age declined by 37 % between 1978 and 2019. Mean weight-at-age of fall spawning Herring from fixed and mobile gears has declined almost continuously over the time period 1978 to present (Tables 7, 11; Figure 6). The mean weight-at-age declined by 32 % between 1978 and 2019. Mean weight-at-age is an indication of stock status, affecting stock biomass for a given stock abundance.

Starting in this assessment, seiner catch from 4vn was re-distributed to the North, Middle and South regions in proportion to the region’s fixed gear landing. In previous assessments, re-distribution was based on seiner landings in each region, resulting in regions without seiner landings receiving no catch redistribution from 4Vn seiner landings. Also starting in this assessment, seiner catch from the edge fishery was re-distributed to North, Middle and South regions in proportion to their fixed gear landings. In previous assessments, these landings were all attributed to the South region.

3.2. CATCH-PER-UNIT EFFORT

The fixed gear fisheries occur on the spawning grounds. Landings from this fishery account for approximately 50 % of the spring spawners catch and more than 95 % of the fall spawners catch. 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). Nets are standardized to a length of 14 fathoms (25.6 m). 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. 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 and the annual telephone survey depending on which has the most data (Table 3). Fall fishing season data on the number of nets set is available since 1978 and on the number of hauls since 1986. Spring fishing season catch and effort DMP records are available since 1990.

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 2018 (37.2 %) is above the average (33.9 %), while the percentage of days without catch in spring 2019 (25.5 %) is lower than the average. In the fall, the days without catch are among the highest in the time series for the two years of the fall fixed gear fishery (40.7 % in 2018, 30.3 % in 2019, average 28.12 %). 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:

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

where I indexes year, J indexes telephone survey area, K indexes week and ϵ is the residual error. 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 9 to 22, whereas the fall spawner analysis was restricted to weeks 27 to 43.

The models explained 39 % 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 2019 for spring spawners and 1986 to 2019 for fall spawners.

The indices presented in Tables 14-15 and Figures 7-8 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 (Figures 7-8). Fixed gear catches of spring spawners in 2018-2019 were composed mostly of ages 5 to 7 (Table 4). The CPUE of spring spawners in 2018 and 2019 decreased from 2017 across all ages and the dominant age in 2019 was age 6 (2013 cohort, Table 14; Figure 7). In the North region, catches of fall spawners in 2018 and 2019 were dominated by age 6 to 8 (2010 to 2013 year-classes). In the Middle region, catches of fall spawners in 2018 and 2019 were dominated by ages 7-8 and 7, respectively (2010-2012 year-classes). In the South region, catches of fall spawners in 2018 and 2019 were dominated by ages 6 to 8 and 6 to 9, respectively (2010 to 2013 year classes; Table 6). The CPUE of fall spawning Herring increased in 2018 for both the North and Middle regions but decrease in the South. In 2019, the CPUE increased in the North and South, but decreased in the Middle region. Across regions, the CPUE of fall spawning younger fish (ages 4 and 5) has remained low since 2011 (Table 15; Figure 8).

3.3. 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 2018 and 2019 acoustic biomass index of the 4Tmno areas for spring and fall spawners combined were 23,313 t, and 18,826 t, respectively. In 2018, the biomass was composed of 35 % spring spawners and 65 % fall spawners. In 2019, the biomass was composed of 38 % spring spawners and 62 % 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. The acoustic survey estimated that catch rates (in numbers) of spring spawners ages 4 to 8 were lower in 2018 and 2019 than in 2017. The catch was dominated by age 4 in 2017, age 5 in 2018 and age 6 in 2019, indicating the 2013 cohort was relatively strong, as also seen in the CPUE index. All values were 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. Age 3 dominated the catch in 2018 (2015 year-class). The acoustic abundance of age 2 and 3 fall spawners was lower in 2019, among the lowest values of the time-series (Table 16; Figure 9).

3.4. EXPERIMENTAL NET INDICES

3.4.1. 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, 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 section 5.1.

3.4.2. Catch-at-age of experimental nets

In the previous assessment, experimental net catch rates were derived from a predictive model (Surette et al. 2016). After analyzing model structure and performance, three issues were identified: 1) the model wasn’t including trips with zero catches, 2) catches were standardized by soak time, but there is no significant relationship between the two and 3) residuals analysis showed severe blocking in estimation of young vs old ages. This index was then revisited. For this assessment, the observed catch at length of each mesh size was summed per day per region, and then the mean catch at length per region per year was calculated. The catch at age data was then constructed using age-length keys as described in 3.4.1. Samples with zero catches were included in the analysis and no correction factor was applied to the catch at age to account for soak time. The selectivity of the different mesh sizes was dealt with within the model (see section 5.1).

Previous assessment models used region-specific age-disaggregated abundance indices from experimental net data. Preliminary work on SCA models indicated that this index contained little information on biomass trends over time (Turcotte et al. 2020). Predicted annual age-aggregated biomass showed little correspondence with the observed indices, and thus the age-aggregated biomass index based on the experimental nets was not used in this assessment. However, information on age structure was considered adequate and the data on proportions-at-age was used in the modelling.

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. In recent years, proportions in the catch at age show greater catches of fish ages 6 to 8 in all regions (Figure 10).

3.5. MULTISPECIES BOTTOM TRAWL INDEX

This index consists of an age-disaggregated index using data from 1994-2019 for the fall spawners only (Table 19; Figure 12). As the index showed extreme high Herring catches for recent years, the index was revisited. After analyzing the catch outliers, evidence pointed out that the diel effect correction factor applied to the data was generating extreme catch values. This adjustment factor corrected for the low catchability/availability of Herring to the bottom trawl at night, when Herring tended to be distributed high in the water column. This coefficient was estimated using survey data from comparative surveys that took place in 1985 and 1992 (Benoît and Swain 2003). Since that period (and following Cod collapse), Herring has been shown to be more and more associated with the bottom in the sGSL, even at night (Annual 4T acoustic survey observations, McQuinn 2009). The application of that correction factor results in overestimation of Herring catches in night tows of the bottom-trawl survey. Thus, in this assessment, the diel adjustment factor was not used to calculate the bottom-trawl survey index (1994-2019).

Prior to this assessment, catch-at-age (mean number per standardized tow) of fall spawning Herring in the multispecies bottom-trawl survey was estimated using a Bayesian estimation model (Surette 2016). As this model used diel-corrected catch values (Surette 2016), and after analyzing the model outputs and predicted vs observed values diagnostic plots, it was decided to use the observed catch rates rather than those predicted from this model.

For this assessment, the annual stratified mean catch at age values (standardized for tow distance) from the survey are used as an index of abundance. This new index offers little difference in PAA 4 to 6, but removes the outliers in years 2010-2012 for the age-aggregated index (McDermid et al. 2018). The new global index suggests 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 in 2019 (Figure 12).

3.6. 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.

4. SPRING SPAWNER COMPONENT ASSESSMENT

In previous assessments, the spring spawners component was assessed using a virtual population analysis (VPA) model estimating time-varying catchability (*q*) in the CPUE of the commercial gillnet fishery (McDermid et al. 2018). For this assessment, SCA models with different assumptions about time-varying parameters were developed (Turcotte et al. 2020), and peer-reviewed by experts in population modeling on February 10 2020. Comments from reviewers and how the comments were incorporated in the assessment are shown in Appendix E. A best model was selected at the review and is the model used in this assessment.

The main differences between VPA and SCA are as follows: 1) VPA assumes that the fishery catch-at-age is known without error; SCA assumes that there is observation error in the PAA in the fishery catches. 2) VPA fits to the abundance indices at age and assumes that indices at different ages in the same year are independent. SCA fits to the age-aggregated biomass indices and to the PAA in the fishery and survey catches; this accounts for the lack of independence between catches at different ages in the same year. 3) VPA is projecting from abundance at age in the terminal (most recent) year; terminal abundances at age are parameters estimated in the model. SCA is forward projecting from abundance at age in the first year and at the first age in all years; these are estimated in the model, either as parameters (the approach used here) or by fitting a stock-recruit relationship.

The pre-assessment work examined two possible non-stationarities: time-varying natural mortality and time-varying catchability to the CPUE in the fixed gear fishery. Allowing fishery catchability and natural mortality to vary over time offered the best fit to indices, minimized the residuals and showed no retrospective pattern in SSB estimates (Turcotte et al. 2020). Fishery-dependent indices such as the commercial gillnet CPUE may not be proportional to abundance due to changes in catchability over time. For example, catch rates can remain high despite decreases in abundance (increased catchability) due to contractions in stock distribution and targeting of aggregations by fishing fleets, as well as due to improved fishing technology and fishing practices. 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 that raised many questions in the past is now 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.

4.1. SPRING SPAWNER MODEL

In this assessment, the spring spawners component is assessed using a SCA model 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 2019 in PAA;
- catch-per-unit-effort (CPUE) index PAA and age-aggregated biomass index from 1990 to 2019 (ages 4 to 10);
- fishery-independent acoustic survey index PAA and age-aggregated biomass index from 1994 to 2019 (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 (Appendix E).

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. 2020 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 2019 (*p* =3) (i.e $S_{1,p} = f\left(s_{1,a,t}\right)$ 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:

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

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 year1:

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

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

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

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

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 2019 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 (2015 to 2019).

4.2. SPRING SPAWNER RESULTS

Residual patterns indicated an acceptable fit of the model to the age-disaggregated CPUE and acoustic indices, without apparent blocking (Figure 13). Fits to the age-aggregated indices are good for both the CPUE and acoustic indices (Figure 14). 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 15).

Catchability to the CPUE index averaged about 0.0021 in the 1990s, increasing to a peak of approximately 0.0069 in 2006, and stabilizing at 0.0057 on average between 2015 and 2019 (Figure 16). Estimated CPUE index catchability increased as the SSB declined (Figure 17).

Natural mortality estimates for the age group 2-6 varied between 0.24 and 0.53 (between 21 % and 41 % annual mortality) over the time series (Figure 18). Estimates decreased slightly from 1978 to 1986, values were then stable until 1995 when *M* increased to reach its highest values between 2000 and 2009. *M* decreased from 0.53 in 2009 to 0.33 in 2015, and has stayed at that level up to 2019. For the age group 7-11+, *M* increased gradually from 0.29 to 0.52 (between 25 % and 41 % annual mortality) between 1978 and 2005 (Figure 18). Starting in 2011, estimates sharply increased to reach 1.03 in 2018 and 2019 (64 % annual mortality).

Abundances of a number of the key predators of Herring in the sGSL have changed dramatically during the time series (Figure 19). Atlantic Cod collapsed in the early 1990s and have declined further since then. Grey Seals have increased by over an order of magnitude over the time series. Atlantic Bluefin Tuna in the sGSL have increased about five-fold beginning in the mid-2000s. We expect that Cod prey primarily on the smaller herring and Grey Seals and Tuna on the larger Herring. Natural mortality for age group 2-6 did not seem to correlate with Atlantic Cod abundance (Pearson's $r = -0.21$), while the estimated *M* trend for age group 7-11+ significantly correlated with the summed Grey Seal and Atlantic Bluefin Tuna relative abundance trend over the same time period (Pearson's $r = 0.91$, Figure 19).

Models from this and previous assessments show estimates to the beginning of the year (January 1). Previous models assumed 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). This assessment is using a model estimating time-varying natural mortality, and it is very high in recent years. It is then 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, it is important to consider the status of the stock at the start of the fishery, i.e. how much of the January 1 SSB survives to the start of the fishery? April 1 SSB is lower, as expected, after removing natural mortality removals (Figure 20). The average difference is 8 %. In 2019, April 1 SSB was 4,291 t lower than January 1 SSB. That proportion of the fish population that was removed by natural mortality is not available to the fishery. Hence, April 1 was used in both models to show SSB, to 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., 1979-1983). Consequently, this value is model dependent. If the model changes, stock biomass may be re-scaled upwards or downwards. With the model change in 2020 including time-varying natural mortality, SSB was scaled upwards over the time series, as expected. The revised LRP is 47,250 t, which is 245 % higher than the former value of 19,250 t.

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, for this 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 132,546 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 80s to highest levels in the mid-80s to mid-90s. SSB declined in the mid-90s to reach the Critical Zone in 2002. SSB increased slightly until 2010, still in the Critical Zone, but then declined again afterwards. The MCMC estimates of

April 1 SSB in 2018 and 2019 were 40,134 t (95 % confidence interval: 26,119 – 63,709) and 33,010 t (95 % CI: 21,014 – 53,709), respectively. The estimate for 2019 is 70 % of the LRP. The probabilities that April 1 SSB was under the LRP (in the critical zone of the Precautionary Approach were 82 % in 2018 and 91 % in 2019 (Figure 21). SSB has been declining between 2017 and 2019.

Estimated recruitment (number of age 2 fish) was highest in the early 1980s, 1990 and 1993 (Figure 22). Recruitment has been relatively stable at lower values since 1993, with slightly higher values between 2005 and 2008. Recruitment declined to lowest values of the time-series after 2008 up to 2019, except a small peak in 2015. Recruitment rate (number of age 2 fish per kg SSB) was highest around 1980 and around 2005, and lowest between 1992 and 2000. Since 2005, recruitment rates have declined to low values except for a small peak in 2013 (Figure 24).

Estimated abundances of recruits to the fishery (age 4 fish) were highest in the mid-1980s, 1992 and 1995 (Figure 23). 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 (Figure 22; Table 20). The 2018 MCMC median spawner (4+) abundance estimate is 268.6 million Herring (95 % CI: 174.9 – 428.1), while the 2019 MCMC median is 245.8 million Herring (95 % CI: 156.4 – 398.2) about 35 % of the average spawner abundance in 1985 to 1995.

Estimated fishing mortality (abundance weighted F_{6-8}) was high in 1979-1980, decreased until 1984 and then increased steadily to over 0.5 in 2004. F then decreased rapidly to a low value (<0.05) in 2010 and has since remained at this low value (Figure 25; *F* values in Table 21). Fully recruited F_{6-8} median MCMC estimate was 0.041 (95 % CI: 0.026 – 0.065) and 0.047 (95 % CI: 0.029 – 0.076) in 2018 and 2019, respectively (annual mortality of 4 % and 5 %).

The spring spawning Herring population trajectory with respect to SSB and fishing mortality levels is shown in Figure 26. 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. Fishing mortality exceeded the removal reference level in 27 of the 42 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.

4.3. SPRING SPAWNER PROJECTIONS

The population model was projected forward to 2021, 2022 and 10 years forward to 2029 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 the average recruitment values of the last five years (2015-2019). 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. Projections were thus conducted using the average of the 2018-2019 *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 Figures 27 and 28, and the probabilities of meeting various objectives are given in Table 22 for each catch level, for ten years. Ten year SSB projections are shown in Figure 29.

Projected April 1 2020 SSB was 26,011 t (95 % CI: 15,541 – 44,409), putting the stock in the Critical Zone of the Precautionary Approach.

4.3.1. Short term projections

At annual catches of 0, 250, 500 or 1,250 t in 2020 and 2021, SSB was expected to increase slightly from 2020 to 2021, and to decrease slightly from 2021 to 2022 (Figure 27, Table 22). The probability of an increase in SSB between April 1 2020 and April 1 2021 was between 50 and 54 % at all catch levels. The probability of a greater than 5 % increase in SSB between April 1 2021 and April 1 2022 was between 32 % and 33 % at all catch levels. For the short term projections, all catch levels (including no catch) resulted in under a 7 % probability that SSB would exceed the LRP to reach the Cautious Zone in 2022. In the short term, there is no chance that the population would reach the USR by 2022.

Catches of 250 t would result in abundance-weighted age 6 to 8 fishing mortality (F) values of 0.021 in 2020 and 0.024 in 2021, lower values than F in recent years. Catches of 500 t would result in F values of 0.043 in 2020 and 0.050 in 2021, values similar to recent F. Catches of 1,225 t (the recent annual TAC) would result in an increase in F from recent years, with values of 0.108 in 2020 and 0.130 in 2021 (Figure 28, Table 22).

4.3.2. Long term projections

Ten years projections in SSB show a constant decline from 2020 to 2029. By 2029, the probability of exceeding the LRP was 0% at all catch levels, with SSB values ranging between 160 and 1,198 tons (Figure 29, Table 22).

5. FALL SPAWNER COMPONENT ASSESSMENT

5.1. FALL SPAWNER MODEL

In this assessment, the fall spawning Herring component is assessed using two SCA models (Turcotte et al. 2020) implemented using AD Model Builder (Fournier et al. 2012). Following the review of candidate models for the fall spawning Herring stock, it was decided to present two models because no best model could be selected based on model performance criteria alone. The models differed only in their treatment of natural mortality (*M*). One assumed that *M* was constant at 0.2 and the other estimated time-varying *M* for two age groups. Both models had advantages and disadvantages in model performance and biological considerations, which will be discussed in section 6. The models are named as follow:

- qSCA: estimates time-varying CPUE catchability (*q*), *M* is fixed at 0.2.
- qmSCA: estimates time varying CPUE *q* and natural mortality (*M*).

Data inputs to the models included:

- o fishery catches at age 2 to 11+ by region from 1978 to 2019, in PAA,
- o catch-per-unit-effort (CPUE) PAA index and age-aggregated CPUE biomass index by region from 1986 to 2019 (ages 4 to 10),
- o proportions at age (PAA) in experimental nets by region from 2002 to 2019 (ages 3 to 9),
- o fishery-independent acoustic survey PAA and age-aggregated biomass index from 1994-2019 (ages 2 and 3),
- o multispecies bottom trawl survey (RV survey) PAA index and age-aggregated biomass index across the sGSL from 1994 to 2019 (ages 4 to 6),
- o 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 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 2019 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. Fall SCA models had the same objective function components has described for the spring spawning Herring assessment model.

Size-at-age of 4T Herring has been in decline since at least the mid-1980s (Figure 6). 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 2019 and the experimental gillnet study from 2002 to 2019 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:

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

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 multimesh 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.

The procedure for converting selectivity at length to annual selectivity at age changed slightly from earlier years. Previously, selectivity at age *a* in year t was based on the length distribution of the CPUE catch at age *a* in year t. However, this calculation should be based on the length distribution at age *a* before selection by the fishery. We adopted this approach here, calculating the length distribution at age in the population before fishing by dividing the length distribution at age in the catch by the selectivity at length.

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 4, the RV survey biomass index 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).

5.2. FALL SPAWNER RESULTS

Some blocking was evident between observed and predicted fishery PAA in both models residuals. 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. Both models showed larger negative residuals for younger and older ages, and positive residuals for ages 5 to 8 in recent years. The Middle and South regions showed negative residuals in ages 5 and 6 between 1978 and 2006. Overall, both models showed larger residuals for ages 1, 2, 10 and 11. Residuals were generally smaller for ages between 3 and 7. The sum of squared residuals was lower for the qmSCA in all regions (Figure 30).

Residual patterns for the CPUE indices were not severe, indicating an adequate fit to these indices. There was a tendency to overestimate PAA 4 and 5, and underestimate PAA 6 to 9 in recent years, in all regions. However, there was no severe blocking of residuals. The sum of squared residuals for CPUE PAA was lower for the qmSCA model than the qSCA model in all regions (Figure 31).

Residual patterns were more important in the experimental net PAA, similar to those for these indices in the 2016 and 2018 assessment. Patterns were similar between regions and models. There was a block of negative residuals for ages 5 to 7 and positive residuals for younger and older ages between years 2002 and 2012. Residuals were mostly negative for ages 3 to 4 in recent years. The sum of squared residuals of experimental nets PAA were lower for the qmSCA model in all regions (Figure 32). No major residuals pattern is apparent in the RV survey and acoustic survey PAA and the sum of squared residuals were similar between models (Figure 33).

Fits to the age-aggregated CPUE indices were very good for both models and all regions, with predicted values consistent with the general trends in the indices (Figure 34). The fit to the age-aggregated RV index were reasonable for the qSCA and better for the qmSCA. The qSCA predicted values tended to underestimate observed values in early years of the index and in high biomass years (e.g., 2010 to 2014). The qmSCA predicted values tended to underestimate observed values in early years of the index, but the fit was good between 2010 and 2019 (Figure 35). The acoustic juvenile index was underestimated by both models in all high biomass years. The trend was similar for both models, but the qmSCA predicted higher values than the qSCA in 2006-2007 (Figure 35). Overall indices, the qmSCA showed a better fit.

Similar to previous assessments, retrospective patterns in SSB were apparent in both models of the fall spawning Herring stock. The qSCA showed a positive retrospective pattern in the North (Mohn's rho = 0.24), negative in the Middle (Mohn's rho = -0.25) and a weak negative pattern in the South (Mohn's rho = -0.09). The qSCA showed very little retrospective pattern in total SSB (Mohn's rho = 0.03). The qmSCA 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 -0.27, similar to the rho value in the qSCA, but in an opposite direction. The patterns were more severe in the Middle and South regions, were Mohn's rho values were -0.45 and -0.38, respectively. Total SSB showed a negative pattern with a Mohn's rho value of -0.36 (Figure 36). While patterns were still apparent in the North and Middle regions, the qSCA retrospective analysis was better than the qmSCA, and also better than retrospective patterns from previous assessments (Turcotte et al. 2020). Important negative retrospective patterns were also apparent in the natural mortality estimates in all regions (Figure 37).

Estimated changes in fully-recruited catchability to the gillnet fishery were generally higher in the qSCA, compared to the qmSCA model. Catchability increased in all regions between 1986 and 2000. In the North region, the qSCA and the qmSCA showed similar trends with an increase until 2000 followed by a decrease, but the qSCA estimates were larger over the time-series. In the Middle region, qmSCA estimates declined after the early 2000s to the lowest values around 2010, and increased slightly afterwards. The qSCA also decreased after 2000 but estimates increased rapidly starting in 2010. In the South region, qSCA estimates generally increased over the time series, whereas the qmSCA estimates were stable at low values, with a maximum around 2000 (Figure 38). In the qmSCA model, catchability increased as SSB declined, with some variation (Figure 39). In the qSCA, catchability increased as SSB declined with some variation in the North and with more variation in the South, but seemed to vary independently of SSB in the Middle region.

Natural mortality was fixed at 0.2 for the qSCA. In the qmSCA model, estimated *M* trends were similar within age groups between 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 40). Then, beginning near 1990, it began to decline, reaching very low levels in recent years (around 0.007 in all regions). For the age group 7-11+, estimates from all regions increased gradually from around 0.2 in the beginning year to between 0.25 and 0.3 in 2000. Starting in 2004, estimates sharply increased to reach a maximum of 0.98 in the North in 2017, 0.75 in the Middle in 2016 and 0.99 in South in 2016. Values levelled off to slightly lower *M* values in recent years in all regions (Figure 40).

It was expected that Cod prey primarily on the smaller herring and Grey Seals and Tuna on the larger Herring. The *M* estimates for age group 2-6 significantly correlated with the trend in Atlantic Cod sGSL abundance in the North (Pearson’s r = 0.95), Middle (Pearson’s r = 0.94) and South (Pearson’s r = 0.90) regions. For the age group 7-11+, the estimated *M* trends significantly correlated with the summed Grey seal and Atlantic Bluefin Tuna relative sGSL abundance indices in the North (Pearson’s r = 0.98), Middle (Pearson’s r = 0.98) and South (Pearson’s r = 0.99) regions (Figure 19).

This assessment used two models, one of them estimating time-varying natural mortality (qmSCA). Models from this assessment and the ones from previous assessments presented estimates at the beginning of the year (January 1). Previous models assumed a constant natural mortality of 0.2, meaning that January 1 SSB and August 1 were not so different, since few fish (about 18 %) were assumed to be removed from natural mortality throughout the year. This assessment is using a model estimating time-varying natural mortality, and it is estimated to be very high in recent years. Because of the very high estimates of natural mortality in recent years, we considered it informative to compare potential catch levels to the SSB surviving to August 1. As expected, August 1 SSB was lower (Figure 41). For the qSCA, the maximum difference between Jan 1 SSB and August 1 SSB was 16,624 t. For the qmSCA, the average difference was 11,979 t, and the maximum difference was 43,420 t in 2010. That proportion of the fish population that was removed by natural mortality is not available to the fishery. Hence, August 1 was used in both models to show SSB, to 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, calculated as the average of the 4 lowest SSB estimates in the early 1980s (i.e., 1980-1983). Consequently, this value is model dependent. If the model changes, stock biomass may be re-scaled upwards or downwards. With the model change in this assessment, there was a change in biomass in the 1980s in both models, as expected. The revised LRP for the qSCA was 45,589 t, a lower value than the former value of 58,000 t. The revised LRP for the qmSCA was 52,825 t.

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, the USR was recalculated for this assessment, as follows. Estimating natural mortality in the fall population models generated higher SSB estimates in the 2010s, compared to the pre-2000s and to the qSCA estimates. Previous assessments defined the Healthy Zone of the Precautionary Approach as SSB above the USR at 172,000 t. From this assessment it is now known that this USR was calculated from a period characterized by lower natural mortality and lower maximum SSB (1978-2001; 244,970 t). Natural mortality was between 3 and 6 times higher depending on region in the 2000s than before the 2000s and maximum total SSB was way higher at 594,798 t. When *M* increases, the level of SSB required for a stock to be healthy also must increase in order to accommodate the greater removals by the high *M*. Thus, the SSB level defining the Healthy Zone in the pre-2000s cannot be used in the high natural mortality period and has to be scaled upwards. The USR was 60 % of the maximum SSB in the lower mortality period (1978-2001). For the high natural mortality period (2002-2019), a second USR was calculated as 60 % of the maximum SSB in that period. The $USR_{1978\text{-}2001}$ was 141,730 t of SSB and $USR_{2002\text{-}2019}$ 335,345 t. To be comparable between models, the qSCA USR was also recalculated as 60 % of max SSB at 135,196 t. USRs were defined as interim values in 2005 and were never re-visited. Considering the new biological information available on both stocks, USR definitions should be updated in the future. However, as discussed in following sections, SSB has been declining since 2009 and is now very close to the LRP, without any probabilities of reaching the USR in the short-term or long-term projections. New interim USR values proposed for this assessment are then sufficient, considering stock status and projections. The LRP and USR were calculated to August 1 to account for seven 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 0.32 as used in previous assessments.

Estimated SSB trends were similar between models before the 2000s, but differed afterwards. 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 in both models. In the qSCA, values increased slightly between 2000 and 2016. SSB declined between 2017 and 2019. In the qmSCA, values increased slightly between 1999 and 2007, then increased rapidly between 2008 and 2013. SSB has been declining rapidly between 2014 and 2019 (Figure 42; Tables 23 to 26). In the Middle region, estimated SSB increased gradually from 1980 to the late 2000s, but has declined consistently from 2010 to 2019 to reach low levels in both models. The maximum SSB estimates around 2010 were higher in the qmSCA model, but with greater uncertainty (Figure 42; Tables 27 to 30). 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 the mid-2000s (qSCA) or early 2010s (qmSCA). In both models, SSB then declined to a low level by 2019 (Figure 42; Tables 31 to 34). Initial trends in total SSB were similar for both models 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. In the qSCA, SSB increased until the early 2000s, before declining to low levels until 2019. In the qmSCA, SSB increased until 2011 to reach a maximum, before rapidly decreasing until 2019 (Figure 42, Tables 35 to 38).

From the qSCA model, the MCMC estimates of August 1 SSB in 2018 and 2019 were 79,962 t (95 % confidence interval: 68,248 – 98,523) and 63,406 t (95 % CI: 52,374 – 80,692), respectively. The estimate for 2019 was 138 % of the LRP. The probabilities that August 1 SSB was under the LRP (in the Critical Zone of the Precautionary Approach) were 0 % in 2018 and 0 % in 2019. The probabilities that August 1 SSB was above the USR (in the Healthy Zone of the Precautionary Approach) were 0 % in 2018 and 0 % in 2019. SSB has been declining between 2017 and 2019 (Figure 42). For the qmSCA, the MCMC estimates of August 1 SSB in 2018 and 2019 were 210,945 t (95 % CI: 167,960 – 256,845) and 174,049 t (95 % CI: 135,029 – 212,670), respectively. The estimate for 2019 was 329 % of the LRP. The probabilities that August 1 SSB was under the LRP (in the Critical Zone of the Precautionary Approach) were 0 % in 2018 and 0 % in 2019. The probabilities that August 1 SSB was above the USR (in the Healthy Zone of the Precautionary Approach) were 0 % in 2018 and 0 % in 2019. SSB has been declining since 2011 (Figure 42).

For the North and South regions and for total recruitment in the qSCA model, recruitment generally increased from a very low value in 1978 to peak values in the early 2000s, except for sporadic poor recruitment in the late 1980s and early to mid-1990s (Figure 43). The Middle Region was the exception, with steady poor recruitment from 1978 to the late 1980s. In all regions and in total, recruitment then declined from high levels in the mid- to late 2000s to the lowest level on record in 2016 or 2017. Recruitment has remained very low since then, though uncertainty in the 2019 estimate is very high.

In the qSCA model, variation in estimated abundance of herring aged 4 years and older (4+) largely reflected variation in recruitment to age 4 (Figure 44). In all regions and in total, age 4 recruitment increased from very low levels in the late 1970s to the highest levels observed in the 2000s. Age 4 recruitment then declined, reaching very low levels in 2018 and 2019, comparable to the levels in the late 1970s. Patterns in recruitment to age 4 differed somewhat in the qmSCA model. Recruitment remained at low levels in most years until the late 1990s and then improved. Recruitment to age 4 was highest in the late 2000s but then declined, reaching very low levels comparable to those in the early 1970s by 2018 and 2019. Abundance at ages 4+ peaked around 2010 but then declined to low levels.

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 and models. Rates started declining in 2004 to reach values comparable to or lower than the lowest values of the time series. Uncertainty was high in 2019 recruitment rate estimates in both models. qmSCA estimates were generally greater than qSCA estimates (Figure 45).

For both models and all regions, selectivity to the CPUE fishery was flat-topped or very slightly dome-shaped early in the time series (Figure 46 and Figure 47). As size at age declined in the 1990s, selectivity increased for the oldest ages, and the dome and then the flat-top were lost, with selectivity increasing steadily with age. As size-at-age declined further, selectivity at age declined and the selectivity curve did not plateau at older ages. For the experimental nets, 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 age 4 and 8, with the plateau generally occurring at an older age in recent years when size-at-age was relatively low.

In the qSCA model, fishing mortality estimates generally increased when compared to previous assessments, as SSB estimates are smaller than for the qVPA used in the previous assessment (McDermid et al. 2018). Estimated abundance-weighted fishing mortality for ages 5 to 10 ($F_{5\text{-}10}$) declined in the North region since 2008, but in the Middle and South regions $F_{5\text{-}10}$ remained relatively high and consistent until 2019 (Figure 48). North region $F_{5\text{-}10}$ averaged 0.80 from 1995 to 2008, declining to an average of 0.27 for the period 2013 to 2019 (Table 39). In the Middle region, estimated $F_{5\text{-}10}$ averaged 0.42 from 1995 to 2019 (Table 41). In the South, estimated $F_{5\text{-}10}$ averaged 0.37 from 1995 to 2019 (Table 43). The weighted average $F_{5\text{-}10}$ over all three regions (weighted by regional abundance of 5 to 10 year olds) was highest in 1980, declined in the early 80s until the early 90s, to increase again to reach 0.78 in 1995. Total average $F_{5\text{-}10}$ then declined to reach 0.29 in 2019 (Figure 48, Table 45). qmSCA $F_{5\text{-}10}$ estimates were similar to qSCA estimates until SSB differed between the two models, in the mid-2000s. As SSB estimates are higher in the qmSCA, associated $F_{5\text{-}10}$ estimates are lower. Average $F_{5\text{-}10}$ decreased to an average value of 0.14 in the North region the last ten years (Table 40), 0.11 in the Middle region (Table 42) and 0.06 in the South region (Table 44). Total average $F_{5\text{-}10}$ in the qmSCA declined from the late-2000s to an average value of 0.11 in the 10 most recent years (Table 46). Total average $F_{5\text{-}10}$ in the qmSCA was 0.10 in 2018 and 0.13 in 2019 (Figure 48, Table 46).

The fall spawning Herring population trajectory with respect to SSB and fishing mortality levels is shown in Figure 49 for the qSCA model and in Figure 50 for the qmSCA model. The figures show the Healthy, Cautious and Critical Zones of the Precautionary Approach. The removal reference in the Healthy Zone for the fall stock is $F_{0.1}$ = 0.32. For the qSCA model, the stock was in the healthy zone (SSB > USR) in most years from 1984 to 2012, except 1996 to 1998, but has declined in the cautious zone (LRP<SSB<USR) since 2012. Fishing mortality exceeded the target level defined by the Precautionary Approach in 32 of the 42 years of the time series. 2018 and 2019 fishing mortality was above the Precautionary Approach removal reference (Figure 49). For the qmSCA model, the figures show the stock trajectory in the low natural mortality period (1978 to 2001), and in the high natural mortality period (2002 to 2019), with their corresponding USR values. In the low natural mortality period, fishing mortality exceeded the Precautionary Approach removal reference from 1978 to 1983, in 1990, and from 1994 to 2001. For the high natural mortality period, fishing mortality exceeded the Precautionary Approach removal reference from 2002 and 2003, and from 2005 to 2007. Fishing mortality was below the Precautionary Approach removal reference from 2008 to 2019 (Figure 50).

5.3. FALL SPAWNER PROJECTIONS

The population models were projected forward to August 1 2021 and August 1 2022 during the MCMC sampling of the joint posterior distribution of the parameters. This takes into account uncertainties in the parameter estimates. Recruitment has been stable at low values between 2016 and 2018, and possibly higher (with high uncertainty) in 2019, at a level similar to 2015. Projections were then conducted using the average recruitment values of the last five years (2015-2019). 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 2018-2019. Projections were conducted using the average of the 2018-2019 *M* values for each age group. Projections were conducted at annual catch options of 2,000 to 24,000 t in increments of 2,000 t. Two year projections of August 1 SSB and F5-10 are shown in Figures 51 and 52, and the probabilities of meeting various objectives are given in Tables 48 and 49 for each catch level, for each model, for ten years. Ten years SSB projections are shown in Figure 53.

Predicted August 1 2020 SSB was 63,925 t (95 % CI: 43,731 – 94,692) in the qSCA and 149,301 t (95 % CI: 97,179 – 217,401) in the qmSCA, putting the stock in the Cautious Zone of the Precautionary Approach in both models.

5.3.1. Short term projections

In both models projections, probabilities of increasing SSB by 2022 decreases as catch increases. In the qSCA projections, SSB was expected to increase slightly from 2020 to 2021 at all catch levels (probabilities of ≥ 5 % increase in SSB between 52 and 94 %), and expected to decrease from 2021 to 2022 at all catch levels (probabilities of ≥ 5 % increase in SSB between 24 and 47 % (Figure 51; Table 47). In the qmSCA projections, SSB was expected to decrease at all catch levels from 2020 to 2021 (probabilities of ≥ 5 % increase in SSB between 17 and 29 %), and from 2021 to 2022 (probabilities of ≥ 5 % increase in SSB between 23 and 29 % (Figure 51; Table 48).

At the target catch level in 2019 (16,000 t), the qSCA probabilities of a ≥ 5 % increase in SSB between 2020 and 2021 are 69 %, and 30 % between 2021 and 2022. The qmSCA probabilities are 22 % and 25 % chance of a ≥ 5 % increase in SSB in the same years. At 2,000 t of catch, the qSCA probabilities of a ≥ 5 % increase in SSB between 2020 and 2021 are 98 %, and 96 % between 2021 and 2022. The qmSCA probabilities are 29 % chance of a ≥ 5 % increase in SSB in the same years (Figure 51, Tables 47 and 48).

In the qSCA, probabilities of SSB being in the Critical Zone (under the LRP) by 2021 were between 0 and 2 %. Probabilities of SSB < LRP by 2022 increased with increasing catch options, with 0 % for 10,000 t of catch and under, and above 10 % at 18,000 t (Table 47). In the qmSCA, probabilities of SSB < LRP by 2021 and 2022 were 0 % (Table 48). In the short term, probabilities of SSB being in the Healthy Zone (SSB > USR) by 2022 were 0 % at all catch options in both models.

In the qSCA, at catch levels from 2,000 to 24,000 t in 2020, the median value of $F_{5\text{-}10}$ over all regions increased from 0.03 to 0.57. In 2021, the same catch levels showed $F_{5\text{-}10}$ between 0.03 and 0.88. At the target 2019 landings (16,000 t), projected $F_{5\text{-}10}$ is 0.33 in 2020 and 0.43 in 2021 (Figure 52, Table 47). In the qmSCA, at catch levels from 2,000 to 24,000 t in 2020, the median value of weighted average $F_{5\text{-}10}$ over all regions increased from 0.01 to 0.18. In 2021, the same catch levels showed $F_{5\text{-}10}$ between 0.02 and 0.30. At the target 2019 landings (16,000 t), projected $F_{5\text{-}10}$ is 0.11 in 2020 and 0.18 in 2021 (Figure 52, Table 48).

5.3.2. Long term projections

Ten-year SSB projections of both models show a constant decline from 2020 to 2029, with only the qSCA showing a small increase in SSB between 2020 and 2021 at lower catch options, followed by a decrease until 2029. No catch options would allow the stock to grow into the Healthy Zone within six years (2020 to 2025). Both models predicted SSB will be in the Critical Zone (SSB < LRP) by 2025 (Figure 53).

By 2029, at annual catch levels between 2,000 t and 24,000 t, the probability of SSB being in the Critical Zone was between 87 and 100 % in the qSCA and 100 % in the qmSCA (Figure 53, Tables 47-48). In the qSCA, predicted SSB in 2029 ranged from 0 and 27,000 t, depending on annual catch option. In the qmSCA, predicted SSB in 2029 ranged from 91 and 2,594 t, depending on annual catch option.

6. DISCUSSIONS AND CONCLUSIONS

6.1. SPRING SPAWNING HERRING

As with previous assessments, this assessment used a model for 4T spring spawning Herring that allowed catchability to the fishery to vary over time (Swain 2016, McDermid et al. 2018). 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.

For the first time for this stock, a population model also allowing natural mortality to vary over time was used in this assessment. Potential sources of natural mortality for both stocks 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. 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.

Natural mortality estimates 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, 2014a), seabirds (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). Of these major predators, Cod, Grey Seals and Tuna 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). The West Atlantic Bluefin Tuna stock biomass declined in the 1970s to its lowest level where it remained for more than two decades, followed by a gradual increase from 2004 to reach 60 % of the 1974 biomass in 2013 (ICCAT 2017). 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). 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). However, more analyses of their distribution, diet and the scale of the increase in abundance (cormorants) are necessary before drawing links with estimated Herring natural mortality. Information on consumption by cetaceans is also very scarce. For the spring spawning Herring stock, the increase in natural mortality for the age group 7-11+ correlates with the increases in the abundance indices of Grey Seal and Bluefin Tuna in the sGSL, the two most important Herring consumers in the sGSL (Benoit and Rail 2016, Tuna: unpublished results). Further analysis of the 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 decline in spring spawning Herring SSB in the 1990s and the following lack of recovery can be explained by the following points. 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 0.18 in 1997 to 0.53 in 2004. Fishing effort was reduced after 2004 and fishing mortality declined until 2012 and has been stable 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.

The decline in spring spawning Herring recruitment has been correlated with long-term changes in the sGSL temperature and composition of the zooplankton community, characterized by declining abundance of the cold-water copepods *Metridia longa* and *Calanus glacialis* and increasing abundance of small warm water copepods (Brosset et al. 2018). The current abundance of large, energy-rich cold-water copepods in the GSL during the spring season (Plourde et al. 2014) may not be sufficient to support strong recruitment events for spring spawners. Pelagic fish such as Herring often exhibit sporadic recruitment with a large fraction of forage fish recruitment dynamics not being driven strongly by SSB (Szuwalski et al. 2019), making long term projections highly uncertain. However, 4T spring spawning Herring recruitment has been stable at low values since 1994. Given the ongoing trend towards warmer conditions and associated shifts in the zooplankton abundance and composition in the sGSL (Blais et al. 2019; Galbraith et al. 2019), spring spawning Herring recruitment is not expected to increase in future years. The low reproductive success of this stock in a warming environment 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).

Under current recruitment, 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 reduces the probabilities of SSB decline in projections. As this stock has been in the Critical Zone since 2004, 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).

6.2. FALL SPAWNING HERRING

As in the previous assessment, this assessment used a model that treated fall spawning Herring as independent populations in three spawning regions. Past assessments used a Virtual Population Analysis (VPA) allowing catchability to the fixed gear fishery (q) to vary over time. For this assessment, SCA models allowing time-varying q, and also time-varying q and natural mortality (M) were developed and peer-reviewed (Turcotte et al. 2020). The model structure and performance review could not identify a single best model based on model performance alone, as the qmSCA showed better fit to indices, but the qSCA showed least retrospective patterns. Hence, both models are shown in the assessment, but their respective weaknesses need to be considered. Large changes in the abundance of predators of Herring have occurred in the sGSL over the past 30 years. The natural mortality of Herring is expected to have varied over time because of these changes. Models that incorporate time-varying M estimate changes in M that are consistent between populations and with the observed changes in predator abundance. If these estimates are correct, estimated parameters from the qSCA model are expected to be biased. This model would then provide over-optimistic SSB projections in the short-term, as natural mortality removals are not accounted for. Also, this model showed important retrospective patterns in the North and Middle regions. The qmSCA model is also biased as SSB is underestimated every year, as seen in the retrospective analysis pattern. As Mohn's rho negative value is consistent between the three regions and total SSB, the scale of the bias towards SSB underestimation can be expected to be similar over the regions and overall. As shown by the retrospective analysis of natural mortality estimates, 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. It may be inevitable unless highly informative data is added to the model to support quicker detections of *M* and SSB changes. The spawning grounds acoustic surveys biomass index may provide that information in future assessments, as enough years of data from this index will be available.

Based on biological considerations for the health of the stock, the qmSCA should be used to provide advice, as it is the most precautionary model. In terms of sustainability and cautious management decisions, underestimating SSB is less problematic than overestimating (as the qSCA is doing by not accounting for *M* removals). Results for both models were provided in the assessment to compare model performance and outcomes, but given current stock status and that it is predicted to decline below the LRP by 2025 under current conditions, the catch options risk analysis should use the most cautious model. The rationale for choosing the qmSCA projections for decision-making stands in the following points:

1. Time-varying *M* was estimated independently for four different population models (spring spawners, North, Middle and South region fall spawners), all showing very similar trends, as expected.
2. *M* for age group 7-11+ shows important changes over the time series, as expected from predator abundance information (see section 6.1). The timing, direction, and rate of change in M7-11+ trends for all models are very similar to the trend in combined major predator abundance change for the same time period. The trends in younger Herring *M* (ages 2-6) were also similar to Atlantic Cod abundance. It is possible to use auxiliary information or covariates to assist *M* estimation from the model (e.g. Marty et al. 2003; Deriso et al. 2008). Here, no covariate was provided to the model. However, the *M* estimates for all stocks were estimated independently and correlated with major Herring predator abundance in the sGSL.
3. The qmSCA model for the spring spawning Herring stock did not show a retrospective pattern, and the *M* trends in the fall stock models are almost identical. Predators effects on spring and fall Herring stocks were expected to be fairly similar.
4. Fisheries management is often based on the assumption that natural mortality is constant through time, yet numerous examples show that predator-prey interactions are dynamic (Lee et al. 2011; Thorson et al. 2015; Skern-Mauritzen et al. 2016; Jacobsen and Essington 2018; Siple et al. 2018). Failure to account for increases in natural mortality due to changes in predator-prey interactions in a stock assessment can result in biased estimates of population parameters and vital rates (Overholtz et al. 2008; Legault and Palmer 2015; Jacobsen and Essington 2018; Jacobsen et al. 2019).

As shown in the fall spawning Herring assessment, failing to account for natural mortality removals generates over-optimistic SSB projections in the short-term. At current catch levels (16,000 t), two year projections in SSB showed over 77 % chance of increasing SSB by 2021 in the qSCA, whereas the qmSCA probabilities of increasing SSB were only 30 %. This arises from two processes: 1) the high uncertainty in the 2019 recruitment value generates the possibility of an increase in SSB in the short-term and 2) fewer fish are removed from natural mortality in the qSCA, keeping SSB higher. Projections are more similar between models in the long-term. Both models showed a continuous decline in SSB until 2029, even in the lowest catch options of the qSCA model. Both models provided the same probabilities of SSB being under the LRP by 2029.

As expected, allowing natural mortality to vary over time generated increases in the qmSCA SSB estimates, especially in the 2000s. As high *M* values are estimated in this time period, much higher herring abundance are needed to accommodate the high loss of herring to natural mortality. This difference in estimated SSB between models is reflected in the recruitment peak in 2006-2008 (seen in the acoustic survey catch at age 2), which is higher in the qmSCA.

The variation in *q* appeared to be more density dependent in the qmSCA than in the qSCA. The qmSCA relationship between *q* and SSB is consistent with the spring spawning stock results and other Herring stocks (Winters and Wheeler 1985), where 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). As discussed in section 6.1, catchability to fisheries is expected to change over time for a number of reasons.

The decline in fall spawning Herring total SSB in the last decade can be explained by the following points. The number of age 2 recruits produced after the high value in 2006 declined rapidly to reach the lowest values of the time series in 2016, 2017 and 2018. The decrease in SSB started in 2011 and is constant until 2019. 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 an ensemble of variable conditions, 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 has been stable at low values since in the last four years (2016-2019). 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). Reducing fishing mortality slightly reduces the probabilities of decline in the short and long term projections. The annual catch level offering the greatest probabilities of increasing SSB in the short and long term is 2,000 t. However, long-term projections are provided with fixed annual catch rates. As the stock is assessed on a two-year cycle, catch options can be adjusted if the decline in SSB was to continue, modifying the outcomes of the projections. Also, the qmSCA model used for projections could be underestimating SSB, which provides pessimistic long-term projections. On the other hand, as SSB declines for a constant level of predation, natural mortality is expected to increase. Long-term projections for this stock are then uncertain and should be interpreted with caution.

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 observed low biomass of both 4T Herring stocks can have negative impacts on several components of the ecosystem.

Compared to previous assessments, uncertainty in SSB estimates are reduced in assessments of both the spring and the fall spawning stocks. Natural mortality estimation accounts for disappearing ages 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 crucial for projections accuracy, providing more realistic outcomes of management measures (Total Allowable Catch).

7. SOURCES OF UNCERTAINTY

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 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.

The estimation of time-varying natural mortality in the qmSCA model generated more important retrospective patterns in SSB compared to the qSCA. As recruitment, catchability and natural mortality are all allowed to be time-varying and selectivity is estimated in time-blocks, it is not likely that a change in the population dynamics isn't accounted for in the models. It is more likely that the source of the pattern is a conflict between the catch and indices age data or a time delay between a change in *M* and the implementation of this change in the model due to the penalty on changing *M*. Two data sources could be used to change or add data to the qmSCA model. 1) A broader range of ages in the current acoustic survey data could be explored. The current acoustic survey provides biomass at age for ages 2 and 3 only, but information is available for older ages. 2) Incorporating the spawning grounds acoustic survey data. The spawning grounds acoustic survey started in 2015 and now offers five years of data only. 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 populations models will provide a well-informed biomass index. Age-composition for the index will be obtained from the experimental nets survey, sampled at the same locations at the same frequency. Along with the addition of data, modeling catchability as density-dependant may also improve *M* estimation, and help removing the retrospective pattern in SSB estimates.

The retrospective pattern in the qmSCA model is a source of uncertainty. As Mohn's rho is similar between the three regions, 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).

Reference points, especially the USR and the F0.1 removal reference in the Healthy Zone, need to be re-visited for future assessments. 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*	-

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
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*	-
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*	-

		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
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*	-
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

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 2018 and 2019 catch and weight-at-age matrices for 4T Herring.

Gear/ Region	Fishery	Zone	Samples	N	Landings (tons)	% TAC landed
2018: Fixed Gear / Gillnets						
Spring						
North	Gaspé (16A) spring	4Tp	2	58	7.6	382.3
North	Chaleur (16B) April	4Tmn	6	158	92.9	145.2
North	Chaleur (16B) May-June	4Tmn	7	174	165.5	
Middle	WP.E.I. (16E) spring	4Tl	4	99	80.0	96.6
Middle	Northumberland Strait (16E) spring	4Th	6	152	100.6	
South	East P.E.I.	4Tgj	2	55	26.1	72.5
South	I. de la Madeleine (16D) spring	4Tf	0	0	3.9	111.6
Fall						
North	Gaspé (16A) fall	4Topq	0	0	1.3	4.2
North	Chaleur (16B) July	4Tmn	4	102	290.7	121.6
North	Chaleur (16B) August	4Tmn	7	143	3214.7	97.3
North	Chaleur (16B) September	4Tmn	6	132	5030.0	
Middle	Escuminac-WP.E.I. (16CE) July – September	4Tl	8	167	3900.7	105.7
South	I. de la Madeleine (16D) fall	4Tf	-	-	-	0.0
South	Pictou (16F) July – September	4Th	6	146	2003.9	78.4
South	Pictou (16F) October	4Th	2	57	427.3	
South	East P.E.I. (16G) August – October	4Tgj	0	0	408.4	20.2
Fixed gear		4T	60	1443	15753.5	62.5
2018: Mobile Gear						
South	Spring Edge fishery – Printemps June	4Tf	1	55	1246.0	100
North	East of Grande-Anse (16B) September-November	4Tmn	5	152	533.2	18.6
Mobile Gear		4T	6	207	1779.2	7.1
2019: Fixed Gear / Gillnets						
Spring						
North	Gaspé (16A) spring	4Tp	0	0	11.1	442.2
North	Chaleur (16B) April	4Tmn	5	120	50.6	187.86
North	Chaleur (16B) May-June	4Tmn	6	146	127.1	
Middle	WP.E.I. (16E) spring	4Tl	0	0	99.6	
Middle	Northumberland Strait (16E) spring	4Th	7	167	174.4	92.43
South	East P.E.I.	4Tgj	5	130	63.2	
South	I. de la Madeleine (16D) fall	4Tf	0	0	0.8	5.8
Fall						
North	Gaspé (16A) fall	4Topq	0	0	1.5	5.4

Gear/ Region	Fishery	Zone	Samples	N	Landings (tons)	% TAC landed
North	Chaleur (16B) July	4Tmn	3	76	243.1	120.8
North	Chaleur (16B) August	4Tmn	9	185	3766.5	97.2
North	Chaleur (16B) September	4Tmn	6	123	3767.4	
Middle	Escuminac-WP.E.I. (16CE) August	4Tl	2	40	771.8	102.1
Middle	Escuminac-WP.E.I. (16CE) September – October	4Tl	10	236	2514.5	
South	I. de la Madeleine (16D) fall	4Tf	2	48	4.7	2.7
South	Pictou (16F) September – October	4Th	8	167	2975.8	95.5
South	East P.E.I. (16G) August - September – October	4Tgj	2	51	801.9	24.9
Fixed gear		4T	65	1489	15374.0	91%
2019: Mobile Gear						
South	Spring Edge fishery – Printemps June	4Tf	0	0	0.0	0
North	East of Grande-Anse (16B) September-October-November	4Tmn	5	161	1162.5	23.8
Mobile Gear		4T	5	161	1162.5	26.2

Table 3. Comparison of 2018 and 2019 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 2018 and 2019, 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
2018							
Spring fishery							
South	1 - Magdalen Islands	DMP	-	-	-	-	-
		Phone	2	17	13.43	86	6
North	2- Quebec	DMP	-	-	-	-	-
		Phone	16	14.6	18.9	86	4.9
North	3- Acadian Peninsula	DMP	6	15.0	15.8	86	-
		Phone	7	14.4	19.3	86	6.4
Middle	4- Escuminac	DMP	7	11.4	16.9	89	-
		Phone	4	15.5	24.7	86	4
Middle	5- Southeast NB	DMP	30	12.8	20.3	86	-
		Phone	10	14.1	22.1	86	2.5
South	6- Nova Scotia	DMP	-	-	-	-	-
		Phone	-	-	-	-	-
South	7- East P.E.I.	DMP	-	-	-	-	-
		Phone	-	-	-	-	-
Middle	8- West P.E.I.	DMP	20	13.1	17.5	86	-
		Phone	5	13.2	19.8	87	4.8
Fall fishery							
South	1 - Magdalen Islands	DMP	1	14.0	-	-	-
		Phone	1	18	9.64	100	10
North	2- Quebec	DMP	22	14.0	-	-	-
		Phone	33	13.3	7.9	100	3.8
North	3- Acadian Peninsula	DMP	130	14.1	10.1	100	-
		Phone	56	13.5	7.6	100	3.7
Middle	4- Escuminac	DMP	14	14.6	9.8	100	-
		Phone	20	14.1	8.9	100	4.9
Middle	5- Southeast NB	DMP	1	14.1	10.7	100	-
		Phone	1	14.0	9.0	100	7
South	6- Nova Scotia	DMP	93	14.1	7.2	100	-
		Phone	33	15.1	6.4	100	4.9
South	7- East P.E.I.	DMP	11	13.6	9.2	100	-
		Phone	2	13.5	9.2	100	3.5
Middle	8- West P.E.I.	DMP	33	12.6	8.7	100	-
		Phone	3	14.0	8.8	100	6.7
2019							
Spring fishery							
South	1 - Magdalen Islands	DMP	-	-	-	-	-
		Phone	3	15.7	12.7	86	3.3
North	2- Quebec	DMP	-	-	-	-	-
		Phone	20	14.3	17.5	86	6.1
North	3- Acadian Peninsula	DMP	1	12.5	14.3	86	-
		Phone	7	14.1	18.8	86	5.9
Middle	4- Escuminac	DMP	8	14.7	23.5	86	-
		Phone	5	14.0	23.0	86	5.8
Middle	5- Southeast NB	DMP	16	14.5	22.4	86	-
		Phone	18	14.4	21.7	86	5.6
South	6- Nova Scotia	DMP	-	-	-	-	-
		Phone	-	-	-	-	-

Region	Telephone survey area	Source	Number of responses	Net length (fathom)	Number of nets set	% of 2⅝ mesh size	Comparison to previous year
South	7- East P.E.I.	DMP	1	16	17.1	86	-
		Phone	-	-	-	-	-
Middle	8- West P.E.I.	DMP	26	13.5	18.7	86	-
		Phone	10	13.3	20.0	86	5.3
Fall fishery							
South	1 - Magdalen Islands	DMP	2	14.0	-	-	-
		Phone	-	-	-	-	-
North	2- Quebec	DMP	28	14.0	-	-	-
		Phone	33	14.0	7.7	100	4.7
North	3- Acadian Peninsula	DMP	148	14.1	10.2	100	-
		Phone	36	13.9	7.8	100	4.4
Middle	4- Escuminac	DMP	17	14.0	9.6	100	-
		Phone	27	13.1	8.3	100	5.1
Middle	5- Southeast NB	DMP	3	14.8	11.7	100	-
		Phone	-	-	-	-	-
South	6- Nova Scotia	DMP	92	14.1	5.9	100	-
		Phone	32	15.5	6.3	100	8.8
South	7- East P.E.I.	DMP	19	13.3	8.5	100	-
		Phone	5	13.8	8.4	100	7.8
Middle	8- West P.E.I.	DMP	39	12.9	12.2	97	-
		Phone	9	13.0	8.2	100	6.2

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	603	1,338	416	327	107	14	0	3,079

Table 5. Spring spawner weight-at-age 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	0.15	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	0.182	0.186	0.213	-	-

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

	Catch-at-age											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
a) North												
1978	-	78	4,166	15,112	18,226	3,219	3,172	12,429	1,043	588	12,264	70,297
1979	-	2,747	7,055	9,223	5,480	4,247	1,301	1,314	2,248	511	2,845	36,971
1980	-	2,046	19,093	5,904	3,473	887	1,828	397	338	364	235	34,565
1981	-	38	4,140	13,002	2,853	596	244	278	56	99	60	21,366
1982	-	176	6,423	7,065	14,318	2,067	389	271	119	58	209	31,095
1983	-	4	238	9,387	3,795	9,056	1,026	415	99	16	103	24,139
1984	-	31	743	9,288	8,609	4,305	3,640	665	136	110	78	27,605
1985	-	50	1,361	4,630	17,980	12,369	6,822	6,303	3,334	843	6	53,698
1986	-	85	1,308	11,272	12,062	26,679	18,091	8,492	4,553	611	959	84,112
1987	-	958	9,069	25,621	15,424	14,506	23,181	12,544	6,238	3,192	1,089	111,822
1988	-	3,401	2,304	16,851	27,655	10,885	11,253	10,181	5,046	3,204	3,356	94,136
1989	-	721	1,217	14,051	23,624	25,115	11,942	6,677	8,284	4,011	3,148	98,790
1990	-	63	5,415	16,060	15,065	20,877	22,045	8,879	6,908	6,437	4,344	106,093
1991	-	0	4,344	42,760	9,956	6,009	8,962	8,250	2,638	1,762	2,904	87,585
1992	-	44	582	10,202	47,067	11,947	6,871	7,112	6,234	3,156	6,069	99,284
1993	-	298	4,311	4,345	24,023	28,219	4,387	2,460	2,516	1,540	1,772	73,871
1994	-	0	0	6,553	10,534	31,558	47,627	9,076	7,049	3,229	5,405	121,031
1995	-	0	1,738	6,333	39,879	15,572	32,348	34,437	5,907	3,469	3,940	143,623
1996	-	44	1,257	17,801	17,071	27,380	6,180	9,891	10,327	1,532	1,750	93,233
1997	-	88	1,479	11,613	33,452	10,224	10,099	1,848	3,271	2,758	874	75,706
1998	-	51	1,504	11,511	26,771	24,579	6,198	7,239	895	1,727	2,449	82,924
1999	-	690	7,392	30,630	29,595	32,392	11,766	2,850	1,817	545	629	118,306
2000	-	793	5,140	25,968	66,271	17,565	7,648	4,027	891	766	360	129,429
2001	-	1,194	7,118	27,441	34,008	33,879	5,257	2,541	788	175	249	112,650
2002	-	76	1,575	28,784	29,655	20,502	12,786	3,268	1,003	817	404	98,870
2003	-	0	4,767	21,265	29,962	20,051	14,752	17,730	4,407	2,061	1,267	116,262
2004	-	71	2,534	32,296	20,952	10,157	5,960	4,393	3,108	677	433	80,581
2005	-	802	3,145	14,180	63,862	24,200	8,867	4,859	3,020	2,067	221	125,223
2006	-	800	1,971	9,311	45,589	42,080	6,875	2,043	3,238	1,366	656	113,929
2007	-	1,491	15,022	9,848	18,055	37,702	25,449	5,486	1,033	891	572	115,549
2008	-	1,385	8,483	23,989	13,395	19,552	15,786	15,442	1,781	622	865	101,300
2009	-	179	5,180	28,524	40,887	10,914	10,705	6,167	1,707	302	253	104,818
2010	-	6	1,811	9,233	36,773	29,886	9,227	6,004	4,389	1,798	199	99,326
2011	-	1,177	749	3,757	8,691	29,240	25,258	3,118	3,147	2,909	779	78,825
2012	-	42	388	470	9,539	18,289	26,715	11,777	2,342	2,758	954	73,274
2013	-	527	447	3,957	10,840	31,420	22,142	11,196	2,536	201	108	83,374
2014	-	36	1,783	688	7,144	11,121	26,082	12,220	8,085	194	60	67,413
2015	-	229	1,252	466	2,966	20,616	14,344	17,718	5,721	1,135	226	64,673
2016	-	19	359	2,375	5,981	15,159	18,760	12,861	4,221	1,973	350	57,931
2017	-	112	102	637	5,314	7,943	14,284	16,573	5,793	2,069	364	52,829
2018	-	0	0	1162	10,667	14,010	11,400	5,411	2,135	787	1	45,573
2019	-	0	38	986	9,029	17,250	6,587	4,186	1,324	428	9	39,837
b) Middle												
1978	-	20	962	4,988	2,470	723	1,042	3,477	195	118	2,787	16,782
1979	-	0	144	3,673	2,048	3,849	901	2,115	1,898	1,314	7,211	23,153
1980	-	117	1,384	1,235	2,417	630	315	242	297	121	110	6,868
1981	-	2	1,001	6,248	1,912	1,150	461	629	31	83	238	11,755

	Catch-at-age											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1982	-	1	45	1,658	1,568	212	139	116	0	0	31	3,770
1983	-	98	3,334	7,272	2,507	2,772	520	168	57	14	14	16,756
1984	-	2	56	2,006	2,818	982	1,028	321	78	11	6	7,308
1985	-	0	11	235	1,370	1,010	562	536	200	41	1	3,966
1986	-	0	47	1,600	1,328	2,455	1,120	435	200	27	46	7,258
1987	-	1	300	935	1,761	1,533	3,063	292	267	299	19	8,470
1988	-	0	817	3,091	2,817	2,473	1,136	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	28	5,939	3,033	10,738	13,998	1,774	635	577	1,025	37,747
1995	-	0	0	214	10,009	3,408	12,249	10,646	1,363	243	4,272	42,404
1996	-	0	11	3,592	2,188	12,193	1,116	3,225	3,647	843	883	27,698
1997	-	0	285	4,835	10,979	1,980	4,125	782	938	1,026	639	25,589
1998	-	0	82	5,383	4,855	10,417	1,911	3,426	737	1,652	2,656	31,119
1999	-	0	0	9,710	12,903	5,104	3,222	1,303	2,854	278	1,330	36,704
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	595	9,546	8,399	7,636	7,127	1,310	172	146	220	35,151
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	36,226
2005	-	154	1,321	11,028	21,752	14,886	4,523	3,630	2,614	1,124	183	61,215
2006	-	1	28	1,890	8,314	13,874	5,124	2,613	1,949	1,544	523	35,860
2007	-	0	369	1,435	3,466	9,831	9,929	3,822	1,528	764	463	31,607
2008	-	0	1,426	12,175	2,575	4,491	5,326	8,515	1,536	1,451	332	37,827
2009	-	0	101	8,185	14,543	3,368	7,438	3,578	1,245	530	245	39,233
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	38,203
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	849	3,125	8,219	6,071	610	407	0	19,357
2019	-	0	0	103	187	1,689	5,691	2,696	3,532	1,081	216	15,195
c) South												
1978	-	1,283	17,975	6,591	2,989	994	1,523	2,940	587	693	4,015	39,590
1979	-	31	333	5,183	2,950	1,817	464	769	477	134	2,217	14,375
1980	-	467	26,206	12,367	21,714	9,522	4,666	1,134	1,224	1,154	712	79,166
1981	-	528	7,044	10,729	2,648	1,150	661	326	165	99	24	23,374
1982	-	0	354	7,033	3,642	3,229	2,347	820	333	82	38	17,878
1983	-	3	548	7,570	5,073	3,269	1,016	1,267	478	48	162	19,434
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	-	407	1,012	20,509	5,750	12,071	3,354	1,636	487	106	164	45,496
1987	-	5	1,093	11,149	12,826	6,146	14,119	6,233	4,296	1,856	1,324	59,047
1988	-	44	405	4,392	16,739	9,682	4,786	6,672	3,048	1,000	683	47,451
1989	-	0	33	1,355	2,076	8,332	4,204	1,803	2,446	622	300	21,171

Year	Catch-at-age										
	1	2	3	4	5	6	7	8	9	10	11+	total
1990	-	0	875	6,772	6,732	7,712	36,015	9,853	4,322	4,591	2,472	79,344
1991	-	0	11	4,956	1,670	1,339	1,201	3,899	1,365	840	1,190	16,471
1992	-	0	74	1,607	7,934	1,495	938	1,681	3,465	1,361	1,329	19,884
1993	-	0	0	302	3,227	3,902	982	405	586	485	1,123	11,012
1994	-	0	1	3,228	1,563	14,241	19,458	2,410	3,386	5,586	9,558	59,431
1995	-	6	466	555	9,072	3,004	13,104	11,620	2,814	3,199	7,433	51,273
1996	-	3	7	4,669	4,030	15,424	6,026	12,269	11,236	2,942	8,751	65,357
1997	-	16	672	4,225	24,096	2,776	9,954	1,688	3,329	3,017	2,766	52,539
1998	-	0	3	9,405	4,526	16,058	4,079	9,381	1,842	3,702	4,920	53,916
1999	-	23	936	10,886	35,641	6,475	14,436	4,031	4,840	1,612	2,826	81,706
2000	-	236	2,003	11,839	33,520	19,907	3,447	4,144	799	1,195	835	77,925
2001	-	831	6,279	4,653	27,094	25,726	15,492	3,327	2,429	684	1,134	87,649
2002	-	954	2,799	23,768	12,044	21,649	17,528	5,119	1,304	1,382	721	87,268
2003	-	201	4,095	11,042	48,276	10,210	18,279	12,323	3,244	565	738	108,973
2004	-	448	2,059	11,615	14,605	27,486	7,034	6,253	3,620	1,066	645	74,831
2005	-	0	3	424	12,345	20,406	31,839	6,051	6,169	1,732	385	79,354
2006	-	240	411	3,085	8,157	20,671	21,003	15,521	5,133	2,724	760	77,705
2007	-	0	562	301	9,253	13,640	24,798	15,408	4,955	2,952	941	72,810
2008	-	0	292	4,858	1,774	6,585	12,063	15,009	6,873	3,646	2,818	53,918
2009	-	0	411	2,398	20,654	10,345	20,617	6,815	3,615	5,240	2,610	72,705
2010	-	0	65	3,008	9,270	32,445	8,390	10,419	6,814	3,819	2,440	76,670
2011	-	0	1	312	7,530	7,478	25,275	8,102	4,030	2,350	4,185	59,263
2012	-	0	0	64	1,410	13,351	14,788	15,946	1,718	481	1,611	49,369
2013	-	18	15	1,843	3,131	12,655	24,697	9,433	5,318	312	207	57,629
2014	-	0	0	669	5,737	3,967	11,170	17,913	4,495	1,963	58	45,972
2015	-	0	61	359	2,207	11,323	5,712	13,762	4,082	2,100	261	39,867
2016	-	694	1819	1697	5,297	10,631	5,826	4,287	1,947	570	39	27,032
2017	-	105	100	424	411	3,834	7,528	2,667	1004	208	19	15,732
2018	-	0	0	25	1,043	4,285	4,227	4,893	938	439	77	15,927
2019	-	0	0	54	80	3,369	8,388	3,536	2,599	826	352	19,204

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

	Weight-at-age										
Year	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	-	-	0.118	0.171	0.197	0.207	0.225	0.231	0.247	0.271	0.213
2019	-	-	-	0.168	0.198	0.203	0.215	0.222	0.229	0.239	0.258
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
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

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
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
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
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

Year	Weight-at-age										
	1	2	3	4	5	6	7	8	9	10	11+
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

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

	Catch-at-age											
Year	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

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

	Weight-at-age										
Year	1	2	3	4	5	6	7	8	9	10	11+
1978	0.078	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	-	-

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

	Catch-at-age											
Year	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

	Catch-at-age											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
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
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
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

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
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
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
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

Year	Catch-at-age											
	1	2	3	4	5	6	7	8	9	10	11+	total
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

Table 11. Fall spawner weight-at-age 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

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

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	0.39	25.5	<0.0001	16.6	<0.0001	49.7	<0.0001
Fall spawner (FS)							
North region	0.56	3.2	<0.0001	17.8	<0.0001	-	-
Middle region	0.69	6.3	<0.0001	13.6	<0.0001	-	-
South region	0.51	4.3	<0.0001	12.4	<0.0001	-	-

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

	Age							
Year	4	5	6	7	8	9	10	11
1990	93.0	51.8	27.4	31.9	49.5	23.0	9.2	3.9
1991	94.2	113.7	73.5	25.5	23.3	35.8	13.2	8.8
1992	326.3	125.4	82.3	37.6	17.3	21.2	15.5	24.6
1993	45.9	337.4	153.6	40.9	20.1	11.5	5.9	22.8
1994	41.8	176.4	347.5	64.8	25.7	8.7	3.1	7.4
1995	118.3	95.6	157.6	256.5	56.8	15.8	10.3	20.1
1996	18.4	527.7	100.1	155.3	103.3	34.0	6.5	11.9
1997	73.1	54.7	508.1	93.5	55.7	52.9	13.6	2.4
1998	89.4	182.3	26.1	345.0	39.5	28.3	22.7	10.1
1999	72.5	103.4	113.2	24.8	176.4	28.4	14.8	12.7
2000	103.1	137.5	131.2	65.1	38.4	100.5	25.1	15.1
2001	111.1	128.4	96.8	48.3	33.0	13.6	64.7	17.0
2002	67.6	176.2	73.2	34.6	19.9	11.1	10.1	11.7
2003	119.5	122.8	142.4	43.6	27.5	11.1	7.6	8.4
2004	22.9	132.8	47.5	74.8	28.3	10.2	3.6	8.8
2005	64.6	57.0	102.7	45.5	35.9	10.0	2.2	3.1
2006	48.4	173.3	61.5	19.7	10.6	14.4	1.0	2.7
2007	82.7	63.4	94.3	70.5	32.6	7.9	6.0	4.5
2008	122.4	135.5	49.6	54.9	11.7	2.3	1.0	0.5
2009	72.1	166.5	206.5	23.4	23.8	6.2	0.4	1.0
2010	46.1	35.8	65.0	31.9	15.2	14.9	0.2	0.5
2011	6.6	50.7	46.5	63.1	29.3	44.8	16.5	0.3
2012	38.6	38.6	58.7	64.8	32.8	21.7	18.0	8.1
2013	30.5	97.0	116.6	150.4	115.0	82.0	5.0	3.9
2014	2.0	52.2	88.9	99.8	124.2	64.5	25.5	7.7
2015	11.6	17.6	88.3	134.7	60.3	44.7	8.6	4.6
2016	1.7	42.1	69.2	107.2	50.2	21.9	6.6	1.4
2017	59.7	63.4	168.0	137.4	102.6	23.4	4.2	0.3
2018	6.0	88.1	69.0	98.0	36.4	11.5	0.4	0.0
2019	26.9	62.1	137.6	42.8	33.6	11.0	1.4	0.0

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

		Age							
	Year	4	5	6	7	8	9	10	11
a) North									
	1986	105.4	103.4	233.1	163.2	77.4	35.4	4.8	8.2
	1987	192.6	116.3	105.5	157.3	72.0	43.6	19.2	6.0
	1988	112.2	192.7	74.0	65.6	60.1	32.0	15.5	15.1
	1989	186.4	304.1	325.0	158.0	72.4	91.1	40.8	32.5
	1990	68.9	62.9	97.7	103.6	39.2	27.4	28.9	20.7
	1991	485.7	123.5	91.1	135.2	129.4	41.6	26.0	42.5
	1992	74.1	449.8	128.6	75.0	81.6	71.8	34.6	65.3
	1993	30.5	313.2	363.2	51.0	28.5	29.3	8.3	10.6
	1994	40.7	65.5	196.1	295.9	56.4	43.8	20.1	33.6
	1995	17.8	129.4	59.9	144.6	153.5	26.8	17.2	18.8
	1996	83.3	100.7	135.5	29.8	56.6	61.7	8.7	10.2
	1997	91.3	314.5	97.0	86.4	16.6	28.9	25.9	7.5
	1998	56.8	155.7	148.6	37.2	35.4	5.1	8.3	15.0
	1999	122.9	147.9	183.9	65.3	12.9	8.2	2.2	3.2
	2000	153.3	500.0	133.0	56.0	30.7	6.0	4.4	2.0
	2001	147.2	186.1	191.7	29.3	13.2	3.6	1.1	1.5
	2002	187.1	204.7	143.5	77.2	20.2	6.0	4.1	1.6
	2003	85.8	180.5	121.2	85.4	102.0	25.5	11.2	7.0
	2004	212.7	158.7	77.1	46.7	36.2	24.8	5.7	3.9
	2005	48.1	537.3	214.1	82.5	45.5	27.3	19.4	1.8
	2006	16.6	102.9	99.8	14.8	4.2	7.9	3.1	1.6
	2007	35.8	106.0	241.0	165.7	35.4	6.6	6.2	3.9
	2008	66.0	42.0	67.1	54.4	52.6	6.4	2.1	3.1
	2009	120.6	205.7	56.6	56.0	32.6	9.1	1.6	1.4
	2010	18.2	155.4	134.1	46.4	31.0	24.4	9.9	1.2
	2011	8.3	31.8	133.5	120.9	13.7	15.7	14.2	3.9
	2012	1.1	62.3	127.8	190.5	85.2	17.0	19.9	6.9
	2013	9.2	78.8	254.0	182.2	93.6	20.1	1.6	0.9
	2014	1.7	80.9	178.3	444.8	204.8	138.5	1.8	1.1
	2015	2.4	69.9	496.7	369.4	445.2	138.4	22.0	5.9
	2016	19.5	80.5	219.2	271.3	189.2	61.6	28.9	5.0
	2017	7.9	74.9	113.0	203.4	236.0	82.5	29.5	5.2
	2018	0.0	18.5	222.4	269.3	210.0	101.8	36.6	4.4
	2019	1.1	14.3	242.5	453.9	157.8	109.5	35.1	11.5
b) Middle									
	1986	132.6	110.0	203.5	92.8	36.0	16.6	2.2	3.8
	1987	79.9	150.6	131.0	261.6	24.7	22.8	25.5	1.6
	1988	68.8	62.7	55.0	25.3	26.5	19.7	0.3	0.0
	1989	23.7	44.0	39.2	21.3	13.1	11.6	5.3	4.3
	1990	47.1	34.1	37.0	65.1	13.4	9.4	7.3	1.6
	1991	155.5	42.1	34.7	45.5	53.8	33.1	15.2	34.8
	1992	103.9	252.2	34.4	14.3	8.1	5.9	2.9	6.7
	1993	9.6	181.8	228.1	38.9	16.4	11.4	12.9	19.7
	1994	14.2	22.9	115.3	155.1	18.9	6.0	7.3	12.4
	1995	2.7	126.0	42.9	154.2	134.0	17.2	3.1	53.8
	1996	61.7	38.1	218.7	18.9	56.8	65.2	15.1	15.7
	1997	125.7	285.5	51.5	107.3	20.3	24.4	26.7	16.6
	1998	53.7	45.2	91.7	18.5	34.5	6.3	13.6	23.4
	1999	118.8	157.8	62.4	39.4	15.9	34.9	3.4	16.3
	2000	202.1	386.4	142.4	46.0	25.5	7.6	6.8	3.0

Year	Age 4	5	6	7	8	9	10	11
2001	108.6	267.3	189.6	57.4	12.4	4.1	0.0	5.8
2002	146.6	130.9	115.8	112.0	20.1	2.8	2.4	3.5
2003	85.2	178.7	83.6	56.4	56.4	12.7	1.7	2.3
2004	126.7	229.9	162.3	115.7	102.7	60.2	20.9	4.0
2005	54.2	334.2	270.6	81.4	70.1	48.3	20.6	1.5
2006	47.4	216.3	385.3	142.3	72.6	54.5	43.1	14.6
2007	51.0	146.2	405.5	418.4	159.3	64.3	31.3	19.4
2008	318.4	67.3	117.4	139.3	222.7	40.2	37.9	8.7
2009	154.3	274.2	63.5	140.3	67.5	23.5	10.0	4.6
2010	12.8	95.8	142.0	41.4	36.2	20.7	9.6	5.4
2011	4.4	22.8	132.8	170.5	32.5	24.4	22.9	6.9
2012	2.3	30.7	137.6	184.6	129.1	14.7	8.3	7.0
2013	17.0	32.3	202.4	302.5	185.4	71.5	5.8	1.2
2014	0.0	48.0	30.1	102.8	113.3	21.4	10.5	0.0
2015	7.0	44.4	425.0	189.0	320.8	126.2	44.8	0.0
2016	18.1	79.9	512.3	420.5	234.6	104.8	37.1	0.0
2017	2.1	17.3	60.0	111.6	137.1	78.0	10.7	0.4
2018	4.0	37.2	154.3	390.3	296.7	29.1	15.8	0.0
2019	4.3	7.8	70.8	238.4	112.9	148.0	45.3	9.0
c) South								
1986	475.8	133.8	280.9	78.0	38.1	11.3	2.5	3.8
1987	129.4	148.9	71.3	163.8	72.2	49.9	21.5	15.4
1988	61.0	233.5	135.1	66.4	92.8	42.4	13.8	9.3
1989	105.4	161.5	648.0	326.9	140.3	190.2	48.4	23.3
1990	109.0	108.3	124.1	579.4	158.5	69.5	73.9	39.8
1991	350.2	118.0	94.6	84.9	275.5	96.5	59.3	84.1
1992	99.2	554.4	80.3	46.9	112.2	248.1	92.2	97.8
1993	29.8	317.9	384.4	96.8	39.9	57.8	47.7	110.7
1994	35.5	7.5	242.9	335.3	45.5	59.8	127.7	212.1
1995	4.1	94.8	32.7	145.8	124.4	33.1	36.4	88.0
1996	44.0	26.4	172.8	62.0	144.5	137.9	35.2	107.0
1997	123.0	734.3	66.0	279.3	48.4	101.0	95.0	84.5
1998	122.7	57.7	205.3	51.8	116.2	22.9	44.8	55.2
1999	152.2	551.2	74.8	166.4	32.5	53.2	19.7	27.3
2000	117.9	460.5	274.8	44.8	53.6	10.4	16.7	10.4
2001	38.5	476.8	446.0	287.0	42.2	33.8	9.2	17.5
2002	379.3	160.9	363.8	302.4	91.0	23.0	19.8	11.7
2003	99.9	824.6	128.2	269.1	171.0	33.5	5.2	7.5
2004	111.1	256.4	564.3	111.5	102.5	50.1	13.8	7.2
2005	9.9	286.7	473.9	739.4	140.5	143.3	40.2	9.0
2006	77.0	210.9	553.1	569.0	422.8	139.5	74.2	20.7
2007	7.9	354.4	518.4	949.6	589.8	189.8	112.8	36.0
2008	129.9	47.4	176.0	322.5	401.2	183.7	97.5	75.3
2009	53.9	464.7	232.8	463.9	153.3	81.3	117.9	58.7
2010	47.8	201.1	737.4	191.8	238.9	156.4	87.7	56.0
2011	7.4	179.4	178.2	602.3	193.1	96.0	56.0	99.7
2012	0.3	12.8	138.3	156.5	166.9	17.8	5.1	17.1
2013	8.8	26.5	236.8	505.7	187.9	89.1	2.8	2.8
2014	5.6	92.1	73.8	290.7	516.6	113.6	55.1	1.9
2015	0.0	57.8	278.8	154.0	436.2	117.4	67.2	7.3
2016	2.4	27.4	85.2	46.7	34.4	15.6	4.6	0.3
2017	9.5	7.7	94.9	192.8	68.4	25.4	5.4	0.5
2018	0.5	17.6	81.3	77.1	91.9	17.2	6.6	1.5
2019	3.0	4.5	187.3	466.3	196.6	144.5	45.9	19.6

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

	Catch-at-age								
Year	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
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
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

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

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2 ⅝"														
1986	0.167	0.351	0.615	0.843	0.948	0.930	0.916	0.834	0.525	0.769	0.537	0.462	0.456	0.446
1987	0.391	0.488	0.601	0.816	0.944	0.946	0.893	0.831	0.769	0.672	0.559	0.391	0.391	0.391
1988	0.188	0.352	0.662	0.838	0.928	0.946	0.902	0.875	0.779	0.725	0.665	0.490	0.442	0.414
1989	0.288	0.404	0.652	0.885	0.964	0.960	0.854	0.829	0.737	0.773	0.558	0.561	0.508	0.405
1990	0.018	0.309	0.608	0.827	0.936	0.934	0.854	0.752	0.758	0.698	0.648	0.575	0.520	0.418
1991	0.216	0.376	0.515	0.755	0.911	0.934	0.924	0.897	0.786	0.743	0.667	0.525	0.424	0.411
1992	0.237	0.255	0.469	0.714	0.934	0.885	0.915	0.859	0.808	0.761	0.681	0.546	0.423	0.391
1993	0.156	0.156	0.441	0.634	0.835	0.938	0.911	0.865	0.830	0.770	0.705	0.713	0.633	0.391
1994	0.042	0.059	0.332	0.627	0.784	0.919	0.953	0.917	0.851	0.807	0.672	0.541	0.726	0.488
1995	0.118	0.425	0.407	0.534	0.681	0.860	0.939	0.915	0.861	0.806	0.834	0.691	0.577	0.434
1996	0.074	0.196	0.402	0.613	0.693	0.814	0.917	0.956	0.862	0.774	0.708	0.746	0.573	0.642
1997	0.029	0.098	0.316	0.559	0.731	0.862	0.937	0.954	0.959	0.832	0.688	0.629	0.704	0.470
1998	0.034	0.138	0.368	0.527	0.722	0.866	0.934	0.947	0.940	0.928	0.752	0.734	0.684	0.571
1999	0.065	0.085	0.323	0.538	0.633	0.814	0.898	0.952	0.929	0.920	0.756	0.601	0.684	0.442
2000	0.009	0.100	0.332	0.501	0.690	0.818	0.917	0.954	0.958	0.901	0.833	0.799	0.711	0.468
2001	0.009	0.069	0.298	0.480	0.630	0.790	0.891	0.957	0.944	0.951	0.896	0.797	0.575	0.501
2002	0.002	0.130	0.286	0.450	0.588	0.731	0.855	0.937	0.947	0.935	0.944	0.875	0.749	0.723
2003	0.050	0.216	0.291	0.433	0.591	0.728	0.829	0.909	0.935	0.959	0.912	0.924	0.694	0.391
2004	0.006	0.100	0.276	0.425	0.580	0.701	0.840	0.910	0.942	0.937	0.899	0.838	0.578	0.510
2005	0.001	0.059	0.239	0.430	0.542	0.643	0.798	0.872	0.915	0.919	0.931	0.852	0.588	0.510
2006	0.014	0.126	0.249	0.400	0.561	0.658	0.769	0.890	0.925	0.959	0.913	0.728	0.915	0.721
2007	0.021	0.049	0.284	0.398	0.558	0.687	0.766	0.838	0.909	0.894	0.903	0.968	0.659	0.373
2008	0.015	0.035	0.185	0.382	0.528	0.655	0.748	0.796	0.880	0.906	0.932	0.953	0.806	0.800
2009	0.024	0.082	0.216	0.319	0.515	0.652	0.754	0.830	0.855	0.883	0.943	0.943	0.956	0.810
2010	0.001	0.028	0.149	0.325	0.388	0.590	0.656	0.741	0.812	0.806	0.898	0.957	0.970	0.771
2011	0.014	0.025	0.098	0.271	0.430	0.470	0.672	0.726	0.806	0.862	0.852	0.917	0.900	0.730
2012	0.000	0.057	0.092	0.212	0.347	0.489	0.541	0.711	0.818	0.893	0.934	0.870	0.656	0.610
2013	0.014	0.032	0.095	0.256	0.342	0.444	0.550	0.602	0.755	0.913	0.853	0.969	0.957	0.948
2014	0.014	0.051	0.172	0.264	0.357	0.404	0.493	0.581	0.628	0.978	0.965	0.937	0.888	0.823
2015	0.008	0.070	0.148	0.298	0.341	0.465	0.516	0.606	0.664	0.797	0.789	0.733	0.700	0.681
2016	0.002	0.069	0.200	0.353	0.445	0.512	0.586	0.651	0.700	0.798	0.899	0.817	0.597	0.579
2017	0.048	0.268	0.210	0.311	0.446	0.525	0.598	0.671	0.775	0.785	0.821	0.749	0.650	0.557
2018	0.014	0.029	0.126	0.303	0.411	0.503	0.569	0.627	0.714	0.784	0.861	0.918	0.904	0.894
2019	0.010	0.017	0.092	0.200	0.351	0.453	0.551	0.606	0.680	0.763	0.842	0.914	0.883	0.883
2 3/4"														
1986	0.068	0.177	0.376	0.630	0.806	0.939	0.968	0.951	0.802	0.958	0.813	0.744	0.738	0.727
1987	0.030	0.266	0.363	0.584	0.809	0.900	0.962	0.942	0.901	0.893	0.821	0.670	0.670	0.670
1988	0.079	0.176	0.419	0.613	0.774	0.899	0.924	0.985	0.929	0.938	0.901	0.765	0.720	0.694
1989	0.132	0.207	0.412	0.693	0.822	0.944	0.966	0.957	0.926	0.950	0.823	0.826	0.774	0.692
1990	0.005	0.163	0.370	0.597	0.855	0.948	0.960	0.934	0.941	0.905	0.871	0.829	0.781	0.700
1991	0.093	0.191	0.292	0.509	0.715	0.933	0.958	0.963	0.955	0.928	0.889	0.793	0.704	0.691
1992	0.105	0.115	0.253	0.465	0.728	0.732	0.951	0.964	0.959	0.945	0.895	0.812	0.704	0.670
1993	0.063	0.063	0.233	0.392	0.602	0.774	0.877	0.969	0.961	0.921	0.905	0.916	0.879	0.670
1994	0.014	0.020	0.162	0.386	0.540	0.732	0.899	0.960	0.959	0.948	0.904	0.810	0.904	0.765
1995	0.059	0.222	0.212	0.306	0.453	0.651	0.776	0.904	0.967	0.948	0.970	0.899	0.841	0.715
1996	0.026	0.083	0.212	0.372	0.448	0.588	0.763	0.878	0.957	0.928	0.909	0.918	0.814	0.895
1997	0.009	0.037	0.155	0.331	0.481	0.640	0.767	0.855	0.931	0.934	0.899	0.870	0.925	0.752
1998	0.010	0.057	0.187	0.301	0.477	0.656	0.770	0.868	0.935	0.950	0.921	0.904	0.913	0.836
1999	0.022	0.031	0.158	0.309	0.396	0.585	0.687	0.878	0.915	0.947	0.937	0.853	0.876	0.724
2000	0.002	0.039	0.165	0.281	0.443	0.587	0.733	0.827	0.918	0.948	0.975	0.955	0.907	0.745
2001	0.002	0.025	0.143	0.265	0.387	0.550	0.683	0.817	0.912	0.912	0.946	0.936	0.823	0.764
2002	0.000	0.057	0.136	0.243	0.351	0.487	0.633	0.767	0.795	0.944	0.935	0.977	0.954	0.940
2003	0.017	0.104	0.140	0.232	0.354	0.482	0.604	0.723	0.824	0.917	0.975	0.976	0.896	0.670
2004	0.002	0.039	0.130	0.226	0.346	0.461	0.617	0.723	0.818	0.899	0.939	0.899	0.844	0.783

Year	Age													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2005	0.000	0.022	0.111	0.230	0.315	0.403	0.569	0.670	0.746	0.846	0.908	0.816	0.828	0.771
2006	0.030	0.050	0.115	0.209	0.333	0.419	0.534	0.698	0.762	0.833	0.870	0.947	0.968	0.943
2007	0.006	0.017	0.135	0.207	0.329	0.446	0.529	0.628	0.736	0.768	0.802	0.933	0.900	0.815
2008	0.005	0.013	0.080	0.199	0.307	0.417	0.510	0.565	0.678	0.735	0.825	0.936	0.956	0.949
2009	0.007	0.031	0.098	0.157	0.299	0.417	0.519	0.618	0.642	0.686	0.850	0.865	0.942	0.983
2010	0.000	0.009	0.064	0.161	0.202	0.364	0.428	0.511	0.592	0.603	0.760	0.882	0.925	0.966
2011	0.030	0.009	0.038	0.133	0.233	0.261	0.446	0.496	0.587	0.691	0.720	0.874	0.943	0.939
2012	0.000	0.022	0.035	0.094	0.175	0.274	0.314	0.478	0.595	0.716	0.846	0.807	0.890	0.859
2013	0.030	0.010	0.038	0.121	0.172	0.240	0.318	0.360	0.517	0.703	0.613	0.958	0.973	0.984
2014	0.030	0.018	0.071	0.125	0.181	0.211	0.275	0.344	0.385	0.934	0.813	0.942	0.947	0.951
2015	0.002	0.025	0.060	0.143	0.170	0.256	0.293	0.366	0.419	0.583	0.949	0.935	0.924	0.916
2016	0.001	0.026	0.092	0.179	0.242	0.292	0.351	0.407	0.453	0.581	0.754	0.624	0.854	0.845
2017	0.016	0.129	0.100	0.154	0.244	0.304	0.360	0.426	0.543	0.597	0.953	0.918	0.862	0.806
2018	0.030	0.009	0.049	0.151	0.218	0.284	0.333	0.382	0.464	0.543	0.662	0.983	0.990	0.995
2019	0.003	0.005	0.036	0.090	0.177	0.246	0.322	0.366	0.433	0.519	0.601	0.684	0.999	0.999

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

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	20,700	14,961	58,435	15,038	14,407	6,723	3,266	3,298	3,471	8,961	113,599
1979	38,657	17,441	11,114	33,931	8,292	8,290	4,104	2,103	1,964	7,223	77,021
1980	39,622	22,779	11,102	5,988	15,803	3,638	3,973	1,946	1,086	4,308	47,844
1981	91,466	27,879	13,985	6,020	3,321	7,754	1,856	1,958	958	2,782	38,635
1982	104,928	69,504	20,001	10,222	4,372	2,408	5,310	1,303	1,444	2,386	47,446
1983	84,481	85,713	53,119	14,774	6,717	3,060	1,229	3,626	874	2,387	85,787
1984	63,305	73,304	71,315	39,206	11,213	4,972	2,065	728	2,234	2,001	133,733
1985	34,488	74,347	62,000	60,929	31,451	9,019	3,438	1,293	607	2,579	171,316
1986	24,418	34,795	73,619	52,269	50,321	26,199	6,003	2,012	765	2,093	213,280
1987	39,088	24,089	30,949	57,394	41,821	38,650	16,302	3,403	1,143	1,627	191,287
1988	31,506	31,426	20,612	23,931	43,741	30,841	23,104	9,617	1,880	1,538	155,266
1989	63,324	39,288	26,080	15,152	17,765	32,015	17,246	12,691	5,161	1,796	127,905
1990	213,027	64,028	39,291	21,637	11,562	12,835	17,795	9,477	6,930	3,561	123,088
1991	82,838	155,411	54,907	30,610	15,207	7,692	7,118	9,390	5,055	5,776	135,755
1992	40,044	62,627	115,242	40,119	20,239	9,232	4,163	3,781	4,969	5,599	203,344
1993	114,191	37,795	50,077	85,480	27,690	13,334	5,368	2,367	2,135	5,781	192,232
1994	22,631	117,139	32,942	39,133	59,751	17,964	7,421	3,112	1,278	4,294	165,895
1995	25,867	17,524	108,207	25,820	27,706	40,497	10,068	4,070	1,708	2,826	220,903
1996	29,005	30,863	14,828	83,224	18,304	18,211	20,889	4,908	2,037	2,104	164,506
1997	35,867	28,452	28,977	11,576	58,632	12,092	9,406	10,593	2,331	2,031	135,639
1998	31,184	29,274	23,952	20,778	7,556	38,859	6,454	4,962	5,402	2,202	110,165
1999	47,120	27,861	22,803	17,064	13,467	4,725	20,437	3,443	2,534	3,804	88,277
2000	26,224	37,929	21,615	15,558	10,276	7,397	2,521	10,495	1,714	3,090	72,665
2001	30,001	18,158	27,359	13,543	7,948	4,726	3,216	1,077	4,423	1,928	64,219
2002	14,380	22,882	12,252	16,626	6,786	3,573	2,004	1,347	434	2,572	45,594
2003	29,584	11,789	16,004	7,496	8,501	3,158	1,531	839	556	1,215	39,300
2004	23,794	24,946	8,258	9,315	3,615	3,666	1,240	583	309	639	27,624
2005	36,844	18,963	18,492	4,750	4,352	1,460	1,327	425	202	322	31,330
2006	38,336	26,194	13,457	11,892	2,851	2,206	566	446	146	149	31,713
2007	42,175	30,882	18,877	8,904	7,563	1,616	991	257	182	115	38,505
2008	61,833	30,825	22,667	12,372	5,446	4,176	729	393	107	114	46,003
2009	36,739	39,939	21,305	14,173	7,101	2,950	2,133	392	178	97	48,328
2010	35,282	23,587	24,977	12,854	8,497	4,127	1,800	1,232	216	151	53,854
2011	15,819	23,258	14,540	16,235	7,719	5,220	2,621	1,113	676	188	48,312
2012	13,202	15,820	16,913	9,967	10,249	4,893	2,807	1,361	587	447	47,224
2013	15,420	13,304	13,821	12,774	7,516	6,935	2,753	1,512	723	583	46,617
2014	13,902	13,547	11,960	10,532	9,300	5,309	3,646	1,390	764	605	43,506
2015	33,049	11,393	11,049	9,099	7,830	6,688	2,491	1,740	630	652	40,180
2016	13,821	27,819	9,610	8,367	6,762	5,420	2,650	975	683	455	34,922
2017	16,040	13,012	22,739	7,752	6,634	5,012	2,016	940	352	399	45,845
2018	6,310	12,875	10,341	18,339	6,017	5,089	1,822	710	341	259	42,919
2019	20,671	5,393	10,307	7,561	14,102	4,449	1,757	645	252	208	39,283

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	183,189	105,357	274,470	64,959	56,190	23,223	11,002	9,917	9,473	24,233	473,467
1979	218,402	115,583	60,863	144,327	33,435	28,845	13,649	6,466	5,829	19,810	313,223
1980	265,385	134,313	60,239	26,589	60,570	13,962	13,720	6,492	3,075	12,194	196,840
1981	626,906	164,673	70,453	26,417	11,194	25,372	6,496	6,383	3,020	7,104	156,439
1982	834,746	413,466	102,305	41,067	15,177	6,420	15,223	3,898	3,830	6,074	193,993
1983	636,155	573,333	273,527	65,026	25,866	9,548	3,982	9,443	2,418	6,144	395,955
1984	667,774	449,994	390,765	179,188	42,216	16,774	5,803	2,420	5,739	5,203	648,109
1985	288,120	485,925	321,743	274,206	125,203	29,482	10,513	3,637	1,517	6,858	773,159
1986	194,719	213,076	351,236	226,961	192,357	87,771	17,902	6,384	2,208	5,085	889,904
1987	259,720	145,464	153,211	242,475	155,236	131,417	50,252	10,249	3,655	4,176	750,671
1988	361,311	195,680	103,789	103,153	161,109	102,976	70,548	26,976	5,502	4,204	578,256
1989	518,625	272,642	137,844	67,945	66,410	103,508	53,080	36,364	13,905	5,003	484,058
1990	1,219,390	390,417	192,790	91,181	44,266	43,185	55,384	28,401	19,456	10,116	484,779
1991	583,774	916,337	289,745	136,653	59,753	27,728	23,215	29,697	15,221	15,848	597,858
1992	387,269	432,506	669,624	201,298	87,085	36,233	15,002	12,525	16,014	16,752	1,054,533
1993	1,229,180	285,673	315,547	469,153	131,607	54,714	20,474	8,458	7,059	18,465	1,025,476
1994	159,595	913,011	209,685	221,715	305,946	82,217	29,674	11,077	4,574	13,802	878,690
1995	310,532	118,969	671,678	146,957	143,035	188,185	42,144	15,170	5,660	9,388	1,222,217
1996	288,611	232,402	87,742	469,399	93,673	86,471	89,308	19,941	7,174	7,116	860,824
1997	308,670	213,765	169,851	61,055	300,370	57,119	40,860	42,087	9,393	6,730	687,465
1998	326,195	221,437	151,499	115,112	38,336	180,490	27,937	19,936	20,525	7,862	561,697
1999	445,370	223,069	149,334	97,066	67,573	21,399	88,472	13,656	9,739	13,866	461,105
2000	210,637	286,254	140,907	88,500	51,585	33,728	10,292	42,403	6,541	11,305	385,260
2001	283,559	131,293	173,598	77,256	40,845	21,561	13,683	4,152	17,090	7,190	355,375
2002	157,508	174,940	78,693	93,563	34,728	16,540	8,326	5,253	1,592	9,309	248,004
2003	353,452	96,390	104,397	42,811	43,460	14,729	6,618	3,314	2,089	4,334	221,753
2004	245,298	213,392	56,485	54,826	18,644	16,994	5,364	2,396	1,198	2,322	158,229
2005	330,737	149,669	125,795	29,339	22,940	6,888	5,518	1,730	771	1,133	194,115
2006	396,441	202,738	90,195	72,555	15,388	10,392	2,410	1,777	537	582	193,835
2007	392,330	245,288	124,436	54,228	41,713	8,257	4,549	1,015	736	460	235,393
2008	501,074	239,508	148,052	72,946	29,839	20,819	3,383	1,764	384	448	277,634
2009	333,994	297,831	141,376	85,846	40,692	15,682	10,138	1,593	819	383	296,527
2010	340,890	191,300	169,912	79,836	47,417	21,723	8,743	5,544	864	649	334,688
2011	239,676	201,896	112,975	99,604	46,056	26,687	12,411	4,926	3,105	845	306,607
2012	195,872	151,388	127,163	70,638	61,298	27,660	14,528	6,664	2,629	2,103	312,682
2013	174,241	129,672	100,082	83,763	46,166	39,581	14,815	7,728	3,534	2,506	298,176
2014	151,772	119,145	88,397	67,687	55,686	29,890	18,813	6,937	3,595	2,802	273,808
2015	343,548	105,983	83,013	61,234	46,303	37,365	13,307	8,285	3,040	2,798	255,344
2016	152,889	244,885	75,369	58,678	42,719	31,657	14,474	5,096	3,157	2,220	233,370
2017	153,932	109,440	174,913	53,535	41,181	29,430	11,296	5,111	1,791	1,886	319,144
2018	64,849	109,574	77,695	123,329	37,190	27,960	10,057	3,811	1,714	1,230	282,987
2019	205,071	46,013	77,615	54,792	86,148	25,599	9,393	3,351	1,265	976	259,138

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	0.021	0.109	0.203	0.225	0.227	0.228	0.228	0.228	0.228	0.228	0.228
1979	0.040	0.205	0.382	0.422	0.427	0.427	0.427	0.427	0.427	0.427	0.427
1980	0.040	0.208	0.387	0.428	0.433	0.434	0.434	0.434	0.434	0.434	0.433
1981	0.014	0.074	0.138	0.152	0.154	0.154	0.154	0.154	0.154	0.154	0.154
1982	0.009	0.046	0.086	0.096	0.097	0.097	0.097	0.097	0.097	0.097	0.097
1983	0.009	0.046	0.086	0.095	0.096	0.096	0.096	0.096	0.096	0.096	0.096
1984	0.004	0.022	0.041	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1985	0.005	0.028	0.053	0.058	0.059	0.059	0.059	0.059	0.059	0.059	0.059
1986	0.009	0.047	0.088	0.097	0.099	0.099	0.099	0.099	0.099	0.099	0.099
1987	0.013	0.067	0.126	0.139	0.140	0.141	0.141	0.141	0.141	0.141	0.140
1988	0.016	0.085	0.159	0.175	0.177	0.178	0.178	0.178	0.178	0.178	0.177
1989	0.015	0.078	0.144	0.160	0.161	0.162	0.162	0.162	0.162	0.162	0.162
1990	0.003	0.016	0.062	0.140	0.185	0.197	0.200	0.200	0.201	0.201	0.195
1991	0.004	0.017	0.068	0.154	0.204	0.217	0.220	0.221	0.221	0.221	0.211
1992	0.003	0.014	0.054	0.124	0.163	0.174	0.176	0.177	0.177	0.177	0.168
1993	0.003	0.015	0.059	0.133	0.176	0.188	0.190	0.191	0.191	0.191	0.181
1994	0.003	0.017	0.065	0.148	0.196	0.208	0.211	0.212	0.212	0.212	0.199
1995	0.004	0.018	0.072	0.164	0.217	0.232	0.234	0.235	0.235	0.235	0.226
1996	0.003	0.017	0.066	0.150	0.198	0.211	0.214	0.214	0.214	0.214	0.207
1997	0.003	0.015	0.060	0.136	0.180	0.192	0.195	0.195	0.195	0.195	0.183
1998	0.004	0.018	0.069	0.156	0.207	0.220	0.223	0.224	0.224	0.224	0.218
1999	0.004	0.022	0.086	0.195	0.257	0.274	0.278	0.278	0.279	0.279	0.270
2000	0.007	0.034	0.135	0.308	0.407	0.433	0.439	0.440	0.440	0.440	0.420
2001	0.007	0.036	0.143	0.324	0.428	0.457	0.462	0.464	0.464	0.464	0.443
2002	0.006	0.032	0.124	0.282	0.373	0.398	0.403	0.404	0.404	0.404	0.384
2003	0.008	0.037	0.147	0.334	0.442	0.471	0.477	0.478	0.479	0.479	0.452
2004	0.009	0.043	0.170	0.386	0.511	0.544	0.551	0.552	0.553	0.553	0.530
2005	0.010	0.027	0.070	0.165	0.312	0.451	0.533	0.570	0.584	0.588	0.374
2006	0.004	0.013	0.033	0.078	0.147	0.212	0.251	0.268	0.275	0.277	0.180
2007	0.006	0.018	0.047	0.110	0.208	0.300	0.355	0.379	0.389	0.392	0.234
2008	0.004	0.011	0.029	0.067	0.127	0.183	0.217	0.232	0.237	0.239	0.154
2009	0.002	0.006	0.016	0.039	0.073	0.105	0.124	0.133	0.136	0.137	0.088
2010	0.002	0.004	0.012	0.028	0.053	0.076	0.090	0.096	0.098	0.099	0.063
2011	0.002	0.004	0.012	0.028	0.052	0.075	0.089	0.095	0.097	0.098	0.065
2012	0.001	0.002	0.006	0.014	0.026	0.037	0.044	0.047	0.048	0.049	0.031
2013	0.002	0.005	0.013	0.030	0.056	0.081	0.096	0.103	0.105	0.106	0.072
2014	0.001	0.004	0.009	0.022	0.041	0.059	0.070	0.075	0.077	0.078	0.052
2015	0.001	0.004	0.010	0.023	0.043	0.062	0.074	0.079	0.080	0.081	0.055
2016	0.001	0.003	0.009	0.021	0.039	0.057	0.068	0.072	0.074	0.075	0.050
2017	0.001	0.004	0.011	0.026	0.049	0.071	0.083	0.089	0.091	0.092	0.061
2018	0.001	0.003	0.007	0.017	0.031	0.045	0.054	0.057	0.059	0.059	0.039
2019	0.001	0.003	0.009	0.021	0.039	0.057	0.067	0.072	0.074	0.074	0.045

Table 22. Risk analysis table of annual catch options (between 0 and 1,250 t) for 2020 and 2021 and subsequent years until 2028, with predicted resulting SSB (kt) in 2021, 2022 and 2029, 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_{6-8}) 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)	2021	28.2	28.0	27.9	27.4
	2022	25.2	25.0	24.8	24.0
	2029	1.2	1.0	0.7	0.2
SSB > LRP	2021	7%	6%	6%	6%
	2022	7%	6%	6%	6%
	2029	0%	0%	0%	0%
5% increase in SSB	2021	54%	53%	53%	50%
	2022	32%	33%	33%	32%
F_{6-8}	2020	0	0.02	0.04	0.10
	2021	0	0.02	0.05	0.13

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	11,364	6,663	7,782	5,698	3,712	2,706	2,965	928	689	1,825	26,305
1979	12,037	7,995	4,407	2,341	1,465	833	711	702	239	556	11,254
1980	9,854	14,133	4,688	1,700	784	460	263	222	215	258	8,590
1981	24,966	16,562	13,065	2,728	850	393	229	136	107	221	17,728
1982	13,917	22,108	20,533	10,103	1,784	510	231	135	80	183	33,560
1983	11,589	22,056	21,243	15,168	6,484	1,093	309	128	82	148	44,654
1984	14,569	18,983	28,748	19,008	11,495	4,723	789	218	85	172	65,237
1985	14,788	21,564	22,777	26,676	15,181	8,914	3,568	580	158	185	78,040
1986	17,237	24,964	26,738	18,788	19,230	10,745	6,050	2,349	379	209	84,489
1987	17,960	29,149	32,721	20,505	12,498	11,713	6,347	3,514	1,348	327	88,974
1988	10,080	20,119	34,972	23,736	11,341	6,681	6,173	3,245	1,780	845	88,773
1989	25,655	15,118	23,208	24,905	14,841	6,837	3,890	3,492	1,848	1,455	80,476
1990	29,533	38,728	18,948	18,222	14,362	8,337	3,744	2,080	1,863	1,750	69,305
1991	10,634	31,993	44,358	12,440	8,905	6,760	3,846	1,689	915	1,590	80,502
1992	14,015	12,960	33,812	32,789	7,456	5,199	3,866	2,149	932	1,367	87,569
1993	8,703	20,587	13,744	25,725	19,176	4,203	2,871	2,099	1,113	1,185	70,116
1994	13,021	12,847	27,963	12,307	17,096	12,148	2,636	1,797	1,254	1,401	76,603
1995	10,086	17,152	15,957	18,315	5,723	7,499	5,237	1,141	770	1,110	55,752
1996	11,374	12,792	19,950	7,854	5,313	1,588	2,095	1,438	319	517	39,074
1997	15,259	15,107	14,565	11,684	3,005	1,919	571	729	497	271	33,240
1998	13,073	22,223	16,643	8,888	4,667	1,153	721	220	271	274	32,837
1999	10,474	18,097	27,713	9,630	3,629	1,810	430	277	82	194	43,765
2000	9,774	16,337	22,122	17,554	3,951	1,402	695	159	104	99	46,084
2001	8,964	13,796	20,899	13,758	7,113	1,507	531	253	61	73	44,196
2002	19,601	14,802	17,757	13,831	6,255	3,065	632	227	104	56	41,927
2003	20,148	26,713	18,144	11,995	6,181	2,702	1,303	266	95	65	40,751
2004	15,868	25,452	29,019	8,763	3,774	1,851	802	387	80	47	44,722
2005	8,074	18,625	27,058	20,676	4,873	1,973	975	410	193	60	56,218
2006	14,875	11,168	21,222	18,182	10,147	2,283	896	450	183	112	53,476
2007	23,474	19,577	13,263	17,199	8,462	3,581	776	309	150	99	43,838
2008	17,641	22,104	25,190	9,143	5,645	2,191	973	188	91	70	43,491
2009	21,966	26,985	37,019	19,413	4,794	2,529	931	333	77	44	65,140
2010	15,926	23,174	23,316	23,405	8,492	1,655	828	303	117	42	58,159
2011	18,264	14,444	23,706	19,242	12,224	3,812	724	358	128	71	60,265
2012	9,349	23,109	13,998	21,053	12,594	6,675	2,048	387	186	105	57,046
2013	8,569	11,199	26,620	13,813	14,579	7,544	3,828	1,171	226	161	67,941
2014	11,489	9,891	12,365	25,626	9,912	8,610	4,242	2,113	648	220	63,736
2015	11,838	14,756	10,521	12,200	19,444	6,395	5,316	2,608	1,203	514	58,200
2016	5,241	10,834	18,293	10,415	9,172	11,994	3,752	3,109	1,503	952	59,189
2017	1,212	5,591	11,508	18,560	8,035	5,718	7,259	2,227	1,902	1,532	56,741
2018	5,672	1,244	5,447	10,694	13,717	5,154	3,638	4,637	1,440	2,228	46,955
2019	11,166	5,639	1,277	5,179	7,498	9,104	3,324	2,303	2,965	2,268	33,918

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	53,014	38,826	35,905	23,269	12,629	9,666	8,784	2,916	2,342	4,548	100,060
1979	117,781	41,837	20,014	8,985	5,237	2,825	2,161	1,964	652	1,541	43,379
1980	136,789	93,632	23,644	6,340	2,614	1,516	818	626	568	635	36,760
1981	153,532	109,907	60,501	10,556	2,681	1,102	639	345	264	507	76,595
1982	206,844	125,401	86,328	36,811	5,571	1,399	575	333	180	402	131,598
1983	161,740	169,013	99,185	55,202	20,907	3,134	787	323	187	327	180,053
1984	182,295	132,282	135,879	71,283	37,269	14,045	2,105	528	217	345	261,671
1985	234,022	149,128	106,770	100,453	50,181	26,134	9,847	1,476	370	394	295,624
1986	228,978	191,326	119,096	73,157	63,195	31,354	16,323	6,150	922	478	310,674
1987	179,524	187,078	151,051	75,163	40,753	34,854	17,283	8,997	3,390	771	332,263
1988	143,914	146,596	146,353	89,287	38,003	20,350	17,392	8,624	4,490	2,076	326,575
1989	353,029	117,576	115,668	91,969	49,423	20,824	11,144	9,525	4,723	3,596	306,871
1990	296,275	288,301	92,104	69,028	47,163	25,039	10,543	5,642	4,822	4,212	258,553
1991	139,007	241,781	223,092	50,353	31,093	20,918	11,096	4,672	2,500	4,003	347,727
1992	262,842	113,575	190,995	141,374	28,220	17,256	11,603	6,155	2,591	3,607	401,800
1993	154,301	214,697	89,312	117,160	75,509	14,907	9,110	6,125	3,249	3,272	318,643
1994	439,760	187,139	383,726	103,247	174,946	44,465	8,774	5,362	3,605	3,838	727,963
1995	261,791	359,323	146,534	254,466	53,608	28,342	18,098	3,571	2,182	3,029	509,830
1996	454,259	213,549	279,668	75,080	121,886	6,312	7,319	4,673	922	1,346	497,207
1997	662,784	371,034	166,021	172,472	32,986	7,444	1,999	2,318	1,480	718	385,438
1998	589,442	541,339	294,411	100,012	86,993	4,284	2,643	710	823	780	490,656
1999	416,807	481,482	426,607	192,824	45,178	6,852	1,530	944	253	573	674,761
2000	736,782	340,299	380,150	265,288	88,972	5,466	2,437	544	336	294	743,486
2001	610,141	602,073	266,920	244,824	126,203	5,745	1,902	848	189	219	646,849
2002	770,797	498,632	481,676	169,195	127,705	11,571	2,217	734	327	158	793,583
2003	549,973	629,829	398,320	338,306	85,803	9,996	4,524	867	287	190	838,293
2004	474,864	448,815	495,726	266,602	185,343	7,195	2,854	1,292	247	136	959,395
2005	255,294	388,210	358,158	354,075	169,810	7,813	3,587	1,423	644	191	895,700
2006	728,042	208,599	308,588	234,151	203,919	9,426	3,383	1,553	616	362	761,997
2007	587,766	595,398	167,991	227,183	144,282	15,031	3,103	1,111	510	321	559,531
2008	559,849	480,309	481,324	119,165	138,145	10,988	4,142	853	305	228	755,150
2009	463,617	457,585	386,252	361,210	70,040	9,095	3,171	1,193	246	154	831,361
2010	276,665	378,948	369,719	284,710	243,307	7,190	3,357	1,168	439	147	910,037
2011	550,429	226,168	306,009	278,187	180,064	17,946	3,031	1,413	492	247	787,389
2012	289,265	450,194	183,212	232,506	190,098	31,546	9,203	1,553	724	378	649,220
2013	246,861	236,647	365,492	139,894	157,463	36,421	17,342	5,055	853	605	723,125
2014	347,517	201,932	192,125	278,055	90,728	40,269	18,920	9,000	2,623	757	632,476
2015	238,603	284,298	164,221	149,653	191,718	29,021	23,392	10,982	5,223	1,962	576,172
2016	99,611	195,212	230,910	127,461	104,016	56,907	16,711	13,459	6,318	4,134	559,916
2017	47,056	81,482	158,776	178,044	88,955	26,531	32,985	9,679	7,795	6,053	508,818
2018	106,272	38,509	66,224	124,669	125,001	25,011	16,295	20,245	5,940	8,499	391,884
2019	148,419	57,682	31,405	51,356	90,249	44,493	15,588	10,149	12,609	8,993	264,842

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	8,958	5,856	7,082	5,222	3,431	2,591	2,946	879	678	1,931	24,761
1979	9,263	6,733	3,806	2,133	1,367	784	676	692	225	571	10,254
1980	7,295	11,628	3,895	1,444	710	427	240	205	206	250	7,376
1981	18,299	13,153	10,898	2,277	729	359	210	122	97	209	14,901
1982	10,383	17,481	17,239	8,669	1,587	469	221	128	75	178	28,566
1983	8,650	17,754	17,802	13,129	5,899	1,034	294	127	81	148	38,513
1984	10,687	15,297	24,752	16,804	10,655	4,608	780	217	88	179	58,082
1985	10,864	17,081	19,683	24,410	14,441	8,903	3,655	603	165	201	72,061
1986	12,603	19,796	22,600	17,096	18,952	11,036	6,357	2,531	414	235	79,222
1987	13,126	22,997	27,560	18,137	12,321	12,553	6,908	3,912	1,539	382	83,312
1988	7,310	15,947	29,351	20,918	10,970	7,236	7,004	3,739	2,099	1,026	82,341
1989	18,681	11,954	19,734	22,078	14,309	7,262	4,411	4,147	2,229	1,812	75,982
1990	21,278	30,897	16,106	16,377	14,042	8,904	4,150	2,461	2,309	2,235	66,583
1991	7,163	25,385	38,133	11,281	9,055	7,523	4,339	1,978	1,144	2,111	75,563
1992	8,791	9,675	29,333	30,666	7,639	5,996	4,449	2,507	1,128	1,835	83,554
1993	6,029	14,387	11,253	24,281	20,344	4,906	3,370	2,459	1,322	1,552	69,487
1994	8,990	9,968	21,644	11,133	18,423	14,762	3,089	2,118	1,475	1,757	74,400
1995	7,285	13,311	13,585	15,428	6,031	9,480	6,414	1,348	914	1,360	54,559
1996	7,864	10,415	16,783	7,175	5,381	2,035	2,712	1,804	386	640	36,915
1997	10,494	11,818	12,981	10,633	3,257	2,328	723	932	615	328	31,797
1998	9,157	17,341	14,372	8,721	5,086	1,510	856	273	338	330	31,485
1999	7,300	14,417	23,996	9,313	4,355	2,433	552	322	99	233	41,304
2000	6,355	12,975	19,572	16,961	4,650	2,065	900	196	116	115	44,575
2001	6,202	10,238	18,478	13,706	8,480	2,209	758	317	73	81	44,103
2002	13,086	11,711	14,780	14,040	7,793	4,608	907	317	128	64	42,637
2003	13,556	20,434	16,158	11,569	7,924	4,288	1,920	374	131	76	42,440
2004	9,970	19,661	24,967	9,351	4,972	3,282	1,322	592	117	63	44,666
2005	6,322	13,479	23,799	20,687	6,411	3,224	1,556	607	266	77	56,627
2006	13,463	10,096	17,458	18,608	12,719	3,790	1,280	628	238	132	54,853
2007	26,158	20,535	13,730	15,133	11,778	7,034	1,357	465	221	131	49,848
2008	22,890	28,622	30,384	10,307	7,376	5,378	2,209	382	159	114	56,309
2009	29,948	40,795	55,849	27,803	9,181	6,666	2,948	978	203	96	103,724
2010	21,923	36,877	41,333	43,414	20,223	6,031	2,614	1,151	412	125	115,303
2011	23,573	23,252	44,435	42,768	37,288	16,743	2,870	1,231	531	260	146,125
2012	10,792	34,952	26,568	48,976	42,328	33,407	7,667	1,310	544	356	161,156
2013	8,352	15,178	47,513	32,297	49,402	39,585	13,726	3,143	548	357	186,570
2014	11,116	11,338	19,828	56,907	34,950	47,632	15,936	5,430	1,247	369	182,300
2015	11,451	16,806	14,251	23,907	60,778	33,682	18,322	6,109	1,927	599	159,574
2016	4,789	12,344	24,625	17,197	25,249	55,956	11,879	6,447	2,117	850	144,319
2017	594	6,020	15,486	30,185	18,305	23,030	19,441	4,050	2,266	1,060	113,823
2018	4,150	718	6,912	17,098	29,329	16,192	8,524	7,228	1,525	1,262	88,070
2019	8,984	4,862	868	7,748	15,469	26,264	6,295	3,255	2,788	1,052	63,739

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	41,790	34,125	32,672	21,326	11,674	9,258	8,729	2,760	2,306	4,814	93,539
1979	90,632	35,229	17,286	8,186	4,885	2,660	2,055	1,937	613	1,580	39,202
1980	101,269	77,038	19,647	5,384	2,367	1,407	746	576	543	615	31,286
1981	112,533	87,282	50,468	8,809	2,300	1,009	584	310	239	481	64,199
1982	154,318	99,154	72,477	31,586	4,956	1,284	548	317	168	392	111,729
1983	120,724	136,048	83,120	47,783	19,020	2,965	748	320	185	326	154,467
1984	133,726	106,596	116,994	63,017	34,545	13,705	2,081	525	224	359	231,450
1985	171,922	118,122	92,265	91,920	47,735	26,100	10,087	1,532	387	429	270,454
1986	167,412	151,720	100,665	66,571	62,284	32,203	17,150	6,628	1,006	536	287,043
1987	131,203	147,595	127,226	66,482	40,177	37,353	18,809	10,017	3,871	901	304,836
1988	104,374	116,200	122,828	78,684	36,760	22,041	19,734	9,937	5,292	2,521	297,797
1989	257,060	92,970	98,357	81,528	47,649	22,118	12,636	11,312	5,696	4,479	283,775
1990	213,460	230,005	78,292	62,037	46,109	26,743	11,688	6,677	5,978	5,376	242,899
1991	93,638	191,848	191,788	45,663	31,618	23,279	12,517	5,470	3,125	5,314	318,774
1992	164,867	84,789	165,697	132,220	28,914	19,901	13,354	7,181	3,138	4,841	375,247
1993	106,897	150,037	73,122	110,585	80,107	17,400	10,693	7,175	3,858	4,287	307,228
1994	476,054	177,443	390,821	105,081	194,696	54,034	10,281	6,318	4,239	4,813	770,282
1995	264,103	377,646	141,436	260,398	57,988	35,827	22,163	4,217	2,591	3,713	528,332
1996	504,622	217,396	291,076	76,591	131,658	8,090	9,473	5,860	1,115	1,667	525,530
1997	691,606	405,702	172,153	186,040	36,974	9,029	2,531	2,964	1,833	870	412,394
1998	646,313	568,773	321,227	109,604	101,102	5,609	3,135	879	1,029	939	543,524
1999	435,287	533,370	457,693	220,562	55,745	9,213	1,963	1,098	308	689	747,271
2000	904,974	368,089	432,650	306,754	115,265	8,052	3,156	673	376	341	867,266
2001	744,904	752,801	302,833	302,978	169,529	8,419	2,718	1,065	227	242	788,012
2002	900,137	628,081	623,796	214,445	186,579	17,395	3,182	1,027	403	177	1,047,004
2003	611,198	768,944	525,121	481,916	132,706	15,860	6,665	1,219	394	222	1,164,103
2004	576,012	531,626	643,840	396,426	325,313	12,761	4,704	1,977	362	183	1,385,565
2005	335,478	502,027	458,102	512,985	294,851	12,765	5,722	2,109	886	244	1,287,664
2006	1,508,030	296,918	433,492	349,667	365,339	15,648	4,830	2,165	798	428	1,172,366
2007	1,136,880	1,328,280	261,884	354,950	260,643	29,522	5,427	1,675	751	425	915,276
2008	1,240,290	1,020,210	1,172,270	210,206	273,408	26,979	9,401	1,728	533	374	1,694,899
2009	892,440	1,120,000	913,397	1,006,710	163,756	23,979	10,048	3,501	643	338	2,122,372
2010	492,280	818,173	1,012,490	789,356	844,037	26,199	10,591	4,437	1,546	433	2,689,090
2011	954,935	456,294	750,846	896,909	668,774	78,822	12,019	4,858	2,036	908	2,415,172
2012	487,606	887,294	423,865	676,745	787,618	157,870	34,459	5,254	2,124	1,287	2,089,221
2013	371,401	453,135	826,202	385,306	598,039	191,114	62,185	13,573	2,070	1,343	2,079,831
2014	492,262	346,206	421,475	751,061	338,187	222,779	71,076	23,126	5,048	1,269	1,834,022
2015	395,725	461,761	322,821	385,912	667,083	152,856	80,628	25,723	8,370	2,286	1,645,679
2016	130,295	369,184	432,420	295,362	342,423	265,494	52,909	27,908	8,904	3,688	1,429,107
2017	79,226	122,918	343,839	394,274	261,759	106,854	88,339	17,604	9,285	4,190	1,226,144
2018	132,645	73,420	115,509	313,954	347,629	78,569	38,177	31,560	6,289	4,814	936,501
2019	119,420	49,725	67,972	104,915	278,740	128,360	29,515	14,341	11,856	4,171	639,870

Table 27. qSCA maximum likelihood estimates of August1 biomass (t) of fall spawners in the Middle region of the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	1,299	4,517	3,263	1,797	887	1,786	1,821	737	312	2,029	12,631
1979	3,325	2,556	3,421	2,604	1,005	393	850	784	282	804	10,143
1980	1,472	4,942	2,703	2,521	602	141	51	129	104	145	6,397
1981	1,439	2,917	5,436	2,081	1,222	225	50	20	46	84	9,164
1982	2,437	5,275	3,816	4,121	571	228	40	8	4	22	8,809
1983	1,471	4,933	3,488	2,770	2,781	357	147	23	4	14	9,583
1984	869	2,892	5,252	2,792	928	733	95	36	6	4	9,846
1985	1,278	5,623	3,952	5,219	1,786	511	384	48	17	6	11,923
1986	2,595	4,633	3,192	2,941	4,001	1,390	390	277	34	15	12,239
1987	1,058	4,693	3,999	3,117	1,790	2,529	799	234	134	29	12,631
1988	1,418	3,797	4,980	4,119	2,571	1,285	1,812	526	132	92	15,516
1989	8,072	6,392	3,085	3,736	2,783	1,510	799	1,011	318	130	13,373
1990	7,441	18,365	5,265	2,783	2,793	1,972	1,005	535	667	304	15,325
1991	1,553	13,101	20,878	4,539	1,841	1,852	1,205	616	342	577	31,850
1992	5,166	3,812	13,482	16,319	2,662	915	918	598	305	462	35,660
1993	2,326	11,870	3,958	11,733	11,695	1,713	636	582	386	474	31,177
1994	5,950	1,331	11,495	2,943	8,273	7,708	1,110	414	386	561	32,890
1995	2,042	4,596	3,599	12,819	2,025	5,311	4,776	750	260	575	30,115
1996	4,629	3,473	9,743	2,952	7,509	1,002	2,392	2,097	351	364	26,410
1997	9,758	10,060	5,263	7,530	1,522	3,296	457	1,084	931	312	20,395
1998	7,748	10,440	11,649	4,323	3,850	672	1,385	196	460	532	23,067
1999	5,782	7,001	18,019	8,906	1,772	1,280	223	440	65	309	31,013
2000	4,269	4,009	14,630	14,288	3,952	650	457	78	155	128	34,338
2001	6,270	10,950	9,323	11,543	7,004	1,624	266	180	29	102	30,072
2002	9,216	13,137	13,653	8,307	6,854	3,807	837	142	92	69	33,761
2003	4,989	21,727	17,068	11,095	5,011	3,562	1,969	422	75	85	39,287
2004	6,572	13,236	25,337	14,275	6,921	2,807	2,004	1,084	229	87	52,743
2005	2,728	5,807	10,821	20,292	9,086	4,040	1,622	1,159	607	189	47,816
2006	8,225	4,928	10,662	10,762	11,962	4,710	2,072	825	584	379	41,955
2007	12,342	18,238	7,370	9,295	9,421	7,243	1,999	774	291	342	36,735
2008	6,570	9,877	16,943	4,737	6,692	4,922	2,631	743	301	248	37,217
2009	6,790	13,563	16,162	17,841	5,289	5,070	2,981	1,475	314	198	49,332
2010	4,412	8,402	12,440	14,579	14,217	2,615	1,751	842	413	153	47,010
2011	6,586	3,982	9,470	11,243	11,749	7,924	902	557	252	171	42,266
2012	4,129	8,915	4,161	8,727	9,058	7,042	3,423	356	216	162	33,147
2013	3,789	5,824	10,919	4,611	7,117	5,877	3,500	1,541	162	168	33,895
2014	2,778	4,704	6,601	11,352	4,126	4,774	3,003	1,600	698	136	32,291
2015	1,965	4,854	5,324	6,719	10,200	2,850	2,591	1,499	767	424	30,375
2016	848	2,822	5,638	6,722	6,541	6,956	1,440	1,205	677	533	29,712
2017	928	1,226	3,569	6,461	5,453	4,306	3,895	742	634	610	25,669
2018	755	1,420	1,613	3,507	5,324	3,440	2,110	1,733	324	565	18,615
2019	2,511	1,109	1,772	1,511	2,920	3,527	1,826	1,044	848	437	13,884

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	20,297	24,061	15,972	7,804	3,246	6,837	5,576	2,054	1,062	4,915	47,465
1979	36,519	16,553	19,078	10,609	3,569	1,275	2,625	2,134	786	2,287	42,364
1980	20,797	29,598	12,461	9,034	1,891	427	144	294	239	344	24,833
1981	26,599	16,944	23,267	7,825	3,533	610	134	45	92	182	35,686
1982	40,432	21,759	13,656	14,782	1,832	596	101	22	7	45	31,042
1983	22,185	33,097	17,757	10,609	9,339	1,081	350	59	13	31	39,239
1984	25,589	18,152	26,778	12,004	3,373	2,319	264	85	14	11	44,849
1985	29,979	20,944	14,776	19,955	6,174	1,537	1,048	119	39	11	43,658
1986	26,301	24,542	17,112	11,699	13,846	4,103	1,018	694	79	33	48,584
1987	19,786	21,530	20,035	13,359	7,572	8,428	2,487	617	421	68	52,986
1988	35,066	16,197	17,570	15,557	8,422	4,458	4,940	1,457	362	286	53,052
1989	136,198	28,703	13,201	13,364	8,856	4,360	2,293	2,540	749	333	45,696
1990	97,179	111,497	23,453	10,462	9,321	5,923	2,908	1,529	1,694	722	56,011
1991	26,437	79,550	90,993	18,229	6,626	5,520	3,492	1,714	901	1,424	128,899
1992	121,029	21,639	64,806	68,735	10,029	3,286	2,718	1,719	844	1,144	153,280
1993	25,626	99,078	17,674	51,033	46,437	6,443	2,104	1,740	1,100	1,273	127,804
1994	66,895	20,978	80,895	13,842	33,558	28,835	3,986	1,301	1,076	1,468	164,961
1995	40,645	54,760	17,121	62,945	8,814	20,011	17,119	2,366	772	1,510	130,658
1996	84,393	33,265	44,526	12,545	29,793	3,615	8,129	6,950	960	926	107,446
1997	136,777	69,071	27,060	32,849	6,141	12,750	1,533	3,446	2,946	800	87,525
1998	107,548	111,943	56,165	19,835	15,578	2,525	5,192	624	1,402	1,525	102,846
1999	74,420	88,008	90,762	39,282	7,461	4,781	764	1,571	189	885	145,696
2000	98,590	60,901	71,422	64,439	15,912	2,514	1,592	254	522	357	157,012
2001	127,871	80,686	49,483	51,696	28,713	6,048	945	598	96	331	137,910
2002	186,559	104,664	65,726	37,324	28,236	14,108	2,950	461	292	208	149,304
2003	110,887	152,698	85,236	49,370	19,970	13,517	6,704	1,401	219	237	176,654
2004	85,197	90,766	124,485	65,128	28,742	10,635	7,155	3,547	742	241	240,675
2005	51,785	69,739	74,025	95,728	39,130	15,927	5,861	3,942	1,954	542	237,109
2006	171,599	42,387	56,804	55,757	51,920	19,057	7,701	2,833	1,905	1,206	197,183
2007	142,093	140,450	34,631	45,871	41,943	29,642	7,755	2,798	1,009	1,104	164,753
2008	112,205	116,306	114,790	28,027	34,973	25,354	13,477	3,205	1,137	856	221,819
2009	90,751	91,838	95,026	92,701	21,090	19,993	10,345	4,911	1,145	710	245,920
2010	49,367	74,274	75,008	76,556	68,734	11,322	7,221	3,272	1,517	571	244,199
2011	122,115	40,403	60,655	60,382	56,497	36,167	3,933	2,183	965	613	221,397
2012	71,185	99,950	33,015	49,027	45,684	33,052	15,432	1,510	823	593	179,136
2013	59,928	58,268	81,705	26,751	37,658	28,504	15,979	6,850	660	617	198,723
2014	62,416	49,053	47,629	66,186	20,516	23,342	13,605	6,987	2,949	549	181,763
2015	35,565	51,091	40,104	38,625	51,101	13,084	11,774	6,344	3,213	1,605	165,850
2016	15,612	29,111	41,761	32,479	29,577	31,468	6,166	5,073	2,691	2,038	151,253
2017	18,078	12,780	23,805	33,915	25,298	19,585	17,072	3,129	2,544	2,367	127,715
2018	14,070	14,797	10,447	19,293	26,091	15,889	9,590	7,690	1,389	2,175	92,564
2019	47,277	11,518	12,099	8,477	14,945	16,876	8,237	4,616	3,654	1,689	70,593

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	2,791	7,523	4,627	2,301	1,001	1,770	1,850	748	338	2,784	15,419
1979	8,646	4,337	4,565	3,181	1,144	370	872	823	296	1,096	12,347
1980	3,871	10,180	3,763	3,296	753	135	49	133	110	187	8,427
1981	4,270	6,064	8,998	2,535	1,424	227	47	19	47	100	13,397
1982	7,796	12,339	6,285	5,830	706	267	52	10	4	31	13,184
1983	4,627	12,440	6,437	3,662	3,290	369	181	30	5	20	13,994
1984	2,625	7,171	10,485	4,344	1,210	859	123	56	10	6	17,093
1985	3,736	13,392	7,745	8,541	2,537	617	524	73	31	12	20,079
1986	7,027	10,679	5,999	4,606	5,440	1,649	495	398	54	29	18,669
1987	2,573	10,019	7,274	4,701	2,359	2,904	1,007	316	205	52	18,817
1988	3,175	7,331	8,448	6,061	3,290	1,441	2,206	703	188	152	22,489
1989	16,883	11,375	4,742	5,173	3,569	1,691	977	1,342	463	218	18,175
1990	13,990	31,314	7,645	3,527	3,271	2,139	1,160	675	912	476	19,804
1991	2,560	20,650	29,875	5,613	2,052	1,900	1,363	742	450	860	42,854
1992	7,516	5,423	18,372	20,630	3,033	931	995	715	387	693	45,756
1993	3,180	15,234	4,971	14,263	13,460	1,770	665	647	473	682	36,931
1994	7,830	1,641	13,316	3,374	9,372	8,221	1,173	442	438	769	37,105
1995	2,616	5,580	4,096	13,873	2,209	5,673	5,155	802	281	739	32,827
1996	5,677	4,178	11,127	3,239	8,079	1,062	2,602	2,305	383	452	29,248
1997	11,842	11,706	6,018	8,366	1,677	3,491	492	1,197	1,038	368	22,648
1998	9,531	12,089	12,957	4,845	4,338	735	1,486	213	514	608	25,696
1999	7,058	8,291	20,138	9,909	2,088	1,472	249	482	72	357	34,769
2000	4,926	4,777	16,947	16,109	4,604	779	522	87	169	146	39,362
2001	6,904	12,460	10,976	13,622	8,472	1,994	321	207	33	115	35,741
2002	10,056	14,363	15,449	9,961	8,684	4,922	1,038	173	107	78	40,413
2003	5,851	23,732	18,714	12,940	6,619	4,971	2,612	537	94	100	46,587
2004	7,803	15,701	28,032	16,201	8,804	4,042	2,786	1,432	290	105	61,692
2005	3,649	7,057	13,155	23,443	11,239	5,588	2,259	1,558	775	229	58,246
2006	13,363	6,827	13,446	13,948	15,750	6,645	2,805	1,125	768	468	54,955
2007	22,841	31,097	10,726	12,329	12,617	10,595	3,371	1,393	537	598	52,165
2008	12,650	19,401	30,686	7,330	9,297	7,334	4,190	1,492	656	541	61,527
2009	13,168	27,980	34,044	34,707	8,660	8,055	4,957	2,914	799	548	94,684
2010	8,303	17,612	27,776	33,396	30,289	5,437	3,532	2,018	1,202	595	104,244
2011	12,117	8,188	21,722	27,682	30,597	23,639	2,532	1,734	954	863	109,723
2012	7,313	18,129	9,468	22,295	25,510	24,777	10,981	1,192	818	843	95,884
2013	6,302	11,502	24,790	11,771	20,839	21,696	11,201	4,885	545	742	96,468
2014	4,818	8,777	14,642	29,091	12,140	18,431	9,899	4,979	2,185	519	91,886
2015	3,657	9,486	11,201	16,881	30,161	10,916	8,464	4,513	2,210	1,275	85,622
2016	1,701	5,933	12,457	16,080	19,138	27,677	5,095	3,968	2,086	1,599	88,100
2017	1,880	2,781	8,492	16,223	15,065	16,139	12,702	2,295	1,846	1,648	74,409
2018	1,549	3,253	4,144	9,496	15,489	12,477	7,066	5,473	984	1,563	56,694
2019	4,624	2,576	4,597	4,414	9,142	13,276	5,968	3,385	2,626	1,235	44,644

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

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	43,603	40,077	22,648	9,990	3,664	6,777	5,665	2,086	1,150	6,744	58,724
1979	94,944	28,087	25,454	12,960	4,066	1,200	2,692	2,240	824	3,119	52,555
1980	54,707	60,962	17,350	11,813	2,364	409	137	303	252	444	33,073
1981	78,905	35,218	38,511	9,534	4,116	616	128	42	94	216	53,257
1982	129,353	50,892	22,494	20,914	2,265	698	128	27	9	64	46,600
1983	69,783	83,466	32,774	14,022	11,046	1,118	432	79	16	45	59,534
1984	77,311	45,015	53,464	18,674	4,399	2,717	340	131	24	19	79,768
1985	87,660	49,883	28,954	32,659	8,769	1,856	1,432	179	69	23	73,940
1986	71,229	56,566	32,153	18,325	18,827	4,866	1,293	998	125	64	76,650
1987	48,131	45,962	36,440	20,149	9,975	9,677	3,137	833	643	122	80,976
1988	78,510	31,270	29,804	22,895	10,779	4,998	6,012	1,948	518	475	77,429
1989	284,843	51,079	20,290	18,506	11,360	4,881	2,803	3,370	1,092	556	62,858
1990	182,707	190,114	34,050	13,257	10,913	6,425	3,356	1,927	2,317	1,133	73,377
1991	43,569	125,387	130,204	22,543	7,383	5,664	3,951	2,063	1,185	2,121	175,114
1992	176,095	30,788	88,316	86,891	11,426	3,345	2,945	2,053	1,072	1,718	197,767
1993	35,032	127,165	22,198	62,039	53,447	6,658	2,197	1,934	1,348	1,832	151,654
1994	88,042	25,862	93,707	15,870	38,016	30,755	4,211	1,389	1,223	2,011	187,183
1995	52,075	66,480	19,486	68,121	9,612	21,372	18,479	2,529	834	1,942	142,377
1996	103,494	40,023	50,850	13,763	32,055	3,833	8,843	7,641	1,046	1,148	119,179
1997	165,988	80,374	30,943	36,500	6,765	13,503	1,650	3,804	3,287	944	97,396
1998	132,295	129,622	62,468	22,229	17,552	2,762	5,570	680	1,568	1,744	114,573
1999	90,850	104,227	101,435	43,708	8,792	5,501	855	1,723	210	1,025	163,250
2000	113,773	72,562	82,731	72,650	18,537	3,011	1,818	282	569	408	180,006
2001	140,811	91,814	58,258	61,008	34,730	7,426	1,142	689	107	370	163,730
2002	203,554	114,426	74,373	44,755	35,775	18,242	3,659	563	339	235	177,941
2003	130,048	166,784	93,454	57,577	26,378	18,867	8,892	1,783	274	280	207,505
2004	101,155	107,672	137,729	73,918	36,560	15,314	9,947	4,687	940	292	279,387
2005	69,262	84,750	89,992	110,596	48,401	22,028	8,162	5,300	2,497	656	287,631
2006	278,805	58,726	71,635	72,260	68,361	26,890	10,426	3,862	2,507	1,492	257,433
2007	262,961	239,486	50,397	60,842	56,175	43,358	13,076	5,035	1,864	1,930	232,678
2008	216,049	228,459	207,903	43,370	48,590	37,783	21,459	6,434	2,476	1,866	369,880
2009	175,993	189,460	200,164	180,335	34,528	31,763	17,200	9,704	2,908	1,962	478,564
2010	92,905	155,693	167,475	175,370	146,435	23,543	14,561	7,838	4,420	2,218	541,860
2011	224,684	83,073	139,135	148,678	147,134	107,891	11,043	6,800	3,659	3,099	567,439
2012	126,057	203,268	75,124	125,243	128,658	116,287	49,500	5,051	3,109	3,090	506,063
2013	99,666	115,074	185,495	68,299	110,270	105,222	51,135	21,713	2,215	2,719	547,068
2014	108,263	91,527	105,639	169,609	60,361	90,121	44,849	21,738	9,228	2,097	503,641
2015	66,198	99,837	84,376	97,037	151,101	50,119	38,467	19,098	9,254	4,821	454,273
2016	31,305	61,202	92,271	77,691	86,538	125,207	21,819	16,705	8,292	6,111	434,634
2017	36,597	28,983	56,646	85,149	69,888	73,413	55,674	9,683	7,412	6,391	364,255
2018	28,877	33,898	26,836	52,243	75,913	57,637	32,109	24,287	4,223	6,020	279,269
2019	87,072	26,746	31,387	24,762	46,800	63,529	26,928	14,967	11,318	4,773	224,464

Table 31. qSCA maximum likelihood estimates of August 1 biomass (t) of fall spawners in the South region of the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	4,062	8,162	5,250	3,727	1,888	1,913	1,425	511	478	1,132	16,324
1979	13,549	5,655	10,403	4,983	2,312	1,058	843	588	200	515	20,900
1980	8,925	10,633	5,741	9,835	3,897	1,573	683	521	361	438	23,049
1981	10,976	11,054	9,670	3,673	3,877	1,008	310	102	83	122	18,844
1982	14,629	16,467	13,780	11,206	2,691	1,943	453	132	40	77	30,323
1983	7,974	24,096	19,504	12,908	7,380	1,347	887	201	60	52	42,338
1984	13,502	13,471	31,296	17,544	9,063	4,427	805	501	115	68	63,820
1985	17,478	22,814	17,020	29,634	13,190	5,824	2,750	494	301	107	69,320
1986	14,399	29,046	29,447	15,330	23,318	9,046	3,852	1,774	309	227	83,303
1987	5,389	18,428	38,780	27,397	11,834	15,550	5,797	2,399	1,080	341	103,177
1988	5,010	8,722	19,398	37,929	20,915	7,595	9,509	3,457	1,416	819	101,038
1989	16,687	7,370	10,284	16,393	30,442	14,668	5,199	6,423	2,246	1,483	87,137
1990	15,228	26,481	9,570	9,273	14,477	24,650	11,499	4,034	4,855	2,722	81,079
1991	4,345	19,542	33,105	9,090	6,342	8,281	12,784	5,854	1,993	3,759	81,209
1992	8,834	6,232	21,526	30,384	7,406	4,662	5,998	9,082	4,146	3,929	87,133
1993	3,010	18,509	6,494	20,425	24,344	5,394	3,497	4,407	6,548	5,892	77,001
1994	16,810	3,750	21,030	6,066	17,309	19,180	4,340	2,778	3,473	9,456	83,631
1995	3,935	10,789	4,740	20,184	4,275	10,609	11,409	2,737	1,638	7,366	62,957
1996	14,623	6,196	13,124	4,909	15,884	3,002	6,692	7,012	1,612	5,109	57,342
1997	17,267	20,659	8,282	18,262	3,374	8,194	1,469	3,178	3,329	3,003	49,090
1998	14,707	17,900	25,766	8,237	12,678	1,951	4,216	758	1,559	3,038	58,204
1999	7,417	21,022	22,692	23,934	5,362	6,390	935	1,985	358	2,026	63,682
2000	27,943	10,648	26,798	24,718	13,707	2,244	2,501	359	756	887	71,969
2001	17,815	37,671	13,512	26,266	15,675	6,705	1,038	1,138	158	670	65,161
2002	20,569	27,788	50,028	13,676	17,315	7,824	3,092	472	501	361	93,269
2003	10,125	25,238	33,844	50,125	9,191	8,692	3,731	1,427	219	391	107,619
2004	8,922	12,613	29,663	30,692	31,862	4,623	4,225	1,733	663	271	103,733
2005	4,191	17,124	15,882	30,754	24,242	20,582	2,940	2,637	1,073	581	98,691
2006	18,543	5,786	21,283	16,394	24,062	15,929	12,794	1,849	1,577	996	94,883
2007	10,318	27,499	6,797	17,876	13,659	16,618	7,974	5,494	763	1,018	70,198
2008	14,098	13,525	32,073	6,899	14,990	9,292	8,019	3,238	2,163	684	77,357
2009	8,886	17,722	16,299	30,931	6,456	11,234	5,160	3,844	1,468	1,246	76,637
2010	4,178	8,028	18,670	16,042	27,445	4,205	4,695	1,697	1,220	851	74,824
2011	4,739	4,061	8,274	16,787	12,754	16,142	1,430	1,192	398	475	57,452
2012	3,942	8,426	4,002	8,612	14,506	8,174	6,740	479	394	272	43,178
2013	3,286	5,810	8,813	3,910	7,639	10,202	3,933	2,700	180	253	37,631
2014	3,834	4,635	6,427	8,081	3,570	5,434	4,989	1,619	1,054	167	31,340
2015	4,652	3,830	4,655	5,967	7,401	2,472	2,452	1,867	555	432	25,801
2016	652	6,012	4,921	4,875	5,577	5,071	1,010	801	561	287	23,102
2017	731	805	7,588	5,822	4,740	3,664	2,155	348	268	262	24,847
2018	1,271	859	949	6,862	4,703	3,055	1,920	995	161	250	18,895
2019	5,816	1,568	1,053	898	5,774	3,528	1,692	943	481	185	14,554

Table 32. qSCA maximum likelihood estimates of January 1 abundance (number in thousands) of fall spawners in the South region of the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	54,555	80,568	37,351	18,143	8,992	7,380	5,042	1,766	1,602	2,998	83,274
1979	108,728	42,591	58,652	23,613	9,312	3,781	2,737	1,762	602	1,550	102,010
1980	104,452	87,136	33,077	42,752	15,673	5,651	2,169	1,528	973	1,182	103,006
1981	129,833	77,528	55,994	15,889	13,364	3,248	904	307	206	283	90,193
1982	219,055	106,125	62,619	41,413	8,345	5,221	1,191	329	111	177	119,406
1983	111,495	179,141	86,063	47,732	24,815	4,061	2,430	551	152	134	165,937
1984	203,223	91,208	145,655	66,897	31,151	13,924	2,206	1,314	298	154	261,599
1985	277,695	166,256	74,195	113,637	44,368	17,954	7,786	1,229	732	252	260,153
1986	122,801	227,219	135,433	58,492	78,874	27,585	10,902	4,713	744	595	317,337
1987	67,711	100,477	185,045	106,552	40,240	48,319	16,483	6,493	2,806	797	406,734
1988	70,787	55,392	81,718	144,141	70,185	22,929	26,687	9,067	3,570	1,981	360,277
1989	235,160	57,924	45,147	64,676	101,775	44,900	14,360	16,669	5,661	3,466	296,653
1990	169,855	192,487	47,332	36,428	49,683	74,932	32,757	10,464	12,145	6,649	270,390
1991	56,331	138,917	156,208	36,267	22,330	25,113	36,338	15,800	5,044	9,058	306,158
1992	197,670	46,107	113,478	125,734	27,566	16,152	17,973	25,970	11,290	10,077	348,240
1993	48,925	161,793	37,661	91,294	95,360	19,868	11,514	12,794	18,484	15,207	302,182
1994	172,323	40,051	132,304	30,554	71,820	73,049	15,132	8,764	9,737	25,639	366,998
1995	75,380	140,980	32,587	103,369	20,392	41,829	41,317	8,526	4,936	19,922	272,877
1996	215,040	61,669	114,687	25,429	68,619	11,770	23,430	23,052	4,755	13,862	285,603
1997	238,327	175,838	49,965	86,831	14,793	31,789	5,192	10,270	10,097	8,153	217,090
1998	256,844	194,904	142,616	38,123	52,249	7,250	14,906	2,421	4,785	8,502	270,851
1999	137,459	210,028	157,957	108,184	22,366	24,547	3,247	6,635	1,077	5,909	329,921
2000	468,057	112,357	169,616	116,706	56,569	8,674	8,927	1,171	2,391	2,517	366,570
2001	313,652	382,723	91,020	128,265	67,540	25,979	3,790	3,876	508	2,129	323,106
2002	300,540	256,465	310,004	68,766	73,931	30,810	11,270	1,633	1,669	1,135	499,218
2003	154,275	245,767	207,899	235,595	40,670	35,203	14,002	5,091	737	1,266	540,462
2004	170,503	126,164	199,297	158,413	140,940	19,738	16,334	6,459	2,347	923	544,451
2005	69,567	139,506	102,745	156,779	108,930	86,274	11,784	9,720	3,842	1,945	482,019
2006	316,372	56,919	113,593	80,733	107,271	66,129	51,045	6,949	5,729	3,411	434,861
2007	152,022	258,984	46,555	92,395	63,433	71,612	32,558	21,672	2,862	3,746	334,832
2008	187,876	124,445	211,812	37,850	72,396	41,772	34,079	13,229	8,526	2,585	422,249
2009	101,478	153,798	101,792	172,355	29,817	48,957	21,238	15,081	5,691	4,757	399,689
2010	48,514	83,064	125,730	82,522	132,644	17,960	18,657	6,477	4,395	3,021	391,408
2011	100,707	39,709	67,884	101,722	62,701	74,988	5,844	4,640	1,525	1,730	321,033
2012	69,469	82,435	32,467	55,086	78,757	38,914	30,785	1,962	1,495	1,041	240,507
2013	55,391	56,867	67,417	26,388	43,083	51,388	18,098	12,143	748	962	220,228
2014	65,140	45,343	46,507	54,797	20,641	28,128	23,936	7,153	4,641	650	186,452
2015	79,778	53,322	37,077	37,761	42,577	13,038	12,065	8,505	2,446	1,798	155,265
2016	11,086	65,302	43,589	30,052	29,023	25,481	4,889	3,604	2,425	1,200	140,263
2017	12,462	9,075	53,388	35,355	23,199	17,751	10,087	1,566	1,106	1,104	143,557
2018	21,686	10,202	7,423	43,470	27,960	15,993	9,469	4,749	719	1,010	110,793
2019	99,082	17,753	8,346	6,046	34,454	19,489	8,769	4,619	2,262	820	84,807

Table 33. qmSCA maximum likelihood estimates of August 1 biomass (t) of fall spawners in the South region of the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	7,957	13,572	7,736	4,883	2,162	1,841	1,402	502	489	1,250	20,265
1979	28,838	9,224	14,787	6,497	2,696	1,028	860	595	200	562	27,225
1980	21,021	18,606	7,784	11,785	4,283	1,508	702	553	378	483	27,476
1981	27,836	22,192	15,193	4,779	4,474	955	299	99	81	120	26,000
1982	38,589	34,008	22,607	14,734	3,100	1,973	495	147	44	87	43,186
1983	20,735	51,755	32,881	17,595	8,429	1,348	1,029	250	76	66	61,674
1984	33,562	28,517	54,830	24,446	10,559	4,328	908	654	161	98	95,984
1985	41,536	46,166	29,389	42,879	15,678	5,804	3,030	627	442	170	98,018
1986	33,119	56,192	48,582	21,796	28,518	9,115	4,290	2,184	438	380	115,303
1987	11,974	34,508	61,168	37,234	14,236	16,126	6,528	2,985	1,484	584	140,345
1988	11,030	15,990	30,026	50,102	24,621	7,938	11,091	4,376	1,981	1,335	131,469
1989	36,525	13,539	15,750	21,386	34,660	14,907	5,985	8,248	3,131	2,419	106,484
1990	31,363	48,892	14,836	12,030	16,139	23,978	12,549	4,986	6,694	4,335	95,548
1991	7,939	34,098	51,911	12,173	7,420	8,346	13,937	7,155	2,759	6,123	109,823
1992	14,604	9,688	31,977	40,756	8,594	4,740	6,457	10,573	5,412	6,465	114,974
1993	4,608	26,349	8,700	26,274	28,650	5,506	3,761	5,019	8,064	9,136	95,111
1994	24,344	5,031	26,246	7,142	19,693	19,981	4,585	3,091	4,092	13,459	98,290
1995	5,572	14,098	5,747	23,045	4,750	11,419	12,561	3,054	1,926	10,550	73,053
1996	19,997	8,117	15,894	5,585	17,553	3,233	7,497	8,031	1,871	7,341	67,004
1997	23,746	26,631	10,259	21,346	3,910	9,280	1,685	3,791	4,059	4,368	58,698
1998	20,407	23,527	31,830	9,963	15,204	2,335	4,989	909	1,941	4,202	71,374
1999	10,879	28,325	29,052	29,421	6,840	8,177	1,168	2,450	448	2,819	80,375
2000	40,631	15,434	35,838	32,364	18,735	3,251	3,426	479	998	1,299	96,390
2001	27,686	54,932	19,715	36,319	22,999	10,616	1,594	1,653	223	990	94,109
2002	34,711	43,868	74,434	21,007	27,868	14,098	5,360	794	797	580	144,939
2003	19,001	43,662	55,021	79,337	16,738	17,716	7,443	2,741	409	692	180,097
2004	17,643	24,476	53,311	53,583	60,613	10,879	9,521	3,828	1,410	541	193,688
2005	9,720	35,323	32,241	58,998	48,478	47,081	6,923	5,956	2,375	1,218	203,270
2006	59,310	14,169	46,498	36,034	54,040	39,430	28,860	4,299	3,517	2,139	214,817
2007	37,105	93,783	17,757	41,764	32,366	43,041	22,035	15,900	2,346	2,973	178,181
2008	51,566	52,335	117,766	19,461	38,222	26,018	23,052	11,527	8,322	2,729	247,098
2009	30,338	70,305	68,443	123,588	20,048	34,078	14,805	12,917	6,278	5,838	285,994
2010	13,202	29,944	80,996	74,053	123,680	17,103	17,625	7,463	6,568	6,132	333,619
2011	14,467	14,121	34,015	80,901	68,339	106,028	7,979	7,981	3,293	5,529	314,065
2012	10,783	28,514	15,445	39,525	80,725	60,170	42,260	3,104	3,189	3,335	247,753
2013	8,514	17,712	33,273	16,916	40,392	75,301	22,003	15,109	1,076	2,308	206,378
2014	10,075	13,431	21,932	34,309	17,819	37,933	27,583	7,961	5,360	1,178	154,076
2015	12,262	11,281	15,134	22,961	36,423	16,583	13,303	9,631	2,642	2,246	118,923
2016	1,904	17,782	16,280	17,917	25,145	35,283	5,899	4,720	3,289	1,627	110,161
2017	2,026	2,637	25,216	21,774	20,371	23,039	12,771	2,128	1,726	1,672	108,697
2018	3,057	2,671	3,492	25,689	20,185	16,643	9,179	5,059	869	1,415	82,530
2019	12,706	4,233	3,676	3,721	24,744	18,961	7,352	4,025	2,235	940	65,655

Table 34. qmSCA maximum likelihood estimates of January 1 abundance (number in thousands) of fall spawners in the South region of the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	106,857	133,960	55,042	23,768	10,297	7,101	4,959	1,734	1,639	3,313	107,851
1979	231,426	69,476	83,371	30,788	10,862	3,675	2,793	1,784	602	1,693	135,568
1980	245,998	152,467	44,853	51,225	17,225	5,418	2,227	1,624	1,020	1,303	124,894
1981	329,265	155,643	87,975	20,669	15,421	3,079	873	297	201	279	128,796
1982	577,853	219,164	102,729	54,448	9,614	5,301	1,300	365	124	201	174,082
1983	289,923	384,765	145,088	65,067	28,341	4,065	2,817	686	193	171	246,428
1984	505,144	193,089	255,187	93,212	36,293	13,611	2,488	1,716	418	221	403,146
1985	659,928	336,441	128,110	164,425	52,737	17,893	8,577	1,561	1,076	401	374,779
1986	282,464	439,583	223,437	83,163	96,462	27,795	12,142	5,800	1,055	998	450,852
1987	150,445	188,146	291,875	144,811	48,407	50,109	18,561	8,079	3,857	1,365	567,065
1988	155,841	101,548	126,495	190,400	82,620	23,965	31,126	11,477	4,993	3,227	474,303
1989	514,727	106,405	69,148	84,375	115,877	45,631	16,532	21,405	7,889	5,650	366,506
1990	349,839	355,397	73,381	47,256	55,387	72,891	35,749	12,934	16,744	10,591	324,934
1991	102,933	242,395	244,942	48,567	26,127	25,311	39,615	19,310	6,981	14,753	425,607
1992	326,778	71,680	168,576	168,656	31,991	16,421	19,346	30,233	14,735	16,584	466,541
1993	74,895	230,321	50,453	117,437	112,231	20,280	12,385	14,569	22,763	23,580	373,698
1994	249,558	53,732	165,121	35,973	81,714	76,101	15,985	9,754	11,473	36,494	432,614
1995	106,744	184,212	39,515	118,023	22,660	45,025	45,489	9,514	5,803	28,532	314,560
1996	294,069	80,794	138,893	28,930	75,830	12,678	26,250	26,403	5,519	19,917	334,420
1997	327,762	226,665	61,892	101,495	17,145	36,001	5,959	12,251	12,312	11,859	258,914
1998	356,385	256,170	176,175	46,111	62,662	8,675	17,640	2,901	5,960	11,758	331,883
1999	201,611	283,000	202,230	132,988	28,532	31,411	4,055	8,191	1,346	8,219	416,972
2000	680,591	162,856	226,838	152,806	77,318	12,568	12,227	1,565	3,157	3,686	490,164
2001	487,430	558,086	132,807	177,355	99,094	41,133	5,823	5,629	720	3,148	465,709
2002	507,177	404,869	461,236	105,632	118,987	55,518	19,533	2,749	2,656	1,825	768,136
2003	289,522	425,181	337,990	372,894	74,066	71,754	27,932	9,780	1,376	2,242	898,034
2004	337,149	244,830	358,179	276,558	268,117	46,442	36,810	14,267	4,993	1,847	1,007,211
2005	161,335	287,759	208,571	300,765	217,831	197,345	27,754	21,950	8,505	4,077	986,798
2006	1,011,940	139,390	248,176	177,454	240,917	163,691	115,148	16,161	12,778	7,324	981,650
2007	546,701	883,244	121,624	215,869	150,316	185,472	89,977	62,722	8,795	10,939	845,713
2008	687,186	481,552	777,744	106,766	184,604	116,968	97,962	47,100	32,802	10,319	1,374,264
2009	346,442	610,128	427,446	688,664	92,590	148,513	60,937	50,673	24,345	22,287	1,515,454
2010	153,275	309,823	545,463	380,952	597,746	73,057	70,040	28,480	23,660	21,771	1,741,169
2011	307,413	138,089	279,063	490,218	335,982	492,560	32,609	31,062	12,622	20,133	1,694,248
2012	190,005	278,976	125,295	252,815	438,294	286,443	193,029	12,722	12,112	12,772	1,333,481
2013	143,526	173,370	254,518	114,160	227,789	379,314	101,238	67,962	4,477	8,757	1,158,216
2014	171,173	131,410	158,711	232,648	103,031	196,361	132,344	35,169	23,598	4,595	886,457
2015	210,297	157,049	120,543	145,305	209,532	87,465	65,449	43,864	11,650	9,338	693,146
2016	32,359	193,133	144,202	110,456	130,861	177,285	28,560	21,245	14,229	6,808	633,645
2017	34,534	29,731	177,413	132,219	99,703	111,629	59,773	9,578	7,120	7,051	604,486
2018	52,175	31,720	27,305	162,733	120,012	87,134	45,269	24,153	3,869	5,724	476,198
2019	216,451	47,923	29,132	25,045	147,661	104,740	38,098	19,720	10,517	4,177	379,090

Table 35. qSCA maximum likelihood estimates of August 1 total biomass (t) of fall spawners in the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	16,726	19,342	16,295	11,222	6,487	6,404	6,211	2,176	1,479	4,985	55,260
1979	28,911	16,206	18,231	9,927	4,781	2,284	2,404	2,074	721	1,875	42,297
1980	20,251	29,708	13,131	14,056	5,284	2,174	998	872	680	841	38,035
1981	37,381	30,533	28,171	8,482	5,949	1,625	589	257	236	427	45,736
1982	30,982	43,851	38,129	25,430	5,045	2,681	725	275	124	282	72,691
1983	21,034	51,085	44,235	30,846	16,645	2,796	1,343	351	146	214	96,576
1984	28,940	35,345	65,295	39,344	21,486	9,882	1,690	755	206	244	138,902
1985	33,544	50,000	43,750	61,529	30,156	15,249	6,702	1,122	476	298	159,283
1986	34,231	58,643	59,378	37,058	46,549	21,182	10,292	4,400	722	451	180,031
1987	24,406	52,270	75,500	51,019	26,122	29,792	12,943	6,147	2,562	697	204,782
1988	16,508	32,638	59,350	65,784	34,826	15,561	17,494	7,228	3,328	1,756	205,327
1989	50,414	28,880	36,576	45,033	48,066	23,015	9,888	10,926	4,412	3,069	180,986
1990	52,201	83,573	33,783	30,279	31,633	34,958	16,248	6,649	7,385	4,776	165,709
1991	16,532	64,635	98,341	26,069	17,088	16,893	17,835	8,159	3,251	5,927	193,562
1992	28,014	23,003	68,819	79,492	17,524	10,776	10,782	11,830	5,383	5,757	210,362
1993	14,039	50,966	24,196	57,883	55,214	11,311	7,004	7,089	8,048	7,550	178,295
1994	35,781	17,928	60,488	21,316	42,678	39,035	8,087	4,989	5,113	11,418	193,123
1995	16,062	32,537	24,296	51,318	12,023	23,419	21,422	4,628	2,668	9,051	148,824
1996	30,625	22,460	42,817	15,715	28,705	5,591	11,179	10,547	2,283	5,990	122,826
1997	42,283	45,826	28,110	37,475	7,900	13,409	2,497	4,991	4,756	3,585	102,724
1998	35,528	50,563	54,058	21,449	21,194	3,776	6,322	1,175	2,289	3,844	114,107
1999	23,673	46,120	68,424	42,469	10,764	9,479	1,588	2,701	505	2,529	138,459
2000	41,986	30,994	63,549	56,560	21,610	4,295	3,653	595	1,014	1,114	152,392
2001	33,049	62,417	43,734	51,567	29,793	9,836	1,834	1,571	248	845	139,428
2002	49,386	55,728	81,438	35,814	30,424	14,696	4,562	840	697	487	168,958
2003	35,261	73,679	69,056	73,216	20,383	14,956	7,003	2,115	389	540	187,657
2004	31,362	51,300	84,019	53,731	42,557	9,281	7,031	3,204	971	404	201,198
2005	14,993	41,556	53,761	71,722	38,201	26,595	5,537	4,206	1,873	830	202,725
2006	41,642	21,881	53,167	45,338	46,171	22,922	15,761	3,124	2,344	1,487	190,314
2007	46,134	65,313	27,430	44,369	31,541	27,442	10,748	6,576	1,204	1,459	150,771
2008	38,309	45,505	74,206	20,779	27,326	16,404	11,624	4,169	2,555	1,002	158,065
2009	37,643	58,270	69,480	68,185	16,540	18,832	9,072	5,653	1,859	1,488	191,109
2010	24,517	39,604	54,426	54,025	50,154	8,475	7,275	2,842	1,750	1,046	179,993
2011	29,589	22,486	41,450	47,272	36,726	27,878	3,056	2,107	778	717	159,983
2012	17,421	40,449	22,161	38,392	36,158	21,892	12,211	1,222	796	538	133,370
2013	15,644	22,832	46,353	22,334	29,335	23,623	11,261	5,411	568	583	139,467
2014	18,100	19,230	25,393	45,059	17,608	18,817	12,234	5,333	2,401	522	127,367
2015	18,454	23,440	20,499	24,887	37,046	11,716	10,359	5,975	2,525	1,371	114,377
2016	6,741	19,669	28,851	22,012	21,289	24,021	6,201	5,115	2,740	1,772	112,003
2017	2,872	7,623	22,665	30,844	18,228	13,687	13,309	3,317	2,804	2,404	107,258
2018	7,697	3,523	8,009	21,063	23,743	11,648	7,668	7,364	1,926	3,043	84,465
2019	19,493	8,317	4,102	7,588	16,191	16,159	6,842	4,290	4,294	2,890	62,356

Table 36. qSCA 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	127,865	143,455	89,228	49,216	24,867	23,883	19,402	6,735	5,006	12,461	230,799
1979	263,028	100,981	97,744	43,207	18,118	7,881	7,523	5,861	2,040	5,378	187,753
1980	262,038	210,366	69,182	58,126	20,178	7,595	3,130	2,448	1,780	2,160	164,600
1981	309,964	204,378	139,761	34,270	19,578	4,960	1,677	696	561	972	202,475
1982	466,331	253,285	162,604	93,006	15,747	7,216	1,866	684	299	624	282,045
1983	295,420	381,251	203,005	113,542	55,061	8,277	3,567	933	352	491	385,229
1984	411,107	241,642	308,312	150,184	71,793	30,288	4,575	1,928	529	510	568,119
1985	541,696	336,328	195,741	234,045	100,723	45,624	18,681	2,824	1,141	657	599,435
1986	378,080	443,087	271,641	143,347	155,916	63,042	28,243	11,557	1,744	1,106	676,596
1987	267,021	309,085	356,131	195,074	88,564	91,601	36,253	16,107	6,617	1,636	791,983
1988	249,767	218,185	245,641	248,985	116,610	47,736	49,019	19,148	8,421	4,343	739,904
1989	724,387	204,203	174,015	170,009	160,054	70,083	27,798	28,733	11,133	7,394	649,219
1990	563,309	592,285	162,888	115,918	106,167	105,894	46,208	17,636	18,660	11,583	584,954
1991	221,775	460,248	470,293	104,849	60,050	51,551	50,926	22,185	8,446	14,485	782,784
1992	581,541	181,321	369,279	335,843	65,815	36,694	32,294	33,843	14,725	14,828	903,320
1993	228,853	475,568	144,647	259,487	217,305	41,217	22,728	20,659	22,833	19,752	748,628
1994	678,978	248,168	596,925	147,643	280,324	146,348	27,892	15,426	14,418	30,945	1,259,921
1995	377,816	555,063	196,242	420,780	82,814	90,182	76,533	14,463	7,890	24,461	913,365
1996	753,692	308,483	438,881	113,054	220,298	21,697	38,878	34,676	6,637	16,134	890,256
1997	1,037,888	615,943	243,046	292,152	53,921	51,982	8,724	16,033	14,523	9,671	690,053
1998	953,834	848,186	493,192	157,970	154,820	14,059	22,741	3,755	7,010	10,807	864,354
1999	628,686	779,518	675,326	340,290	75,005	36,180	5,541	9,150	1,519	7,367	1,150,378
2000	1,303,429	513,557	621,188	446,433	161,453	16,654	12,955	1,969	3,249	3,168	1,267,068
2001	1,051,664	1,065,482	407,422	424,785	222,456	37,771	6,637	5,322	793	2,678	1,107,865
2002	1,257,896	859,761	857,406	275,285	229,871	56,488	16,437	2,828	2,288	1,501	1,442,105
2003	815,135	1,028,294	691,455	623,271	146,443	58,716	25,230	7,359	1,243	1,692	1,555,408
2004	730,564	665,745	819,508	490,143	355,025	37,567	26,343	11,298	3,336	1,301	1,744,521
2005	376,646	597,455	534,928	606,582	317,870	110,013	21,231	15,085	6,440	2,678	1,614,827
2006	1,216,013	307,905	478,985	370,641	363,110	94,612	62,128	11,334	8,251	4,979	1,394,040
2007	881,881	994,832	249,177	365,448	249,659	116,284	43,417	25,581	4,381	5,171	1,059,117
2008	859,930	721,060	807,926	185,042	245,514	78,115	51,697	17,287	9,968	3,670	1,399,218
2009	655,846	703,221	583,070	626,266	120,947	78,045	34,754	21,185	7,081	5,621	1,476,969
2010	374,545	536,286	570,457	443,789	444,685	36,472	29,235	10,918	6,351	3,739	1,545,644
2011	773,251	306,279	434,548	440,291	299,263	129,101	12,809	8,236	2,982	2,590	1,329,820
2012	429,919	632,579	248,694	336,619	314,540	103,511	55,421	5,025	3,041	2,013	1,068,863
2013	362,180	351,782	514,614	193,034	238,204	116,313	51,419	24,047	2,261	2,184	1,142,076
2014	475,073	296,328	286,261	399,038	131,885	91,738	56,461	23,140	10,213	1,955	1,000,691
2015	353,946	388,711	241,401	226,039	285,396	55,143	47,231	25,831	10,882	5,364	897,286
2016	126,309	289,625	316,261	189,991	162,616	113,856	27,766	22,137	11,434	7,372	851,433
2017	77,596	103,337	235,969	247,314	137,453	63,867	60,144	14,374	11,445	9,525	780,090
2018	142,029	63,508	84,095	187,432	179,052	56,893	35,353	32,685	8,048	11,684	595,241
2019	294,777	86,952	51,850	65,880	139,648	80,858	32,593	19,385	18,525	11,502	420,241

Table 37. qmSCA maximum likelihood estimates of August 1 total biomass (t) of fall spawners in the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	19,706	26,951	19,445	12,406	6,594	6,202	6,199	2,129	1,505	5,965	60,445
1979	46,746	20,294	23,158	11,810	5,207	2,183	2,408	2,110	721	2,229	49,825
1980	32,187	40,413	15,442	16,525	5,746	2,070	990	891	694	920	43,279
1981	50,405	41,408	35,089	9,590	6,626	1,542	556	240	226	429	54,298
1982	56,768	63,827	46,130	29,232	5,392	2,708	767	285	124	297	84,936
1983	34,012	81,949	57,120	34,386	17,617	2,751	1,504	407	162	235	114,181
1984	46,874	50,985	90,067	45,593	22,424	9,794	1,811	926	259	283	171,158
1985	56,136	76,639	56,816	75,830	32,655	15,324	7,209	1,302	638	383	190,158
1986	52,749	86,667	77,181	43,499	52,910	21,800	11,142	5,112	906	644	213,194
1987	27,672	67,524	96,002	60,072	28,916	31,583	14,442	7,213	3,229	1,018	242,475
1988	21,516	39,268	67,825	77,081	38,881	16,615	20,300	8,817	4,268	2,512	236,300
1989	72,088	36,868	40,227	48,636	52,538	23,860	11,372	13,736	5,823	4,448	200,641
1990	66,631	111,102	38,587	31,933	33,451	35,021	17,859	8,121	9,915	7,046	181,935
1991	17,663	80,133	119,919	29,067	18,527	17,769	19,639	9,874	4,352	9,094	228,241
1992	30,910	24,786	79,683	92,051	19,267	11,667	11,901	13,796	6,927	8,993	244,284
1993	13,817	55,970	24,924	64,819	62,455	12,183	7,795	8,125	9,860	11,370	201,530
1994	41,165	16,640	61,206	21,649	47,488	42,964	8,847	5,651	6,005	15,985	209,795
1995	15,473	32,989	23,429	52,346	12,990	26,572	24,130	5,203	3,121	12,649	160,439
1996	33,538	22,711	43,803	15,998	31,013	6,330	12,811	12,140	2,640	8,432	133,166
1997	46,082	50,154	29,258	40,346	8,844	15,098	2,900	5,920	5,713	5,064	113,143
1998	39,094	52,956	59,158	23,529	24,628	4,580	7,330	1,395	2,794	5,140	128,555
1999	25,237	51,034	73,186	48,643	13,284	12,083	1,969	3,254	619	3,409	156,447
2000	51,912	33,186	72,357	65,433	27,989	6,094	4,848	762	1,283	1,560	180,327
2001	40,792	77,630	49,169	63,646	39,951	14,819	2,674	2,178	329	1,186	173,953
2002	57,853	69,941	104,664	45,008	44,345	23,629	7,305	1,284	1,032	722	227,990
2003	38,408	87,828	89,894	103,846	31,282	26,975	11,975	3,652	633	868	269,123
2004	35,416	59,837	106,310	79,136	74,390	18,203	13,629	5,853	1,817	709	300,046
2005	19,691	55,858	69,194	103,129	66,128	55,892	10,738	8,122	3,416	1,524	318,142
2006	86,136	31,092	77,402	68,590	82,508	49,865	32,944	6,052	4,523	2,740	324,624
2007	86,103	145,415	42,213	69,226	56,761	60,669	26,763	17,758	3,104	3,702	280,195
2008	87,106	100,358	178,836	37,098	54,895	38,731	29,451	13,401	9,136	3,385	364,934
2009	73,454	139,079	158,335	186,098	37,888	48,799	22,710	16,810	7,280	6,483	484,402
2010	43,427	84,434	150,104	150,863	174,192	28,571	23,771	10,631	8,182	6,852	553,166
2011	50,157	45,561	100,172	151,351	136,223	146,410	13,381	10,946	4,778	6,652	569,913
2012	28,887	81,595	51,481	110,796	148,564	118,354	60,908	5,606	4,552	4,534	504,794
2013	23,167	44,391	105,576	60,985	110,632	136,583	46,930	23,136	2,169	3,406	489,416
2014	26,009	33,547	56,402	120,307	64,910	103,996	53,419	18,370	8,793	2,066	428,262
2015	27,370	37,572	40,586	63,749	127,362	61,180	40,088	20,253	6,780	4,120	364,119
2016	8,394	36,059	53,362	51,195	69,531	118,916	22,872	15,135	7,493	4,076	342,579
2017	4,500	11,439	49,194	68,182	53,741	62,208	44,913	8,473	5,837	4,381	296,929
2018	8,756	6,642	14,549	52,283	65,003	45,312	24,769	17,760	3,378	4,240	227,294
2019	26,314	11,670	9,140	15,883	49,356	58,501	19,615	10,665	7,649	3,228	174,037

Table 38. qmSCA maximum likelihood estimates of January 1 total abundance (number in thousands) of fall spawners in the southern Gulf of St. Lawrence.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	192,250	208,162	110,361	55,084	25,635	23,135	19,353	6,581	5,095	14,870	260,115
1979	417,002	132,791	126,111	51,934	19,813	7,535	7,539	5,961	2,039	6,392	227,325
1980	401,974	290,468	81,850	68,423	21,956	7,234	3,110	2,504	1,816	2,362	189,254
1981	520,703	278,143	176,954	39,012	21,838	4,704	1,585	650	535	975	246,252
1982	861,524	369,209	197,700	106,949	16,835	7,283	1,977	709	301	656	332,411
1983	480,430	604,279	260,982	126,872	58,408	8,149	3,997	1,085	394	543	460,429
1984	716,181	344,700	425,645	174,903	75,237	30,033	4,910	2,372	666	599	714,364
1985	919,510	504,446	249,329	289,004	109,241	45,849	20,095	3,272	1,532	853	719,174
1986	521,105	647,869	356,255	168,059	177,573	64,863	30,585	13,426	2,187	1,598	814,545
1987	329,779	381,703	455,541	231,442	98,559	97,140	40,506	18,929	8,371	2,388	952,876
1988	338,725	249,018	279,127	291,980	130,159	51,004	56,872	23,362	10,802	6,223	849,529
1989	1,056,630	250,453	187,795	184,409	174,886	72,630	31,970	36,087	14,678	10,685	713,139
1990	746,006	775,516	185,723	122,550	112,409	106,059	50,793	21,537	25,038	17,101	641,210
1991	240,140	559,630	566,934	116,773	65,128	54,254	56,083	26,844	11,291	22,188	919,495
1992	667,740	187,256	422,589	387,767	72,331	39,668	35,645	39,467	18,945	23,143	1,039,555
1993	216,824	507,523	145,774	290,061	245,785	44,338	25,276	23,678	27,970	29,699	832,579
1994	813,654	257,037	649,649	156,924	314,426	160,890	30,476	17,461	16,935	43,317	1,390,079
1995	422,922	628,338	200,437	446,542	90,259	102,225	86,131	16,260	9,228	34,187	985,269
1996	902,185	338,213	480,819	119,284	239,543	24,602	44,566	39,903	7,680	22,731	979,129
1997	1,185,356	712,741	264,988	324,035	60,885	58,533	10,140	19,019	17,432	13,673	768,704
1998	1,134,993	954,565	559,870	177,944	181,315	17,046	26,345	4,460	8,557	14,441	989,979
1999	727,748	920,597	761,358	397,258	93,069	46,125	6,874	11,011	1,864	9,933	1,327,492
2000	1,699,338	603,507	742,219	532,210	211,120	23,631	17,200	2,519	4,101	4,435	1,537,436
2001	1,373,145	1,402,701	493,898	541,341	303,353	56,978	9,684	7,384	1,054	3,760	1,417,451
2002	1,610,868	1,147,376	1,159,405	364,832	341,341	91,156	26,374	4,339	3,398	2,237	1,993,082
2003	1,030,768	1,360,909	956,565	912,387	233,150	106,480	43,489	12,782	2,043	2,744	2,269,642
2004	1,014,316	884,128	1,139,748	746,902	629,990	74,517	51,461	20,930	6,294	2,321	2,672,163
2005	566,075	874,536	756,665	924,346	561,083	232,138	41,638	29,359	11,888	4,977	2,562,094
2006	2,798,775	495,034	753,303	599,381	674,617	206,229	130,404	22,187	16,084	9,244	2,411,448
2007	1,946,542	2,451,010	433,905	631,661	467,134	258,352	108,479	69,433	11,409	13,294	1,993,667
2008	2,143,525	1,730,221	2,157,917	360,342	506,602	181,729	128,821	55,261	35,812	12,559	3,439,043
2009	1,414,875	1,919,588	1,541,007	1,875,709	290,874	204,255	88,185	63,877	27,896	24,587	4,116,390
2010	738,460	1,283,689	1,725,428	1,345,678	1,588,218	122,799	95,192	40,756	29,626	24,423	4,972,118
2011	1,487,032	677,456	1,169,044	1,535,805	1,151,890	679,273	55,671	42,720	18,316	24,140	4,676,859
2012	803,668	1,369,538	624,284	1,054,803	1,354,570	560,600	276,988	23,027	17,345	17,149	3,928,766
2013	614,593	741,579	1,266,215	567,765	936,098	675,650	214,558	103,248	8,762	12,819	3,785,115
2014	771,698	569,143	685,825	1,153,318	501,579	509,261	248,269	80,033	37,874	7,961	3,224,119
2015	672,220	718,647	527,740	628,254	1,027,716	290,440	184,543	88,685	29,274	16,446	2,793,098
2016	193,960	623,519	668,893	483,509	559,822	567,986	103,288	65,857	31,425	16,607	2,497,386
2017	150,357	181,632	577,898	611,642	431,350	291,896	203,786	36,864	23,818	17,631	2,194,885
2018	213,697	139,038	169,650	528,930	543,554	223,341	115,555	80,000	14,381	16,558	1,691,969
2019	422,943	124,395	128,491	154,722	473,201	296,629	94,541	49,028	33,691	13,121	1,243,424

Table 39. qSCA 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. F_{5-10} is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.037	0.463	1.185	1.291	1.298	1.298	1.298	1.298	1.298	1.298	1.295
1979	0.029	0.371	0.950	1.035	1.040	1.040	1.040	1.040	1.040	1.040	1.038
1980	0.019	0.237	0.606	0.661	0.664	0.664	0.664	0.664	0.664	0.664	0.662
1981	0.002	0.041	0.297	0.439	0.451	0.451	0.451	0.451	0.451	0.451	0.443
1982	0.002	0.035	0.247	0.366	0.375	0.376	0.376	0.376	0.376	0.376	0.367
1983	0.001	0.018	0.130	0.193	0.198	0.198	0.198	0.198	0.198	0.198	0.194
1984	0.001	0.014	0.102	0.151	0.155	0.155	0.155	0.155	0.155	0.155	0.153
1985	0.001	0.025	0.178	0.263	0.270	0.271	0.271	0.271	0.271	0.271	0.267
1986	0.002	0.036	0.260	0.385	0.395	0.396	0.396	0.396	0.396	0.396	0.391
1987	0.003	0.046	0.326	0.482	0.494	0.495	0.495	0.495	0.495	0.495	0.490
1988	0.002	0.037	0.265	0.391	0.402	0.402	0.402	0.402	0.402	0.402	0.397
1989	0.003	0.044	0.316	0.468	0.480	0.481	0.481	0.481	0.481	0.481	0.474
1990	0.003	0.056	0.404	0.598	0.613	0.614	0.614	0.614	0.614	0.614	0.607
1991	0.002	0.036	0.256	0.379	0.389	0.389	0.389	0.389	0.389	0.389	0.385
1992	0.002	0.040	0.289	0.427	0.438	0.439	0.439	0.439	0.439	0.439	0.431
1993	0.002	0.030	0.217	0.321	0.330	0.330	0.330	0.330	0.330	0.330	0.325
1994	0.004	0.064	0.460	0.680	0.698	0.699	0.699	0.699	0.699	0.699	0.693
1995	0.006	0.106	0.759	1.123	1.152	1.154	1.154	1.154	1.154	1.154	1.137
1996	0.005	0.087	0.625	0.925	0.949	0.950	0.950	0.950	0.950	0.950	0.938
1997	0.004	0.077	0.550	0.813	0.834	0.835	0.835	0.835	0.835	0.835	0.820
1998	0.004	0.076	0.546	0.808	0.829	0.830	0.830	0.830	0.830	0.830	0.816
1999	0.004	0.077	0.549	0.812	0.833	0.834	0.834	0.834	0.834	0.834	0.819
2000	0.005	0.079	0.563	0.833	0.855	0.856	0.856	0.856	0.856	0.856	0.838
2001	0.004	0.069	0.495	0.732	0.751	0.752	0.752	0.752	0.752	0.752	0.739
2002	0.004	0.068	0.486	0.719	0.738	0.739	0.739	0.739	0.739	0.739	0.727
2003	0.006	0.097	0.693	1.025	1.052	1.053	1.054	1.054	1.054	1.054	1.037
2004	0.003	0.046	0.326	0.483	0.495	0.496	0.496	0.496	0.496	0.496	0.488
2005	0.003	0.059	0.419	0.620	0.636	0.637	0.637	0.637	0.637	0.637	0.624
2006	0.003	0.030	0.241	0.720	0.891	0.911	0.913	0.913	0.913	0.913	0.787
2007	0.004	0.036	0.288	0.861	1.064	1.089	1.091	1.092	1.092	1.092	0.945
2008	0.003	0.035	0.276	0.824	1.019	1.043	1.045	1.045	1.045	1.045	0.920
2009	0.003	0.027	0.211	0.630	0.779	0.797	0.799	0.799	0.799	0.799	0.670
2010	0.002	0.022	0.175	0.525	0.649	0.664	0.665	0.665	0.665	0.665	0.563
2011	0.002	0.016	0.124	0.370	0.457	0.468	0.469	0.469	0.469	0.469	0.408
2012	0.001	0.013	0.105	0.315	0.389	0.398	0.399	0.399	0.399	0.399	0.351
2013	0.002	0.015	0.120	0.360	0.445	0.455	0.456	0.456	0.456	0.456	0.414
2014	0.001	0.011	0.091	0.271	0.335	0.343	0.344	0.344	0.344	0.344	0.301
2015	0.001	0.012	0.093	0.278	0.344	0.352	0.353	0.353	0.353	0.353	0.326
2016	0.001	0.012	0.091	0.273	0.338	0.345	0.346	0.346	0.346	0.346	0.321
2017	0.001	0.010	0.076	0.227	0.281	0.287	0.288	0.288	0.288	0.288	0.258
2018	0.001	0.009	0.072	0.216	0.267	0.273	0.273	0.274	0.274	0.274	0.253
2019	0.001	0.011	0.084	0.250	0.309	0.317	0.317	0.317	0.317	0.317	0.300

Table 40. qmSCA 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. F_{5-10} is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.048	0.557	1.261	1.351	1.356	1.356	1.356	1.356	1.356	1.356	1.354
1979	0.040	0.461	1.044	1.118	1.122	1.122	1.122	1.122	1.122	1.122	1.121
1980	0.026	0.300	0.679	0.728	0.730	0.731	0.731	0.731	0.731	0.731	0.729
1981	0.004	0.063	0.346	0.453	0.460	0.460	0.460	0.460	0.460	0.460	0.455
1982	0.003	0.054	0.294	0.384	0.391	0.391	0.391	0.391	0.391	0.391	0.386
1983	0.002	0.028	0.154	0.202	0.205	0.205	0.205	0.205	0.205	0.205	0.203
1984	0.001	0.022	0.118	0.155	0.158	0.158	0.158	0.158	0.158	0.158	0.156
1985	0.002	0.037	0.204	0.266	0.271	0.271	0.271	0.271	0.271	0.271	0.269
1986	0.003	0.053	0.292	0.382	0.389	0.389	0.389	0.389	0.389	0.389	0.386
1987	0.004	0.066	0.363	0.475	0.483	0.483	0.483	0.483	0.483	0.483	0.480
1988	0.003	0.054	0.297	0.389	0.396	0.396	0.396	0.396	0.396	0.396	0.393
1989	0.004	0.065	0.354	0.463	0.470	0.471	0.471	0.471	0.471	0.471	0.467
1990	0.005	0.080	0.437	0.572	0.582	0.582	0.582	0.582	0.582	0.582	0.578
1991	0.003	0.050	0.276	0.361	0.367	0.367	0.367	0.367	0.367	0.367	0.365
1992	0.003	0.057	0.314	0.410	0.417	0.417	0.417	0.417	0.417	0.417	0.413
1993	0.003	0.042	0.231	0.303	0.308	0.308	0.308	0.308	0.308	0.308	0.306
1994	0.005	0.090	0.494	0.646	0.657	0.658	0.658	0.658	0.658	0.658	0.654
1995	0.009	0.148	0.811	1.062	1.079	1.080	1.080	1.080	1.080	1.080	1.072
1996	0.007	0.123	0.672	0.879	0.894	0.895	0.895	0.895	0.895	0.895	0.888
1997	0.006	0.106	0.582	0.761	0.774	0.774	0.774	0.774	0.774	0.774	0.766
1998	0.006	0.103	0.563	0.737	0.749	0.750	0.750	0.750	0.750	0.750	0.742
1999	0.006	0.104	0.572	0.748	0.760	0.761	0.761	0.761	0.761	0.761	0.753
2000	0.006	0.106	0.579	0.757	0.769	0.770	0.770	0.770	0.770	0.770	0.761
2001	0.005	0.090	0.492	0.644	0.655	0.655	0.655	0.655	0.655	0.655	0.649
2002	0.005	0.087	0.476	0.623	0.634	0.634	0.634	0.634	0.634	0.634	0.628
2003	0.007	0.119	0.652	0.853	0.867	0.868	0.868	0.868	0.868	0.868	0.861
2004	0.004	0.058	0.318	0.416	0.423	0.423	0.423	0.423	0.423	0.423	0.419
2005	0.005	0.075	0.412	0.540	0.549	0.549	0.549	0.549	0.549	0.549	0.543
2006	0.003	0.042	0.321	0.560	0.589	0.591	0.591	0.591	0.591	0.591	0.573
2007	0.003	0.046	0.353	0.615	0.647	0.649	0.649	0.649	0.649	0.649	0.633
2008	0.002	0.034	0.256	0.446	0.469	0.470	0.470	0.470	0.470	0.470	0.459
2009	0.001	0.021	0.157	0.275	0.289	0.290	0.290	0.290	0.290	0.290	0.280
2010	0.001	0.014	0.105	0.183	0.192	0.193	0.193	0.193	0.193	0.193	0.186
2011	0.001	0.009	0.065	0.114	0.120	0.120	0.120	0.120	0.120	0.120	0.117
2012	0.001	0.007	0.056	0.099	0.104	0.104	0.104	0.104	0.104	0.104	0.102
2013	0.001	0.008	0.063	0.110	0.116	0.116	0.116	0.116	0.116	0.116	0.114
2014	0.000	0.007	0.053	0.092	0.097	0.097	0.097	0.097	0.097	0.097	0.095
2015	0.001	0.008	0.058	0.101	0.107	0.107	0.107	0.107	0.107	0.107	0.106
2016	0.001	0.009	0.066	0.115	0.121	0.121	0.121	0.121	0.121	0.121	0.120
2017	0.001	0.009	0.067	0.117	0.123	0.124	0.124	0.124	0.124	0.124	0.121
2018	0.001	0.009	0.071	0.125	0.131	0.131	0.131	0.131	0.131	0.131	0.129
2019	0.001	0.012	0.092	0.161	0.169	0.169	0.169	0.169	0.169	0.169	0.168

Table 41. qSCA 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. $F_{5\text{-}10}$ 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	0.004	0.032	0.209	0.582	0.734	0.757	0.760	0.760	0.761	0.761	0.704
1979	0.010	0.084	0.547	1.524	1.923	1.983	1.990	1.991	1.991	1.991	1.743
1980	0.005	0.041	0.265	0.739	0.932	0.961	0.964	0.965	0.965	0.965	0.790
1981	0.001	0.016	0.254	1.252	1.579	1.601	1.603	1.603	1.603	1.603	1.372
1982	0.000	0.003	0.053	0.259	0.327	0.332	0.332	0.332	0.332	0.332	0.269
1983	0.001	0.012	0.192	0.946	1.193	1.210	1.211	1.211	1.211	1.211	1.072
1984	0.000	0.006	0.094	0.465	0.586	0.595	0.595	0.595	0.595	0.595	0.507
1985	0.000	0.002	0.034	0.165	0.209	0.212	0.212	0.212	0.212	0.212	0.179
1986	0.000	0.003	0.048	0.235	0.296	0.301	0.301	0.301	0.301	0.301	0.274
1987	0.000	0.003	0.053	0.261	0.330	0.334	0.335	0.335	0.335	0.335	0.304
1988	0.000	0.005	0.074	0.363	0.458	0.465	0.465	0.465	0.465	0.465	0.419
1989	0.000	0.002	0.032	0.160	0.202	0.205	0.205	0.205	0.205	0.205	0.186
1990	0.000	0.003	0.052	0.257	0.324	0.328	0.329	0.329	0.329	0.329	0.304
1991	0.000	0.005	0.081	0.398	0.502	0.508	0.509	0.509	0.509	0.509	0.452
1992	0.000	0.002	0.039	0.192	0.242	0.246	0.246	0.246	0.246	0.246	0.203
1993	0.000	0.003	0.044	0.219	0.276	0.280	0.281	0.281	0.281	0.281	0.250
1994	0.000	0.003	0.051	0.251	0.317	0.321	0.322	0.322	0.322	0.322	0.308
1995	0.000	0.007	0.111	0.548	0.691	0.701	0.701	0.701	0.701	0.701	0.614
1996	0.000	0.006	0.104	0.514	0.649	0.658	0.658	0.658	0.658	0.658	0.625
1997	0.000	0.007	0.111	0.546	0.689	0.698	0.699	0.699	0.699	0.699	0.614
1998	0.001	0.010	0.158	0.778	0.981	0.995	0.996	0.996	0.996	0.996	0.895
1999	0.000	0.009	0.143	0.704	0.888	0.900	0.901	0.901	0.901	0.901	0.756
2000	0.000	0.008	0.123	0.608	0.767	0.778	0.779	0.779	0.779	0.779	0.648
2001	0.000	0.005	0.082	0.405	0.511	0.518	0.518	0.518	0.518	0.518	0.449
2002	0.000	0.005	0.086	0.425	0.537	0.544	0.544	0.545	0.545	0.545	0.488
2003	0.000	0.004	0.069	0.341	0.430	0.436	0.436	0.436	0.436	0.436	0.383
2004	0.000	0.004	0.063	0.309	0.390	0.396	0.396	0.396	0.396	0.396	0.346
2005	0.000	0.005	0.083	0.412	0.519	0.527	0.527	0.527	0.527	0.527	0.457
2006	0.000	0.002	0.014	0.085	0.361	0.699	0.812	0.833	0.836	0.836	0.337
2007	0.000	0.002	0.012	0.071	0.303	0.588	0.684	0.701	0.703	0.704	0.321
2008	0.000	0.002	0.014	0.084	0.359	0.696	0.809	0.829	0.833	0.833	0.444
2009	0.000	0.002	0.016	0.099	0.422	0.818	0.951	0.975	0.978	0.979	0.334
2010	0.000	0.003	0.017	0.104	0.442	0.857	0.996	1.021	1.025	1.025	0.357
2011	0.000	0.002	0.013	0.079	0.336	0.652	0.757	0.776	0.779	0.779	0.329
2012	0.000	0.002	0.010	0.064	0.272	0.527	0.612	0.627	0.630	0.630	0.301
2013	0.000	0.002	0.011	0.065	0.278	0.540	0.627	0.643	0.645	0.645	0.365
2014	0.000	0.001	0.010	0.059	0.250	0.484	0.563	0.577	0.579	0.579	0.252
2015	0.000	0.002	0.011	0.067	0.285	0.552	0.642	0.658	0.660	0.661	0.308
2016	0.000	0.001	0.008	0.050	0.212	0.412	0.478	0.490	0.492	0.492	0.257
2017	0.000	0.002	0.010	0.062	0.265	0.514	0.597	0.612	0.614	0.615	0.321
2018	0.000	0.001	0.009	0.055	0.236	0.457	0.531	0.544	0.546	0.547	0.307
2019	0.000	0.001	0.009	0.052	0.223	0.433	0.503	0.516	0.518	0.518	0.343

Table 42. qmSCA 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. $F_{5\text{-}10}$ is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.002	0.016	0.120	0.461	0.678	0.716	0.720	0.721	0.721	0.721	0.626
1979	0.005	0.044	0.330	1.264	1.858	1.963	1.975	1.977	1.977	1.977	1.570
1980	0.002	0.021	0.161	0.616	0.906	0.957	0.963	0.964	0.964	0.964	0.686
1981	0.001	0.010	0.173	0.999	1.336	1.360	1.362	1.362	1.362	1.362	1.117
1982	0.000	0.002	0.035	0.200	0.268	0.273	0.273	0.273	0.273	0.273	0.209
1983	0.000	0.007	0.125	0.721	0.965	0.982	0.983	0.983	0.983	0.983	0.838
1984	0.000	0.003	0.055	0.318	0.425	0.433	0.433	0.433	0.433	0.433	0.350
1985	0.000	0.001	0.019	0.113	0.151	0.154	0.154	0.154	0.154	0.154	0.123
1986	0.000	0.002	0.029	0.170	0.228	0.232	0.232	0.232	0.232	0.232	0.205
1987	0.000	0.002	0.034	0.194	0.260	0.265	0.265	0.265	0.265	0.265	0.232
1988	0.000	0.003	0.047	0.271	0.363	0.369	0.369	0.370	0.370	0.370	0.320
1989	0.000	0.001	0.021	0.124	0.166	0.169	0.169	0.169	0.169	0.169	0.148
1990	0.000	0.002	0.036	0.209	0.279	0.284	0.285	0.285	0.285	0.285	0.257
1991	0.000	0.003	0.057	0.332	0.445	0.453	0.453	0.453	0.453	0.453	0.388
1992	0.000	0.002	0.028	0.161	0.215	0.219	0.219	0.219	0.219	0.219	0.171
1993	0.000	0.002	0.032	0.186	0.249	0.254	0.254	0.254	0.254	0.254	0.219
1994	0.000	0.002	0.038	0.221	0.295	0.300	0.301	0.301	0.301	0.301	0.284
1995	0.000	0.005	0.085	0.491	0.656	0.668	0.669	0.669	0.669	0.669	0.568
1996	0.000	0.005	0.079	0.458	0.612	0.623	0.624	0.624	0.624	0.624	0.584
1997	0.000	0.005	0.084	0.485	0.649	0.661	0.661	0.661	0.661	0.661	0.562
1998	0.000	0.007	0.119	0.689	0.922	0.939	0.940	0.940	0.940	0.940	0.823
1999	0.000	0.007	0.109	0.633	0.847	0.862	0.863	0.863	0.863	0.863	0.695
2000	0.000	0.005	0.090	0.524	0.701	0.713	0.714	0.714	0.714	0.714	0.569
2001	0.000	0.003	0.056	0.326	0.437	0.444	0.445	0.445	0.445	0.445	0.373
2002	0.000	0.003	0.057	0.330	0.441	0.449	0.449	0.449	0.449	0.449	0.394
2003	0.000	0.003	0.046	0.266	0.355	0.361	0.362	0.362	0.362	0.362	0.311
2004	0.000	0.003	0.043	0.247	0.330	0.336	0.336	0.336	0.336	0.336	0.288
2005	0.000	0.003	0.055	0.316	0.423	0.431	0.431	0.431	0.431	0.431	0.365
2006	0.000	0.001	0.011	0.100	0.303	0.368	0.375	0.375	0.375	0.375	0.240
2007	0.000	0.001	0.010	0.084	0.256	0.311	0.316	0.317	0.317	0.317	0.218
2008	0.000	0.001	0.011	0.097	0.294	0.356	0.363	0.364	0.364	0.364	0.268
2009	0.000	0.001	0.010	0.086	0.260	0.316	0.322	0.322	0.322	0.322	0.160
2010	0.000	0.001	0.007	0.064	0.194	0.235	0.239	0.240	0.240	0.240	0.138
2011	0.000	0.000	0.005	0.044	0.135	0.164	0.167	0.167	0.167	0.167	0.112
2012	0.000	0.000	0.004	0.036	0.110	0.133	0.136	0.136	0.136	0.136	0.098
2013	0.000	0.000	0.004	0.038	0.117	0.141	0.144	0.144	0.144	0.144	0.115
2014	0.000	0.000	0.004	0.035	0.105	0.127	0.130	0.130	0.130	0.130	0.085
2015	0.000	0.000	0.004	0.036	0.110	0.133	0.135	0.136	0.136	0.136	0.098
2016	0.000	0.000	0.003	0.029	0.087	0.106	0.108	0.108	0.108	0.108	0.084
2017	0.000	0.000	0.004	0.038	0.116	0.141	0.144	0.144	0.144	0.144	0.107
2018	0.000	0.000	0.004	0.033	0.101	0.123	0.125	0.126	0.126	0.126	0.098
2019	0.000	0.000	0.004	0.033	0.100	0.121	0.123	0.123	0.123	0.123	0.105

Table 43. qSCA 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. $F_{5\text{-}10}$ is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.048	0.117	0.259	0.467	0.666	0.792	0.851	0.876	0.885	0.889	0.642
1979	0.021	0.053	0.116	0.210	0.299	0.356	0.383	0.394	0.398	0.400	0.265
1980	0.098	0.242	0.533	0.963	1.374	1.633	1.756	1.806	1.826	1.833	1.168
1981	0.002	0.014	0.102	0.444	0.740	0.803	0.812	0.813	0.813	0.813	0.610
1982	0.001	0.010	0.071	0.312	0.520	0.565	0.571	0.571	0.572	0.572	0.374
1983	0.001	0.007	0.052	0.227	0.378	0.410	0.415	0.415	0.415	0.415	0.291
1984	0.001	0.006	0.048	0.211	0.351	0.381	0.385	0.386	0.386	0.386	0.275
1985	0.001	0.005	0.038	0.165	0.275	0.299	0.302	0.302	0.302	0.302	0.212
1986	0.001	0.005	0.040	0.174	0.290	0.315	0.318	0.319	0.319	0.319	0.259
1987	0.001	0.007	0.050	0.218	0.362	0.394	0.398	0.398	0.398	0.398	0.303
1988	0.001	0.005	0.034	0.148	0.247	0.268	0.271	0.271	0.271	0.271	0.200
1989	0.000	0.002	0.015	0.064	0.106	0.115	0.117	0.117	0.117	0.117	0.098
1990	0.001	0.009	0.066	0.289	0.482	0.524	0.529	0.530	0.530	0.530	0.476
1991	0.000	0.002	0.017	0.074	0.124	0.135	0.136	0.136	0.136	0.136	0.118
1992	0.000	0.002	0.018	0.077	0.128	0.138	0.140	0.140	0.140	0.140	0.103
1993	0.000	0.001	0.009	0.040	0.067	0.072	0.073	0.073	0.073	0.073	0.058
1994	0.001	0.006	0.047	0.204	0.341	0.370	0.374	0.374	0.374	0.374	0.336
1995	0.001	0.006	0.048	0.210	0.350	0.380	0.384	0.384	0.384	0.384	0.298
1996	0.001	0.010	0.078	0.342	0.569	0.618	0.625	0.626	0.626	0.626	0.554
1997	0.001	0.009	0.071	0.308	0.513	0.557	0.563	0.564	0.564	0.564	0.418
1998	0.001	0.010	0.076	0.333	0.555	0.603	0.609	0.610	0.610	0.610	0.498
1999	0.002	0.014	0.103	0.448	0.747	0.811	0.820	0.821	0.821	0.821	0.567
2000	0.001	0.011	0.079	0.347	0.578	0.628	0.634	0.635	0.635	0.635	0.445
2001	0.001	0.011	0.080	0.351	0.585	0.635	0.642	0.643	0.643	0.643	0.462
2002	0.001	0.010	0.074	0.325	0.542	0.589	0.595	0.595	0.595	0.596	0.474
2003	0.001	0.010	0.072	0.314	0.523	0.568	0.574	0.574	0.575	0.575	0.382
2004	0.001	0.005	0.040	0.175	0.291	0.316	0.319	0.319	0.320	0.320	0.241
2005	0.001	0.005	0.041	0.179	0.299	0.325	0.328	0.329	0.329	0.329	0.257
2006	0.000	0.001	0.007	0.041	0.204	0.509	0.657	0.687	0.692	0.693	0.318
2007	0.000	0.001	0.007	0.044	0.218	0.543	0.701	0.733	0.738	0.739	0.343
2008	0.000	0.001	0.006	0.039	0.191	0.476	0.615	0.644	0.648	0.649	0.338
2009	0.000	0.002	0.010	0.062	0.307	0.765	0.987	1.033	1.040	1.041	0.340
2010	0.000	0.002	0.012	0.075	0.370	0.923	1.192	1.246	1.255	1.257	0.410
2011	0.000	0.001	0.009	0.056	0.277	0.690	0.891	0.932	0.939	0.940	0.341
2012	0.000	0.001	0.007	0.046	0.227	0.566	0.730	0.764	0.769	0.770	0.326
2013	0.000	0.001	0.007	0.046	0.226	0.564	0.728	0.762	0.767	0.768	0.415
2014	0.000	0.001	0.008	0.052	0.259	0.646	0.835	0.873	0.879	0.880	0.407
2015	0.000	0.002	0.010	0.063	0.313	0.781	1.008	1.055	1.062	1.063	0.427
2016	0.000	0.001	0.009	0.059	0.292	0.727	0.938	0.982	0.988	0.990	0.411
2017	0.000	0.001	0.006	0.035	0.172	0.428	0.553	0.579	0.583	0.583	0.224
2018	0.000	0.001	0.005	0.032	0.161	0.401	0.518	0.542	0.545	0.546	0.197
2019	0.000	0.001	0.006	0.038	0.189	0.471	0.608	0.636	0.640	0.641	0.339

Table 44. qmSCA 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. $F_{5\text{-}10}$ is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.025	0.068	0.175	0.377	0.625	0.806	0.895	0.930	0.943	0.948	0.580
1979	0.011	0.032	0.081	0.175	0.290	0.374	0.415	0.431	0.437	0.439	0.239
1980	0.052	0.144	0.369	0.795	1.316	1.698	1.886	1.960	1.987	1.997	1.041
1981	0.001	0.010	0.074	0.360	0.662	0.735	0.745	0.746	0.746	0.746	0.516
1982	0.001	0.007	0.051	0.247	0.455	0.505	0.512	0.513	0.513	0.513	0.301
1983	0.001	0.005	0.037	0.178	0.328	0.364	0.369	0.369	0.369	0.369	0.234
1984	0.001	0.004	0.034	0.164	0.301	0.335	0.339	0.340	0.340	0.340	0.219
1985	0.000	0.003	0.026	0.127	0.235	0.260	0.264	0.264	0.264	0.264	0.166
1986	0.000	0.004	0.028	0.135	0.249	0.277	0.280	0.281	0.281	0.281	0.213
1987	0.001	0.004	0.035	0.169	0.311	0.345	0.349	0.350	0.350	0.350	0.246
1988	0.000	0.003	0.024	0.115	0.212	0.236	0.239	0.239	0.239	0.239	0.164
1989	0.000	0.001	0.010	0.051	0.093	0.104	0.105	0.105	0.105	0.105	0.084
1990	0.001	0.006	0.047	0.226	0.417	0.463	0.469	0.470	0.470	0.470	0.408
1991	0.000	0.001	0.011	0.056	0.103	0.114	0.116	0.116	0.116	0.116	0.096
1992	0.000	0.002	0.012	0.058	0.106	0.118	0.119	0.120	0.120	0.120	0.081
1993	0.000	0.001	0.006	0.031	0.057	0.063	0.064	0.064	0.064	0.064	0.048
1994	0.001	0.004	0.033	0.159	0.293	0.325	0.330	0.330	0.330	0.330	0.289
1995	0.001	0.004	0.034	0.164	0.303	0.336	0.341	0.341	0.341	0.341	0.252
1996	0.001	0.007	0.054	0.264	0.485	0.539	0.546	0.547	0.547	0.547	0.473
1997	0.001	0.006	0.049	0.237	0.436	0.484	0.490	0.491	0.491	0.491	0.345
1998	0.001	0.007	0.051	0.250	0.461	0.512	0.518	0.519	0.519	0.519	0.407
1999	0.001	0.009	0.068	0.330	0.607	0.675	0.683	0.685	0.685	0.685	0.444
2000	0.001	0.006	0.048	0.235	0.433	0.481	0.488	0.488	0.489	0.489	0.323
2001	0.001	0.006	0.044	0.214	0.394	0.438	0.444	0.445	0.445	0.445	0.305
2002	0.001	0.005	0.037	0.179	0.330	0.366	0.371	0.372	0.372	0.372	0.288
2003	0.001	0.004	0.033	0.163	0.300	0.333	0.337	0.338	0.338	0.338	0.215
2004	0.000	0.002	0.017	0.081	0.148	0.165	0.167	0.167	0.167	0.167	0.122
2005	0.000	0.002	0.016	0.076	0.140	0.155	0.157	0.158	0.158	0.158	0.120
2006	0.000	0.000	0.003	0.030	0.126	0.184	0.193	0.194	0.195	0.195	0.129
2007	0.000	0.000	0.003	0.030	0.124	0.182	0.191	0.192	0.192	0.192	0.126
2008	0.000	0.000	0.003	0.024	0.099	0.145	0.152	0.153	0.153	0.153	0.110
2009	0.000	0.000	0.003	0.030	0.125	0.184	0.193	0.194	0.194	0.194	0.081
2010	0.000	0.000	0.002	0.021	0.089	0.131	0.138	0.138	0.138	0.138	0.075
2011	0.000	0.000	0.002	0.015	0.062	0.092	0.096	0.097	0.097	0.097	0.058
2012	0.000	0.000	0.001	0.013	0.053	0.078	0.082	0.082	0.082	0.082	0.056
2013	0.000	0.000	0.002	0.014	0.060	0.089	0.093	0.093	0.093	0.093	0.073
2014	0.000	0.000	0.002	0.019	0.078	0.114	0.120	0.120	0.120	0.120	0.080
2015	0.000	0.000	0.002	0.020	0.082	0.120	0.126	0.127	0.127	0.127	0.081
2016	0.000	0.000	0.002	0.018	0.074	0.109	0.114	0.115	0.115	0.115	0.079
2017	0.000	0.000	0.001	0.012	0.050	0.073	0.077	0.077	0.077	0.077	0.049
2018	0.000	0.000	0.001	0.012	0.051	0.075	0.079	0.079	0.079	0.079	0.046
2019	0.000	0.000	0.002	0.014	0.060	0.088	0.093	0.093	0.093	0.093	0.072

Table 45. qSCA maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of fall spawners in the southern Gulf of St. Lawrence. F_{5-10} is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.005	0.028	0.056	0.043	0.025	0.024	0.020	0.007	0.005	0.012	0.956
1979	0.006	0.019	0.036	0.030	0.015	0.007	0.009	0.007	0.002	0.007	0.831
1980	0.013	0.044	0.035	0.052	0.025	0.011	0.004	0.003	0.002	0.003	1.051
1981	0.001	0.006	0.030	0.021	0.017	0.004	0.001	0.000	0.000	0.001	0.719
1982	0.001	0.005	0.027	0.030	0.007	0.004	0.001	0.000	0.000	0.000	0.356
1983	0.000	0.005	0.021	0.032	0.025	0.004	0.002	0.000	0.000	0.000	0.340
1984	0.000	0.003	0.023	0.030	0.019	0.009	0.001	0.001	0.000	0.000	0.232
1985	0.001	0.005	0.022	0.049	0.027	0.013	0.005	0.001	0.000	0.000	0.235
1986	0.001	0.008	0.037	0.041	0.052	0.022	0.010	0.004	0.001	0.000	0.323
1987	0.001	0.009	0.059	0.063	0.037	0.039	0.016	0.007	0.003	0.001	0.381
1988	0.000	0.006	0.043	0.062	0.036	0.016	0.017	0.007	0.003	0.002	0.287
1989	0.001	0.005	0.038	0.049	0.036	0.016	0.008	0.007	0.003	0.002	0.255
1990	0.001	0.018	0.042	0.054	0.056	0.057	0.025	0.010	0.010	0.006	0.514
1991	0.000	0.009	0.067	0.029	0.018	0.014	0.011	0.005	0.002	0.004	0.267
1992	0.001	0.005	0.060	0.083	0.018	0.011	0.008	0.007	0.003	0.003	0.251
1993	0.000	0.007	0.021	0.052	0.044	0.008	0.004	0.003	0.003	0.003	0.197
1994	0.002	0.012	0.187	0.080	0.157	0.067	0.013	0.007	0.007	0.013	0.525
1995	0.002	0.039	0.115	0.342	0.075	0.063	0.049	0.009	0.005	0.012	0.783
1996	0.003	0.020	0.188	0.085	0.174	0.016	0.027	0.023	0.004	0.011	0.756
1997	0.003	0.031	0.098	0.185	0.039	0.033	0.006	0.010	0.009	0.006	0.645
1998	0.003	0.044	0.180	0.109	0.116	0.010	0.016	0.003	0.005	0.007	0.721
1999	0.002	0.041	0.263	0.233	0.061	0.030	0.005	0.008	0.001	0.006	0.721
2000	0.004	0.028	0.236	0.301	0.121	0.012	0.009	0.001	0.002	0.002	0.694
2001	0.003	0.046	0.143	0.245	0.149	0.024	0.004	0.003	0.001	0.002	0.611
2002	0.003	0.037	0.263	0.160	0.149	0.034	0.010	0.002	0.001	0.001	0.612
2003	0.003	0.064	0.297	0.438	0.120	0.036	0.016	0.004	0.001	0.001	0.714
2004	0.001	0.021	0.178	0.177	0.144	0.014	0.009	0.004	0.001	0.000	0.378
2005	0.001	0.024	0.161	0.287	0.161	0.041	0.009	0.006	0.003	0.001	0.471
2006	0.002	0.006	0.076	0.177	0.222	0.056	0.043	0.009	0.006	0.004	0.563
2007	0.002	0.022	0.049	0.203	0.180	0.073	0.031	0.019	0.003	0.004	0.633
2008	0.002	0.017	0.136	0.102	0.167	0.049	0.036	0.012	0.007	0.003	0.635
2009	0.001	0.013	0.084	0.247	0.073	0.061	0.033	0.021	0.007	0.006	0.499
2010	0.001	0.009	0.068	0.163	0.237	0.031	0.032	0.012	0.007	0.004	0.497
2011	0.001	0.004	0.039	0.113	0.119	0.084	0.010	0.007	0.002	0.002	0.375
2012	0.000	0.006	0.020	0.079	0.104	0.052	0.036	0.003	0.002	0.001	0.337
2013	0.000	0.004	0.045	0.053	0.090	0.061	0.031	0.016	0.001	0.001	0.404
2014	0.000	0.002	0.018	0.082	0.041	0.043	0.034	0.013	0.007	0.001	0.310
2015	0.000	0.004	0.016	0.047	0.094	0.028	0.028	0.017	0.007	0.004	0.338
2016	0.000	0.002	0.022	0.038	0.050	0.051	0.013	0.011	0.006	0.004	0.320
2017	0.000	0.001	0.013	0.044	0.036	0.025	0.025	0.006	0.004	0.004	0.262
2018	0.000	0.000	0.005	0.029	0.044	0.020	0.014	0.012	0.003	0.004	0.247
2019	0.000	0.001	0.003	0.014	0.038	0.031	0.014	0.009	0.007	0.004	0.314

Table 46. qmSCA maximum likelihood estimates of the instantaneous rate of fishing mortality (F) of fall spawners in the southern Gulf of St. Lawrence. $F_{5\text{-}10}$ is the January 1 abundance-weighted average F for ages 5 to 10 years.

	Age										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.005	0.029	0.054	0.042	0.025	0.023	0.020	0.007	0.006	0.015	0.912
1979	0.007	0.020	0.033	0.031	0.016	0.007	0.009	0.007	0.003	0.009	0.765
1980	0.016	0.046	0.033	0.052	0.027	0.011	0.005	0.004	0.003	0.003	0.957
1981	0.001	0.007	0.031	0.021	0.017	0.004	0.001	0.000	0.000	0.001	0.632
1982	0.001	0.007	0.027	0.030	0.007	0.003	0.001	0.000	0.000	0.000	0.309
1983	0.000	0.006	0.022	0.031	0.024	0.003	0.002	0.000	0.000	0.000	0.304
1984	0.000	0.003	0.025	0.031	0.018	0.008	0.001	0.001	0.000	0.000	0.206
1985	0.001	0.006	0.023	0.049	0.027	0.012	0.005	0.001	0.000	0.000	0.201
1986	0.001	0.010	0.037	0.040	0.053	0.021	0.010	0.004	0.001	0.001	0.283
1987	0.001	0.011	0.058	0.060	0.037	0.038	0.016	0.008	0.003	0.001	0.328
1988	0.000	0.007	0.041	0.059	0.036	0.016	0.017	0.007	0.003	0.002	0.247
1989	0.001	0.006	0.036	0.044	0.035	0.016	0.008	0.008	0.004	0.003	0.224
1990	0.001	0.021	0.039	0.049	0.053	0.051	0.025	0.011	0.012	0.008	0.456
1991	0.000	0.010	0.063	0.027	0.018	0.014	0.011	0.005	0.002	0.005	0.233
1992	0.001	0.005	0.056	0.078	0.018	0.011	0.009	0.007	0.003	0.004	0.212
1993	0.000	0.007	0.018	0.049	0.044	0.008	0.005	0.004	0.003	0.003	0.171
1994	0.003	0.016	0.202	0.077	0.163	0.070	0.013	0.008	0.007	0.016	0.485
1995	0.002	0.057	0.118	0.329	0.076	0.068	0.052	0.009	0.005	0.015	0.719
1996	0.004	0.027	0.207	0.081	0.174	0.016	0.028	0.024	0.005	0.013	0.692
1997	0.005	0.045	0.106	0.183	0.040	0.033	0.006	0.011	0.010	0.007	0.579
1998	0.004	0.061	0.197	0.108	0.121	0.011	0.017	0.003	0.005	0.008	0.636
1999	0.003	0.059	0.286	0.237	0.067	0.033	0.005	0.008	0.001	0.007	0.631
2000	0.006	0.040	0.269	0.306	0.135	0.014	0.010	0.001	0.002	0.002	0.593
2001	0.004	0.071	0.158	0.253	0.165	0.027	0.005	0.004	0.001	0.002	0.494
2002	0.005	0.057	0.318	0.167	0.173	0.040	0.011	0.002	0.001	0.001	0.474
2003	0.005	0.094	0.358	0.487	0.147	0.044	0.018	0.005	0.001	0.001	0.536
2004	0.002	0.032	0.216	0.205	0.189	0.018	0.011	0.005	0.001	0.000	0.281
2005	0.002	0.039	0.197	0.335	0.213	0.047	0.011	0.007	0.003	0.001	0.342
2006	0.004	0.013	0.141	0.208	0.266	0.049	0.029	0.006	0.004	0.002	0.341
2007	0.004	0.062	0.093	0.230	0.202	0.066	0.025	0.015	0.003	0.003	0.349
2008	0.003	0.035	0.304	0.100	0.161	0.043	0.027	0.010	0.006	0.002	0.274
2009	0.001	0.024	0.147	0.313	0.068	0.044	0.020	0.014	0.006	0.005	0.182
2010	0.000	0.011	0.109	0.163	0.244	0.020	0.015	0.007	0.005	0.004	0.141
2011	0.001	0.004	0.050	0.116	0.121	0.072	0.006	0.005	0.002	0.003	0.093
2012	0.000	0.007	0.024	0.074	0.119	0.054	0.026	0.002	0.002	0.002	0.084
2013	0.000	0.004	0.053	0.047	0.096	0.071	0.024	0.011	0.001	0.001	0.099
2014	0.000	0.002	0.023	0.079	0.047	0.055	0.029	0.009	0.005	0.001	0.089
2015	0.000	0.004	0.019	0.045	0.105	0.034	0.022	0.011	0.004	0.002	0.098
2016	0.000	0.003	0.029	0.038	0.059	0.065	0.012	0.008	0.004	0.002	0.102
2017	0.000	0.001	0.024	0.051	0.045	0.032	0.024	0.004	0.003	0.002	0.099
2018	0.000	0.001	0.008	0.043	0.059	0.024	0.013	0.009	0.002	0.002	0.099
2019	0.000	0.001	0.006	0.018	0.061	0.039	0.012	0.006	0.004	0.002	0.127

Table 47. Risk analysis table from the qSCA model of annual catch options (between 2,000 and 24,000 t) for 2020 and 2021 and subsequent years until 2028, with predicted resulting SSB (kt) in 2021, 2022 and 2029, resulting probabilities (%) of SSB being greater 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)	2021 SSB (kt)	2022 SSB (kt)	SSB < LRP in 2021 (%)	SSB < LRP in 2022 (%)	SSB < LRP 2029 (%)	SSB > USR in 2021 (%)	SSB > USR in 2022 (%)	SSB > USR in 2029 (%)	SSB 2021 > 2020 (%)	SSB 2022 >2020 (%)	5% increase SSB 2020 to 2021 (%)	5% increase SSB 2021 to 2022 (%)	Average $F_{5\text{-}10}$ in 2020	Average $F_{5\text{-}10}$ in 2021
2,000	86.207	89.185	0	0	87	1	4	0	98	96	94	47	0.03	0.03
4,000	84.391	85.799	0	0	94	0	3	0	96	93	92	44	0.07	0.07
6,000	82.668	82.726	0	0	97	0	2	0	94	88	89	42	0.11	0.11
8,000	81.062	79.707	0	0	98	0	2	0	91	82	84	40	0.15	0.15
10,000	79.555	76.491	0	0	99	0	1	0	88	76	81	37	0.19	0.20
12,000	77.753	73.424	0	2	99	0	1	0	85	69	77	34	0.24	0.27
14,000	76.040	70.272	0	4	100	0	1	0	80	62	72	32	0.28	0.34
16,000	74.471	67.056	0	7	100	0	1	0	77	56	69	30	0.33	0.43
18,000	72.497	64.030	0	12	100	0	0	0	73	50	64	29	0.39	0.52
20,000	70.950	61.517	1	16	100	0	0	0	68	44	60	27	0.44	0.64
22,000	69.524	58.988	1	22	100	0	0	0	65	40	56	25	0.51	0.76
24,000	67.968	56.339	2	27	100	0	0	0	61	35	52	24	0.57	0.88

Table 48. Risk analysis table from the qmSCA model of annual catch options (between 2,000 and 24,000 t) for 2020 and 2021 and subsequent years until 2028, with predicted resulting SSB (kt) in 2021, 2022 and 2029, resulting probabilities (%) of SSB being greater 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)	2021 SSB (kt)	2022 SSB (kt)	SSB < LRP in 2021 (%)	SSB < LRP in 2022 (%)	SSB < LRP 2029 (%)	SSB > USR in 2021 (%)	SSB > USR in 2022 (%)	SSB > USR in 2029 (%)	SSB 2021 > 2020 (%)	SSB 2022 >2020 (%)	5% increase SSB 2020 to 2021 (%)	5% increase SSB 2021 to 2022 (%)	Average $F_{5\text{-}10}$ in 2020	Average $F_{5\text{-}10}$ in 2021
2,000	144.440	131.175	0	0	100	0	0	0	39	29	29	29	0.01	0.02
4,000	143.296	129.356	0	0	100	0	0	0	38	28	27	28	0.03	0.04
6,000	142.502	128.254	0	0	100	0	0	0	36	27	26	28	0.04	0.06
8,000	141.189	126.839	0	0	100	0	0	0	35	26	25	28	0.06	0.08
10,000	140.459	124.735	0	0	100	0	0	0	34	24	24	27	0.07	0.10
12,000	139.502	123.143	0	0	100	0	0	0	33	23	23	27	0.08	0.13
14,000	138.681	121.677	0	0	100	0	0	0	31	21	21	26	0.10	0.15
16,000	137.395	119.884	0	0	100	0	0	0	30	20	22	25	0.11	0.18
18,000	136.308	118.546	0	0	100	0	0	0	28	19	20	25	0.13	0.21
20,000	135.451	116.897	0	0	100	0	0	0	27	19	19	25	0.14	0.24
22,000	133.994	115.126	0	0	100	0	0	0	26	17	17	25	0.16	0.27
24,000	133.604	114.065	0	0	100	0	0	0	25	16	17	23	0.18	0.30

FIGURES

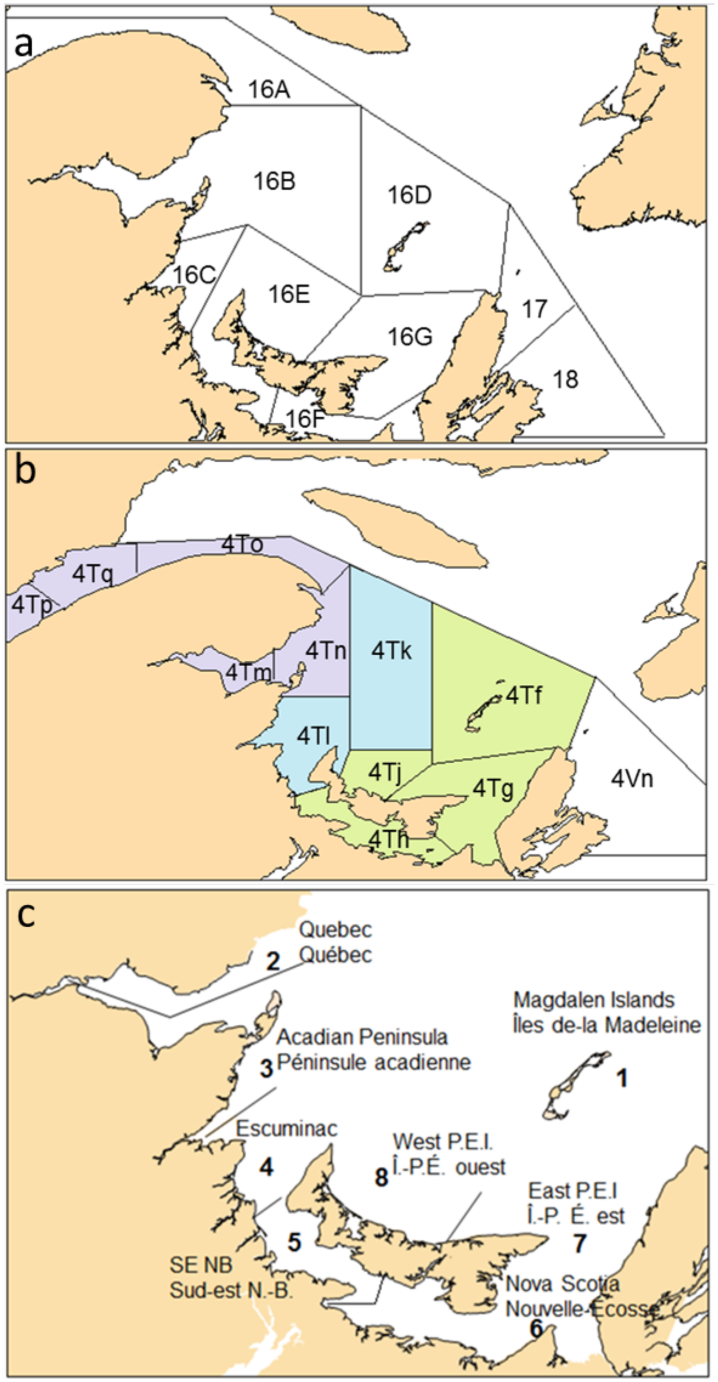

Figure 1. Southern Gulf of St. Lawrence Herring fishery management zones (upper panel, a), Northwest Atlantic Fisheries Organization (NAFO) Divisions 4T and 4Vn, where purple represents the North region, blue = Middle region, and green = South region (middle panel, b), and geographic areas used in the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

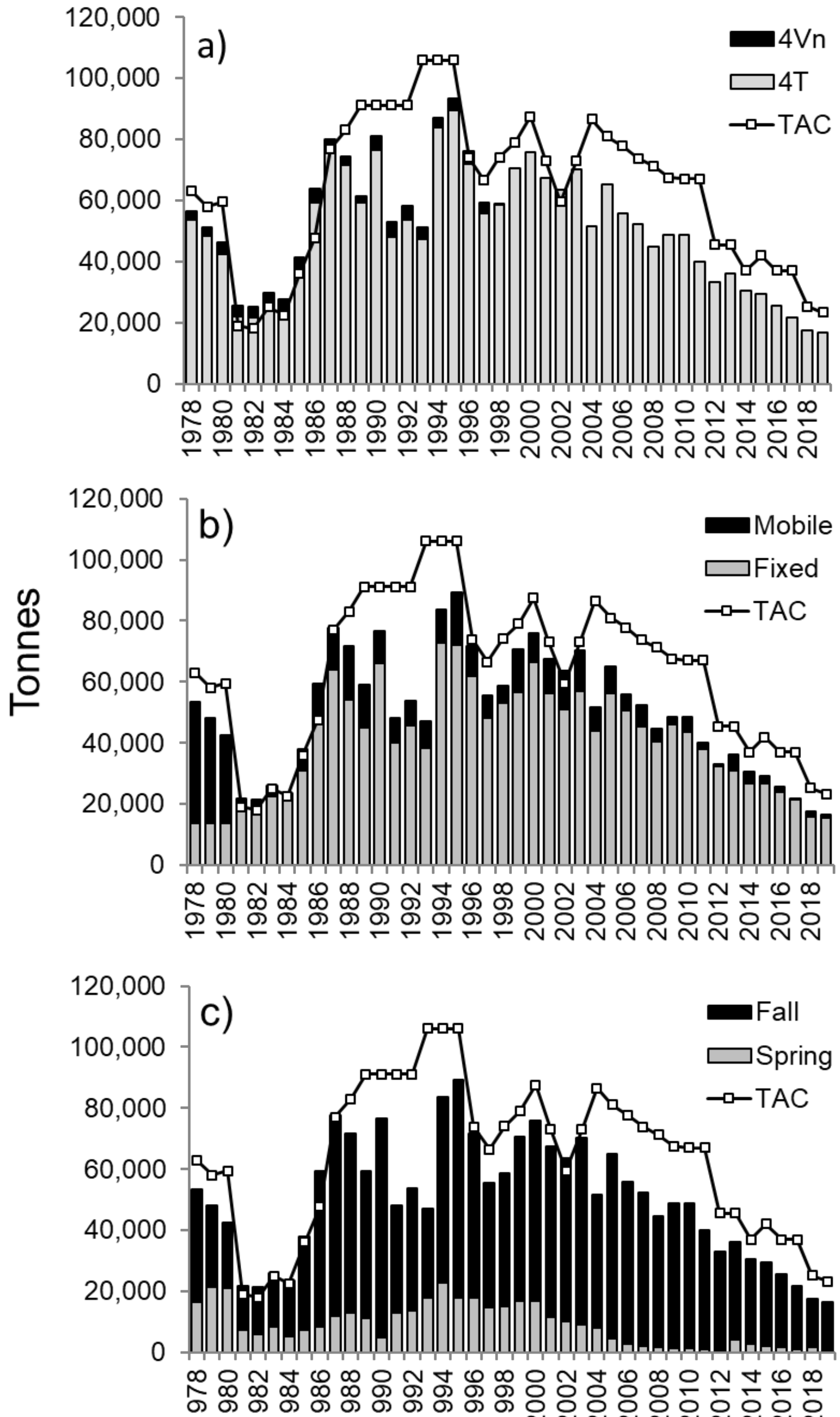

Figure 2. Reported landings (tonnes) of southern Gulf of St. Lawrence Atlantic Herring (spring and fall spawners combined) by NAFO Division (upper panel, a), by gear fleet (middle panel, b), and by fishing season (lower panel, c), 1978 to 2019. In all panels, the corresponding annual TAC (tonnes) is shown. For landings by season, the landings in Div. 4Vn were attributed to the fall fishing season. Data for 2018 and 2019 are preliminary.

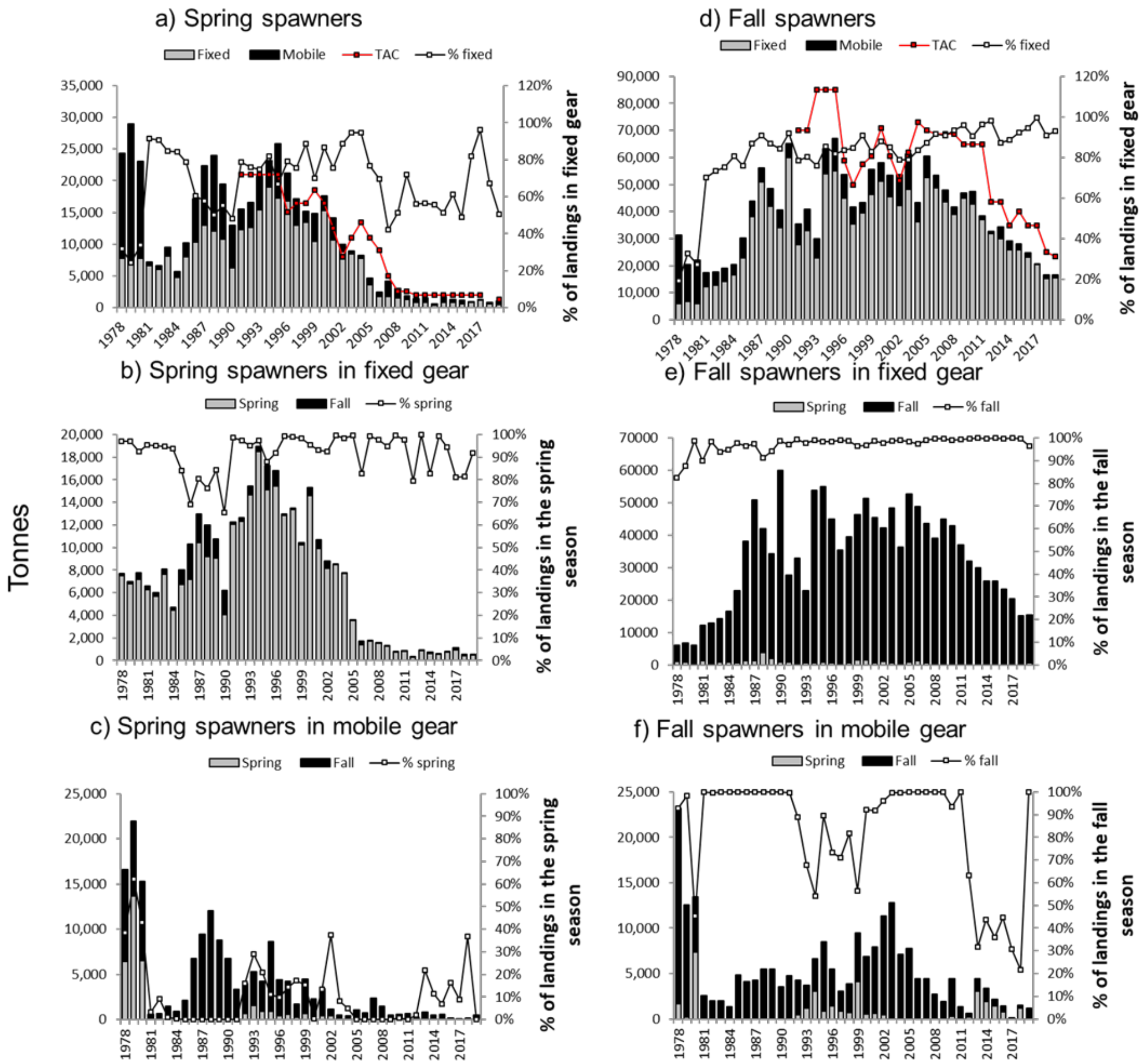

Figure 3. Estimated landings (tonnes) of the spring spawner component (SS) (left) and fall spawner component (right) of Atlantic Herring from the southern Gulf of St. Lawrence, 1978 to 2019. Panel a and d shows the estimated landings by gear type and the proportion of the landings attributed to the fixed gear fleet and the TAC for the spawner component (red symbols) for 1991 to 2019. 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 2019 are preliminary.

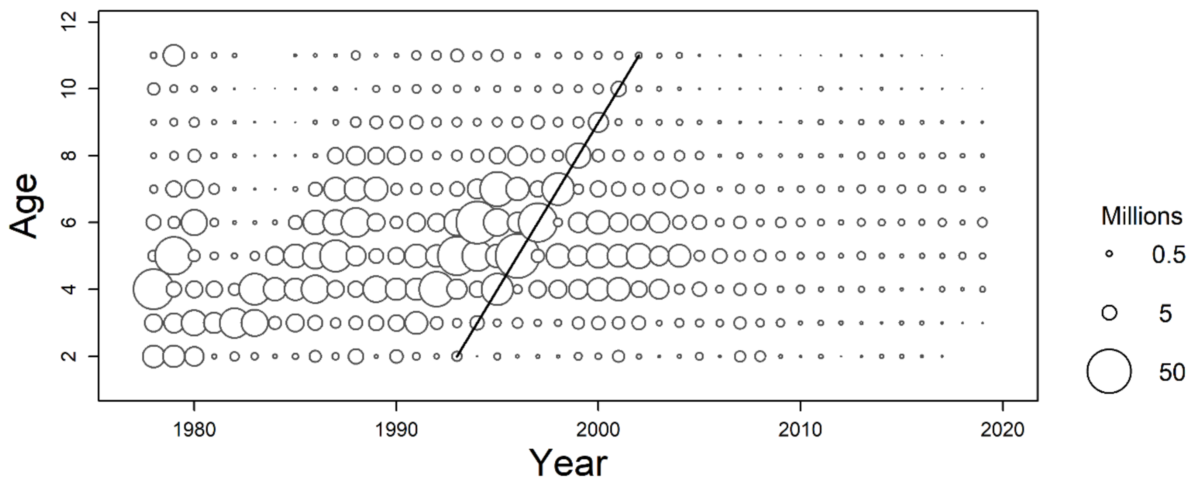

Figure 4. Catch-at-age of the spring spawner component from the fishery, all gears combined, 1978 to 2019. Size of the bubble is proportional to the catch numbers by age and year. The diagonal line represents the most recent strong year-class (1991). The values indicated at age 11 represent catches for ages 11 years and older.

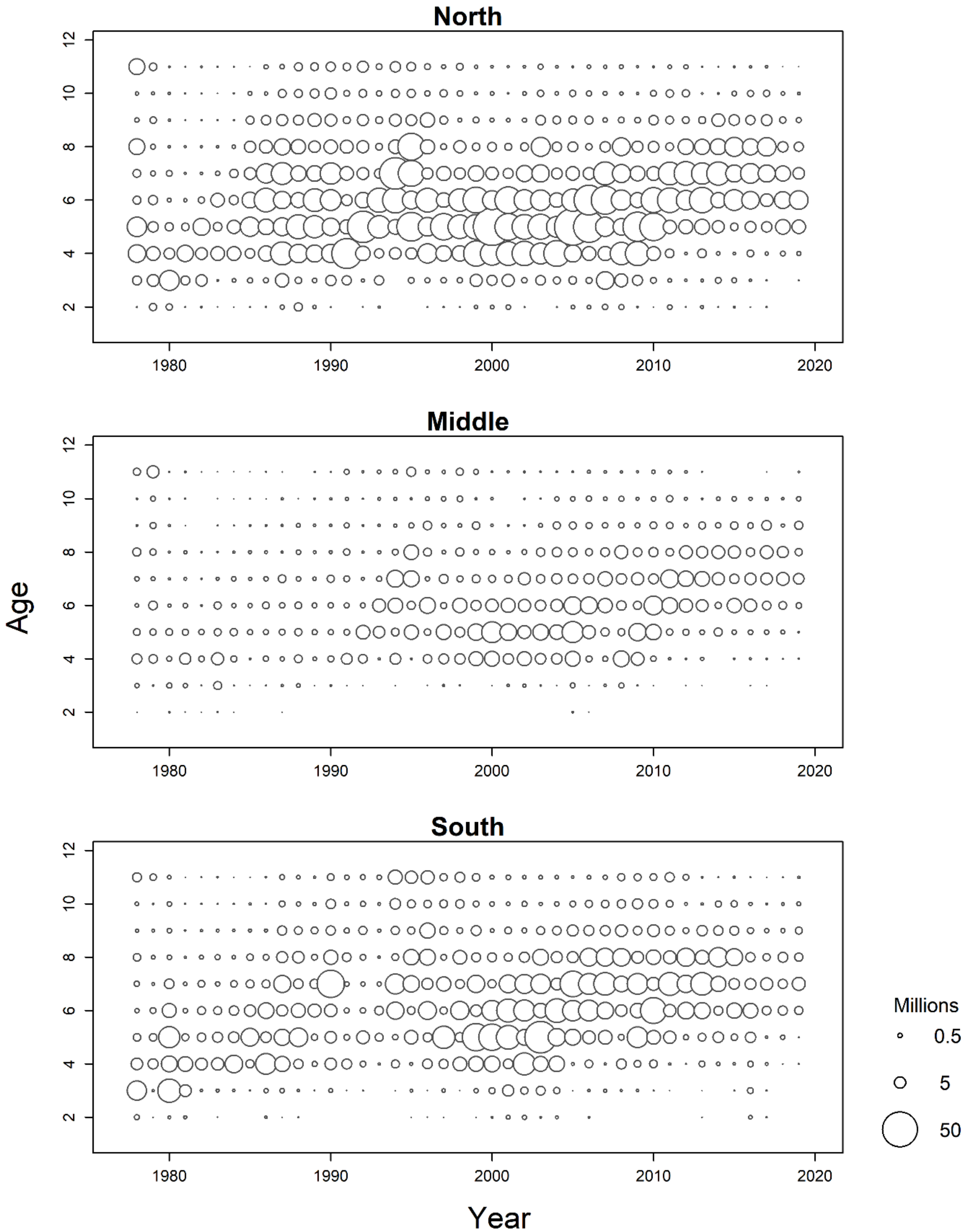

Figure 5. Bubble plots of fishery catch-at-age (number) by region for both mobile and fixed gear combined, 1978 to 2019. The size of the bubble is proportional to the number of fish in the catch by age and year. The values indicated at age 11 represent catches for ages 11 years and older.

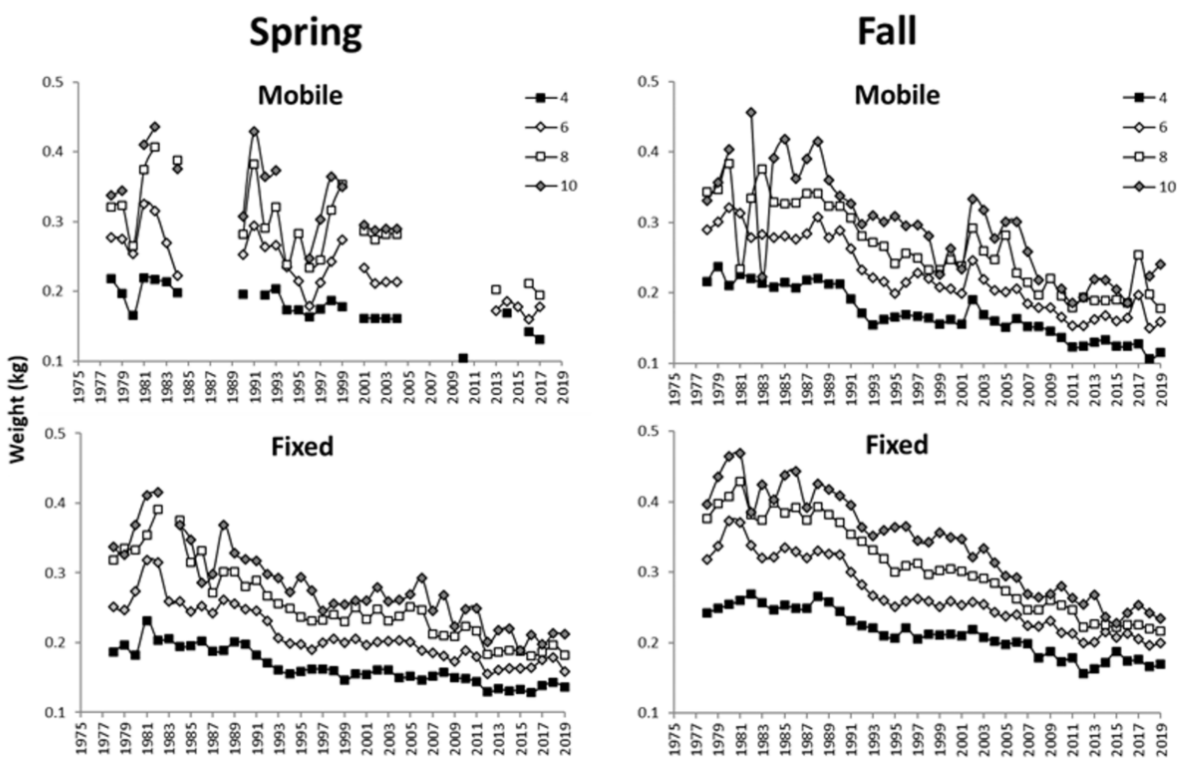

Figure 6. Mean weight (kg) of Atlantic Herring for ages 4, 6, 8, and 10 of spring spawners (left panels) sampled from catches in the spring season and fall spawners (right panels) sampled from catches in the fall season from mobile (upper panels) and fixed (lower panels) commercial gears, in NAFO Div. 4T for 1978 to 2019.

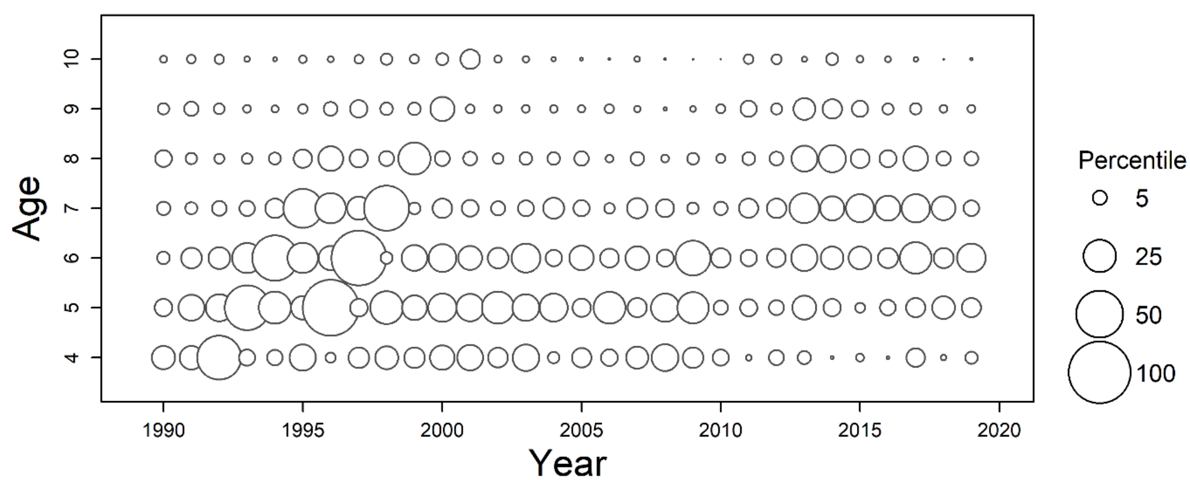

Figure 7. Bubble plot of spring spawner Herring fixed gear catch-per-unit-effort values (number per net-haul per trip) at age, 1990 to 2019. The size of the bubble is proportional to the maximum CPUE index value.

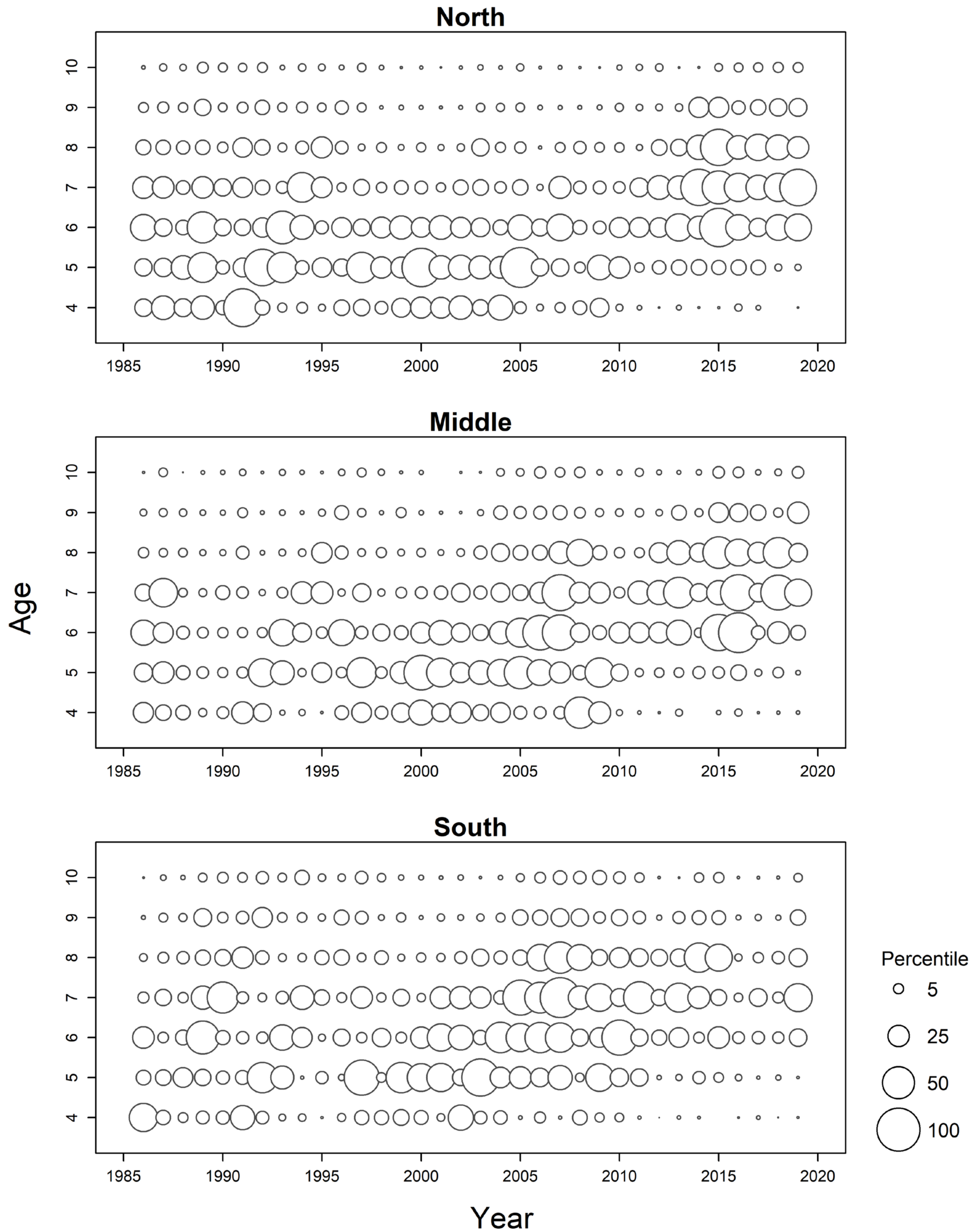

Figure 8. Fall spawner (FS) fixed gear age-disaggregated catch-per-unit-effort values (number per net-haul per trip) by region (upper panel North, middle panel Middle, and lower panel South), 1986 to 2019. The size of the bubble is proportional to the CPUE index value.

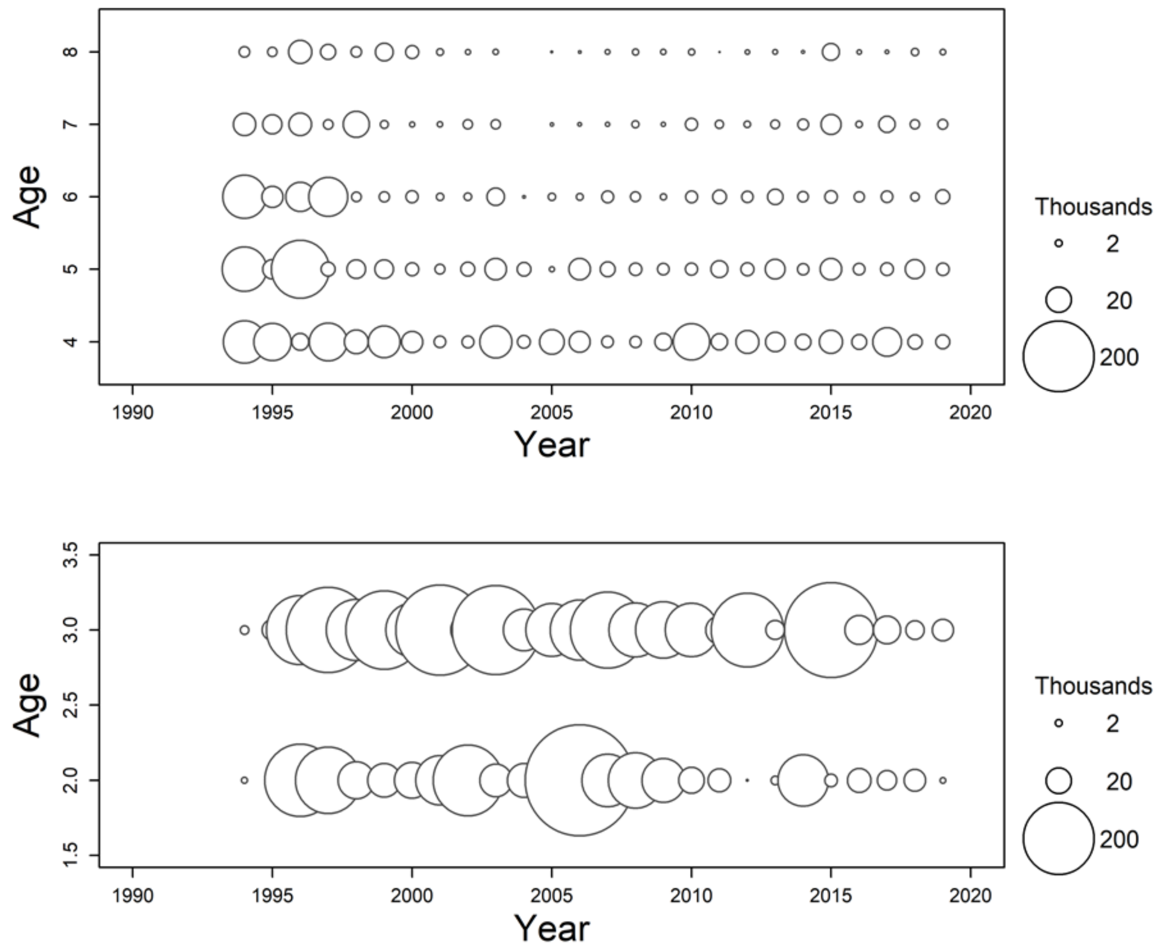

Figure 9. Bubble plot of abundance-at-age (number) from the fisheries-independent acoustic survey for spring spawners (upper panel; ages 4 to 8) and fall spawners (lower panel; ages 2 to 3) from 1994 to 2019.

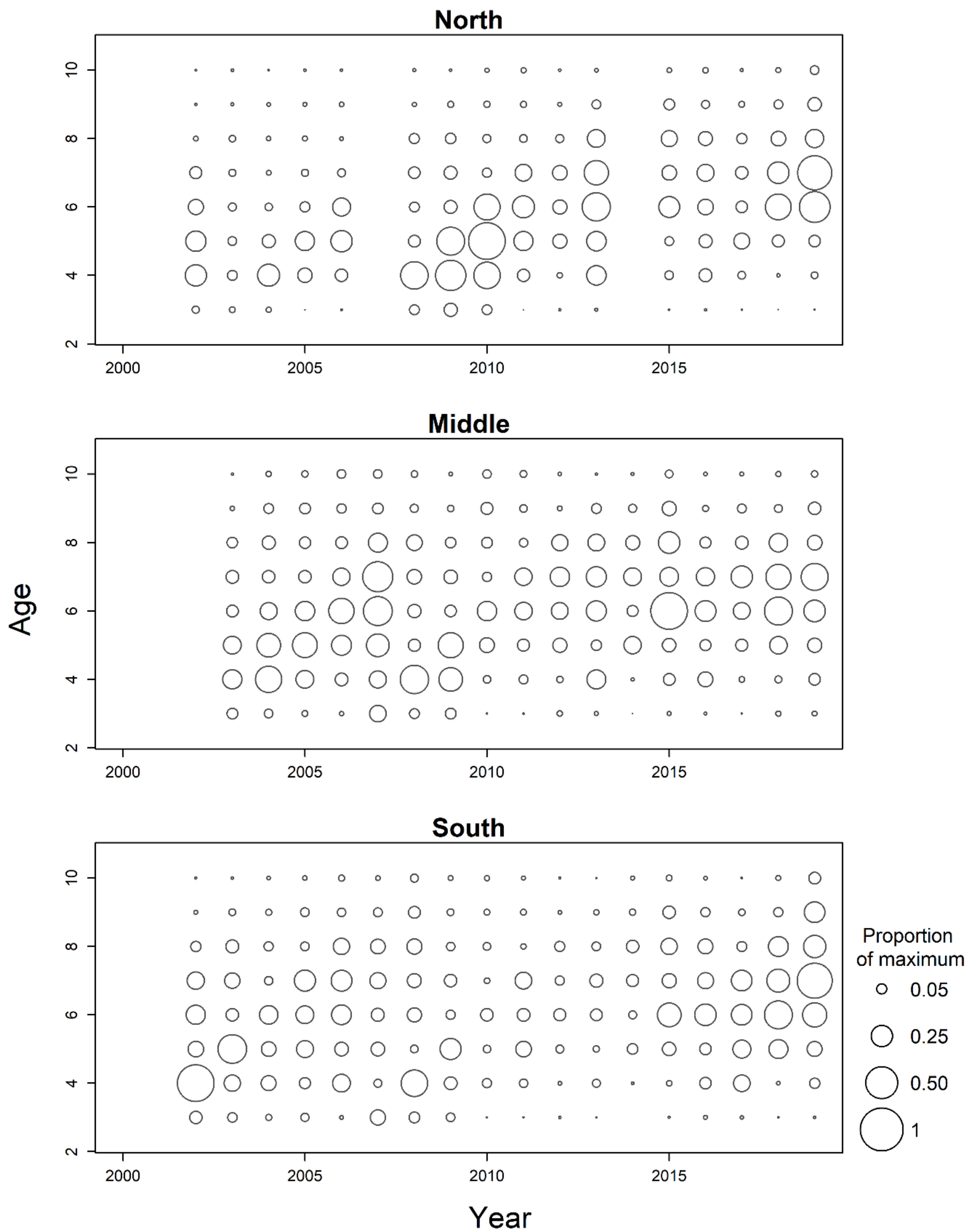

Figure 10. Bubble plots of catch-at-age indices (number) of fall spawners from the experimental netting survey by region (upper panel North, middle panel Middle, and lower panel South) from 2002 to 2017. The size of the bubble is proportional to the index value.

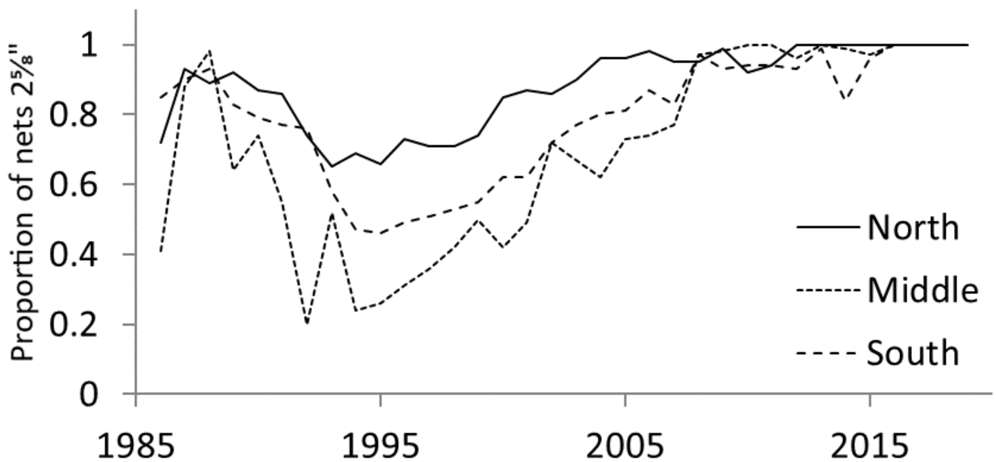

Figure 11. Variations in the proportions of gillnets with mesh sizes 2 ⅝ inches by region, 1986 to 2019. It is assumed that all other nets used were of mesh size 2 ¾.

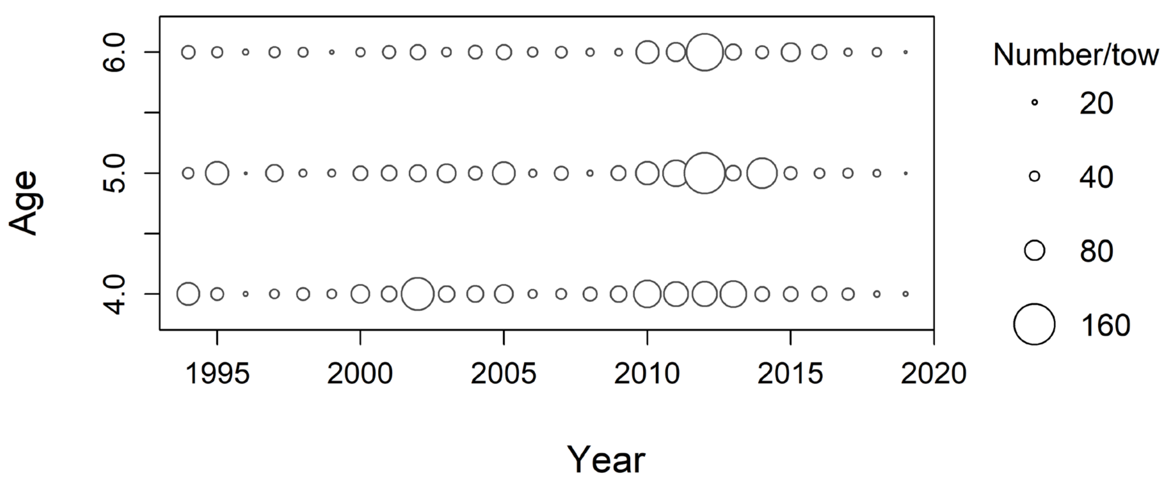

Figure 12. Multispecies bottom trawl survey abundance index (number of fish per standardized tow) for fall spawning Herring ages 4 to 6 years, 1994 to 2019.

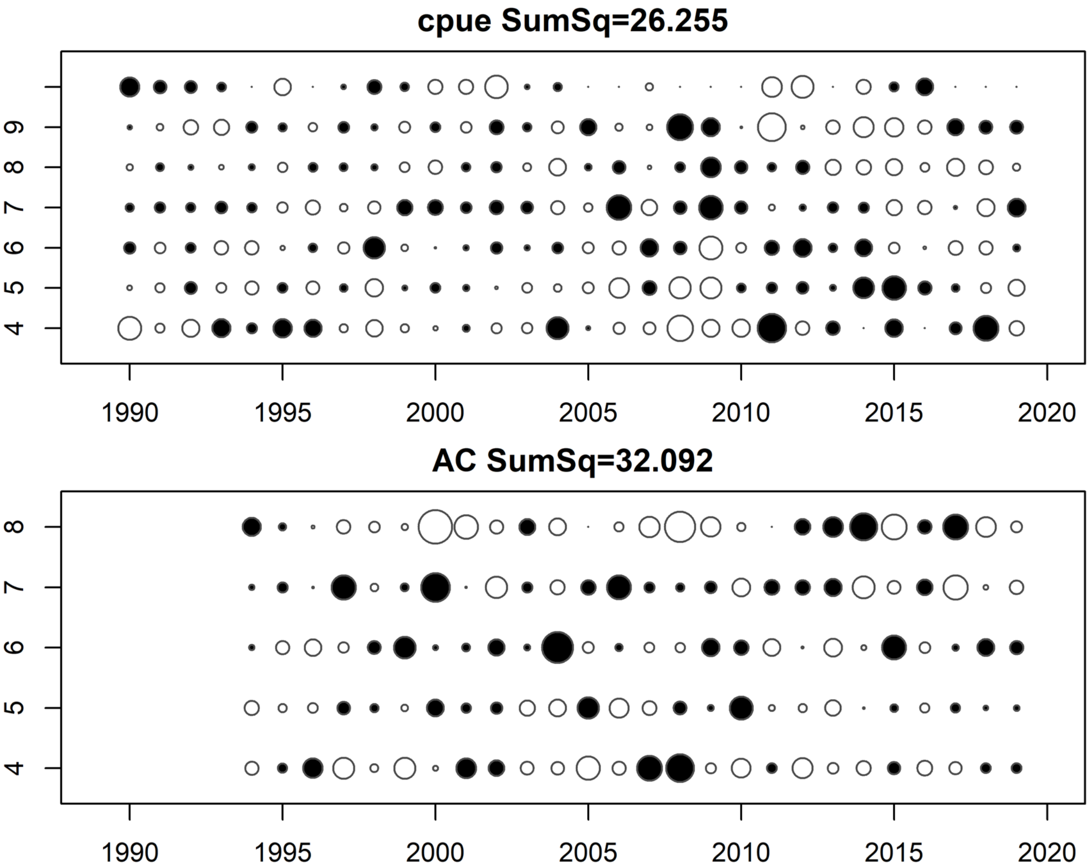

Figure 13. Residuals in PAA (observed – predicted indices) for the population model of spring spawners in the southern Gulf of St. Lawrence. The upper panel shows residuals for the CPUE index and the bottom panel shows residuals for the acoustic index. Rows are for ages and columns for years. Circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

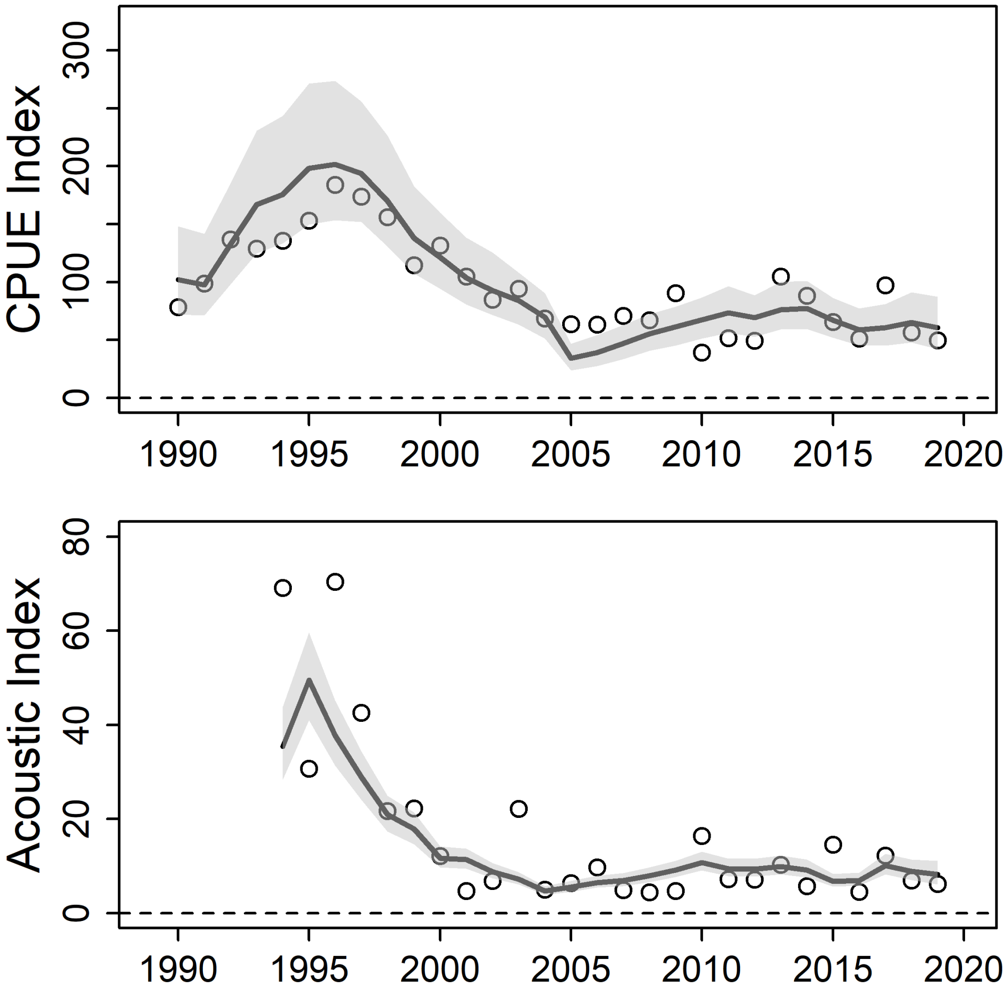

Figure 14. Observed (circles) and predicted (lines and shading) age-aggregated CPUE (upper panels) and acoustic (lower panels) indices for the population model of spring spawners in the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95 % confidence intervals of the predictions based on MCMC sampling.

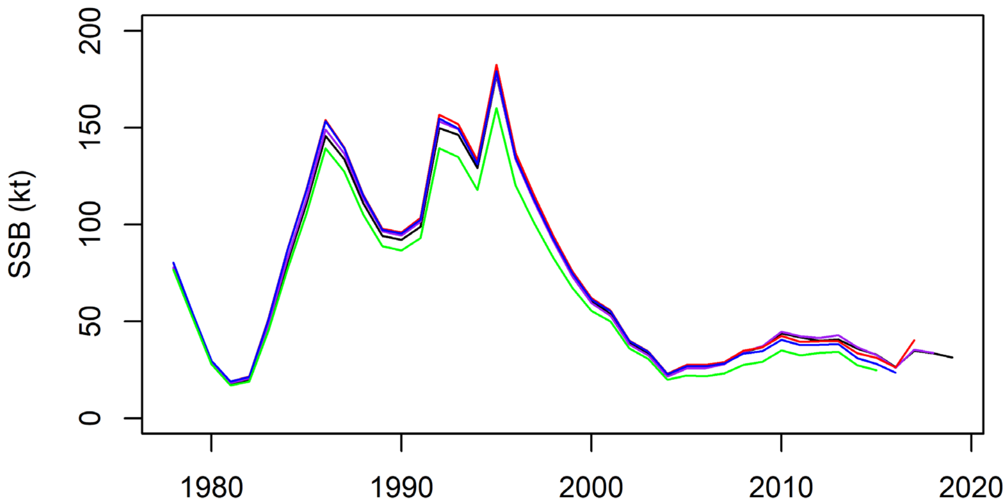

Figure 15. Retrospective patterns in estimated spawning stock biomass (SSB) of ages 4 to 10 and years 2019 to 2015 for spring spawners in the southern Gulf of St. Lawrence. Lined colors correspond to peels between years 2015 and 2019.

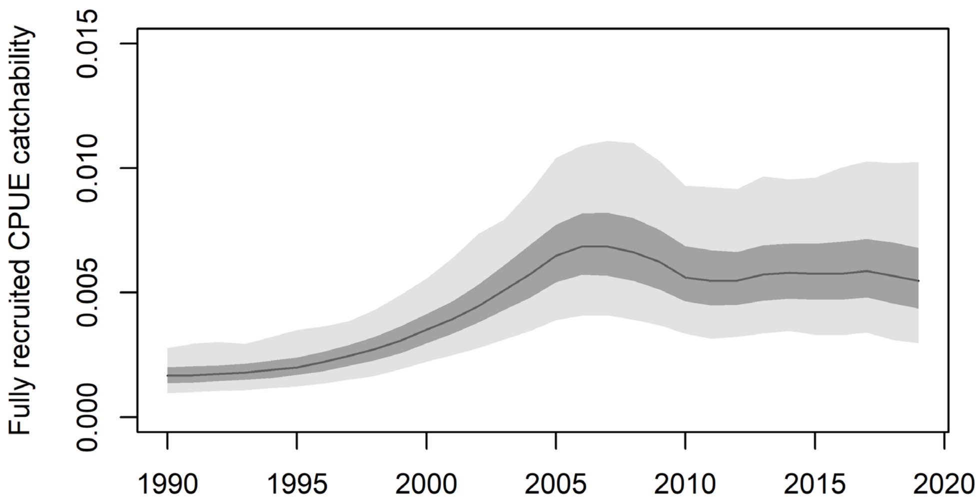

Figure 16. Estimated fully-recruited catchability to the CPUE index (q) from the spring spawners population model. Lines show the median estimates and shading their 50% (dark shading) and 95% (light shading) confidence interval based on MCMC sampling.

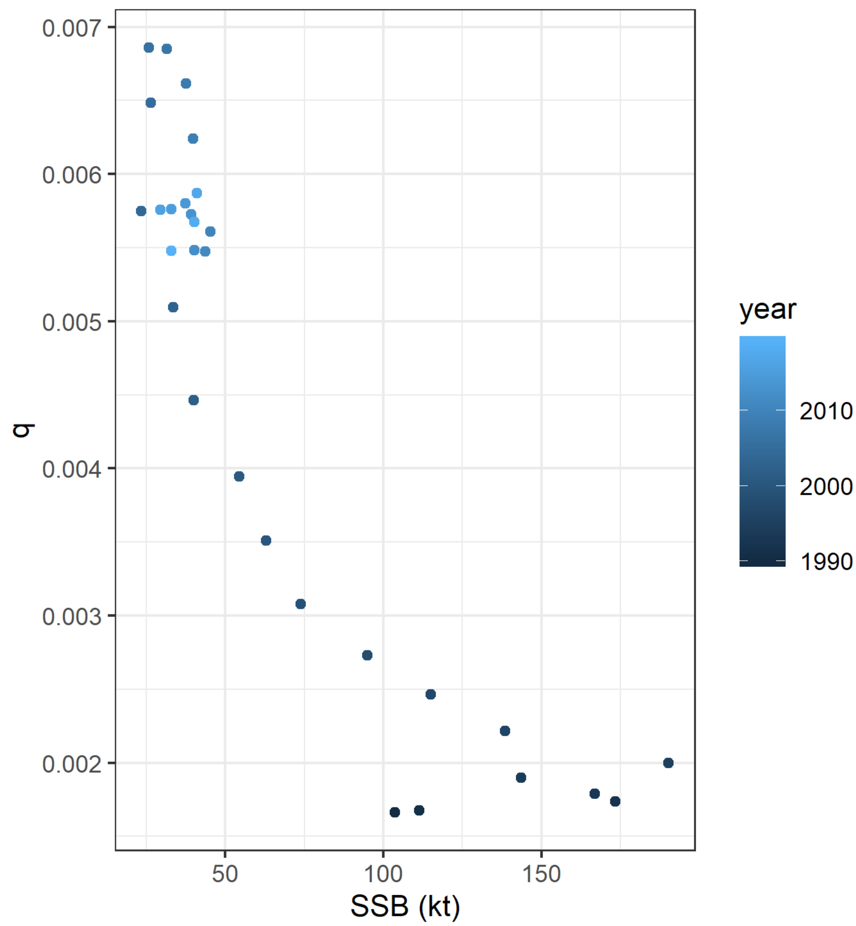

Figure 17. Fully-recruited catchability to the CPUE gillnet fishery (q) in function of SSB (kilotons) for spring spawning Herring between 1990 and 2019.

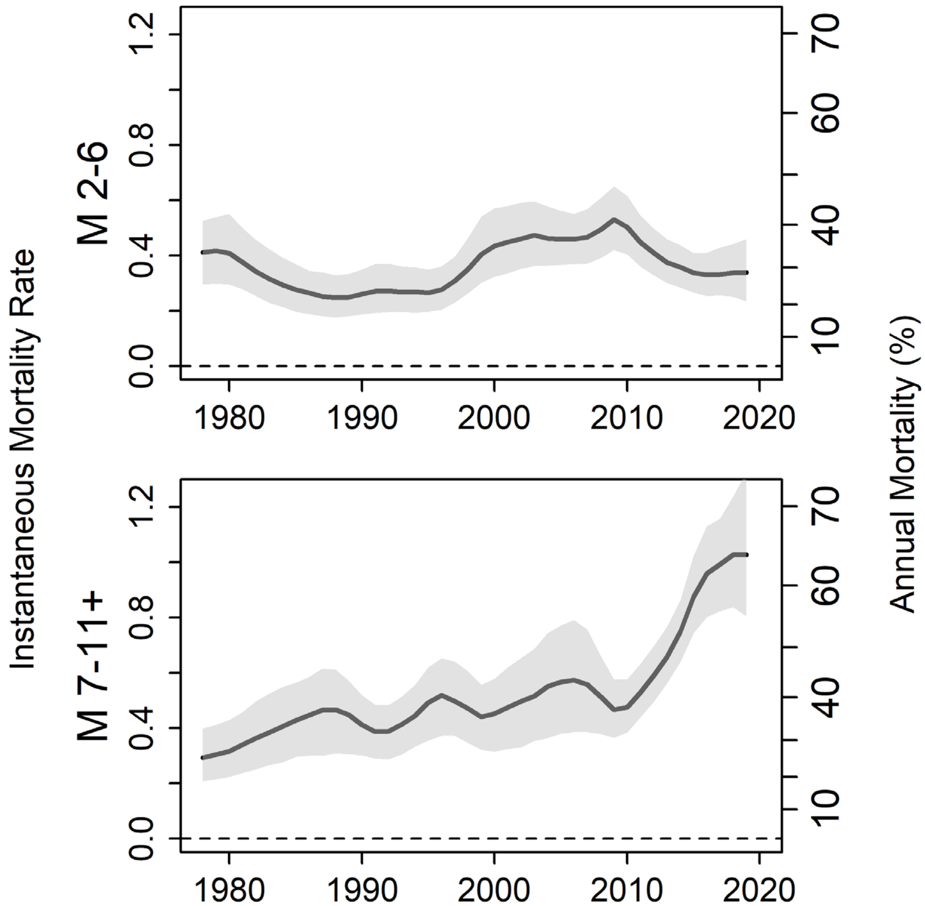

Figure 18. Estimated instantaneous natural mortality rate (left axis) and annual mortality (%, right axis) of spring spawning Atlantic Herring from the population model, for ages 2 to 6 (upper panel) and 7 to 11+ (lower panel). Lines show the median estimates and shading their 95 % confidence interval based on MCMC sampling.

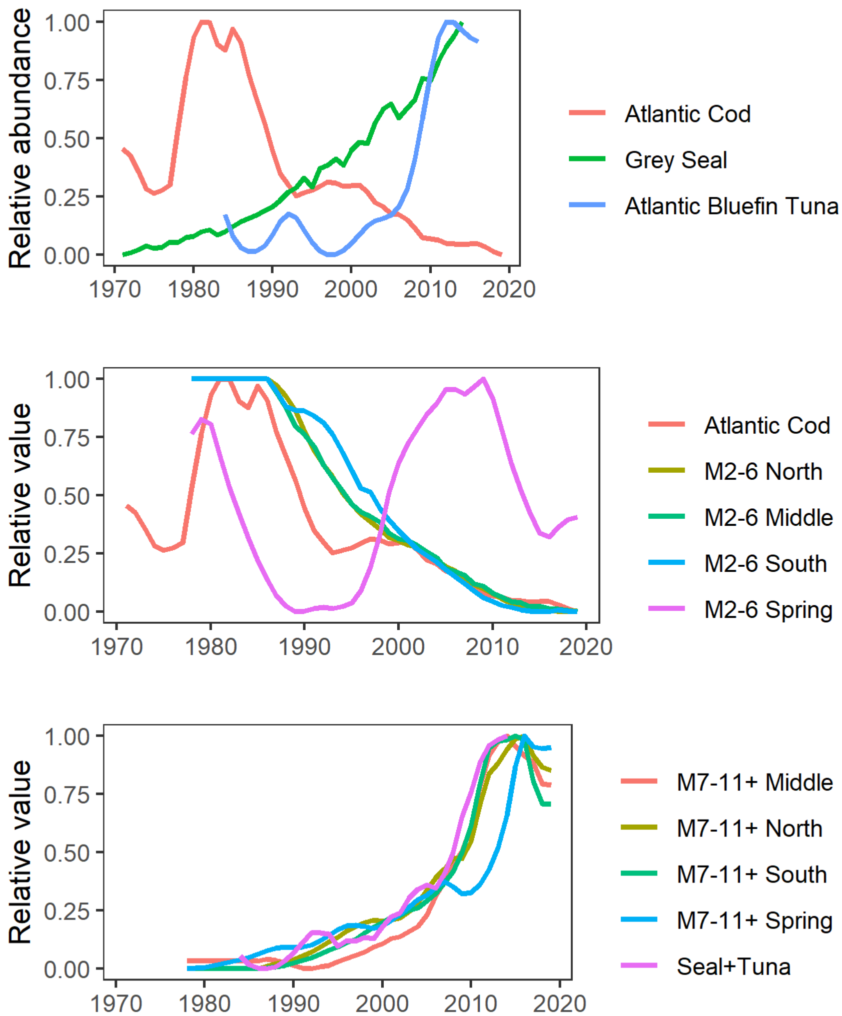

Figure 19. Scaled (0-1) relative abundance indices for herring major predators (Atlantic cod, Grey seal, Atlantic Bluefin Tuna) between 1970-2019 (upper panel). Scaled relative value of Atlantic cod sGSL abundance and natural mortality estimates for age group 2-6 (M2-6) in qmSCA spring and fall herring stock models (middle panel). Scaled relative value of the summed sGSL indices of abundance for Grey Seals and Atlantic Bluefin Tuna, and natural mortality estimates for age group 7-11+ (M7-11+) in qmSCA spring and fall herring stock models (lower panel). Natural mortality estimates are median MCMC estimates.

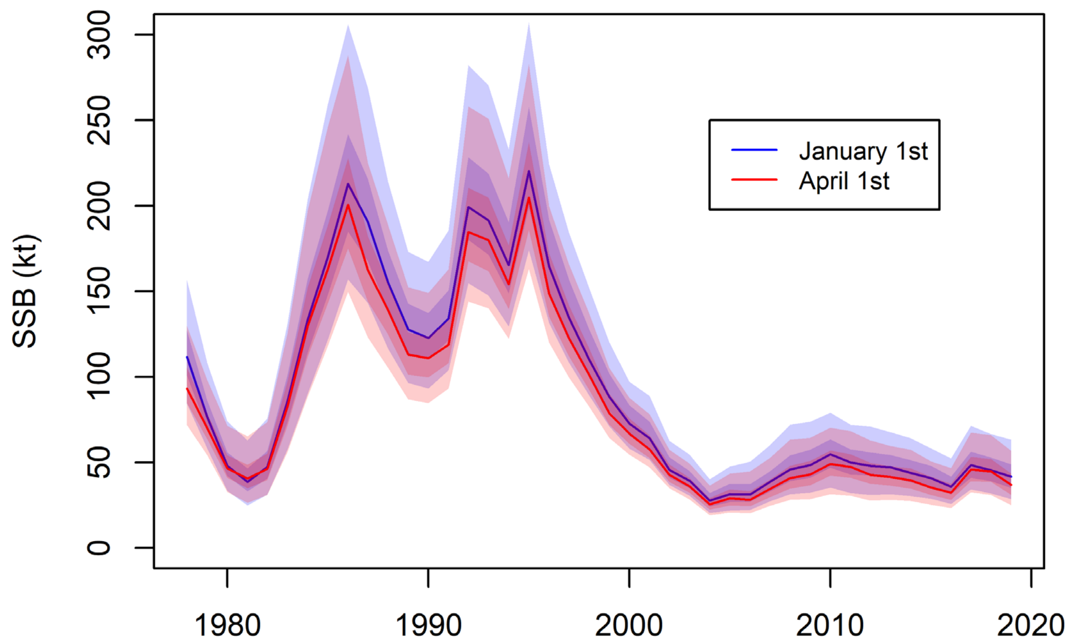

Figure 20. Estimated January 1 (blue line and shading) and April 1 (red line and shading) SSB of the spring spawner component of Atlantic Herring in the southern Gulf of St. Lawrence. The solid line is the median MCMC estimate and shading its 50 % (dark shading) and 95 % (light shading) confidence intervals.

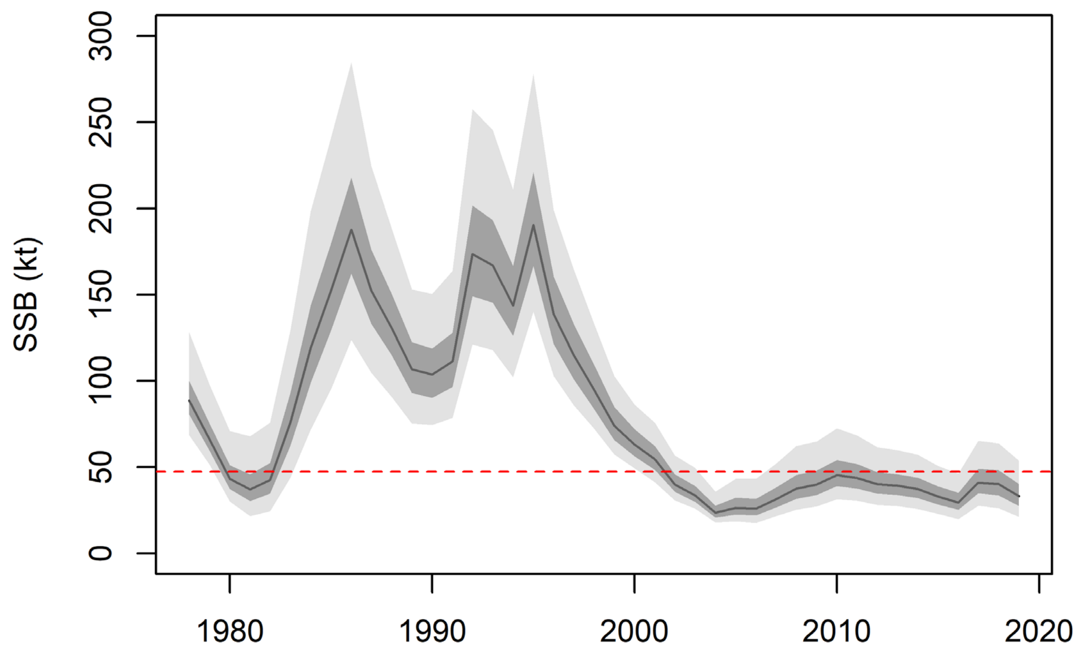

Figure 21. Estimated beginning of the fishing season (April 1) SSB of the spring spawner component of Atlantic Herring in the southern Gulf of St. Lawrence, 1978 to 2019. The solid line is the median MCMC estimate and shading its 50 % (dark shading) and 95% (light shading) confidence intervals. The red dashed horizontal line is the Limit Reference Point (LRP) (47,250 t of SSB).

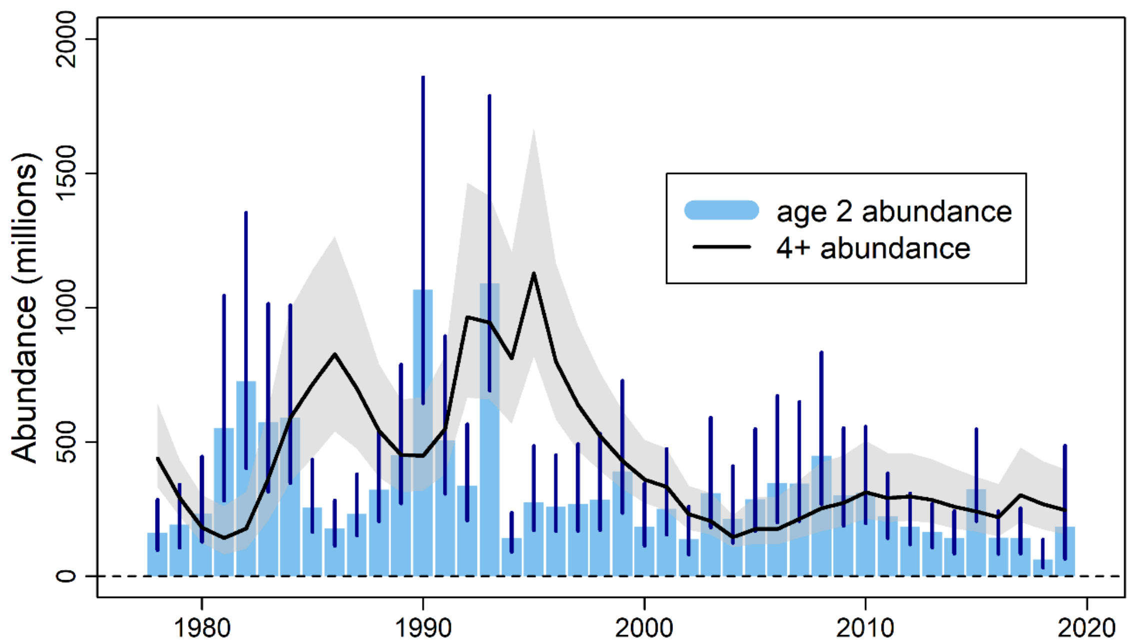

Figure 22. Estimated January 1 abundance of 2 year old Herring (blue bars), and Herring 4 years and older (black line) of the spring spawner component in the southern Gulf of St. Lawrence. Black line show the median MCMC estimate and vertical lines and shading show 95 % confidence interval.

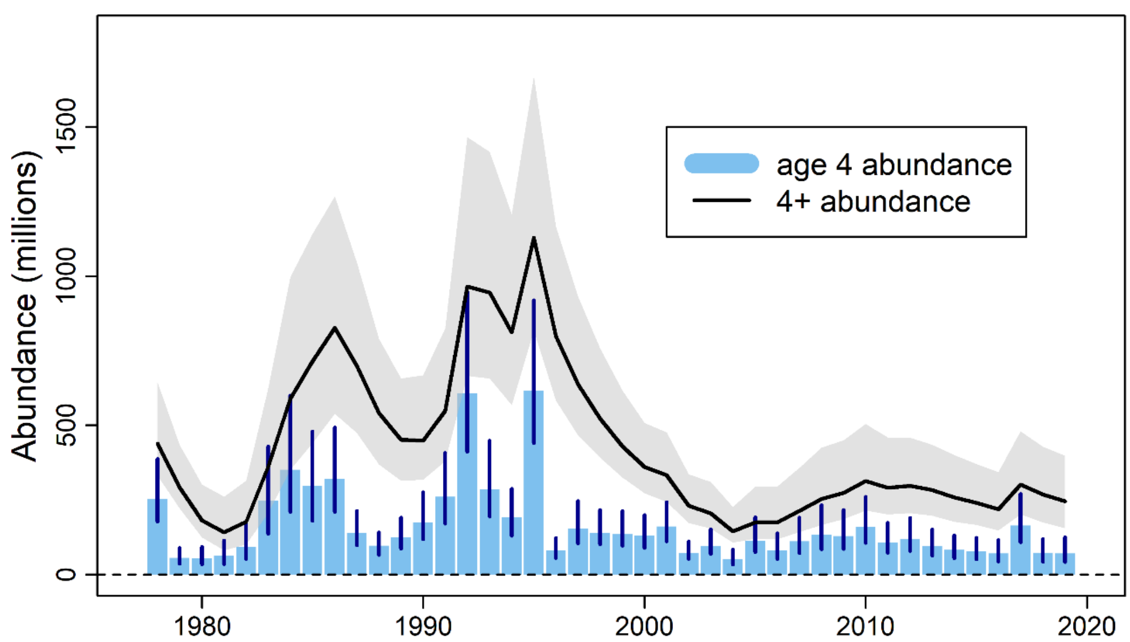

Figure 23. Estimated January 1 abundance of 4 year old Herring (blue bars), and Herring 4 years and older (black line) of the spring spawner component in the southern Gulf of St. Lawrence. Black line show the median MCMC estimate and vertical lines and shading show 95 % confidence interval.

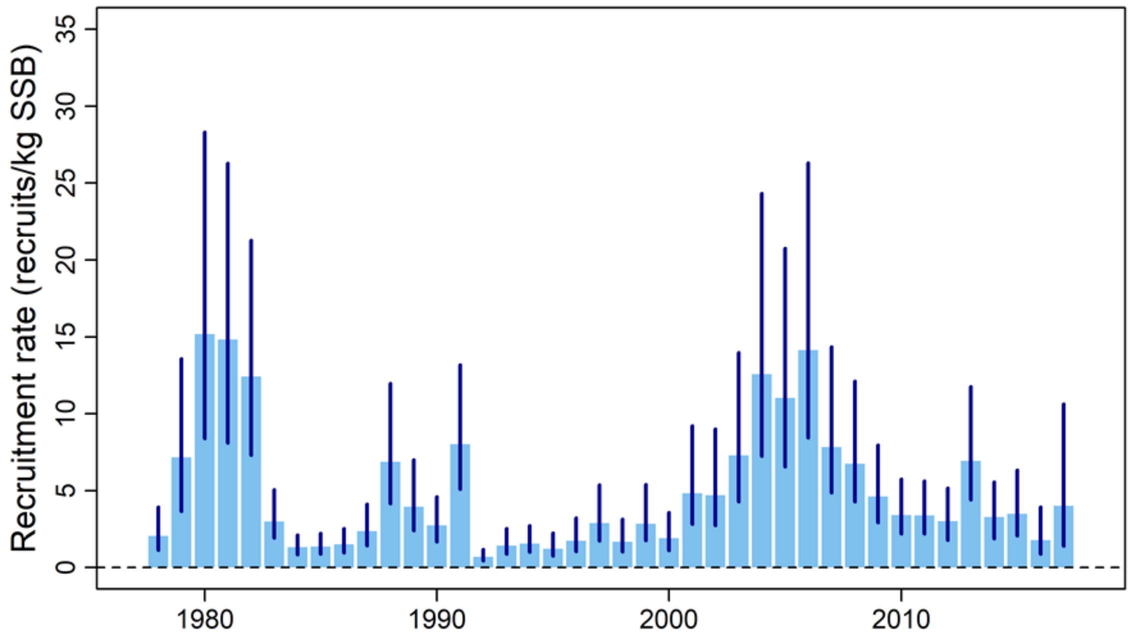

Figure 24. Recruitment rates for age 2 recruits for the 1978 to 2017 cohorts of spring spawning Atlantic Herring in NAFO Div. 4T. Vertical lines indicate 95 % confidence intervals.

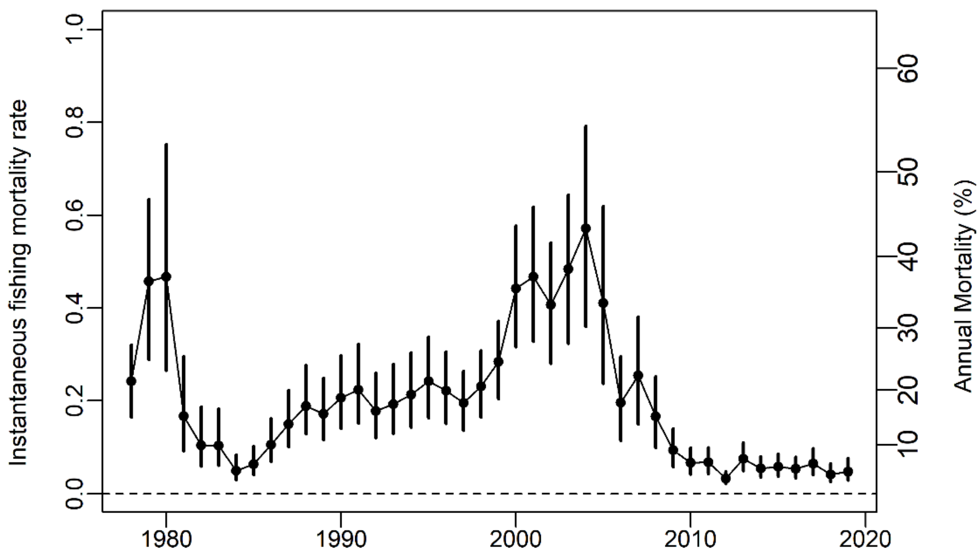

Figure 25. Estimated January 1 abundance weighted age 6 to 8 fishing mortality (F6-8, left axis; annual exploitation rate, right axis) of spring spawning Herring in the southern Gulf of St. Lawrence. Circles are the median estimates and vertical lines their 95 % confidence intervals.

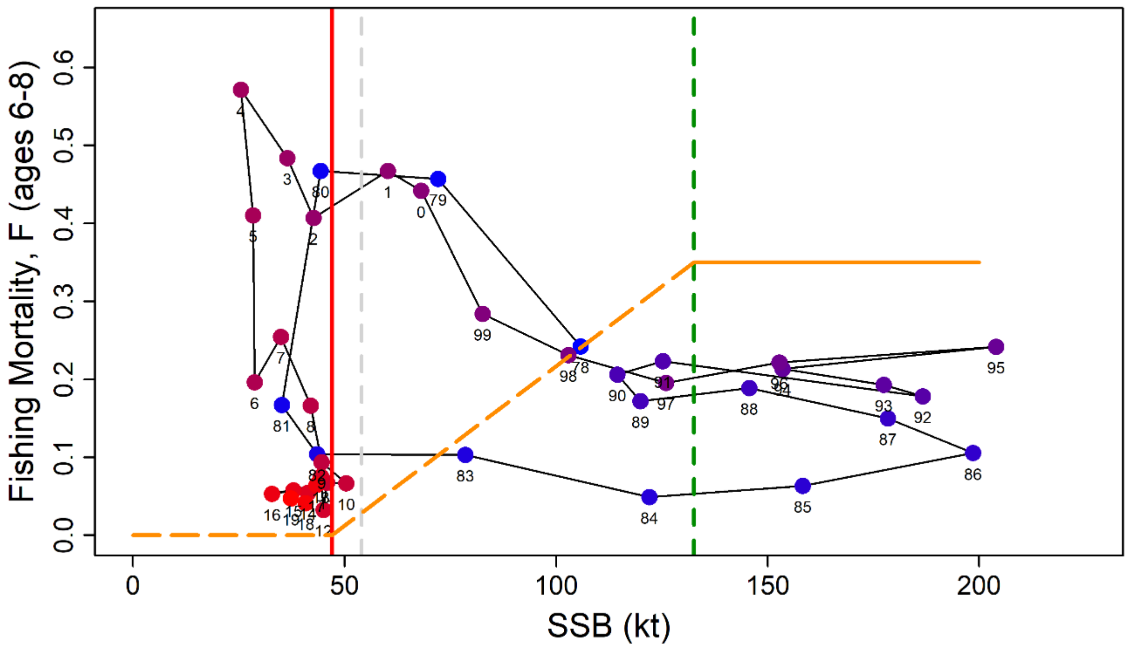

Figure 26. The southern Gulf of St. Lawrence Atlantic Herring spring spawner component trajectory in relation to SSB (kt = thousand t) and abundance weighted fishing mortality rates for ages 6 to 8 years. The red vertical line is the LRP and the green dashed vertical line is the Upper Stock Reference (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. The vertical dashed grey line is the LRP from the previous assessment. Point labels are years (83 = 1983, 0 = 2000). Colour coding is from blue in the 1970s and early 1980s to red in the 2000s.

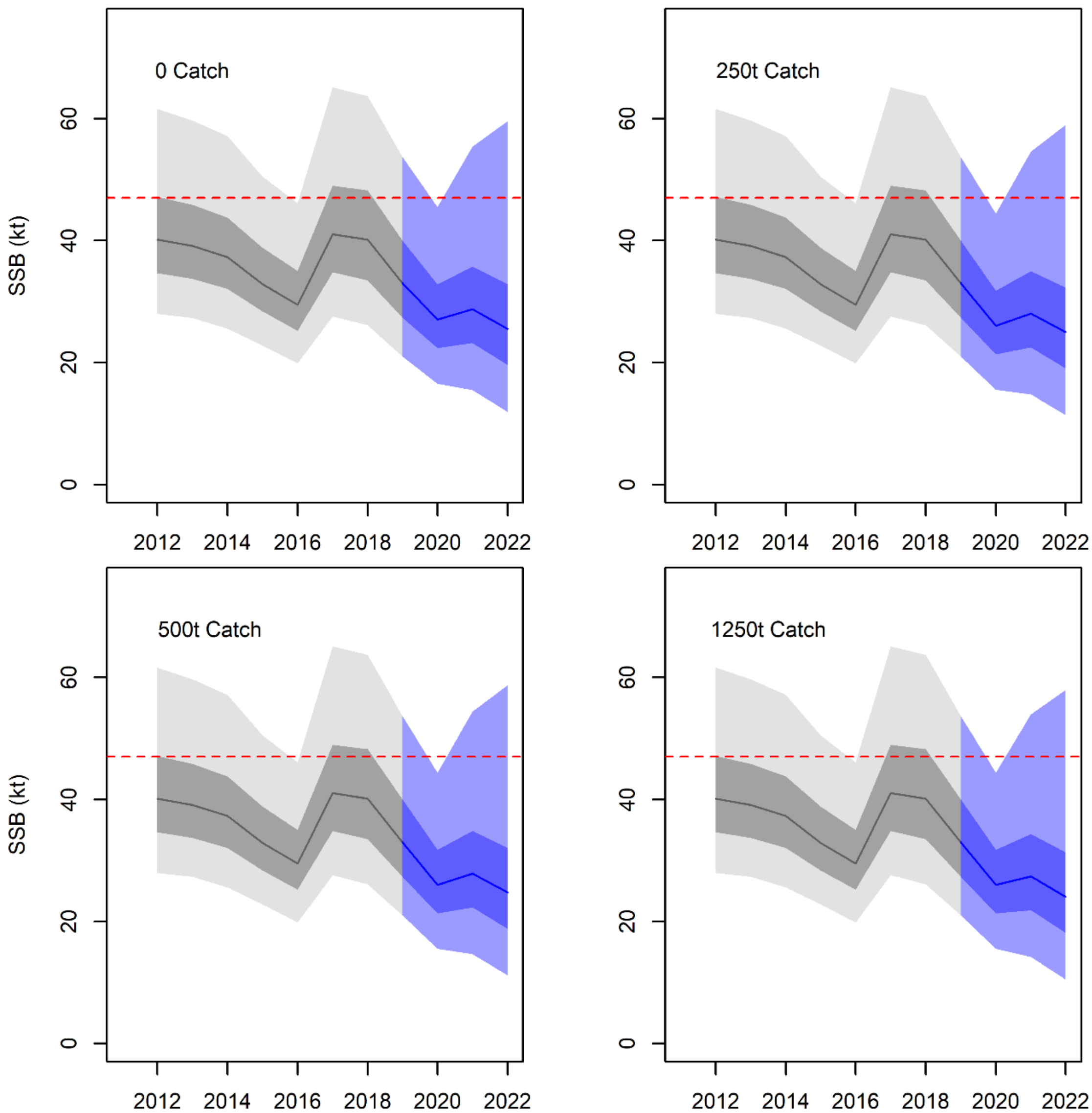

Figure 27. Projected April 1 SSB (in kt) of spring spawning Atlantic Herring from the southern Gulf of St. Lawrence under a recent 5 years average recruitment level and 2 years average natural mortality level at various catch levels in 2020 and 2021. Lines show the median estimates of the April 1 SSB, 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.

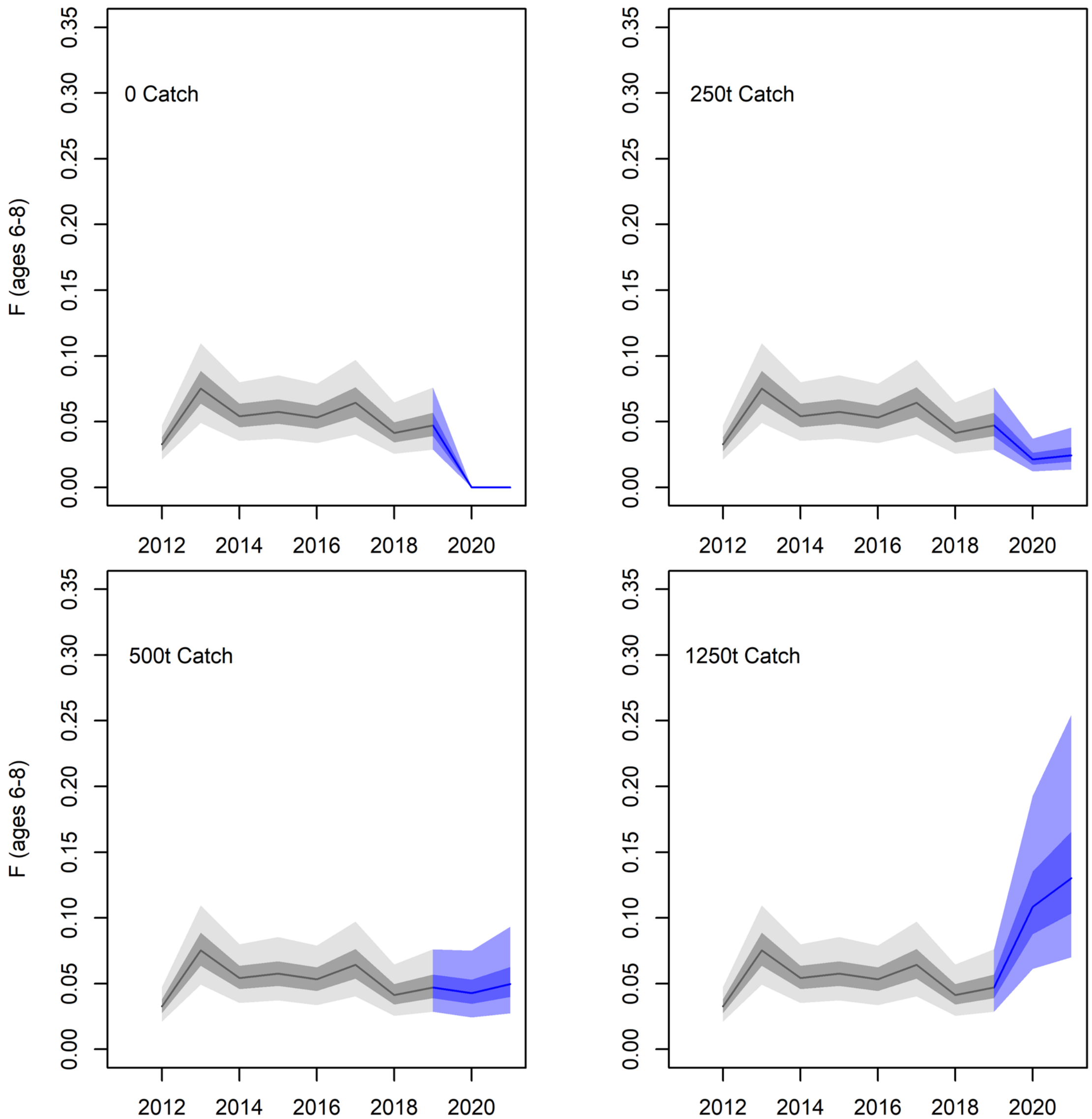

Figure 28. Projected ages 6 to 8 fishing mortality rate (F) of spring spawner Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels in 2020 and 2021. Lines show the median estimates of fishing mortality, dark shading the 75 % confidence interval and light shading the 95 % confidence intervals of these estimates (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period.

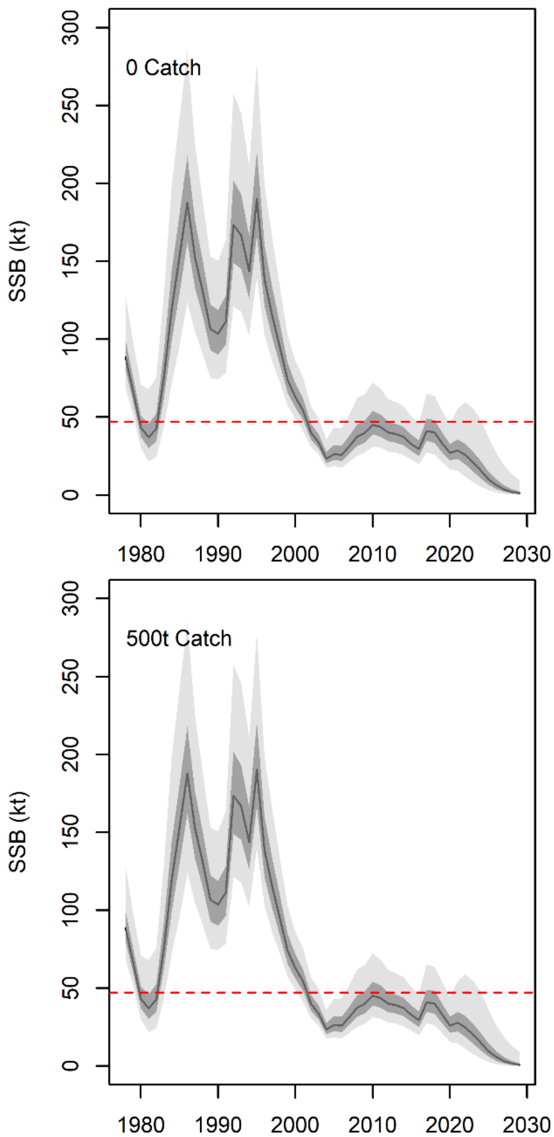

Figure 29. Projected April 1 SSB (in kt) of spring spawner Atlantic Herring from the southern Gulf of St. Lawrence under a recent 5 years average recruitment level and 2 years average natural mortality level at various catch levels in all years between 2020 and 2029. Lines show the median estimates of 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.

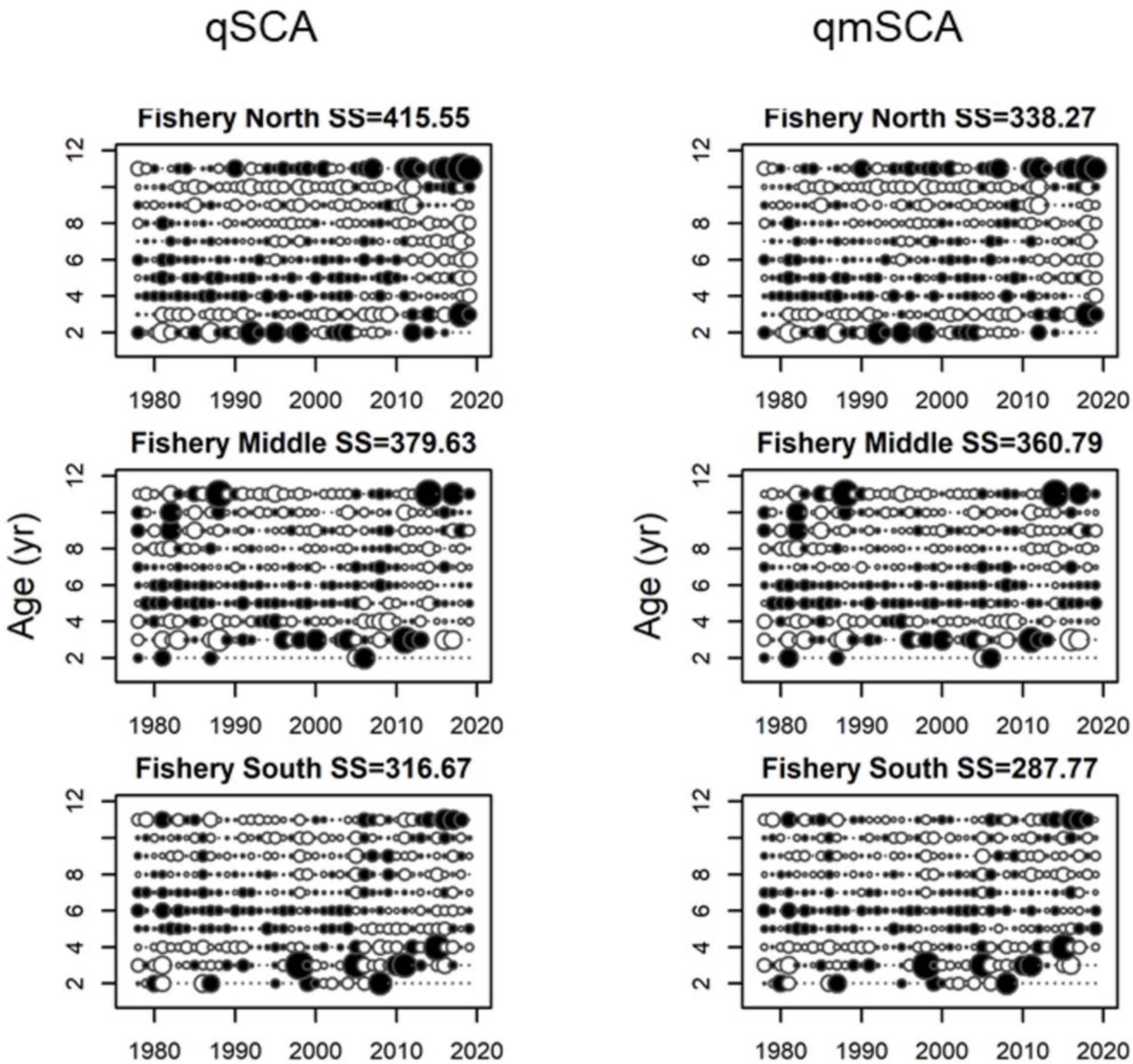

Figure 30. Fishery catch PAA residuals by region (North, Middle and South) for the qSCA (left) and qmSCA (right) population models of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals.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

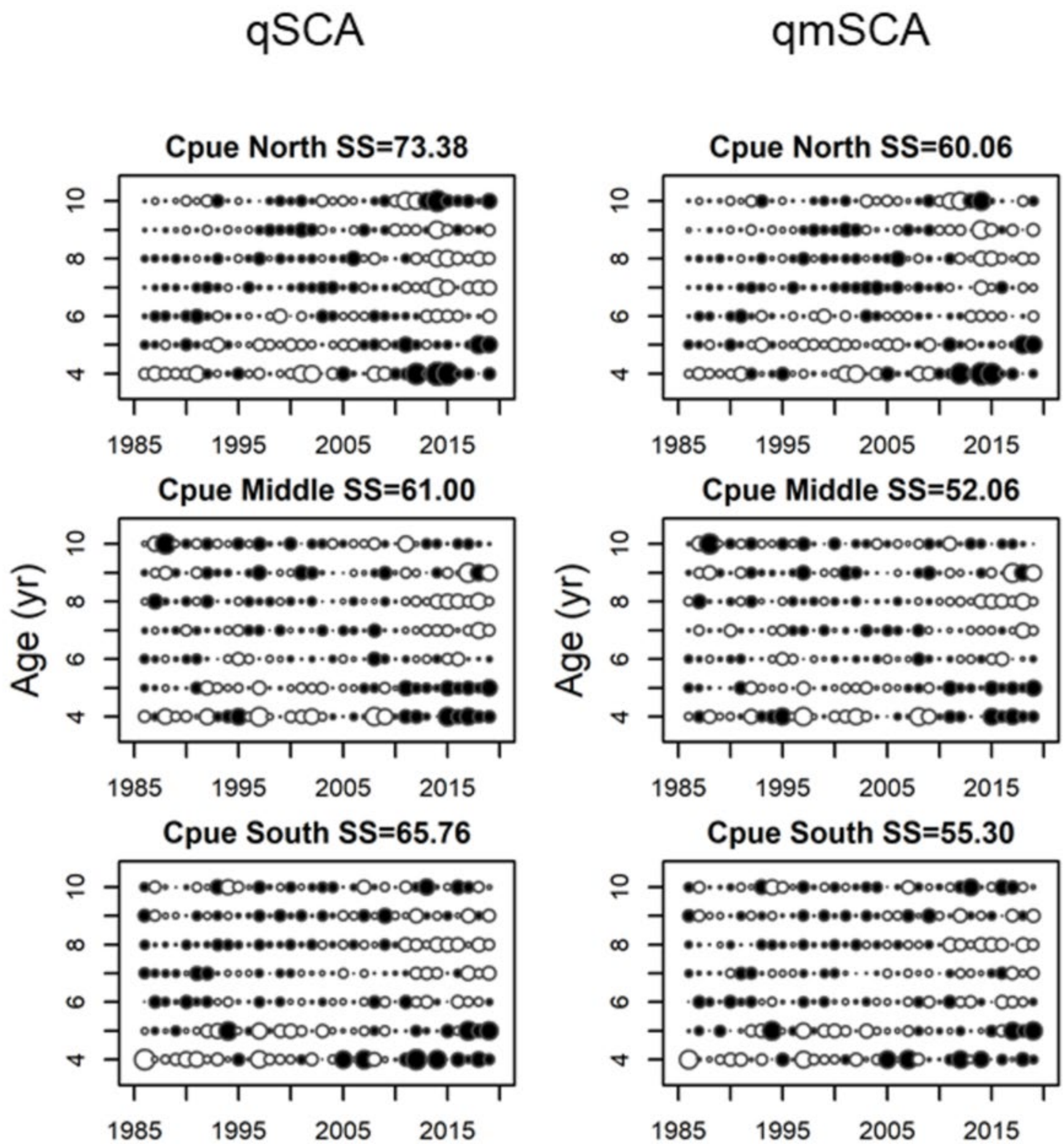

Figure 31. CPUE index PAA residuals by region (North, Middle and South) for the qSCA (left) and qmSCA (right) population models of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

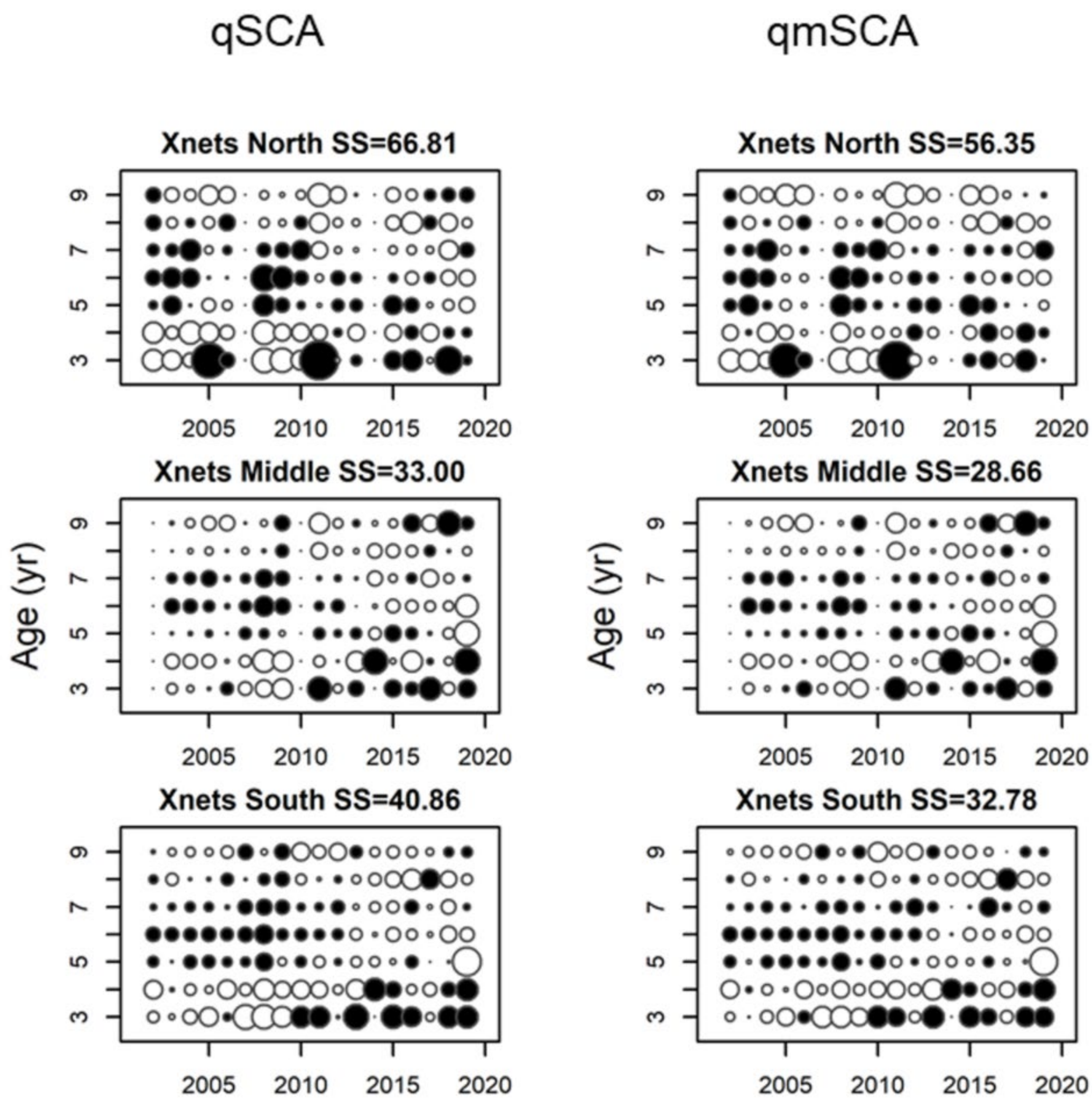

Figure 32. Experimental nets index PAA residuals by region (North, Middle and South) for the qSCA (left) and qmSCA (right) population models of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

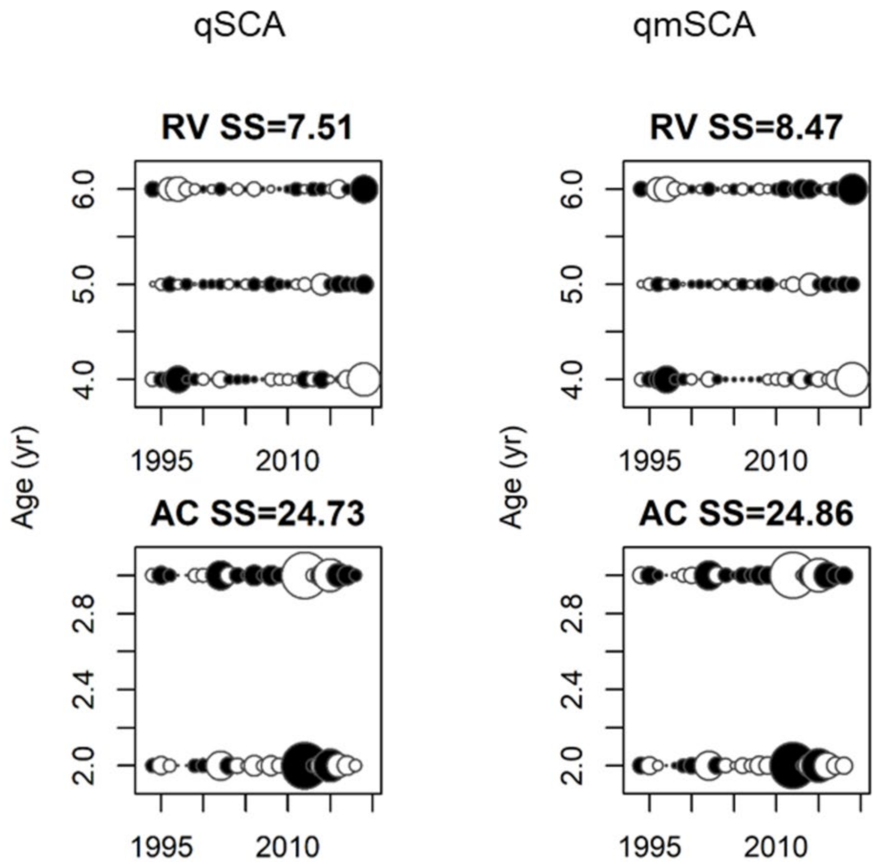

Figure 33. RV survey index (top) and Acoustic survey index (AC, bottom) PAA residuals for the qSCA (left) and qmSCA (right) population models of fall spawning Herring from the southern Gulf of St. Lawrence. Rows are for ages and columns are years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted).

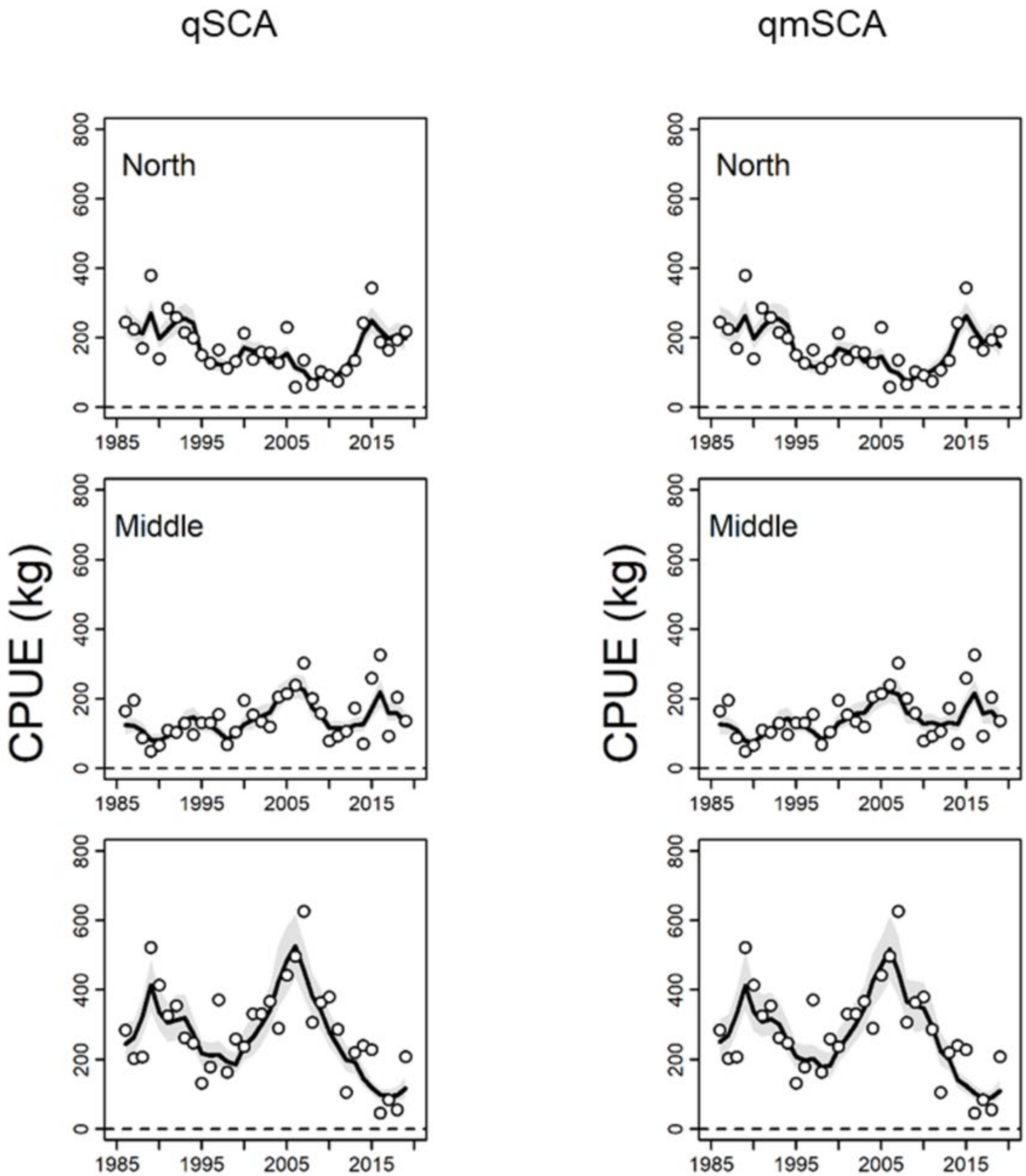

Figure 34. Observed (circles) and predicted (lines and shading) age-aggregated commercial gillnet CPUE indices by region (CPUE North, CPUE Middle, CPUE South) for the qSCA (left) and qmSCA (right) models for fall spawners from the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95 % confidence intervals of the predictions based on MCMC sampling.

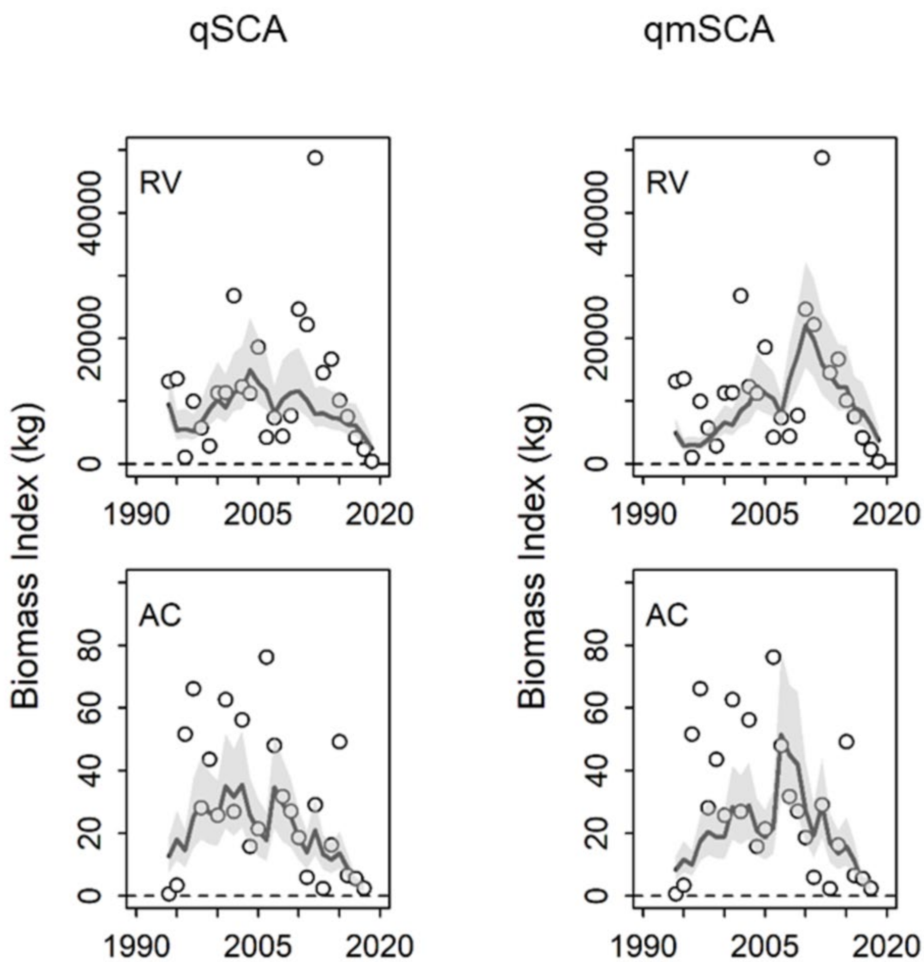

Figure 35. Observed (circles) and predicted (lines and shading) age-aggregated RV indices (RV, all regions combined) and acoustic indices (AC, all regions combined) for the qSCA (left) and qmSCA (right) models for fall spawners from the southern Gulf of St. Lawrence. The lines show the median predicted indices and the shading the 95 % confidence intervals of the predictions based on MCMC sampling.

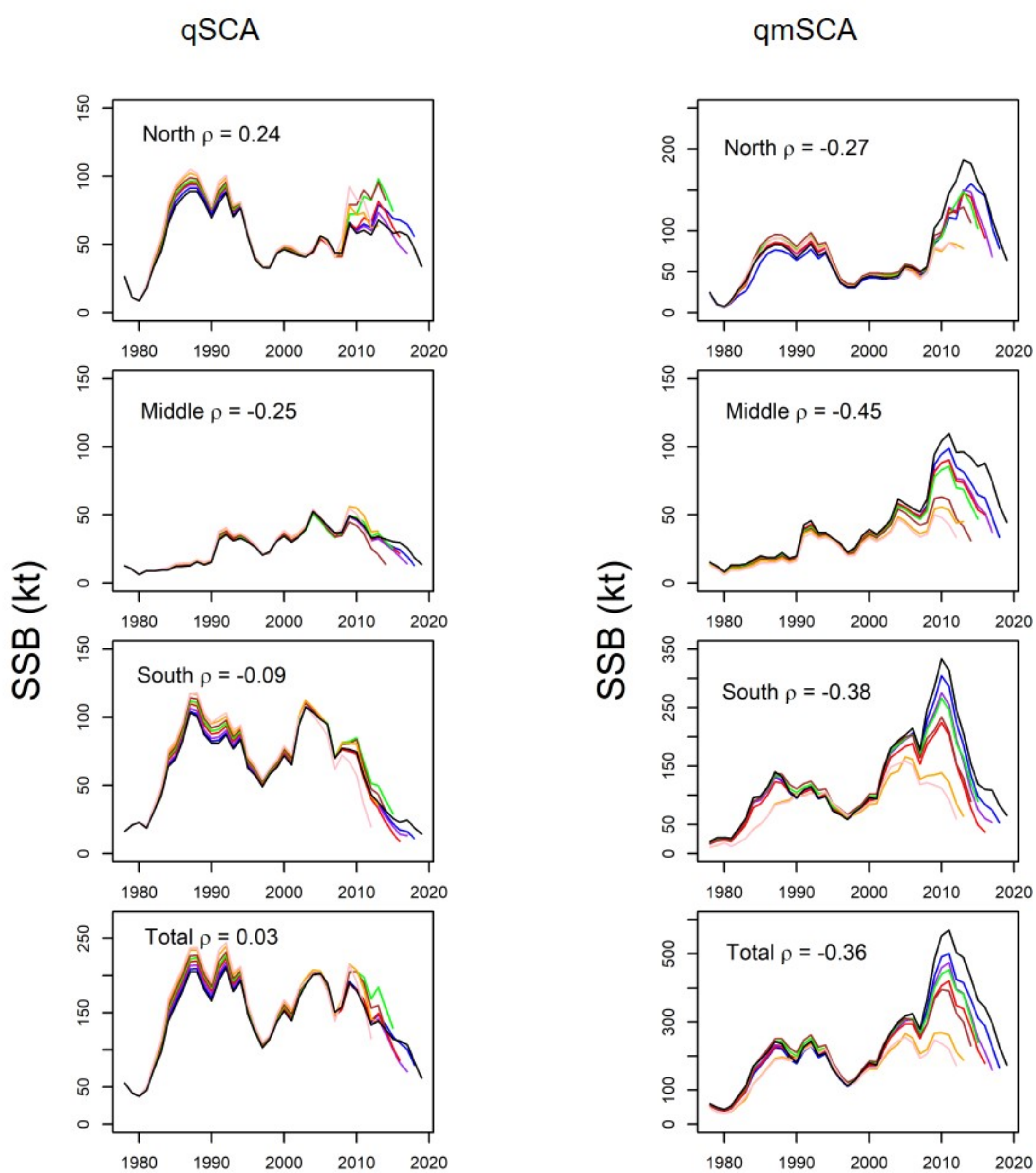

Figure 36. Retrospective patterns in SSB and Mohn's rho of fall spawners within the three regions (North, Middle, South) and overall for the qSCA (left) and qmSCA (right) population models of Atlantic Herring of the southern Gulf of St. Lawrence. Colored lines shows retrospective peels between 2012 and 2019.

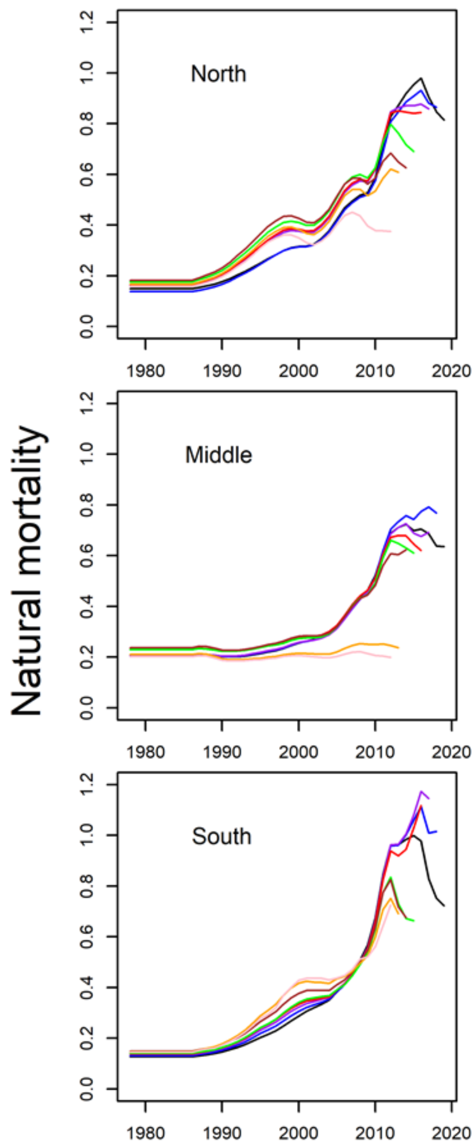

Figure 37. Retrospective patterns in natural mortality estimates of fall spawners within the three regions (North, Middle, South) for the qmSCA population model of Atlantic Herring of the southern Gulf of St. Lawrence. Colored lines shows retrospective peels between 2012 and 2019.

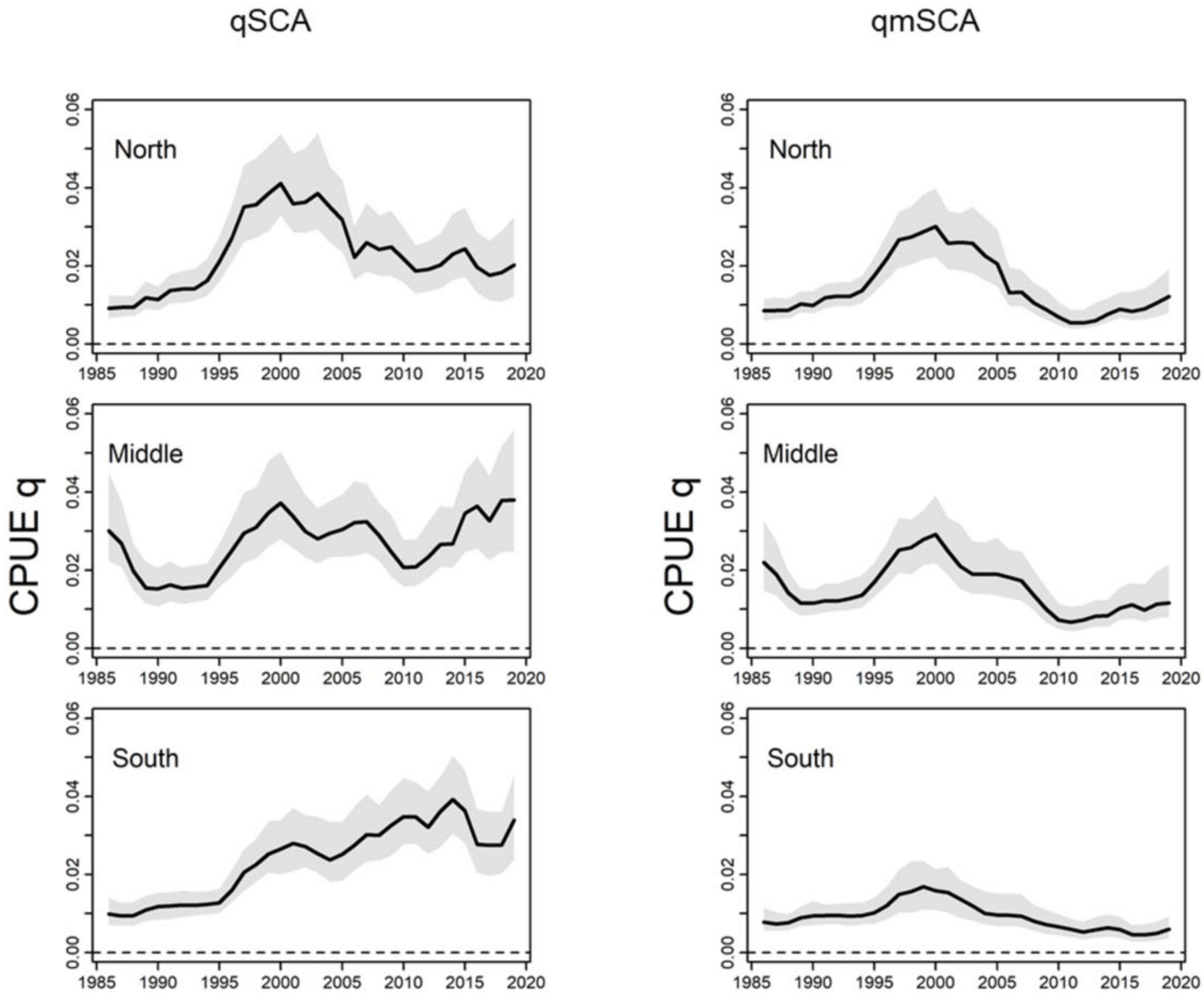

Figure 38. Estimated fully-recruited catchability for the commercial gillnet CPUE index by region (North, Middle, South), for the qSCA (left) and qmSCA (right) population models of fall spawning Atlantic Herring in the southern Gulf of St. Lawrence. Lines show the median estimates and shading their 95 % confidence intervals based on MCMC sampling.

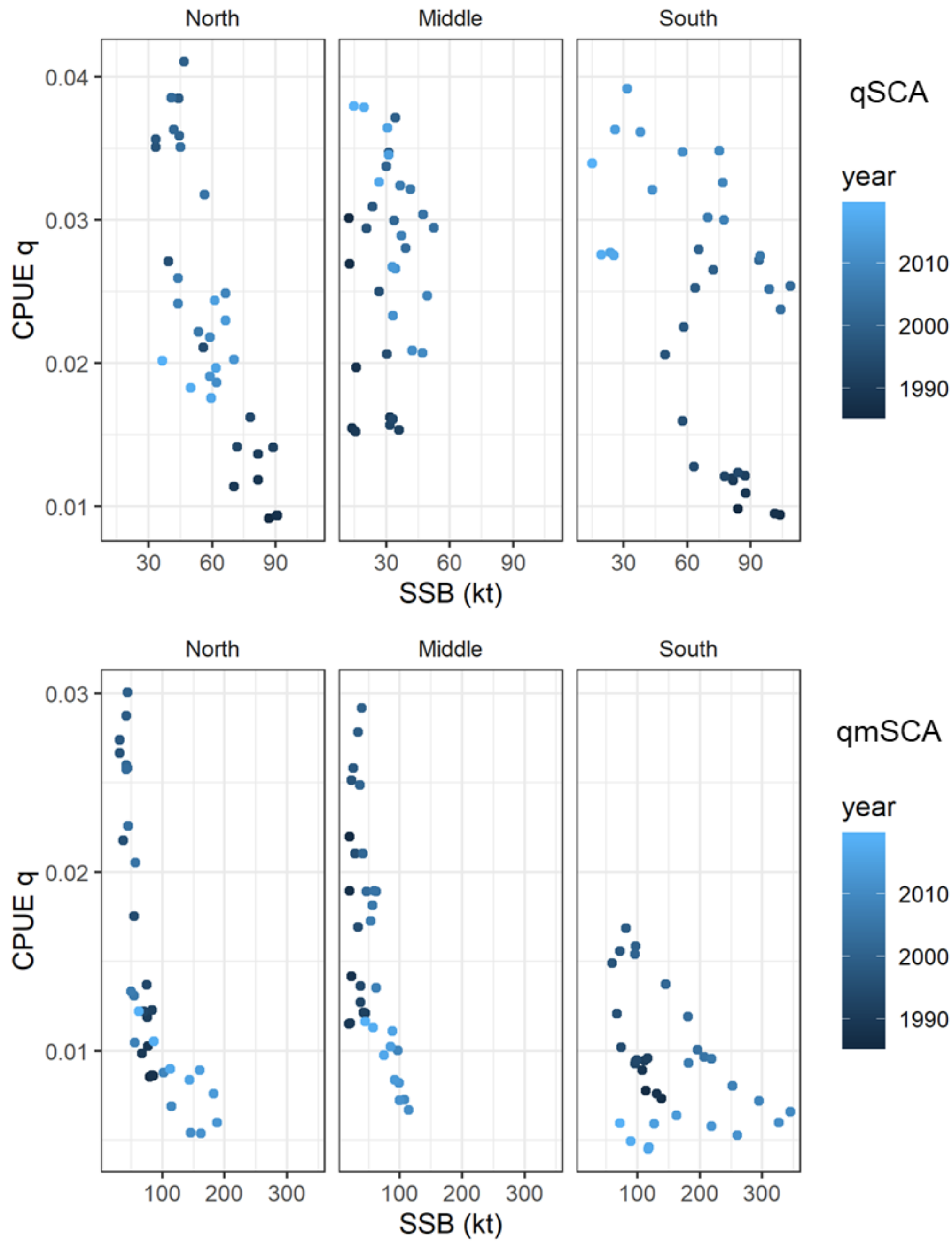

Figure 39. Estimated fully-recruited catchability for the commercial gillnet CPUE index in relation to SSB by region (North, Middle, South), for the qSCA (top panel) and qmSCA (bottom panel) population models of fall spawning Atlantic Herring in the southern Gulf of St. Lawrence.

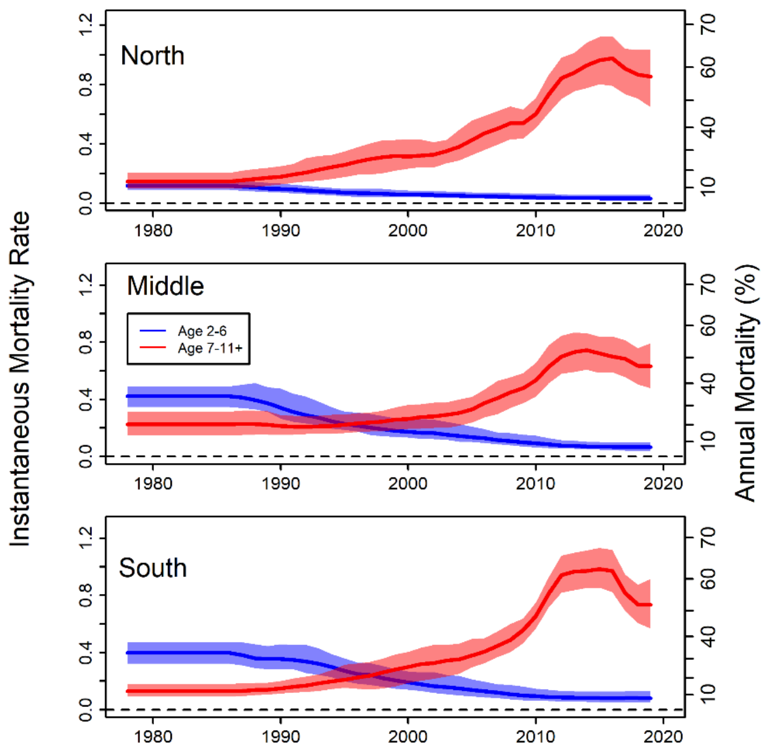

Figure 40. Estimated instantaneous natural mortality rate (left axis) and annual mortality (%, right axis) of fall spawning Atlantic Herring for three regions of the sGSL (North, Middle, South) from the qmSCA population model, for ages 2 to 6 (blue) and 7 to 11+ (red). Lines show the median estimates and shading their 95 % confidence interval based on MCMC sampling.

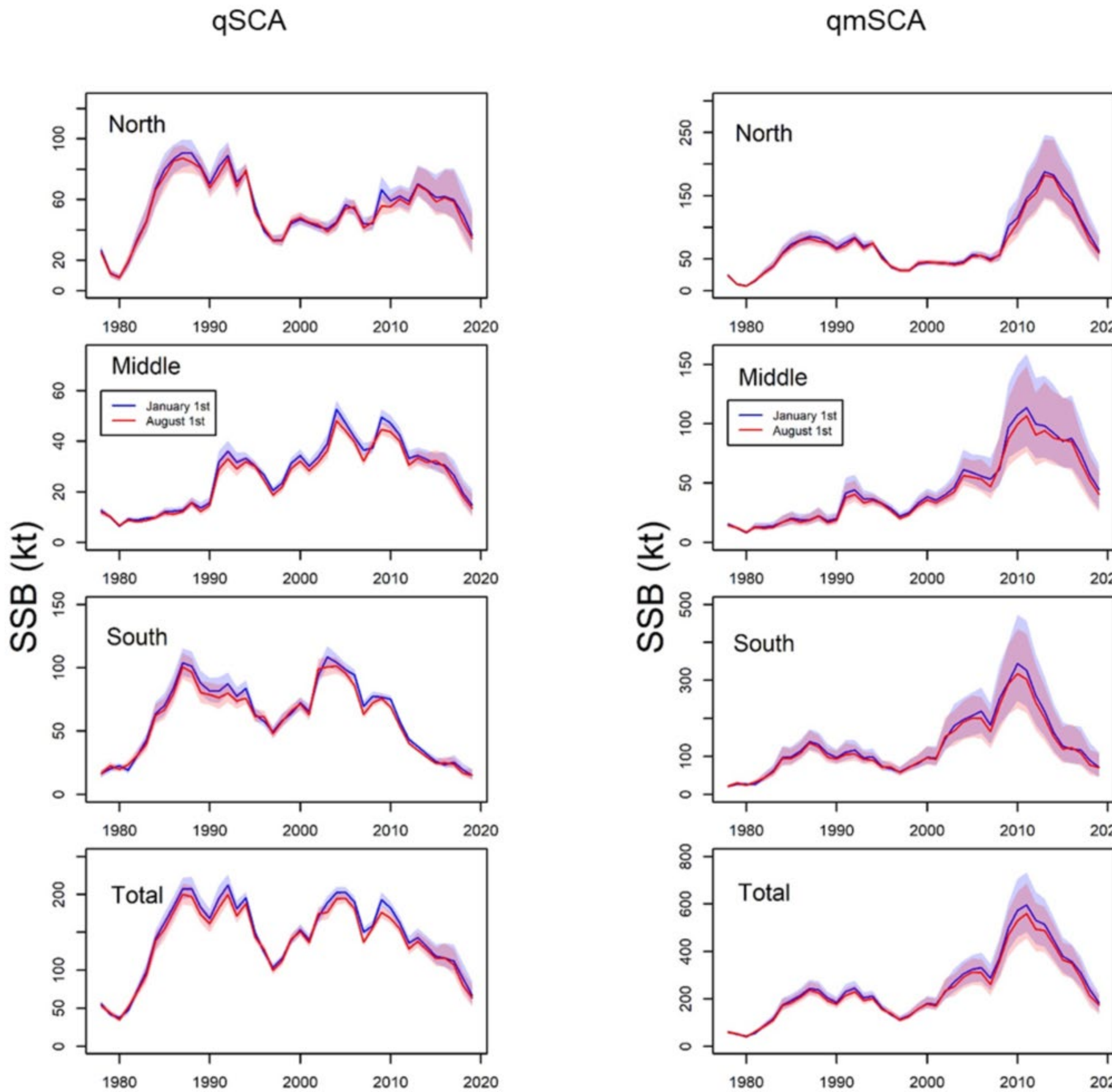

Figure 41. Estimated January 1 (blue line and shading) and August 1 (red line and shading) SSB of the fall spawner component of Atlantic Herring in three regions (North, Middle, South) of the southern Gulf of St. Lawrence for the qSCA (left) and qmSCA (right) population models. The solid line is the median MCMC estimate and shading is 95 % confidence intervals.

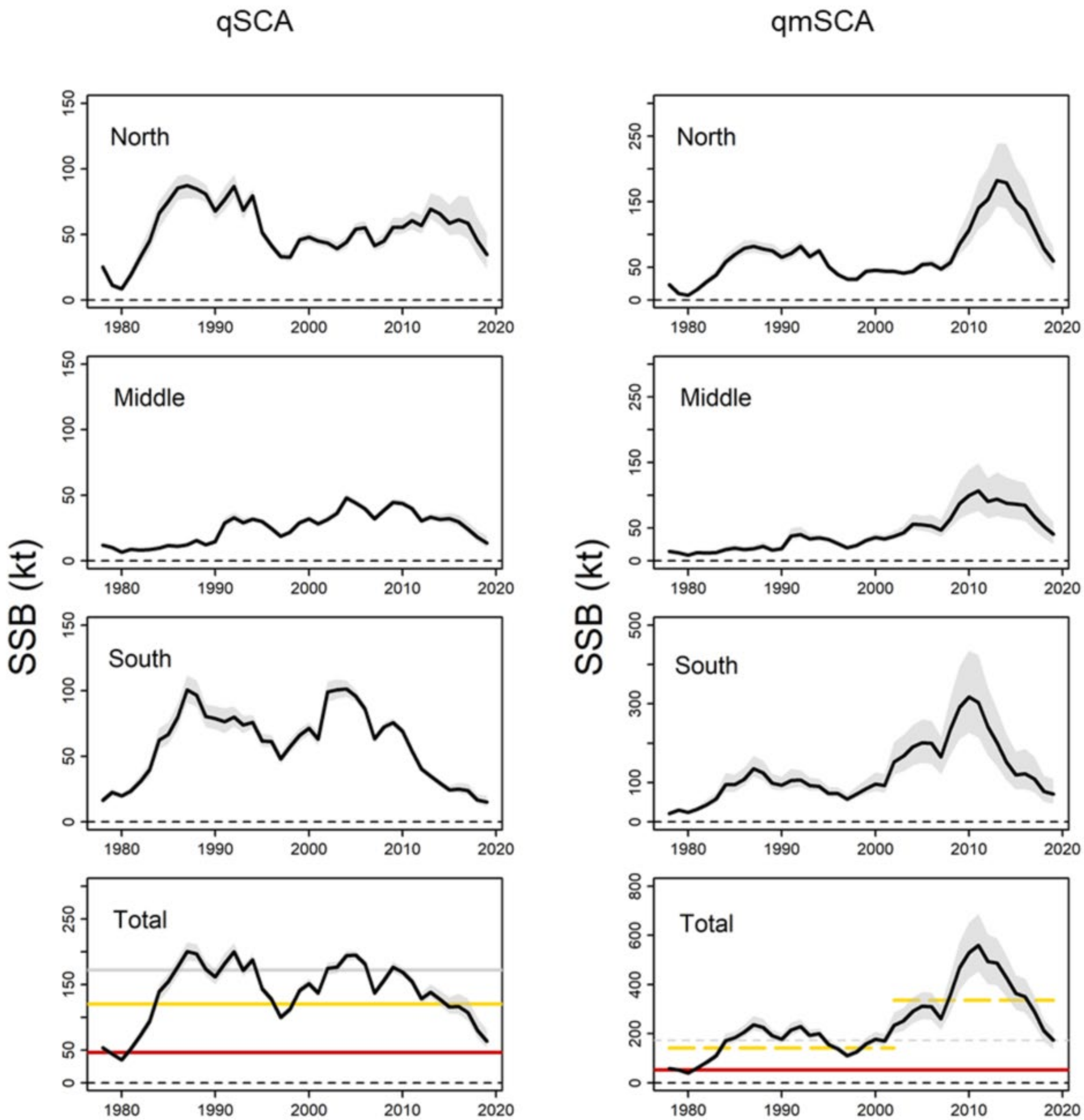

Figure 42. Estimated beginning of fishing season (August 1) SSB of fall spawning Herring by region and overall (Total) for the southern Gulf of St. Lawrence for the qSCA (left panel) and qmSCA (right panel) models. The black line shows the median estimates of the MCMC sampling and the shading their 95 % confidence intervals. In the bottom panels for Total, the solid and dashed yellow horizontal lines represent the USR level and the red horizontal line is the LRP. The grey horizontal line is the USR from the previous assessment. SSB, USR and LRP values are adjusted to August 1st using natural mortality estimates at age for 7 months.

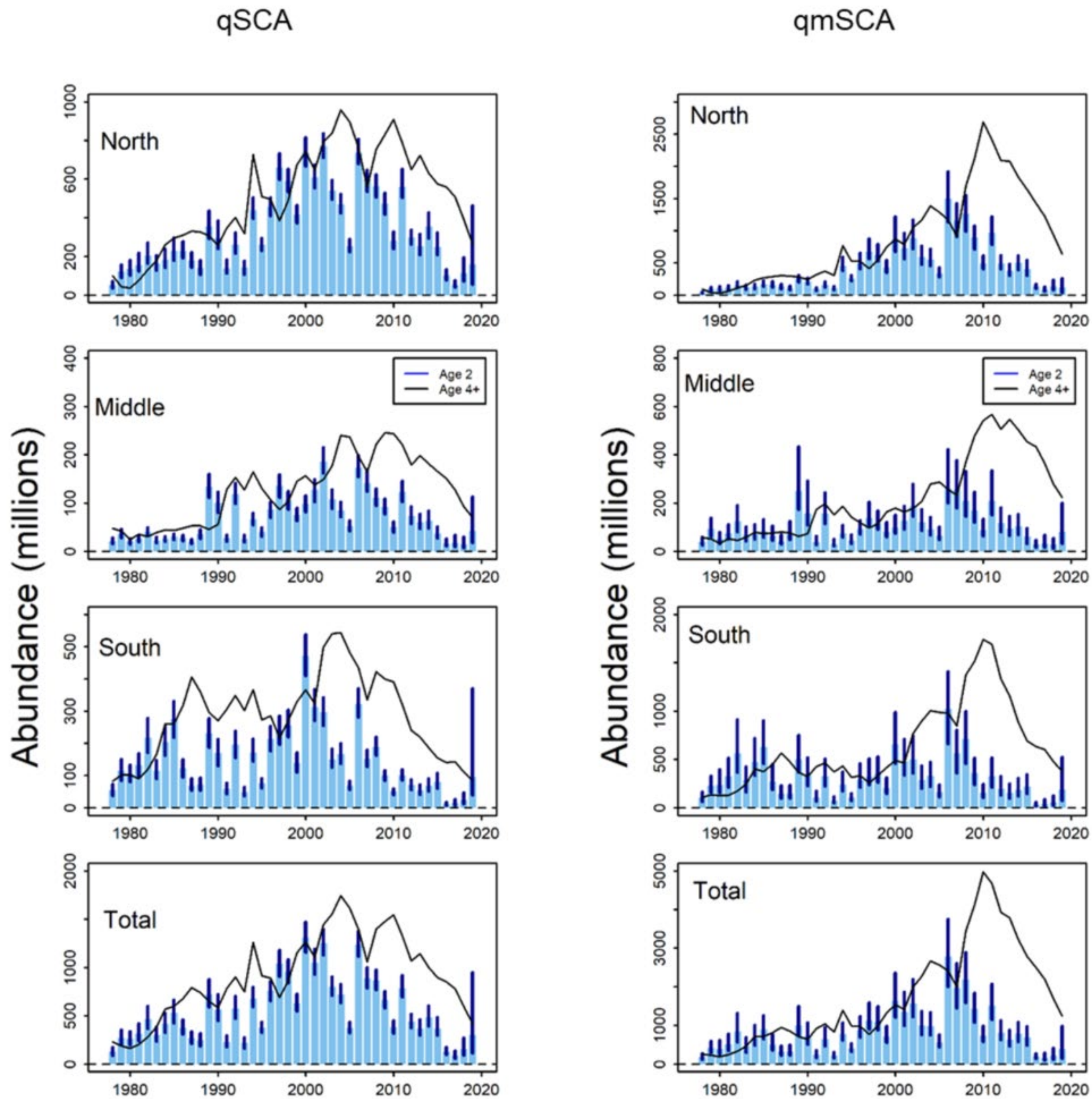

Figure 43. Estimated January 1 abundance of 2 year old Herring (blue bars), and Herring 4 years and older (black line) of the fall spawner component in three regions (North, Middle, South) in the southern Gulf of St. Lawrence for the qSCA (left) and qmSCA (right) population models. Black line show the median MCMC estimate and vertical lines show 95 % confidence interval.

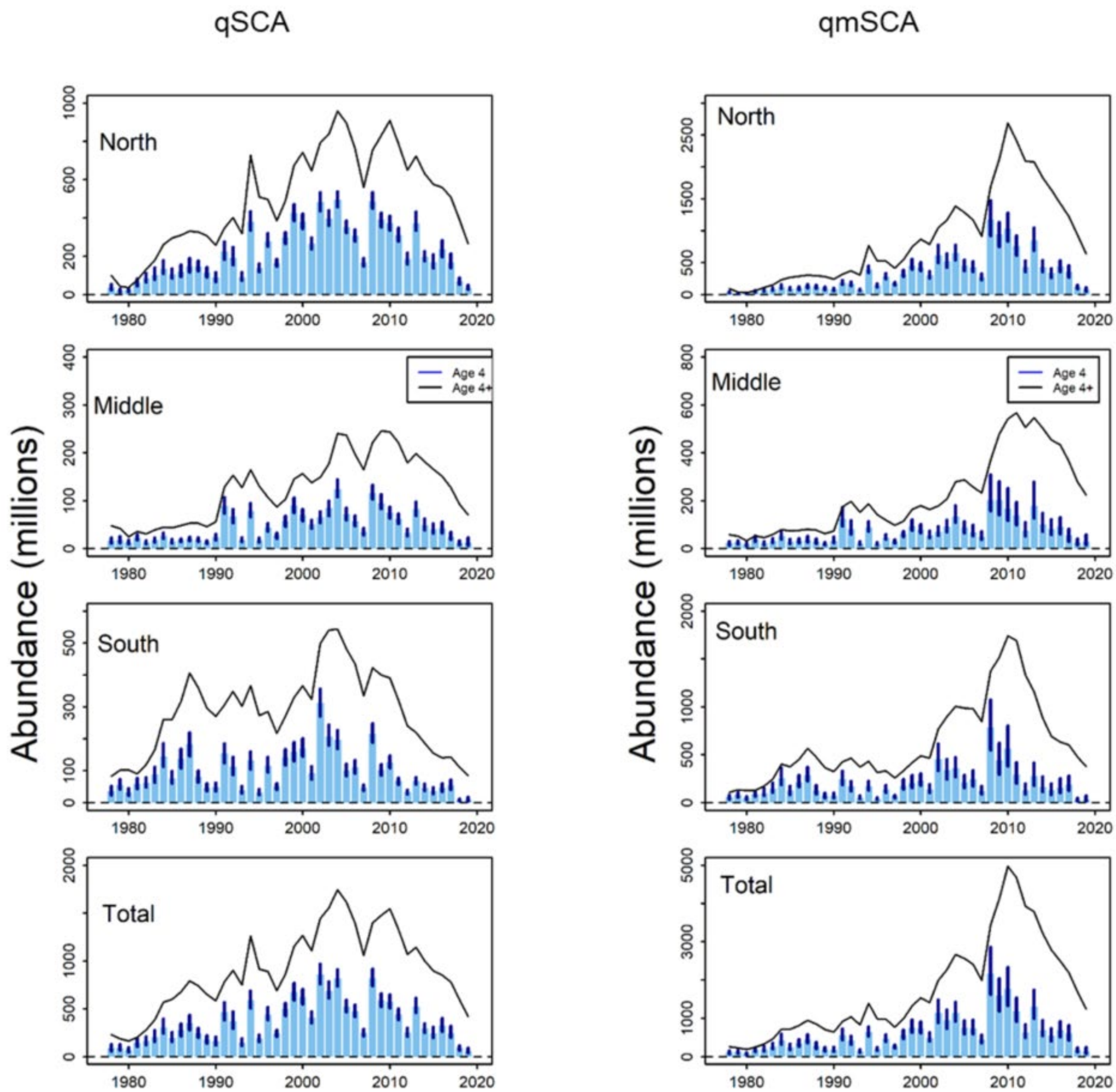

Figure 44. Estimated January 1 abundance of 4 year old Herring (blue bars), and Herring 4 years and older (black line) of the fall spawner component in three regions (North, Middle, South) in the southern Gulf of St. Lawrence for the qSCA (left) and qmSCA (right) population models. Black line show the median MCMC estimate and vertical lines show 95 % confidence interval.

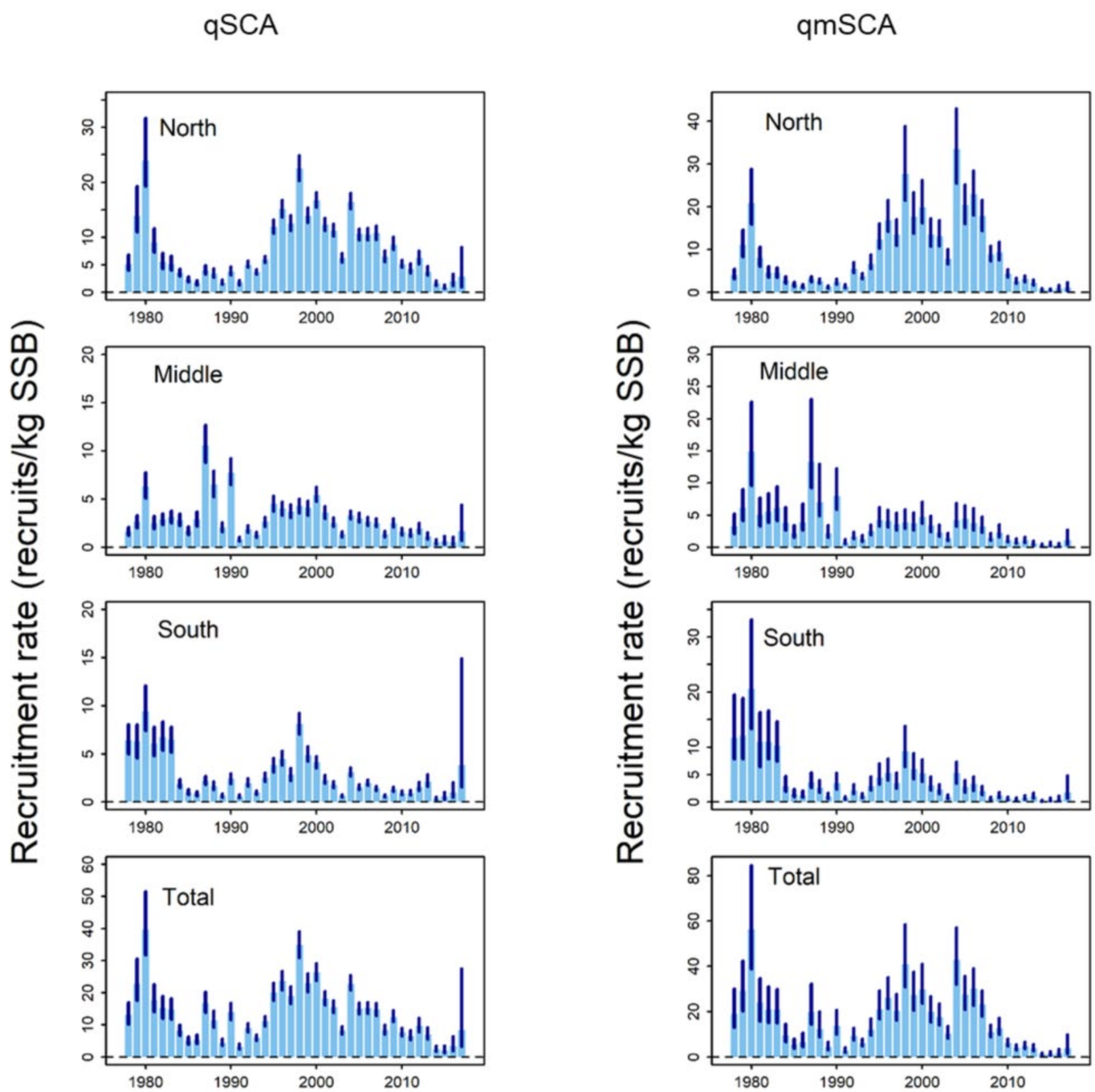

Figure 45. Estimated recruitment rate (recruits per kg of SSB) at age 2 (circles) of fall spawners in the three regions (North, Middle, South) and summed over regions (Total) of the southern Gulf of St. Lawrence, for the qSCA (left) and the qmSCA (right) population models. Bars show the median estimates and vertical lines show the 95 % confidence intervals.

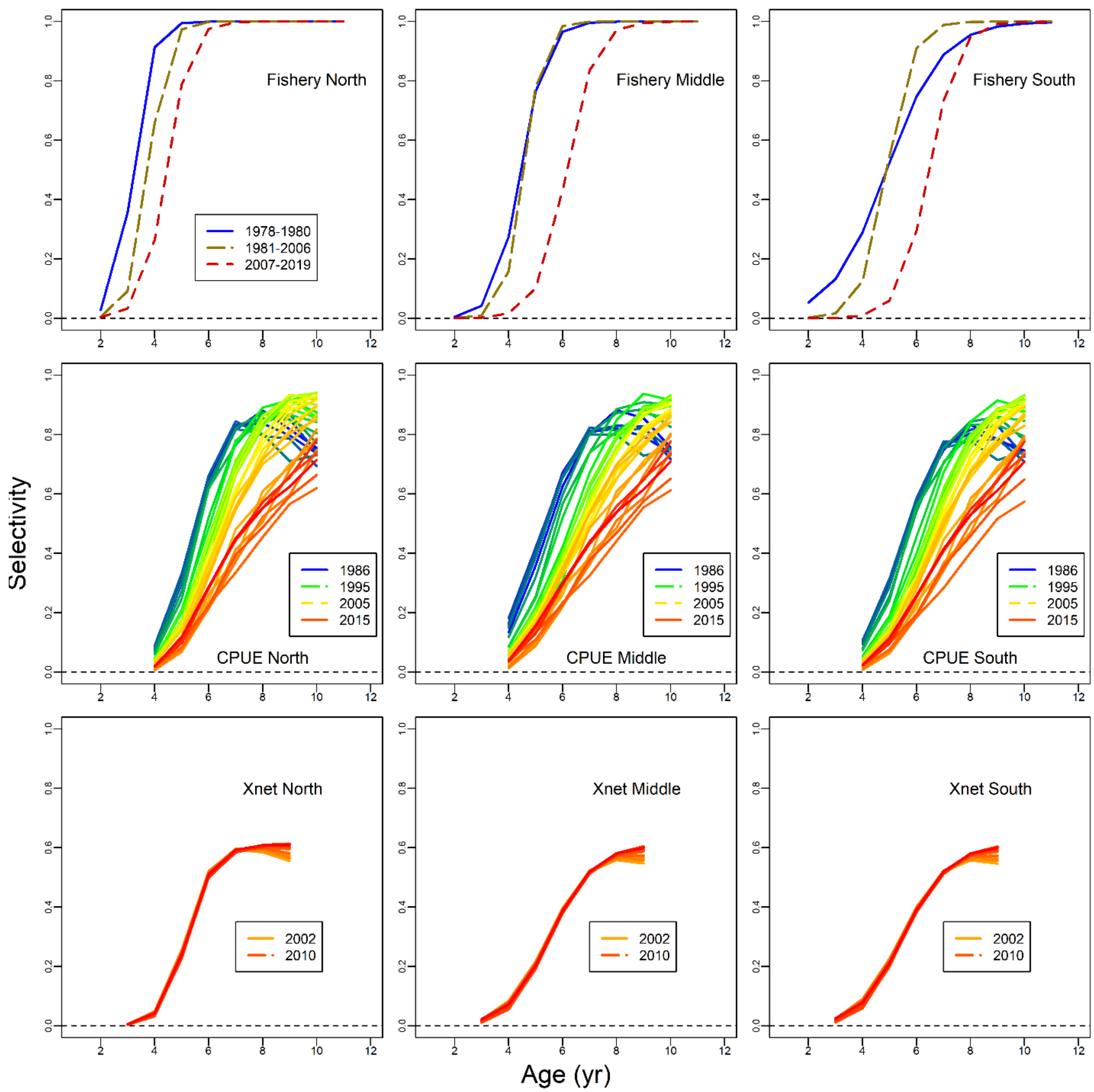

Figure 46. Estimated fishery (top row), CPUE (Middle row) and experimental nets (bottom row) selectivity for three populations of the southern Gulf of St. Lawrence (North in the left column, Middle in the Middle column and South in the right column), for the qSCA population model. Lines show the maximum likelihood estimates for years or time-periods identified in respective figure legends.

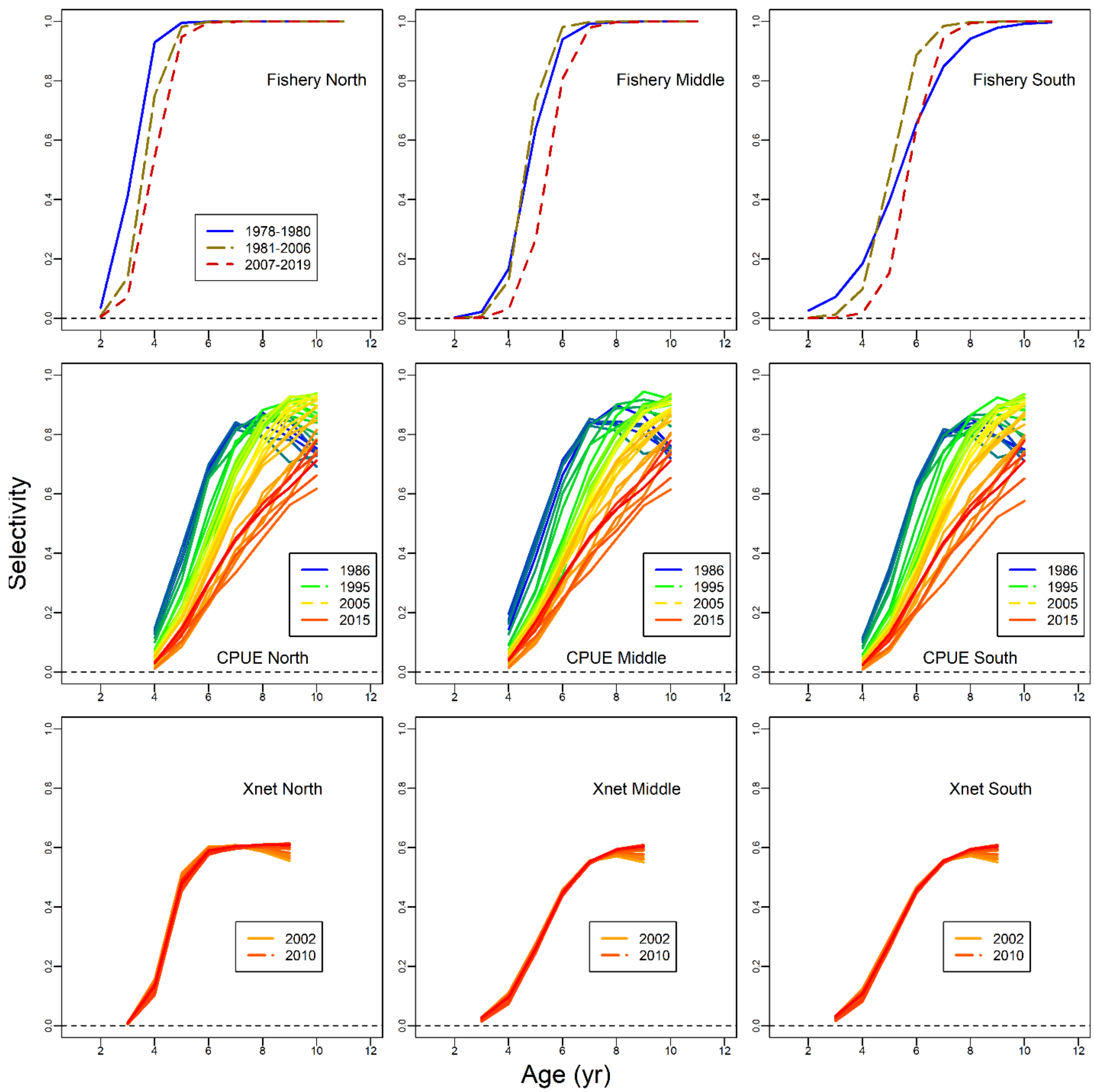

Figure 47. Estimated fishery (top row), CPUE (Middle row) and experimental nets (bottom row) selectivity for three populations of the southern Gulf of St. Lawrence (North in the left column, Middle in the Middle column and South in the right column), for the qSCA population model. Lines show the maximum likelihood estimates for years or time-periods identified in respective figure legends.

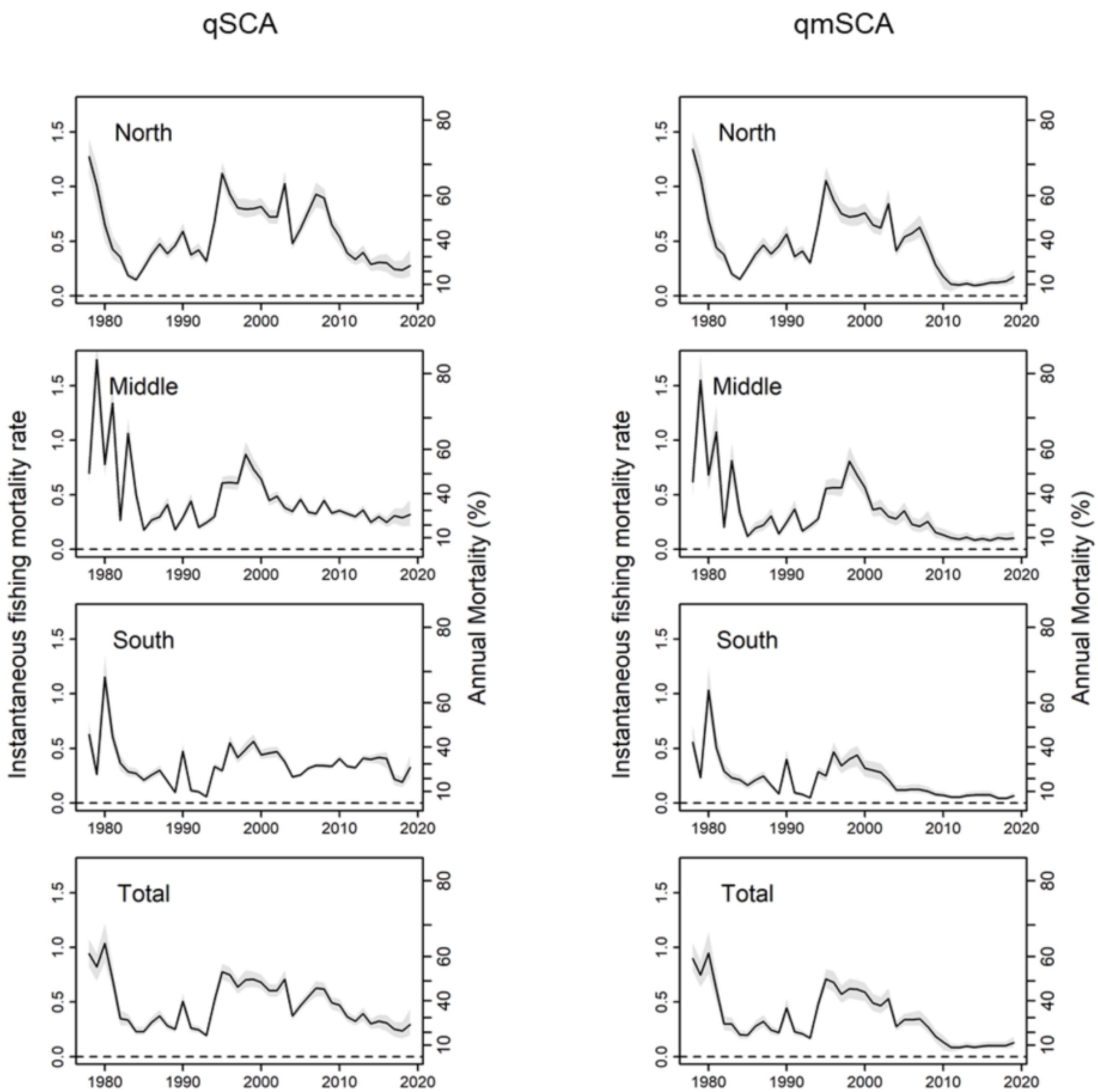

Figure 48. Estimated beginning-of-the-year abundance averaged age 5 to 10 fishing mortality (F5-10, left axis; annual exploitation rate, right axis) of fall spawning Herring by region and averaged over regions (weighted by region-specific abundance at ages 5-10 years) in the southern Gulf of St Lawrence for the qSCA (left panel) and qmSCA (right panel) models. Lines show the median estimates and shading their 95 % confidence intervals.

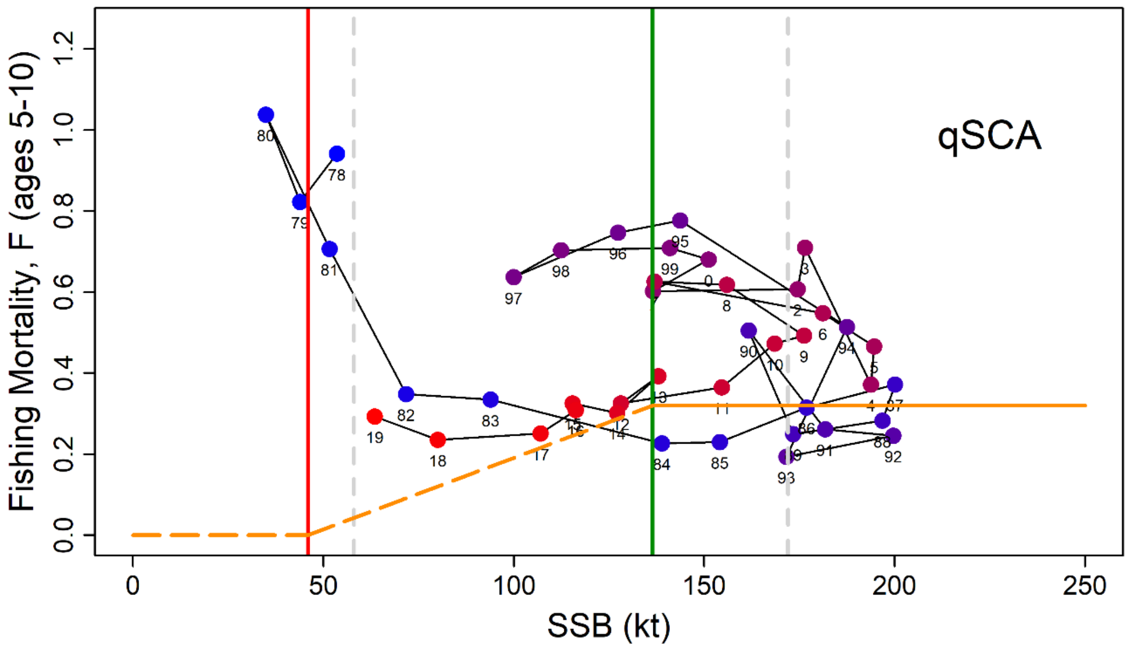

Figure 49. The southern Gulf of St. Lawrence Atlantic Herring fall spawner component trajectory in relation to SSB and fishing mortality rates for ages 5 to 10 years for 1978 to 2019 for the qSCA population model. The red vertical line is the LRP and the green vertical line is the USR. The orange solid horizontal line is the removal rate reference value (F0.1 = 0.32) in the Healthy Zone and orange dashed line is the default harvest decision rule of the Precautionary Approach Framework in the Cautious and Critical Zones. Vertical grey line are the LRP and USR from the previous assessment. Point labels are years (83 = 1983, 0 = 2000). Colour Coding is from blue in the 1970s and early 1980s to red in the 2000s.

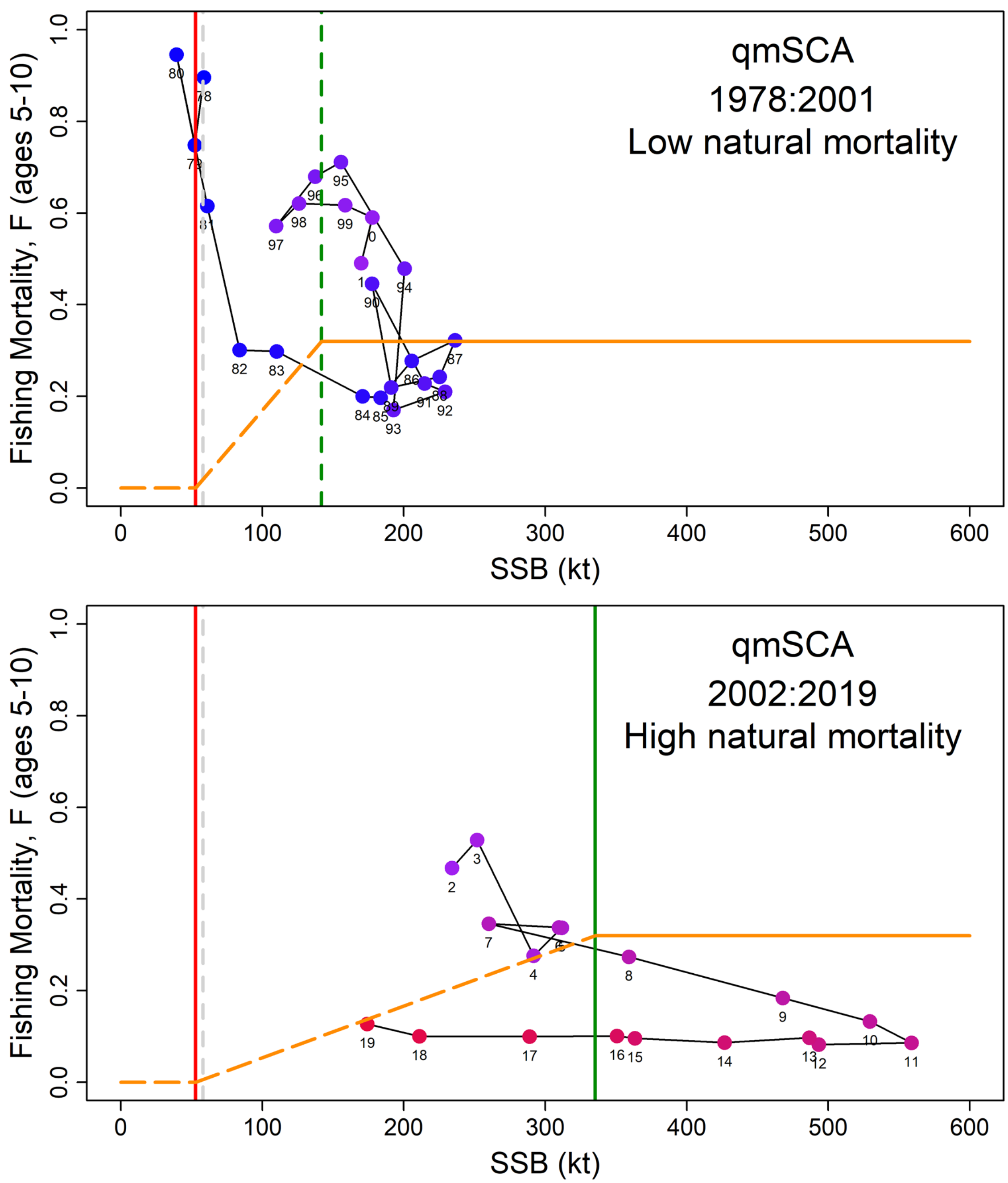

Figure 50. The southern Gulf of St. Lawrence Atlantic Herring fall spawner component trajectory in relation to SSB and fishing mortality rates for ages 5 to 10 years for 1978 to 2001 (lower natural mortality, upper panel) and 2002 to 2019 (higher natural mortality, lower panel) for the qmSCA population model. The red vertical line is the LRP and the green vertical line is the USR. The orange solid horizontal line is the removal rate reference value (F0.1 = 0.32) in the Healthy Zone and dashed orange line is the default harvest decision rule of the Precautionary Approach Framework in the Cautious and Critical Zones. Dashed vertical grey line is the LRP from the previous assessment. Point labels are years (83 = 1983, 0 = 2000). Colour Coding is from blue in the 1970s and early 1980s to red in the 2000s.

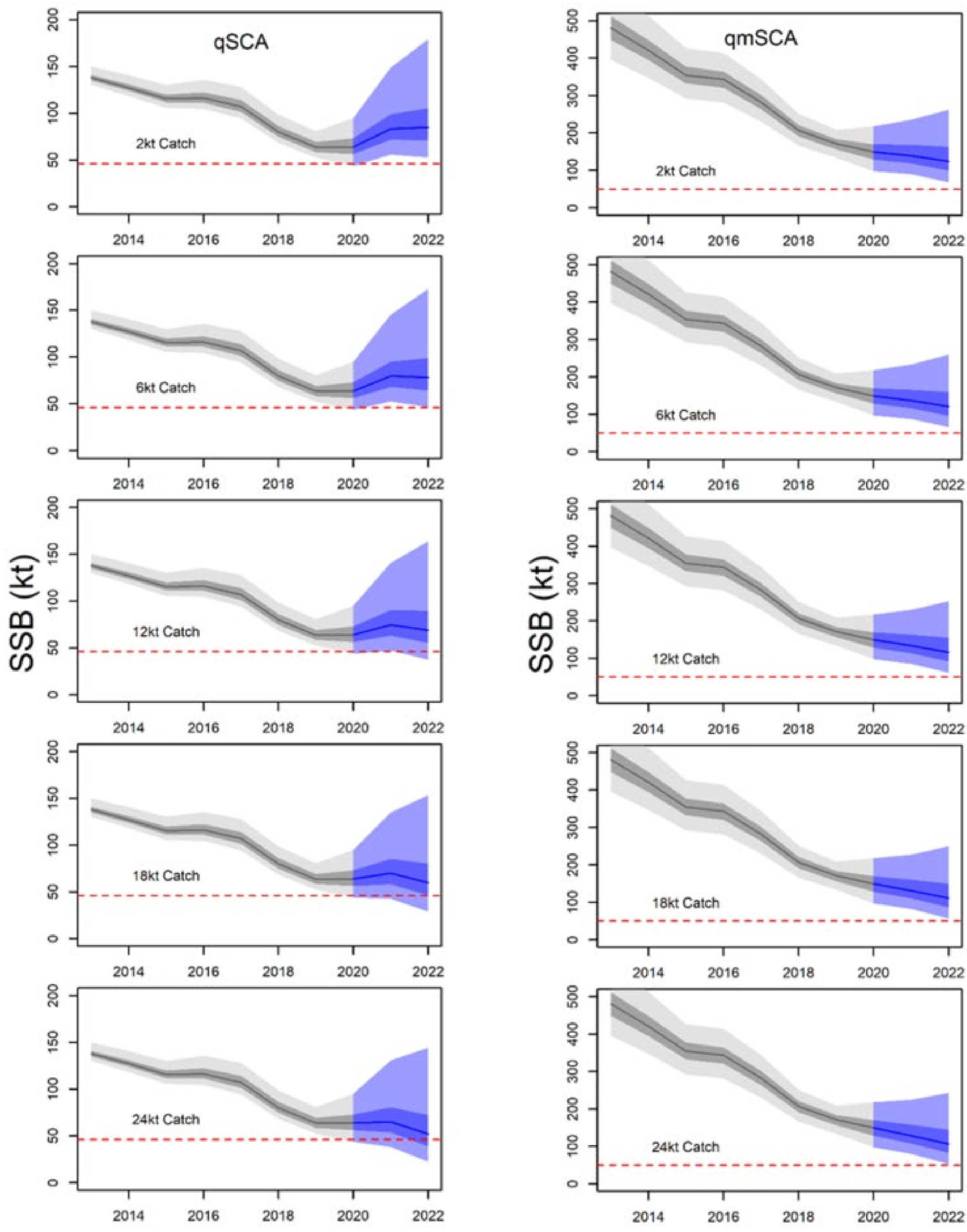

Figure 51. Projected SSB (in kt) of fall spawning Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels in 2020 and 2021 for the qSCA (left) and the qmSCA (right), under a 5 recent years average recruitment and 2 recent years average natural mortality scenario. Lines show the 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.

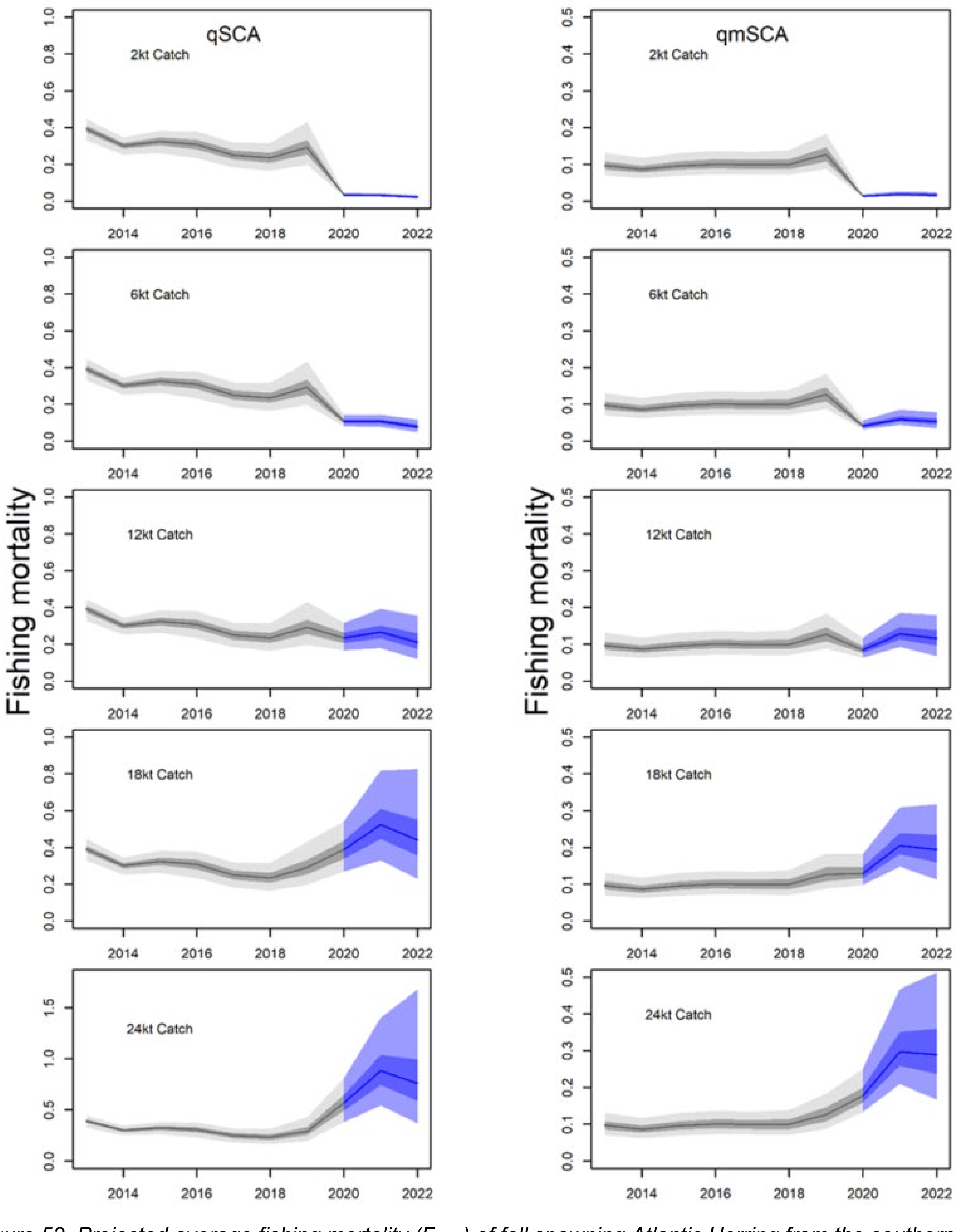

Figure 52. Projected average fishing mortality ($F_{5\text{-}10}$) of fall spawning Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels in 2020 and 2021 for the qSCA (left) and the qmSCA (right), under a 5 recent years average recruitment and 2 recent years average natural 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.

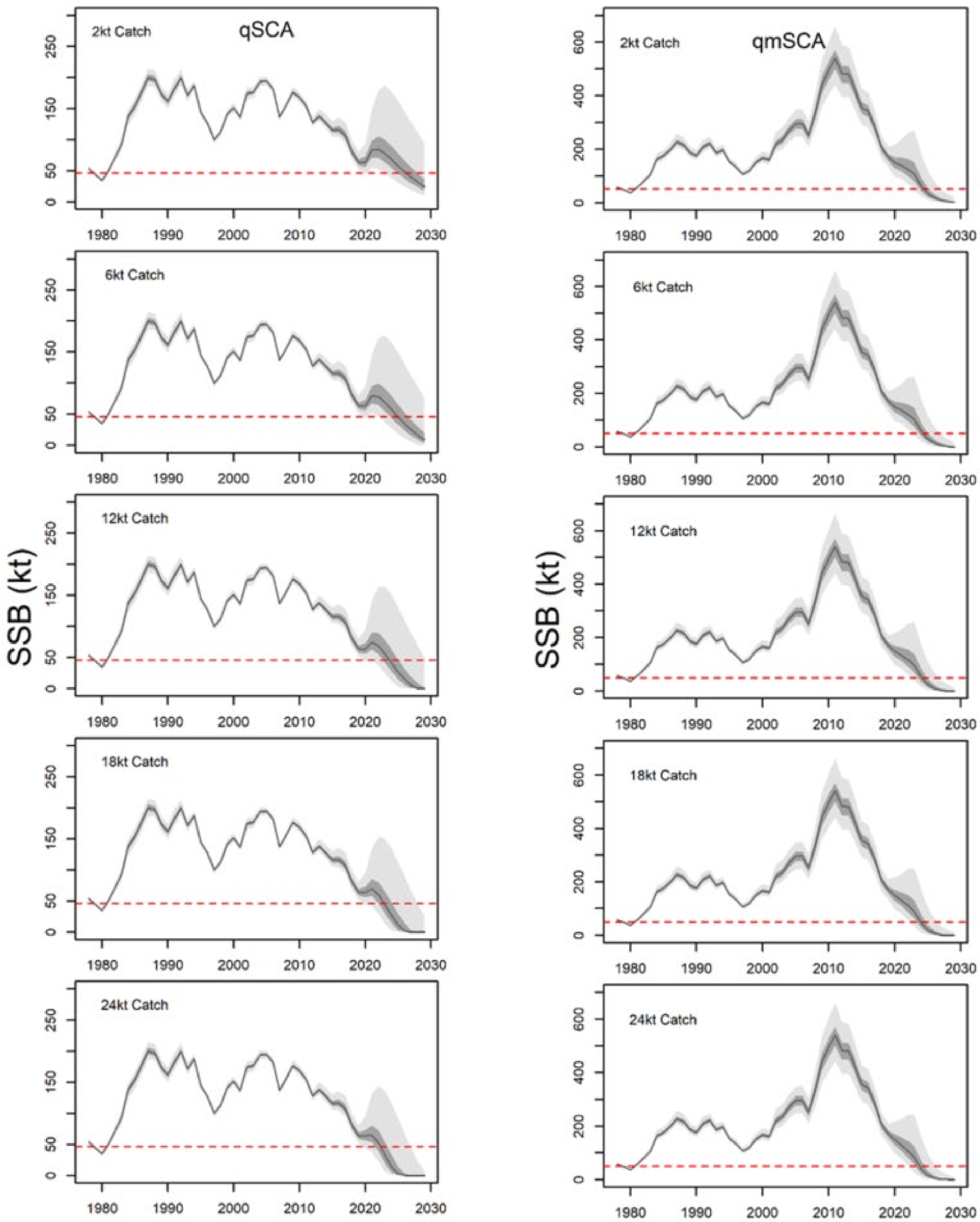

Figure 53. Ten years projections of SSB (in kt) of fall spawning Atlantic Herring from the southern Gulf of St. Lawrence at various catch levels for the qSCA (left) and the qmSCA (right), under a 5 recent years average recruitment and 2 recent years average natural mortality scenario. Lines show the median estimates of August 1 SSB, light shading shows the 95 % and dark shading shows the 50 % confidence intervals (based on MCMC sampling). The red horizontal line is the LRP.

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 2018 and 2019.

The results show an overall agreement of 88 % and a coefficient of variation (CV) of 1.4 % for the primary reader and an agreement of 88 % (1.7 % CV) for the secondary reader (Figure A1). The CV is considered to be a more robust measure of the precision of age determination (Campana et al. 1995). From the reading bias plot, there was no bias present, and age determination is more variable for older (9+) Herring (Figure A1).

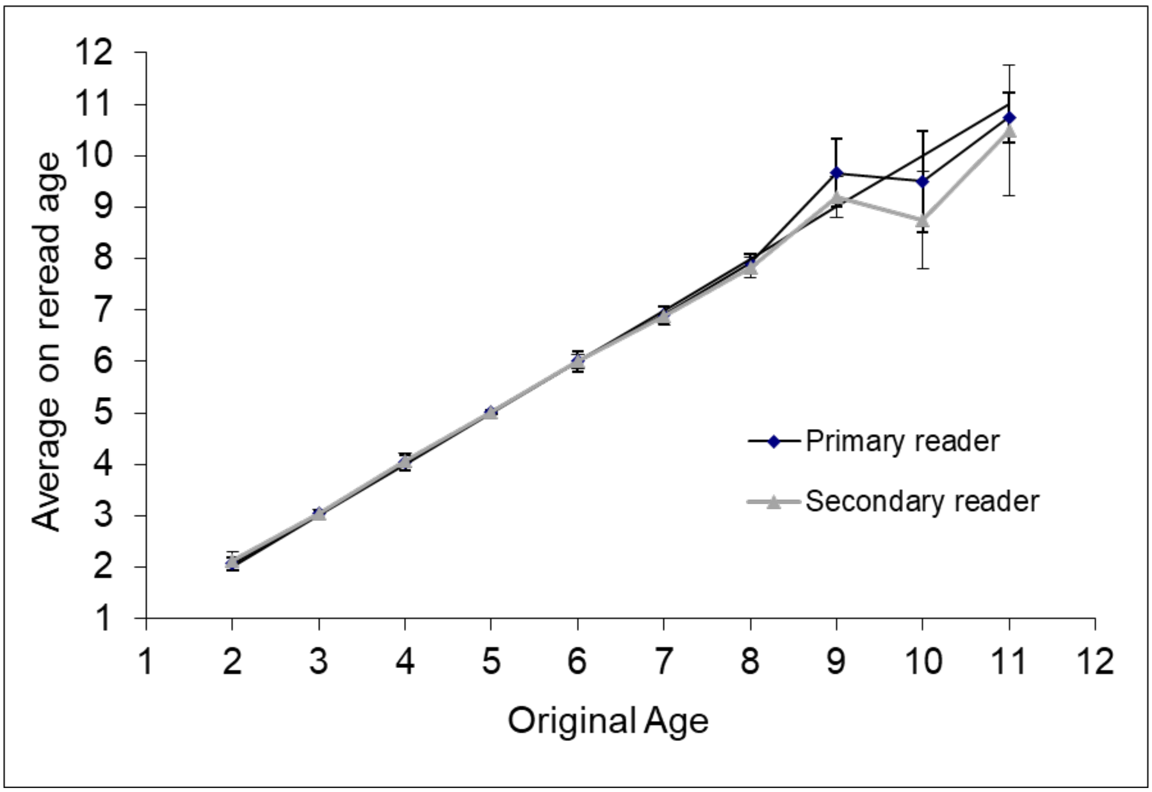

Figure A1. Comparison of ages obtained during the validation test with the original ages assigned. Bars indicate the coefficient of variation. Straight line indicates original ages.

APPENDIX B. FISHERY-INDEPENDENT ACOUSTIC SURVEY RESULTS

The 2018-2019 acoustic surveys were carried out between sepetember 23 and October 10 in the 4Tmno areas (i.e., Chaleurs-Miscou; Figure B1 and B2) and the biomass of Herring were estimated to be 23,315 and 18,829 t, respectively. The distribution of Herring in the area can be seen in Figure B1-B2 and Table B1-B2. The 2018 and 2019 acoustic biomass indices of the Chaleurs-Miscou area for the combined spring (SS) and fall (FS) spawner groups was among the lowest recorded in the history of the survey (Figure B2).

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 2018.

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
Cap Bon Ami	-	69	0.00	0.0000	0	0	0.0
Malbaie	-34.72	95.6	-68.06	0.0005	44	73	163.4
Anse à Beaufils	-	96	0.00	0.0000	0	0	0.0
Chaleur							
Grande Rivière	-	106.4	0.00	0.0000	0	0	0.0
Newport	-	124.9	0.00	0.0000	0	0	0.0
Shigawake	-	265.6	0.00	0.0000	0	0	0.0
New Carlisle	-34.47	169	-63.18	0.0013	227	162	71.2
New Richmond	-	111.6	0.00	0.0000	0	0	0.0
Belledune	-34.47	266	-50.97	0.0224	5,948	2,179	36.6
Nepisiguit	-34.47	211.3	-49.99	0.0281	5,932	1,603	27.0
Maisonnette	-34.26	145	-53.08	0.0131	1,904	661	34.7
Miscou							
West Miscou	-34.32	330.5	-53.96	0.0109	3,593	1,535	42.7
North Miscou	-34.72	295.7	-68.68	0.0004	119	99	83.5
Miscou NW	-35.84	444	-62.29	0.0023	1,005	523	52.0
Miscou NE	-35.84	352.8	-60.30	0.0036	1,265	844	66.7
Miscou SW	-35.84	552.2	-59.53	0.0043	2,362	1,215	51.4
Miscou SE	-35.84	521.3	-63.40	0.0018	915	721	78.8
2018 Total					**23,315**		

Table B2. Herring biomass densities and estimates by stratum and area from the fishery-independent acoustic surveys conducted in 2019.

Stratum	Average TS (dB/kg)	Stratum Area (km²)	Mean Sa (/m²)	Density (kg/m2)	Biomass (tons)	SE (tons)	SE (%)
Gaspé							
Rivière au Renard	-	124.6	0.00	0.0000	0	0	0.0
Cap Bon Ami	-	69	0.00	0.0000	0	0	0.0
Malbaie	-	95.6	0.00	0.0000	0	0	0.0
Anse à Beaufils	-	96	0.00	0.0000	0	0	0.0
Chaleur							
Grande Rivière	-34.72	106.4	-66.12	0.0007	77	79	103.7
Newport	-34.69	124.9	-60.42	0.0027	334	382	114.5
Shigawake	-34.69	265.6	-55.64	0.0080	2,133	817	38.3
New Carlisle	-34.47	169	-56.32	0.0013	1,168	645	55.2
New Richmond	-34.28	111.6	-56.59	0.0058	656	128	19.6
Belledune	-34.13	266	-53.24	0.0123	3,264	891	27.3
Nepisiguit	-35.02	211.3	-52.40	0.0183	3,859	2,044	53.0
Maisonnette	-34.83	145	-53.03	0.0152	2,198	500	22.8
Miscou							
West Miscou	-34.53	330.5	-57.42	0.0051	1,700	682	40.1
North Miscou	-35.23	295.7	-63.48	0.0015	441	235	53.3
Miscou NW	-35.84	444	-59.63	0.0042	1,852	1,798	97.1
Miscou NE	-	352.8	0.00	0.0000	0	0	0
Miscou SW	-	552.2	0.00	0.0000	0	0	0
Miscou SE	-35.84	521.3	-62.44	0.0022	1,141	355	29.4
2019 Total					**18,829**		

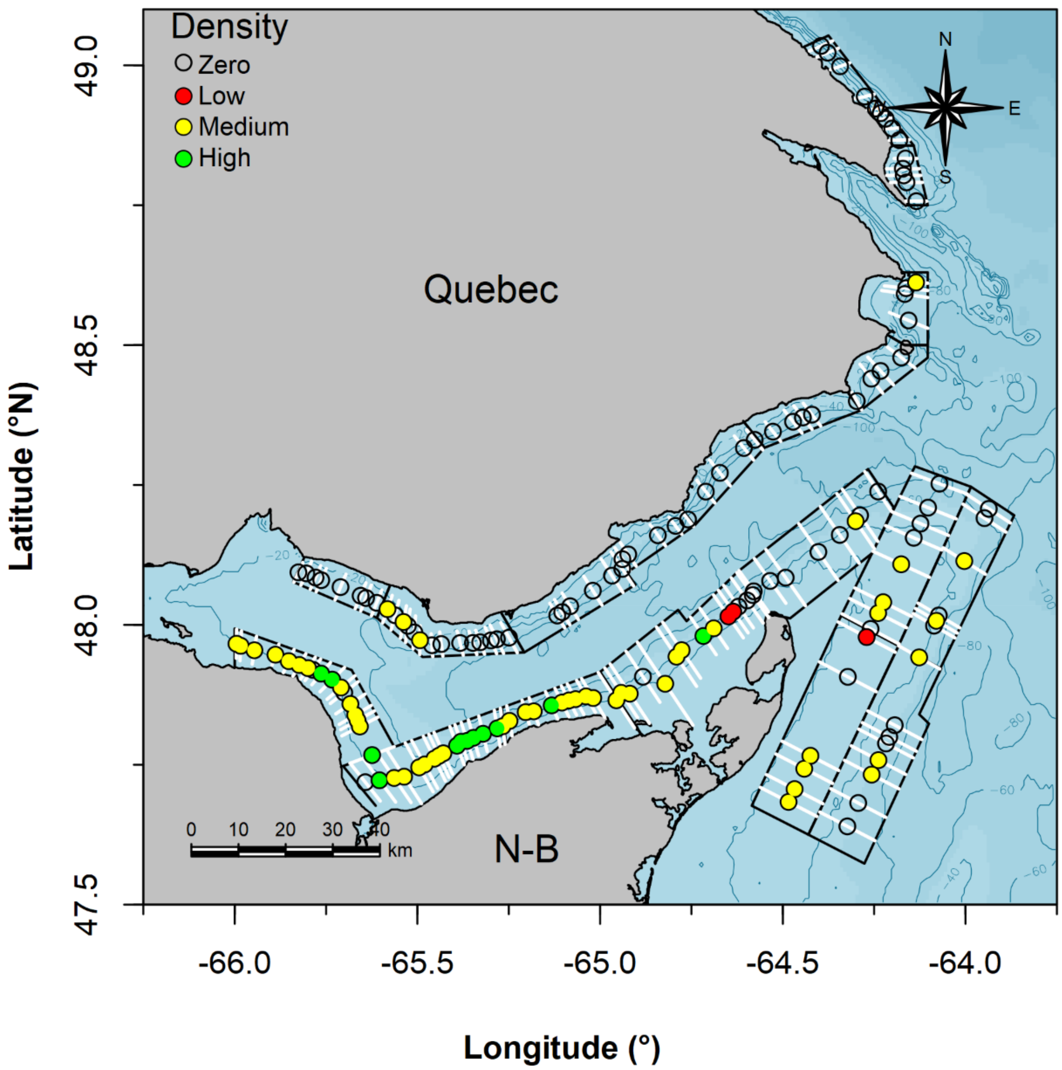

Figure B1. Surveyed transects covered during the 2018 acoustic surveys (whites lines) and Herring biomass density (colored circles, kg/m², Low, Medium or High, by transect).

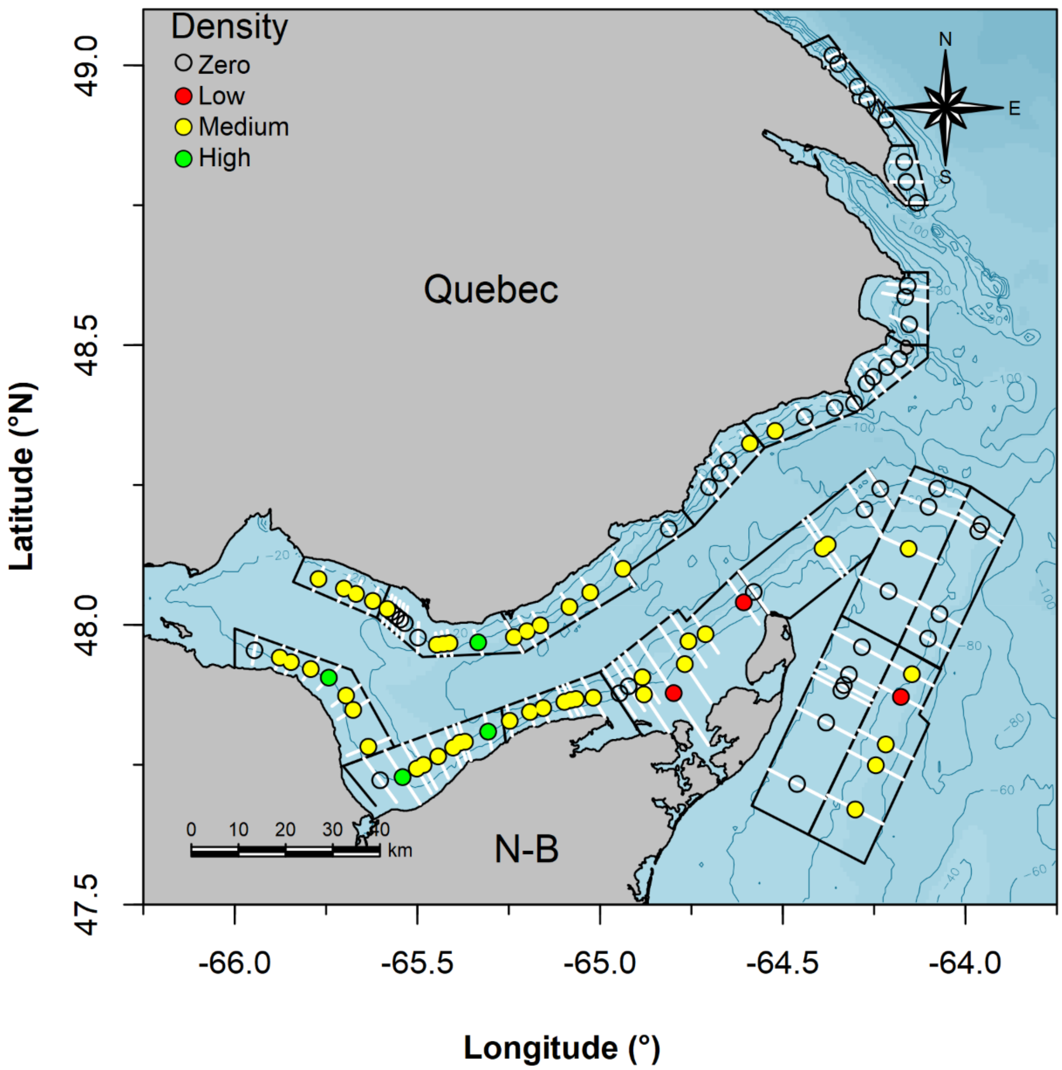

Figure B2. Surveyed transects covered during the 2019 acoustic surveys (whites lines) and Herring biomass density (colored circles, kg/m², Low Medium or High, by transect).

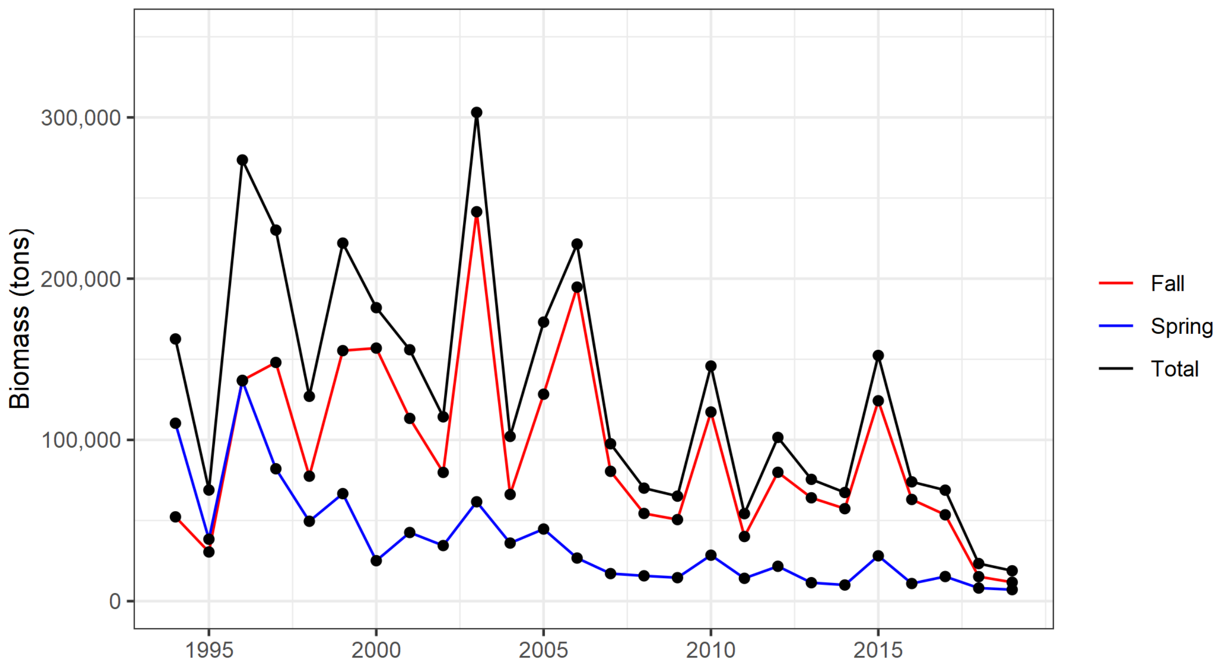

Figure B3. Acoustic survey total biomass (black) of spring (red) and fall (blue) spawners between 1994 and 2019.

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 (Table 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). 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 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 and 2019. Miscou shows a decreasing trend in biomass from 2017 to 2019, with the lowest biomass in 2019, similar to that observed in Gaspe in 2019. 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 for the Escuminac/Richibucto region was observed in 2019;however, sampling effort in this region was low in all years. 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 was the highest mean nightly biomass of all six sampling regions in that year. In general, West PEI and East PEI show lower nightly biomass each year compared to the other regions. Pictou shows intermediate biomass with a general decreasing trend, with the highest biomass level observed in 2015.

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 2018 and 2019 (Figure C4). The results show a general decrease in average nightly biomass in all geographic regions over time. 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 in 2018 and 2019.

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.

Table C1. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2018.

Herring Fishing Area	Region	Area	Date	Mean Target Strength (dB kg^{-1})	Area (km^2)	Mean Backscatter (dB m^{-2})	Biomass Density (kg m^{-2})	Biomass Estimate (t)	Biomass Estimate Standard Error (t)
16B	North	Gaspe	17-08-2018	-35.59	38.6	-42.01	1.21E-03	39	39
16B	North	Gaspe	25-08-2018	-35.59	38.6	0.00	0.00E+00	0	0
16B	North	Gaspe	01-09-2018	-35.59	38.6	-53.12	1.95E-02	788	643
16B	North	Gaspe	08-09-2018	-35.59	38.6	0.00	0.00E+00	0	0
16B	North	Gaspe	24-09-2018	-35.59	38.6	-56.97	9.67E-03	351	157
16B	North	Miscou	17-08-2018	-35.59	386.9	-40.17	2.57E-02	10235	6690
16B	North	Miscou	24-08-2018	-35.59	386.9	-19.22	1.86E-05	8	8
16B	North	Miscou	31-08-2018	-35.59	386.9	-34.09	2.76E-04	51	51
16B	North	Miscou	15-09-2018	-35.59	386.9	-58.06	5.85E-03	869	562
16B	North	Miscou	27-09-2018	-35.59	386.9	0.00	0.00E+00	0	0
16E	Middle	West PEI	17-08-2018	-35.56	111.3	0.00	0.00E+00	0	0
16E	Middle	West PEI	24-08-2018	-35.56	111.3	-14.06	2.15E-03	759	283
16E	Middle	West PEI	31-08-2018	-35.56	111.3	0.00	0.00E+00	0	0
16E	Middle	West PEI	07-09-2018	-35.56	111.3	-27.27	8.02E-03	613	0
16E	Middle	West PEI	15-09-2018	-35.56	111.3	-26.00	1.14E-02	2125	1410
16E	Middle	West PEI	27-09-2018	-35.56	111.3	0.00	0.00E+00	0	0
16F	South	Pictou	04-09-2018	-35.31	127.2	-20.79	3.02E-02	1209	0
16F	South	Pictou	14-09-2018	-35.31	127.2	-11.69	9.72E-04	39	38
16F	South	Pictou	23-09-2018	-35.31	127.2	0.00	0.00E+00	0	0
16F	South	Pictou	28-09-2018	-35.31	127.2	0.00	0.00E+00	0	0
16F	South	Pictou	06-10-2018	-35.31	127.2	0.00	0.00E+00	0	0
16G	South	East PEI	12-10-2018	-35.82	56.1	-52.45	2.24E-02	994	854
16G	South	East PEI	05-11-2018	-35.82	56.1	0.00	0.00E+00	0	0

Table C2. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2019.

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	Gaspe	15-08-2019	-35.48	38.6	-54.29	2.15E-02	978	902
16B	North	Gaspe	24-08-2019	-35.48	38.6	-59.40	8.65E-03	326	287
16B	North	Gaspe	30-08-2019	-35.48	38.6	-58.45	6.02E-03	223	106
16B	North	Gaspe	06-09-2019	-35.48	38.6	-34.01	9.77E-02	2418	1837
16B	North	Gaspe	12-09-2019	-35.48	38.6	-60.37	1.73E-02	838	755
16B	North	Gaspe	23-09-2019	-35.48	38.6	-52.67	3.57E-02	1677	1573 **
16B	North	Gaspe	03-10-2019	-35.48	38.6	-61.08	7.01E-03	255	169**
16B	North	Miscou	14-08-2019	-35.48	386.9	-24.85	1.66E-03	823	581
16B	North	Miscou	06-09-2019	-35.48	386.9	-41.27	1.61E-03	293	195
16B	North	Miscou	13-09-2019	-35.48	386.9	-43.93	6.18E-04	137	84
16B	North	Miscou	27-09-2019	-35.48	386.9	-60.52	3.24E-03	1019	702
16B	North	Miscou	30-09-2019	-35.48	386.9	-52.96	1.84E-02	2719	1367**
16B	North	Miscou	03-10-2019	-35.48	386.9	-36.95	7.19E-05	7	7 **
16B	North	Miscou	07-10-2019	-35.48	386.9	-26.67	8.20E-03	1515	612**
16C	Middle	Escuminac	01-09-2019	-35.53	145.5	-68.04	6.29E-04	73	43
16E	Middle	West PEI	18-08-2019	-35.34	111.3	0.00	0.00E+00	0	0
16E	Middle	West PEI	06-09-2019	-35.34	111.3	-12.79	6.56E-03	2324	1459
16E	Middle	West PEI	13-09-2019	-35.34	111.3	-43.38	1.01E-02	3153	3374
16E	Middle	West PEI	18-09-2019	-35.34	111.3	-10.31	6.44E-02	1958	1907
16F	South	Pictou	03-09-2019	-35.43	127.2	0.00	0.00E+00	0	0
16F	South	Pictou	13-09-2019	-35.43	127.2	-23.24	8.21E-03	3241	3259
16F	South	Pictou	20-09-2019	-35.43	127.2	-44.09	1.55E-02	756	707
16F	South	Pictou	27-09-2019	-35.43	127.2	-30.36	1.61E-03	425	327
16F	South	Pictou	03-10-2019	-35.43	127.2	-12.37	4.55E-04	75	76
16G	South	East PEI	13-09-2019	-35.72	56.1	-56.82	8.66E-03	359	162
16G	South	East PEI	21-09-2019	-35.72	56.1	-60.75	4.55E-03	170	123

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

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

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

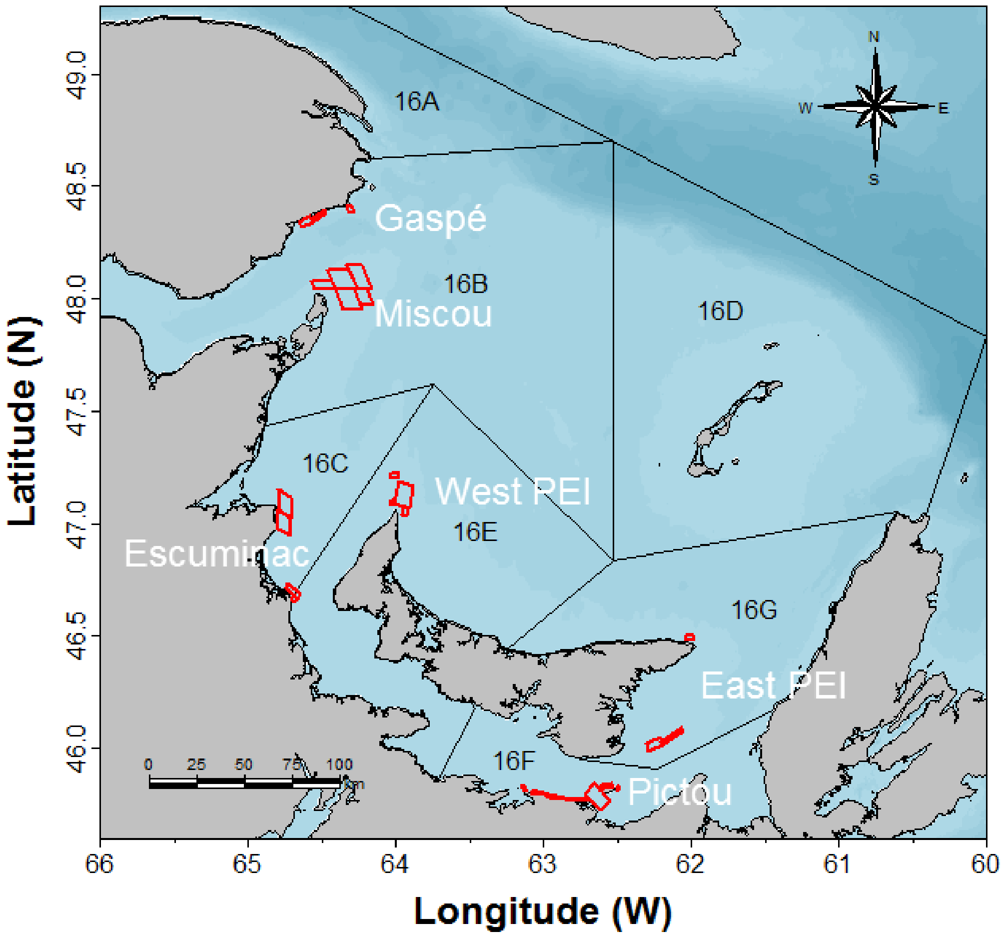

Figure C1. Spawning grounds surveyed during the spawning ground acoustic surveys.

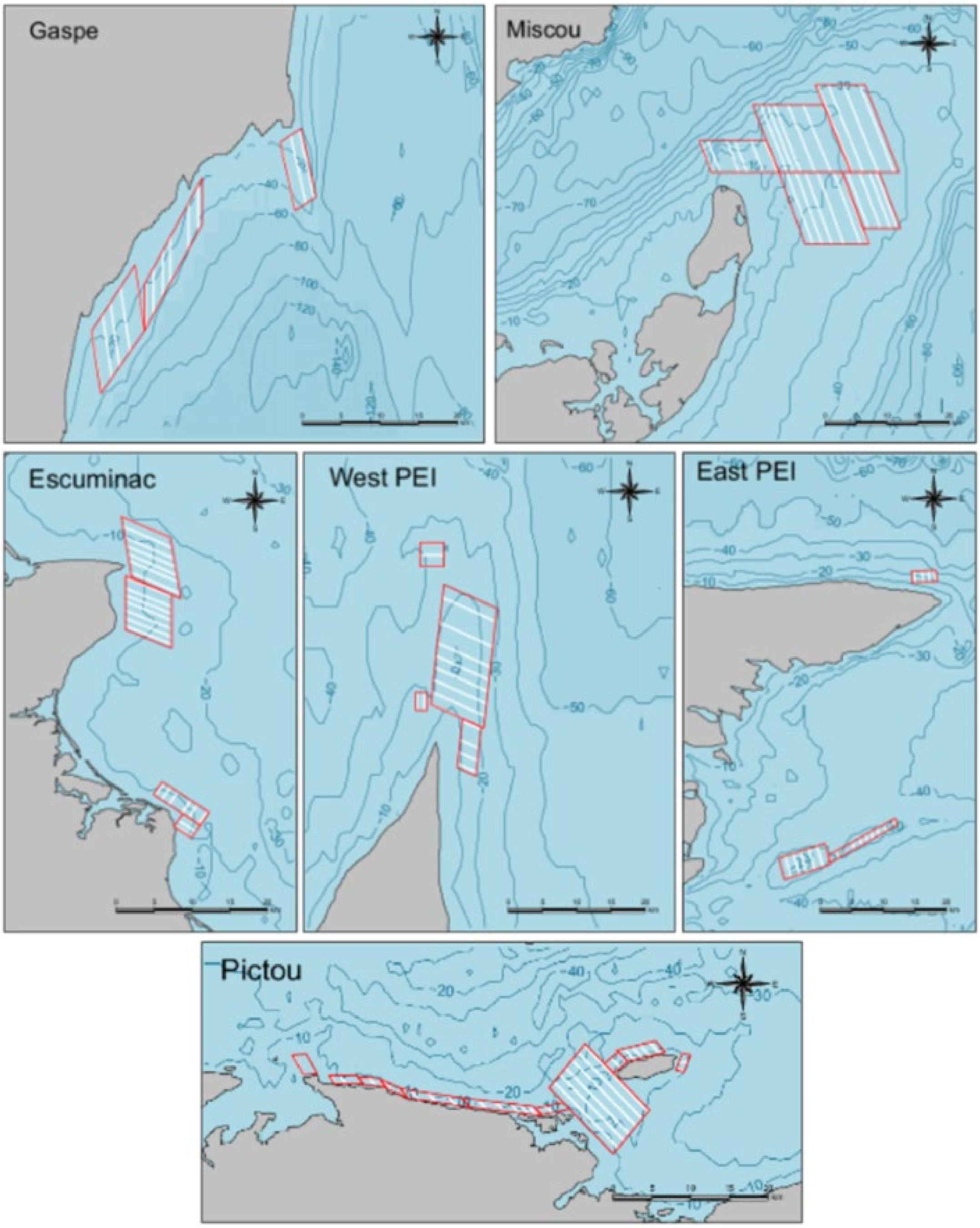

Figure C2. Strata (red boxes) and transects (white lines) surveyed during the spawning ground acoustic surveys.

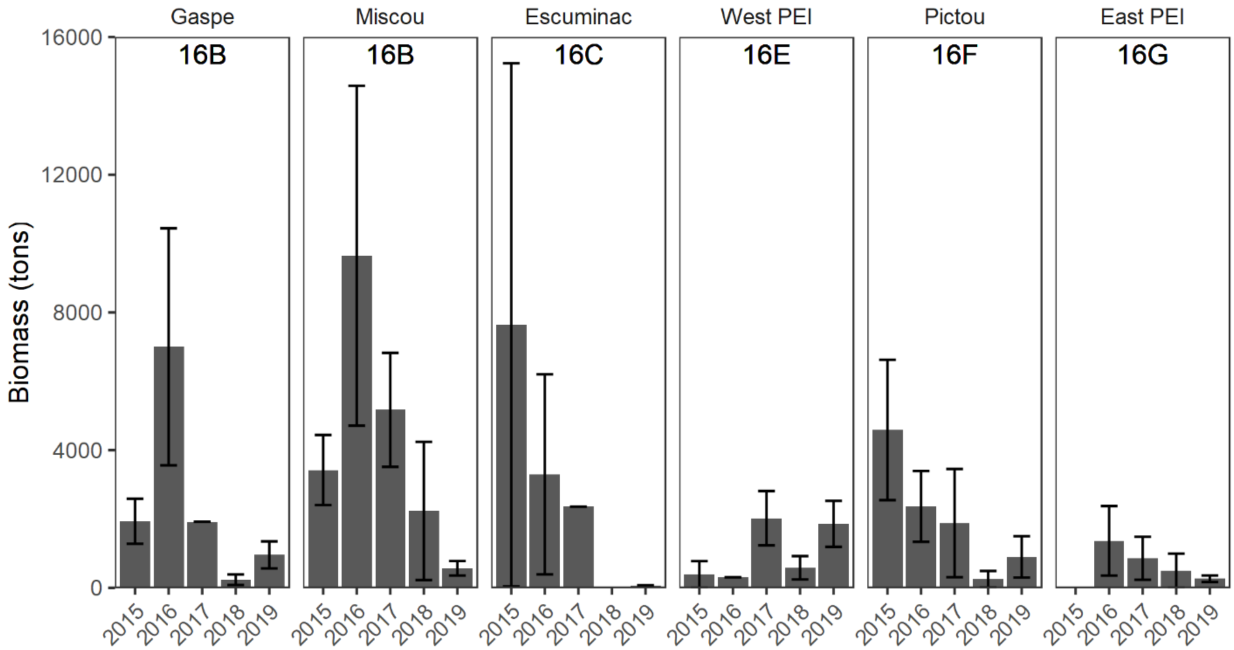

Figure C3. Nightly Atlantic Herring biomass estimates (tons; mean ± one standard error bar) by spawning ground from the spawning ground acoustic surveys for years 2015 to 2019.

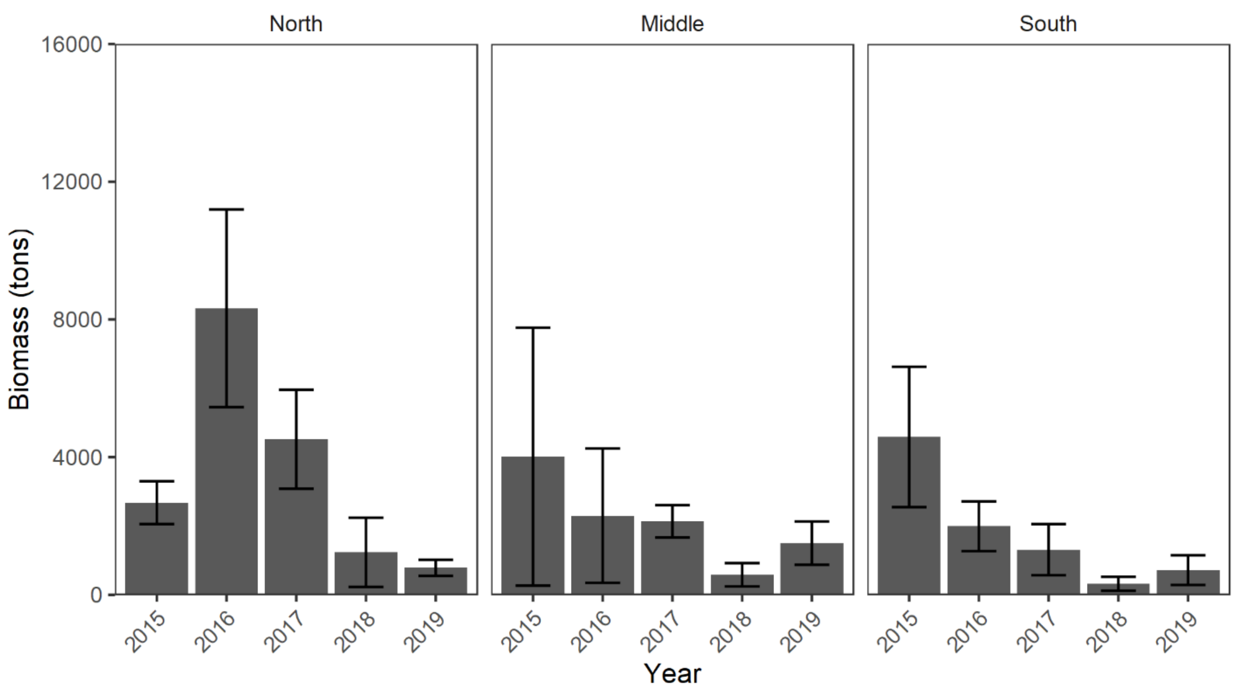

Figure C4. Nightly Atlantic Herring biomass estimates (tons; mean ± one standard error bar) by geographic region (North, Middle, South) from the spawning ground acoustic surveys for years 2015 to 2019.

APPENDIX D. MULTISPECIES BOTTOM-TRAWL SURVEY RESULTS

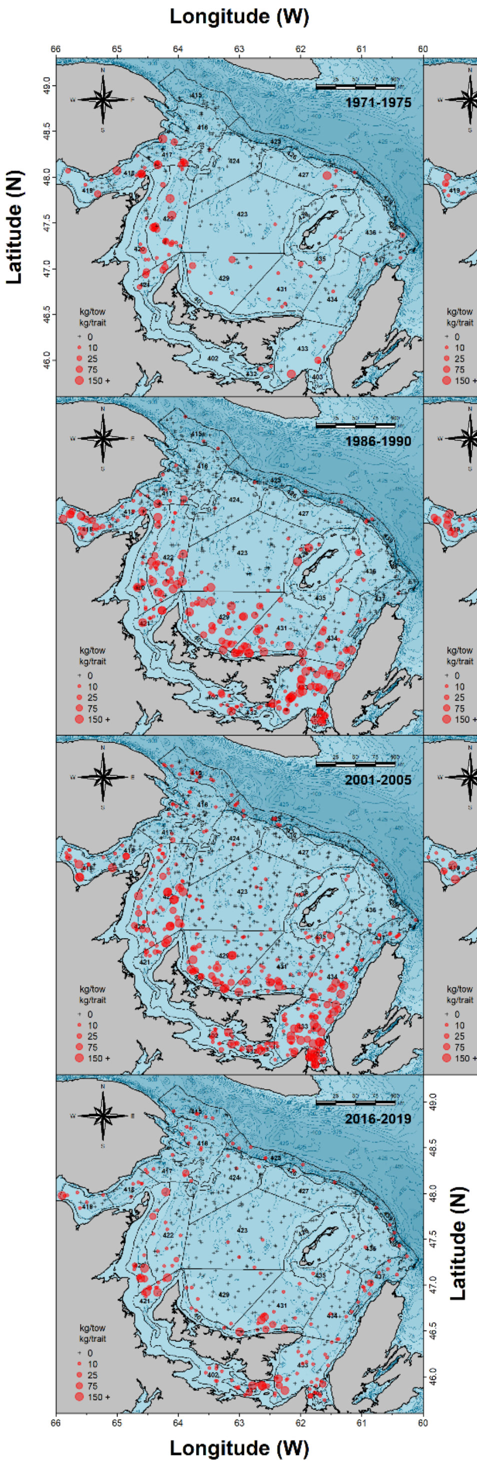

Figure D1. Spatial distribution of Herring catches over time in the southern Gulf of St. Lawrence from the multispecies bottom-trawl survey. The dots indicate the location of fishing sets.

APPENDIX E. MODEL STRUCTURE AND PERFORMANCE REVIEW

External experts provided a peer review of proposed population models for both spring and fall spawning Herring (Turcotte et al. 2020). A single population was modelled for the spring spawners whereas the fall model consisted of three populations assumed to be independent beginning at recruitment. Models allowed for time-varying catchability to the gillnet fishery and/or natural mortality. These models were compared to a model that assumed stationary population dynamics except for recruitment. The review focused on the models with time-varying dynamics. The reviews were discussed by Webex on February 10.

The assessment team described the models and presented diagnostics such as goodnes of fit (observed – predicted residuals for the age-aggregated biomass indices and the PAA in catches by the fishery and in the indices). Retrospective patterns were also examined. Based on these diagnostics, the assessment team favoured the spring model with both time-varying fishery catchability (*q*) and natural mortality (*M*) and the fall models with either time-varying fishery *q* or with both time-varying natural mortality (*M*) and fishery *q*. The reviewers did not object to this proposal.

The fixed gear (gillnet) fishery targets spawning aggregations. Catchability to fisheries targeting aggregations is expected to increase as population size decreases (Paloeimo and Dickie 1964, Winters and Wheeler 1985, Rose and Kulka 1999). In models that allowed catchability to the gillnet fishery to vary over time, estimated catchability was consistent with this expectation, increasing as population size declined. Given these expectations and results, the reviewers argued that time-varying catchability to the gillnet fishery should be incorporated in these models by default. The question then becomes “does including time-varying *M* add anything to the models?” In the spring model, adding time-varying *M* improved the fit of the model. In the fall model, fit was also improved by adding time-varying *M*. However, adding time-varying *M* to the fall model also resulted in a more important retrospective pattern than in the qSCA. However, for both models, the estimated patterns in time-varying *M* were all consistent with ecosystem data that were independent of the models. For all four populations (1 spring and 3 fall), both estimated *M* of older Herring and abundance of key predators of Herring (grey seals, Tuna) increased over time. The close similarity between these populations in estimated time trends in *M* of these older Herring supports the hypothesis that these results are not spurious.

It can be difficult to distinguish changes in *q* from changes in *M*. The reviewers suggested that future assessments should consider explicitly modelling *q* to the gillnet fishery as a density-dependent process. This could help to disentangle any confounding variation between *q* and *M*. This will be examined in future work. Predation mortality is also expected to be density dependent, increasing as prey abundance decreases (Gascoigne and Lipcius 2004). However, this may be difficult to model here due to confounding effects between changes in prey and predator abundance, but would be worth examining in future analyses.

The reviewers also suggested examining model-independent evidence for changes in mortality, in particular estimates of mortality based on cohort catch curves. Following Sinclair 2001, we estimated total mortality *Z* using a linear model with $\log_e$ catch rate as the dependent variable, cohort as a factor and age as a covariate. Ages were restricted to 7 to 11+ years. Analyses were conducted in moving 5-year blocks, with results indexed by the middle year in the block. Due to time restrictions, this analysis has so far been conducted only for fishery catch curves of the spring spawners. To obtain a model independent estimate of fishing mortality, fishery catch can be divided by an index of population abundance. This has often been done for groundfish using survey catch rates at the scale of trawlable abundance. No index at a comparable scale is available for these Herring stocks, so estimates of *Z* were compared to model estimates of abundance (based on the spring qm model). Catch and abundance were restricted to ages 7-

11+ and averaged over 5 year blocks. Estimates of Z increased to relatively high levels in the 2000s and 2010s when estimates of fishing mortality (catch/abundance) declined to very low levels (Figure E.1). This is consistent with high *M* during this period. In the future, this analysis should be repeated for the fall spawner populations and for other data on catch at age (the CPUE and acoustic catch at age in the spring and the CPUE and experimental net data in the fall). Analyses should also be conducted to estimate fishing mortality as an instantaneous rate.

Questions were asked about the modelling and the calculation of residuals for the proportions of age. PAA were modelled based on a multivariate logistic model with residuals calculated as described by equation T4.6 in Neuenhoff et al. 2019. The reviewers considered this to be acceptable. However, they did identify an error in the calculation of residuals for the diagnostic plots. The final term in equation T4.6 had been omitted in the calculations for these plots. This error has been corrected for the plots in this Research Document.

The reviewers also suggested additional analyses for evaluating the models: 1) retrospective analyses of the 2-year projections, 2) comparing prior and posterior distributions of the parameters, 3) examining posterior predictive distributions of the data, and conducting simulation tests. We were unable to conduct these analyses in the time available to complete and finalize the draft research document for final distribution (March 2).

A reviewer noted that in many cases there was a high frequency of very small PAA. It was suggested that, when this occurred, adjacent ages should be grouped together into +groups or –groups in order to avoid very small proportions in age groups. We were unable to successfully implement this change in the fall models in the time available, but were able to implement it for the spring model. The main impact on the results was an increase in estimated biomass in the early 1980s and a slight decrease in recent years. A consequence of the increased estimate of biomass in the early 1980s was an increase in the level of the LRP. This was somewhat counteracted by the slight decrease in recent estimates of biomass.

Because most of the fishery catch is taken in a relatively short period, The reviewers suggested trying models in future assessments that are more explicit about the timing of the fishery. In these models, a fraction of M would be applied before the fishery, then the catch would be removed, and finally the remainder of natural mortality would be removed. This will be examined in the future.

Because M is now estimated to be very high for older Herring, the reviewers suggested removing the natural mortality experienced before the fishery to estimate the SSB that survives and is available to the fishery. This has been done for all the models presented here.

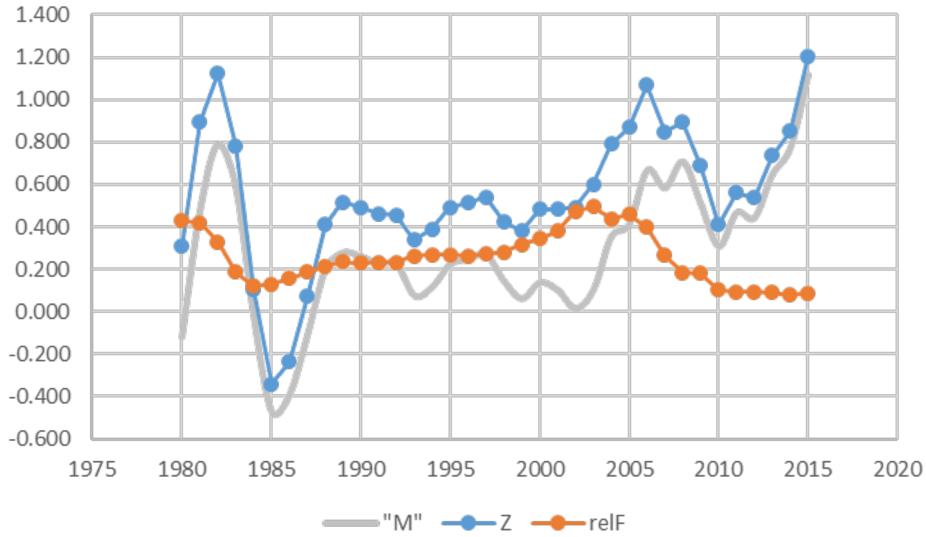

Figure E1. Estimates of the instantaneous rate of total mortality (Z) and annual fishing mortality (relF) for spring spawning Herring aged 7-11+ years, estimated in moving 5-year blocks. The grey line shows Z minus relF, a rough index of natural mortality.