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Assessment of the NAFO Division 4T southern Gulf of St. Lawrence Atlantic herring (*Clupea harengus*) in 2016 and 2017

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Foreword

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

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ABSTRACT

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

SS were assessed using a virtual population analysis (VPA) which allowed for time-varying catchability to the gillnet fishery. The model estimated that SS spawning stock biomass (SSB) has been in the critical zone of the Precautionary Approach (PA) framework since 2004. The median SSB at the start of 2018 is estimated to be approximately 12,000 t, 65% of the limit reference point (LRP = 19,250 t). The instantaneous rate of fishing mortality (F) on aged 6 to 8 year old SS herring exceeded the removal reference level (F0.1; F = 0.35) until 2012. Under various recruitment scenarios (low, mixed, or high recruitment), SSB is expected to decrease at any catch options over 500 t for the next two years. By 2027, the probability of exceeding the LRP was most favorable under the high recruitment scenarios and low catches (<1,500 t), however under the low recruitment scenarios even with no catch there was only a 13% probability of SSB exceeding the LRP.

FS were assessed as regionally-disaggregated populations using a VPA which allowed for time-varying catchability to the gillnet fishery. Estimated SSB has been declining in all three regions in recent years, though it increased in the South over the last two years. Summed over all three regions, SSB at the start of 2018 is estimated to be approximately 112,000 t with a 97% probability of being within the cautious zone of the PA framework (SSB is below the upper stock reference (USR = 172,000 t)). Averaged over all regions, F of aged 5 to 10 exceeded F0.1 (F=0.32) from 1994 to 2011, but remained below since 2012. The median projected value of SSB at the start of 2020 remained below the USR at all catch levels between 10,000 and 50,000 t, with the probability of being below the USR varying from 90% at 10,000 t to 99% at 50,000 t. The probability that F of aged 5 to 10 FS will exceed F0.1 in 2019 is estimated to increase from 0% at catches of 10,000 t to 99.6% at 50,000 t.

1. INTRODUCTION

Atlantic Herring (*Cupea harengus*) in the southern Gulf of St. Lawrence (sGSL) are found in the area extending from the north shore of the Gaspe Peninsula to the northern tip of Cape Breton Island, including the Magdalen Islands, encompassing the Northwest Atlantic Fisheries Organization (NAFO) Division 4T. Adults overwinter off the north and east coast of Cape Breton in the NAFO divisions 4T and 4Vn (Claytor 2001; Simon and Stobo 1983; Fig. 1). Studies in the early 1970s indicated that sGSL 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 in the sGSL are managed across seven herring fishing areas (HFA) in area 16 (A-G; Fig. 1a). These herring fishing areas cover the same region as NAFO Div. 4T (Fig. 1).

Atlantic Herring is a pelagic species that schools particularly during feeding, spawning periods, and annual migrations. First spawning typically occurs at age four. Eggs are attached to the sea floor and large females can produce up to 360,000 eggs (Messieh 1988).

The herring population in the sGSL consists of two spawning components, spring spawners (SS) and fall spawners (FS). 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 SS and FS herring of NAFO Div. 4T are considered distinct stocks which are assessed separately. Recent genetic studies have confirmed genetic differentiation among these stocks (Lamichhaney et al. 2017). Herring also show high spawning site fidelity (Wheeler and Winters 1984; McQuinn 1997; Brophy et al. 2006) and local stocks are targeted by the gillnet fishery which takes place on the spawning grounds. FS herring in sGSL are therefore assessed using regionally-disaggregated assessment models (North, Middle, South regions; Fig. 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 (> 19.8m). Nonetheless, some “small seiners” (<19.8m) can also participate in the inshore fishery as part of the gillnet fleet. The fixed gear fishery is focused in NAFO Div. 4T, whereas the mobile gear fishery occurs in NAFO Div. 4T and occasionally in Div. 4Vn (Fig. 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 fishery, mobile gear fleets fish along the northern boundary of NAFO region 4Tf, this is referred to as the “Edge” fishery. Both SS and FS herring are harvested in the spring and fall fisheries and must therefore be separated into the appropriate groups.

Prior to 1967, sGSL herring were mainly exploited by fixed gear and average landings during 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 for the period 1967 to 1972. Since 1981, the fixed gear fleet has accounted for most of the catch of SS and FS herring (McDermid et al. 2015).

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

The population modelling is conducted for the assessment SS and FS herring to the end of 2017 (or to Jan. 1 of 2018), with projections for Jan. 1 of 2019, 2020, and 2027.

2. DATA SOURCES

For the SS herring, a single NAFO Div. 4T model is used.

For the FS herring, a regionally-disaggregated model for three regions (North, Middle, South) that encompass the entire NAFO Div. 4T area is used. The regions are defined on the basis of traditional herring spawning beds and fishing areas (Fig. 1):

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

The choice of three regions was dictated by geographic proximity of spawning beds and is the finest level of disaggregation that can presently be supported by the available data. The regionally-disaggregated models include inputs that are region-specific (e.g., catch-at-age, catch-per-unit-effort) and inputs that are common to the entire area (e.g., acoustic survey index, size-at-age).

When calculating region-specific catches-at-age, catches made by herring seiners during the fall fishery were attributed to the region in which they were made, whereas catches made during the late spring and summer were attributed to the South region, which is most proximate to the location of capture. Catches made in NAFO Div. 4Vn during a winter fishery that took place prior to 1999 were attributed to the regional catches in proportion to those regional catches.

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 TACs are set for the sGSL SS and FS components, separately. In 2016 and 2017, the TACs were set at 2,000 t for the SS and 35,000 t for the FS, for a total of 37,000 t (Table 1; Fig. 2). Seventy-seven percent of the TAC for each spawning component was allocated to the fixed gear fleet with the remaining 23% for the mobile gear fleet (Table 1).

The preliminary estimated landings of SS herring in both the spring and fall fisheries were 966 t and 1,189 t for 2016 and 2017 respectively (Table 1; Fig. 3). The 2016 and 2017 TAC was 2,000 t. Most of the SS herring were estimated to have been landed in the fixed gear fleet over the 1981 to 2017 period. In 2016 and 2017, the fixed gear fleet was estimated to have landed 82% and 96%, respectively, of the total harvests of SS herring (Table 1; Fig. 3). More than 80% of the SS herring landed by the fixed gear fleet is landed during the spring fishing season, whereas most (> 80%) of the SS herring landed by the mobile fleet is landed in the fall season (Fig. 3).

The preliminary landings of FS in 2016 and 2017 were 24,677 t and 20,523 t respectively (Table 1; Fig. 3). The 2016 and 2017 TACs were 35,000 t. Over the 1978 to 2017 period, most

of the FS herring have been landed in the fixed gear fleet. In 2016 and 2017, the fixed gear fleet was estimated to have landed 94% and 99%, respectively, of the total harvests of FS herring (Fig. 3). The majority (nearly 100%) of the FS herring captured in the fixed gear fishery are landed during the fall fishing season. The mobile fleet has landed varying amounts of FS herring in the fall, 31% to 45% during 2016 and 2017 (Fig. 3).

During 2010 to 2017, the mean proportion of the total catch caught by fixed gear was 63% for the SS and 93% for the FS (Table 1). The majority of the 2016 and 2017 FS fixed gear catches occurred in herring fishing areas 4Th (South) and 4Tmn (North; Table 2). Meanwhile, the majority of the 2016 and 2017 fixed gear catches during the fall season occurred in herring fishing area 4Tmn (North; Fig. 1; Table 2). The mobile gear (Edge) spring season fishery landed 1,120 t and 90 t in 2016 and 2017 respectively. The fall season mobile gear catches in 2016 and 2017, 771 t and 816 t, respectively, were all from herring fishing area 4Tmn (North region; Fig. 1; Table 2).

In 2016, 48% of the SS TAC was attained compared to 59% in 2017. In 2016, 71% of the FS TAC was attained compared to 59% in 2017. Herring fishing area percentages of TAC attained are found in Table 2.

Management measures were introduced in 2010 to improve the status of SS component. These measures include:

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

2.1.1 Spawning stock assignment

Three methods are used to assign herring samples to either SS or FS 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 a 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 fixed gear catches and 75% of the total annual 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 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 FS. The GSI discriminant function reclassified at least 20% of these developing gonads as spent gonads resulting in a classification of SS. A change was made to the decision rules for the GSI method such that a “spent” gonad in June is classified as a FS.

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 of Atlantic Herring in the sGSL (details in LeBlanc and LeBlanc 1996). The sGSL was divided into eight telephone survey areas corresponding to the areas where the major fisheries occur (Fig. 1c). A subset of active commercial licence holders was asked a series of questions concerning the number, dimensions, and mesh size of nets used, the frequency of fishing, 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 an aggregated biomass index in the population model. The telephone survey responses provide information on fishing effort related to the number of nets, mesh size, and fishing frequency.

The 2016 fixed gear telephone survey contacted 194 fishermen randomly selected out of approximately 553 active commercial licence holders in both seasons combined. Thirty-five fishermen from the spring fishery and 126 fishermen from the fall fishery responded, for a total of 161 respondents. The 2017 fixed gear telephone survey contacted 170 fishermen randomly selected out of approximately 513 active commercial licence holders in both seasons combined. Thirty-nine fishermen from the spring fishery and 100 fishermen from the fall fishery responded, for a total of 139 respondents. The distribution of respondents across the eight telephone survey areas in terms of mean net hauls, net lengths, and trend in the abundance from the previous year are summarized in Table 3. Overall, fishermen felt that abundances in the 2017 spring fishery season were similar to those of 2016 and to those in the previous assessment. For the fall fishery, there was a sense that the 2017 abundance in the North and Middle regions had declined slightly when compared to 2016 and the previous assessment whereas the abundance of herring in the South region had continued to decline since 2015 (Table 3).

The gillnet fishery data used for the abundance index were those with the greatest number of records in a given year (Table 3). In the spring fishery, mesh sizes of gillnets have been relatively constant at 2½”. In the fall fishery, 2⅝” mesh is the most common; however in 1992 many fishers started using bigger mesh sizes (2¾”). By 2002, the proportion of 2⅝” mesh reverted to pre-1992 numbers. The proportion of 2⅝” mesh in 2016 and 2017 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 (SS or FS) 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 in the southern Gulf has been conducted. The standard annual survey area occurs in the NAFO 4Tmno areas where sGSL herring aggregate in the fall. In some years, the acoustic survey also covered waters north of P.E.I. The survey uses a random stratified design of parallel transects within predefined strata. Surveys are conducted at night with two vessels: an acoustic vessel to quantify the biomass of fish schools using a hull-mounted 120 KHz single beam transducer, and a fishing vessel to sample aggregates of fish with a pelagic trawl (LeBlanc and Dale 1996; LeBlanc et al. 2015). The acoustic survey covered a total transect distance of 702 km in 2016 and 885 km in 2017 within the NAFO 4Tmno areas (Appendix Figure B1). Appendix Figure B1 shows the distribution of estimated herring schools during the 2015 to 2017 survey. Biological samples are used to separate the observed biomass into spawning components and ages, determine species composition, and size distribution for the estimation of the target strength (LeBlanc and Dale 1996; LeBlanc et al. 2015).

The 2015, 2016, and 2017 acoustic biomass indices of the NAFO 4Tmno areas for SS and FS herring combined were 157,373 t, 63,493 t, and 69,023 t, respectively. The biomass was composed of 19% SS and 81% FS on average over the three years. A complete summary of the acoustic survey results is available in Appendix B.

2.5 EXPERIMENTAL NETS

In this industry partnership project between DFO and the provincial fishery associations, experimental gillnets, consisting of multiple panels of varying mesh size, were deployed approximately weekly by fixed gear fishermen during the fall herring fishery. These modified gillnets catch a wider range of fish sizes than the commercial gear and provide information on the relative selectivity of various mesh sizes. Catches from the experimental nets project have been used to estimate the relative size-selectivity of gillnets of different mesh sizes and to produce age-disaggregated abundance indices (Surette et al. 2016a). Both are inputs to the FS assessment model.

Each experimental gillnet had five panels of different mesh sizes, 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 fishery fishing on the Miscou Bank (North region; 16B), Gaspé (North; 16B), Escuminac (Middle; 16C), West PEI (Middle; 16E), Fisherman’s Bank (South; 16G), and Pictou (South; 16F) spawning grounds participated in the study (Fig. 1a). The target fishing procedure was a one hour soak and nets were set during the commercial fishery activities on the fishing grounds. Data from Pictou prior to 2015 were corrected for gillnet depth as nets in this region were 5 m (17 feet) deep compared with the standard 2.4 m (8 feet) used on other spawning grounds. A correction factor of 8/17 (in feet) was applied to the Pictou nets to address the difference in net depth size.

2.6 SPAWNING GROUND ACOUSTIC SURVEYS

In 2015, a spawning ground acoustic survey project was initiated that follows the design of the fishery-independent acoustic survey (Section 2.4). 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 the provincial fishery associations. Surveys are conducted by fishermen according to protocols developed by DFO. The survey is conducted at night during the fall fishery weekend fishery closures except in herring fishing areas 16C and 16E (Middle; Fig. 1a). The Middle region does

not have weekend closures, therefore the survey can only be conducted pre- and post-season. The spawning ground acoustic survey is intended 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 pilot project has not been incorporated into the assessment models. The results of the first three years of data are summarized in Appendix C. The results highlight the importance of following protocol and weekly surveys in assessing local relative abundances. While the results are not used in this assessment, the goal is to include these results in later assessments when annual and consistent data are 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 NAFO 4T herring throughout the sGSL in September (Hurlbut and Clay 1990; Savoie 2014). Total catch weights and numbers, a representative length frequency, and representative individual length-weight data have 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 spawner group and age. 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 Chaleur Bay (Appendix Figure D1). The number and weight of the 19 to 26 cm length group of herring per tow decreased in 2016 with a slight increase in 2017. This size-class represents the herring not recruited to the fishery and of ages 2 to 3 (Appendix Figure D2). The numbers and weights of herring large enough to be captured in the fall fishery (> 26 cm) decreased from 2016 to 2017.

3. INPUTS AND INDICES

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

Catch-at-age and weight-at-age matrices for sGSL herring SS and FS components are derived for each of the fixed and mobile gear fleet catches. 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 weight-at-age by spawning component are presented for the fixed gear (for SS, Tables 4 and 5; for FS Tables 6 and 7) and the mobile gear (for SS, Tables 8 and 9; for FS, Tables 10 and 11) fishery catches. Region-specific catch-at-age and weight-at-age are reported for the fall spawner fixed gear catches (Tables 6 and 7).

The dominant age in the 2016 SS catch was age 7, belonging to the 2009 year-class. In 2017 it was age 5, belonging to the 2012 year-class (Tables 4 and 8; Fig. 4). For FS, the dominant age in 2016 and 2017 was 6 and 7 years, respectively (Tables 6 and 10; Fig. 5), thus the 2010 year-class.

Beginning of year weights-at-age are calculated from the weights-at-age for fixed and mobile gears combined. It is calculated from the average of the weight-at-age and the weight-at-age for the following age-class. The 2017 beginning of year weights-at-age were averaged from the 2014 to 2017 commercial weights adjusted to the beginning of the year. Mean weights-at-age of the SS caught in the mobile and fixed gears in the spring season have declined since the 1990s for mobile gear, and since the mid-1980s for the fixed gear (Tables 5 and 8; Fig. 6). Mean

weights-at-age of FS herring from fixed and mobile gears have declined almost continuously over the time period 1978 to present (Tables 7 and 11; Fig. 6). Lower mean weights are an indication of the status of the stock (fish are becoming smaller at age) and affect the stock biomass estimate when numbers are converted to weight.

3.2 CATCH-PER-UNIT EFFORT

The fixed gear fisheries occur on the spawning grounds and landings from this fishery account for approximately 60% of the SS and more than 90% of the FS catch. Fixed gear catch and effort data were used to construct age-disaggregated abundance indices for SS and FS NAFO 4T herring, based on catch-per-unit-effort (CPUE). The fixed gear CPUE indices are defined as catches in kg/net-haul/day (or kg/net-haul/trip). Age-specific CPUE indices for ages 4 to 10 are used in the assessments for the stock.

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 fishery data on the number of nets set are available since 1978 and the number of hauls since 1986. Fall fishery catch and effort DMP records are available since 1990. Nets are standardized to a length of 14 fathoms (25.6 m).

The percent of fixed gear fishing days with no catch has been recorded since 2006 based on responses during the telephone survey (Table 12). The percentage of days with no catch in the spring fishery of 2017 is slightly higher than average, while the percentage of days in the fall is among the highest in the time series. Since this information is available only for the most recent period, it is not presently included in the calculation of fishing effort.

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

$$\ln(CPUE_{ijk}) = \alpha + \beta_1 I + \beta_2 J + \beta_3 K + \epsilon \quad (1)$$

where i (I) indexes year, j (J) indexes telephone survey area , k (K) indexes week, α is the intercept, β is the slope, and ϵ is the residual error. For the SS, the model was applied to the data for the whole stock area. For the FS, GLMs were run by region (North, Middle, and South) and did not include the area term. The SS analysis was limited to weeks 9 to 22 whereas the FS analysis was restricted to weeks 27 to 43.

The models explained over 40% of the variance in the data and the factors for year, week, and area were statistically significant (Table 13). Age-specific CPUE indices for ages 4 to 10 are used in the assessments for the SS and FS components. The age-specific abundance indices for ages 4 to 10 were derived by dividing the gillnet catch-at-age by the standardized effort (CPUE) from the multiplicative GLM model. The CPUE age-specific abundance indices include the years 1986 to 2017. The indices presented in Tables 14 and 15 and Figures 7 and 8 account only for catch and effort, and do not account for possible changes in selectivity / catchability, which are addressed as part of the population modelling. The CPUE index for SS and FS shows internal consistency as the abundance of cohorts is correlated between years (Figs. 7 and 8). The overall SS CPUE was higher in 2017 than in 2016 (Table 14). The CPUE of SS increased in 2017 across all ages except age 10 (Table 14; Fig. 7). The CPUE of FS declined in 2017 for both the North and Middle regions but increased in the South from the low

levels observed in 2016 (Table 15; Fig. 8). Across regions, the CPUE of FS younger fish (ages 4 and 5) has remained low since 2009 (Fig. 8).

Fixed gear catches of SS in 2016 and 2017 were composed mostly of ages 6 to 8 (Table 4; Fig. 4). In the North and Middle regions, catches of FS in 2016 were dominated by ages 6 and 7 and in 2017 by ages 7 and 8 (2009 and 2010 year-classes). In the South region, catches of FS in 2016 and 2017 were dominated by ages 7 and 8 respectively (2009 year-class; Table 6; Fig. 5).

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 have been surveyed yearly since 1994. The age-disaggregated acoustic abundance indices for ages 2 to 10 for SS and FS are presented in Table 16.

The SS assessment model uses the age-disaggregated abundances for ages 4 to 8 (Table 16). The acoustic survey estimated that catch rates (in numbers) of SS of ages 4 to 8 were greater in 2015 and 2017 than in 2014 and 2016, however all values were consistent with the low abundances estimated since the early 2000s (Fig. 7). The acoustic survey catches of the SS in 2015, 2016, and 2017 were dominated by the 2013 year-class (ages 2, 3, and 4, respectively). In 2015, the abundance of age 2 (2013 year-class) also dominated the SS abundance (Table 16; Fig. 7).

For the FS assessment model, the acoustic survey provides a useful 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 in areas throughout the sGSL spawning. The 2012 year-class dominated the FS abundances in 2015, 2016, and 2017 (ages 3, 4, and 5 respectively; Table 16). The acoustic abundance of age 2 and 3 FS in 2015 was over six times greater than in 2016 and 2017. The abundances in 2016 and 2017 returned to the lower levels of the time series (Table 16; Fig. 9).

3.4 EXPERIMENTAL NET INDICES

3.4.1 Catch-at-age of experimental nets

Region-specific age-disaggregated abundance indices are generated for the FS assessment from standardized experimental net data (Table 17). This index includes catch-at-age based on a one hour soak time. The experimental net index suggests an increase in young herring (ages 2 to 4) until 2009, after which the numbers decline. No major trend was observed in older herring over the time series (Table 17; Fig. 10). The index shows an increased abundance of herring in the North, no strong trend in the Middle region, and an overall decline in the South region, particularly at younger ages (Fig. 10).

3.4.2 Relative selectivity index

A relative selectivity index was developed to correct 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. Annual age-length keys were first derived from age samples collected from the commercial gillnet fishery from 1986 to 2017 and the experimental gillnet study from 2002 to 2017 during the months of August to October. Annual catch-at-length estimates for the commercial gillnet fishery from 1986 to 2017 were then calculated using length frequency samples gathered over the same months. The age-length keys and catch-at-length estimates were combined to yield catch-at-lengths by age and year. At this point, two selectivity-

at-length curves, estimated from the gillnet selectivity study and assumed constant over time, were applied to these catch-at-lengths, one corresponding to the 2⅝" mesh size and the other to the 2¾" mesh size. Summing over lengths yields annual catch-at-age estimates for the commercial fishery by mesh size. The ratio of the mesh size adjusted catch-at-ages to the fishery catch-at-age yields selectivity-at-age proportions by mesh size and year. These selectivity-at-age proportions (Table 18; Fig. 11) were then applied to catch-at-age CPUEs for the 2⅝" and 2¾" mesh sizes. A weighted sum of these two CPUEs using the proportion of fishery catches from each of the two mesh sizes yielded an adjusted CPUE catch-at-age for the fall fishery.

3.5 MULTISPECIES BOTTOM TRAWL INDEX

Catches of herring in the multispecies bottom-trawl survey can be quite variable, even within areas where herring are common (e.g., see Savoie 2014). This index consisted of an age-disaggregated index using data from 1994 to 2017 for the FS only (Table 19; Fig. 12). Catch-at-age (mean number per standardized tow) of FS herring in the multispecies trawl survey was estimated using a Bayesian estimation model (Surette et al. 2016b). The index suggests an increasing trend in four year old FS herring from the mid-1990s to 2011, and generally higher abundance of six year old FS herring in the 2000s compared to the 1990s (Fig. 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

The assessment of SS uses a virtual population analysis (VPA) fit to two indices of abundance at age; fishery catch rates at ages 4 to 10 years (the CPUE index), and abundance indices at ages 4 to 8 years based on a fall acoustic survey. Prior to the 2016 assessment (which used data to the end of 2015), the fit of the VPA model to the CPUE index was poor, with severe residual patterns between the observed indices and the model predictions. The model also displayed a strong "retrospective pattern", with estimates of spawning stock biomass (SSB) in a given year progressively declining as additional years of data were added to the analysis. These results suggested that the model failed to incorporate one or more non-stationary processes in the population dynamics of this stock or in the observation model relating indices of abundance to population abundance. The 2016 assessment examined two possible non-stationarity factors: time-varying natural mortality (*M)* and time-varying catchability (*q*) to the fixed gear fishery (and thus to the CPUE index). Allowing *q* to vary over time resolved these problems but time-varying *M* did not (Swain 2016a). Fishery dependent indices are an important component of the assessment. 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 elevated 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.

This assessment uses the same model as the 2016 assessment, with catchability to the spring-spawning herring fishery allowed to vary over time.

4.1 SPRING SPAWNER MODEL

The SS component is assessed using a virtual population analysis (VPA) model implemented using AD Model Builder (Fournier et al. 2011). The SS model incorporated ages 2 to 11+ (i.e.,

11 years and older) and began in 1978. Abundance of the plus group (11+) was estimated using the F-ratio method (Gavaris 1999). M was assumed to be constant at 0.2 for all years and ages. Data inputs to the model included:

- fishery catches at ages 2 to 11+ (in numbers) (Tables 4 and 8),
- catch-per-unit-effort (CPUE) index from 1990 to 2017 (ages 4 to 10 years) (Table 14),
- fishery-independent acoustic survey index from 1994-2017 (ages 4 to 8) (Table 16).

Model parameters included abundance at ages 5 to 11+ at the beginning of 2018, q at age to the fishery (i.e., the CPUE index, ages 4-10) and to the acoustic survey (ages 4-8), and the standard deviation (SD) of observation error at age for each of the indices. All parameters were estimated on the log scale.

The model allowed for process error in fully-recruited catchability (q) to the fixed gear fishery. Catchability to the fishery was estimated for 1990 to 2017 (the years with CPUE data) and was modelled as selectivity at age times fully recruited q (Swain 2016a). Selectivity was modelled as a logistic function of age for ages 4 to 9, but was freely estimated for age 10 to allow for dome-shaped selectivity at age. Fully-recruited q was freely estimated for 1990 and then allowed to vary over time following a random walk:

$$q_{1990} = q_{init} \text{ and } q_t = q_{t-1} e^{qdev_t} \text{ where t > 1990.} \quad (2)$$

The q deviations were assumed to be normally distributed with a mean of 0 and a standard deviation of 0.1. The objective function for the model included a term penalizing departures of the q deviations from 0.

Model estimates and their uncertainty were evaluated based on MCMC sampling, with every 500th of 2,500,000 samples saved. Because the youngest age in the abundance indices is age 4, it is not possible for this model to obtain direct estimates of abundance at ages 2 to 4 at the beginning of 2018, ages 2 to 3 at the beginning of 2017, and age 2 at the beginning of 2016. These were obtained using the estimated average recruitment rate in the most recent five years and the estimated SSB producing a particular cohort. For example, the abundance at age 4 at the start of 2018 was obtained based on the average recruitment rate to age 4 for the 2009 to 2013 cohorts and SSB in 2012. Prior to the 2016 assessment, this was done outside of the model. In this assessment, this was incorporated within the model, thus accounting for additional uncertainty. However, these estimates still do not account for the uncertainty associated with the assumption the recruitment rates for these terminal cohorts equal the average rates for the preceding five cohorts.

4.2 SPRING SPAWNER RESULTS

Residual patterns were similar to those observed for the corresponding model in the 2016 assessment and indicated an acceptable fit of the model to the age-disaggregated CPUE (Fig. 13). The fit to the CPUE index remained far superior compared to the 2016 model assuming no non-stationarity in M and q and to the model allowing time-varying M (see Fig. 4 in Swain 2016a). The fit to the acoustic index also remained similar to that of the 2016 model, though blocking of negative and positive residuals is now slightly more pronounced for this index. Fits to the age-aggregated indices lead to the same conclusions (Fig. 14). The retrospective pattern of this model also remains acceptable, with no progressive changes in past estimates in a consistent direction as additional data are added to the model (Fig. 15).

The limit reference point (LRP) for NAFO Div. 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 four lowest spawning stock biomass (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 2016 there was a slight change in biomass in the 1980s. Thus the LRP was re-calculated. The revised LRP is 19,250 t, slightly lower than the former value of 22,000 t.

Catchability to the fishery and to the CPUE index averaged about 0.006 in the 1990s, increasing to a peak of approximately 0.032 from 2007 to 2017 (Fig. 16). Estimated catchability increased as the stock declined below 60,000 t of spawner biomass (Fig. 17). Recent estimates (2008-2016) of spawning stock biomass (SSB) were slightly lower than those estimated in the 2016 assessment (Fig. 18; Table 20). The Monte Carlo Markov Chain (MCMC) estimates of SSB at the beginning of 2017 and 2018 were 11,744 t (95% confidence interval: 6,463 – 28,171) and 12,446 t (95% CI: 6,418 – 30,365), respectively. The estimate for 2018 is 65% of the LRP. The probabilities that the projected SSB was above the LRP at the start of 2017 and 2018 were <11% and 15%, respectively.

Recruitment rates (the number of recruits divided by the SSB that produced them) were unusually high in the early 1980s (Fig. 19). This may reflect compensatory increases in recruitment success at low SSB and/or other ecosystem changes promoting good recruitment (e.g., reduced predation on larvae by other collapsed pelagic fishes; Swain and Sinclair 2000). Recruitment rates have been much lower since then, though periods of moderately high recruitment rates occurred in the late 1980s and early 1990s and between 2005 and 2011. Recruitment rates were slightly lower in 2012 but appear high in 2013 though the confidence intervals are very high for that year. Recruitment rates during the recent period of low abundance are considerably lower than in the earlier low-abundance period. This may reflect effects of climate change (Melvin et al. 2009) or other ecosystem changes.

Estimated abundances of age 4 herring at the start of 2017 and 2018 were higher than those since 2005 (Fig. 20; Table 21), however the confidence intervals in 2017 are quite large. The age 4 abundance in 2018 depends on the assumption that recruitment rate for this cohort is the average of the rate for the preceding five cohorts. Recruitment rates and uncertainty vary among these five cohorts (Fig. 20). The error bar for 2018 in Figure 20 does not take into account the uncertainty in the recruitment rate for this cohort as it depends on the assumption that its recruitment rate was the average of the five preceding cohorts. If the recruitment rate of the 2013 cohort was instead low, like that of the previous cohorts, age-4 abundance in 2018 would resemble the low 2016 value.

The most recent estimate of spawner (4+) abundance is for 2017, since the 2018 value depends on the recruitment rate assumed for the 2013 cohort. The maximum likelihood estimate (MLE) for 2017 is 82.9 million (Table 21), and the MCMC median is 80.2 million herring (95% CI: 42.3 – 206.5), about 20% of the average spawner abundance in 1985 to 1995.

Estimated exploitation rates were very high in 1980 and in most years from 2000 to 2011 (Fig. 21; F values in Table 22). Estimated exploitation rates exceeded the reference level (F0.1 = 0.35) in most years from 1988 to 2011 (Fig. 21). The estimated exploitation rate declined below F0.1 in 2012 to a low value of 0.19 and has since remained below F0.1 in subsequent years with the exception of 2013 (Table 22). Exploitation rates in 2015 to 2017 averaged 0.24.

The SS population trajectory with respect to spawning stock biomass and fishing mortality levels is shown in Figure 22. The stock has been in the critical zone (SSB < LRP = 19,250 t) since 2004 and experienced fishing mortalities above the F0.1 level until 2012. F has been below F0.1 since 2014.

4.3 SPRING SPAWNER PROJECTIONS

The population model was projected forward for the two years to the start of 2020 and 10 years forward to the start of 2027 during the MCMC sampling of the joint posterior distribution of the parameters. This takes into account uncertainties in the parameter estimates. Projections were conducted at several levels of annual catch (0 to 3,000 t in increments of 500 t).

No model estimates are available for abundances at ages 2 to 4 in 2018. These are generally estimated in the projection using recruitment rates at ages 2 to 4 and estimates of the SSB producing each cohort. Projection results depend strongly on what recruitment rates are realized in the projection years. SS are the first recruited to the fishery at age 4, an age with very low catchability to the fishery. The estimates of age 4 recruits for the 2012 and 2013 year-classes are preliminary, as the 2013 cohort has only been observed once (at age 4) and the 2012 cohort has been observed twice (at ages 4 and 5). Consequently, the cohort strength is highly uncertain for the 2013 cohort and only slightly less uncertain for the 2012 cohort. With additional years of observation, the strength of these year-classes will become less uncertain and may be revised. For example, in the 2016 assessment, the 2010 and 2011 cohorts were estimated to be very weak (i.e., produced by low recruitment rates), but with two additional years of data the recruitment rates that produced these cohorts appear to have been relatively strong.

Due to variable recruitment in recent years, projections were conducted under three different scenarios about recruitment during the projection period: (1) high recruitment, (2) low recruitment, and (3) mixed recruitment. The recruitment in the projections differs from the contemporary model as it does not use the highly uncertain estimate of the 2013 year-class recruitment. Recruitment rates were estimated to be relatively high for the 2006 to 2013 year-classes. For the high recruitment rate scenario, the recruitment rate in each iteration of each year was randomly selected from those estimated for the 2007 to 2012 cohorts. The current period of high recruitment was preceded by a period of very weak recruitment rates from 1992 to 2005. It is possible that recruitment rates will decline back to this lower level during the projection period. Therefore, for the low recruitment rate scenario, recruitment rates were randomly selected from those estimated for the 1999 to 2005 cohorts. The mixed recruitment scenario contains a mixture of high and low recruitments rates. In this scenario, recruitment rates were randomly selected from those estimated for the 1999 to 2012 cohorts. This random selection was repeated in each of the 2,500,000 MCMC iterations. This procedure was also used to obtain estimates of age-2 abundance at the start of 2019 and 2020. For each iteration and each year, vectors of beginning of year weights at age in the population and weights at age in the fishery catch were randomly selected from the last five years (2013 to 2017).

Projections of SSB and ages 6 to 8 fully recruited F are shown in Figures 23 and 24, and the probabilities of meeting various objectives are given in Table 23 for each catch level.

4.3.1 Short term projections

Uncertainty in the projections was high and results depended on the assumed recruitment regime (Fig. 23 and 24). In both 2018 and 2019, SSB was expected to increase slightly at annual catches of 0 and 500 t assuming high recruitment, remain stable (0 t) or decline (500 t) assuming low recruitment, and increase (0 t) or decline (500 t) assuming mixed recruitment. At an annual catch of 1,500 t, SSB was expected to decline in all cases except in 2019 with high recruitment rates (when SSB remained roughly stable). At catches over 1,500 t, SSB was expected to decline in all cases.

The probability of an increase in SSB between the beginning of 2019 and the beginning of 2020 decreased from 80% at 0 t of catch to 49% at 1,000 t of catch and 10% at 2,500 t of catch under

the high recruitment scenario. At the mixed and low recruitment scenarios, the probability of the SSB increasing was 58% and 39% respectively at 0 t (Table 23). For the short term projections, all catch levels (including no catch) and recruitment rates resulted in little probability that SSB would exceed the LRP at the start of 2020 (20% at high recruitment and 0 t of catch, 8% at 2,500 t; at low recruitment 6% at 0 t, 2% at 2,500 t). In the short term there is no chance that the population would be at or above the Upper Stock Reference (USR) in 2020 even with no catch regardless of the recruitment scenario. Over the short term, the probability that age 6 to 8 fully recruited F would be greater than the removal rate reference level of F0.1 = 0.35 was small at 1,000 t of catch (0%), increasing to 9% at 1,500 t of catch with low recruitment, and 57% at 2,500 t of catch with low recruitment. Since 2009, the TAC has been set to 2,000 t annually. At 2,000 t, the probability of an increase in SSB ranges from 0% (low recruitment) to 19% (high recruitment). Furthermore, at 2,000 t there is at most a 9% probability that SSB will exceed the LRP at the start of 2020.

4.3.2 Long term projections

By 2027, the probability of exceeding the LRP was most favorable under the high recruitment scenario and low catches (<1,500 t), however at the low recruitment scenarios even with no catch there was only a 13% probability of SSB exceeding the LRP (Table 23). With no catch, the probability that SSB will exceed the USR in 2027 is 11% in the high recruitment scenario, 0% in the low recruitment scenario, and 2% in the mixed scenario. At 2,000 t, the probability of SSB exceeding the LRP by 2027 ranges from 2% (low recruitment scenario) to 38% (high recruitment scenario). Furthermore at 2,000 t there is at most a 4% chance of reaching the USR by 2027.

5. FALL SPAWNER COMPONENT ASSESSMENT

5.1 FALL SPAWNER MODEL

The FS component is assessed using a VPA model implemented using AD Model Builder (Fournier et al. 2011). The FS model incorporated ages 2 to 11+ (i.e., 11 years and older) and began in 1978. Abundance of the plus group (11+) was estimated using the F-ratio method (Gavaris 1999). *M* was assumed to be constant at 0.2 for all years and ages. Data inputs to the model included:

- fishery catches by region at ages 2 to 11+ (in numbers) (Table 6 and 10),
- catch-per-unit-effort (CPUE) index by region from 1986 to 2017 (4 to 10 years) (Table 15),
- fishery-independent acoustic survey index across the sGSL from 1994 to 2017 (ages 2 and 3) (Table 16),
- catch rates at age in experimental nets by region from 2002 to 2017 (ages 3 to 9 or 10) (Table 17),
- the proportion of gillnets with 2⅝ inch mesh (Fig. 11) and the relative selectivity to the gillnet fishery by age, year and mesh size in each region (Table 18), and
- multispecies bottom trawl survey index (RV index) across the sGSL from 1994 to 2017 (ages 4 to 6) (Table 19).

Model parameters included abundance at ages 5 to 11+ at the beginning of 2018, *q* at age to the fishery (i.e., the CPUE index, ages 4 to 10) and each of the indices, and the standard deviation (SD) of observation error at age for each of the indices. All parameters were estimated on the log scale.

Catchability to the fixed gear fishery was modelled as described in Swain (2016a, b). It was modelled as selectivity at age times fully recruited *q*. Fully-recruited *q* was freely estimated for 1990 and then allowed to vary over time following a random walk. The *q* deviations were assumed to be normally distributed with a mean of 0 and a standard deviation of 0.1. The objective function included a term penalizing departures of the *q* deviations from 0. Catchability and selectivity-at-age were estimated separately for each region.

Model estimates and their uncertainty were evaluated based on MCMC sampling, with every 500th of 2,501,000 samples saved. Indices for age 3 herring were available for each region in the final year (2017). This permitted estimation of the abundances of all mature ages (4+) at the beginning of 2018. Thus, an estimate of SSB for each region in 2018 can be obtained without using an assumed recruitment rate to estimate age 4 abundance in 2018. However, the age 4 abundance estimates for 2018 are based on single observations (the age-3 experimental net index for each regions), and uncertainty may remain high for these estimates. This is incorporated within the models, thus accounting for this uncertainty.

5.2 FALL SPAWNER RESULTS

Similar to the results of the previous assessments, residual patterns for the CPUE indices were not severe (Fig. 25), indicating an adequate fit to these indices. Nevertheless, there was a tendency to overestimate abundance at ages 8+ in the Middle region in the late1980s and early 1990s and to overestimate abundances at ages 4 and 5 in all regions in most years since 2010.Still the time varying catchability model provides an improvement compared to earlier models that assume constant catchability. Analysis of constant catchability models produced evidence of severe blocking of residuals, with negative residuals for nearly all age-year cells prior to 1995 and positive in most cells since 2005 (Swain, 2016b).

Residual patterns for the experimental net indices were similar to those for these indices in the 2016 assessment (Fig. 26). There was a block of negative residuals in 2003 to 2005 and positive residuals in 2008 and 2010 in the North region. As in 2015, a number of year effects were evident (e.g., 2004 in the North region, 2007 in the Middle region, and 2010 in the South region). Year effects were also evident in the RV and acoustic indices (Figs. 25 and 26). We were unable to use the experimental net data for the Middle region in 2017 as only a single net was set.

The limit reference point (LRP) for FS 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 four lowest spawning stock biomass (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 2014 there was a slight change in biomass in the 1980s. Thus the LRP was re-calculated. The revised LRP is 58,000 t, slightly greater than the former value of 51,000 t.

Fits to the age-aggregated CPUE indices were reasonably good, with predicted values consistent with the general trends in the indices (Fig. 27). Fits were also generally acceptable for the age-aggregated experimental net indices (Fig. 28). These indices were quite noisy particularly in the Middle region. In the South, the predicted values failed to capture an apparent increasing trend in the most recent years. Trends were minor for these short indices. The fit to the age-aggregated RV index and acoustic juvenile index were reasonable (Figs. 27 and 28) however predicted values tended to underestimate observed values in high biomass years (e.g., 2015 in the acoustic index (Fig. 27) or 2012 in the RV index (Fig. 28).

Similar to the 2016 model, retrospective patterns for the Middle and South regions were negligible (Fig. 29). The retrospective pattern was greatest in the North region, though not in a

consistent direction. Initially, the estimates for 2009 and 2010 decreased as data for 2011 to 2015 were added to the North model. Estimates for 2012 to 2014 tended to increase as data for 2012 to 2015 were added. Finally, the addition of data for 2016 and 2017 resulted in large declines in the estimates of SSB for 2009 to 2016. The changes in the estimates in the North with the addition of the 2016 and 2017 data have resulted in a substantial revision in the perceived status of this stock in the recent period (since about 2010). The addition of the most recent years of data resulted in the assessments from previous years being overly optimistic. As the North contains the largest biomass, this change means that the advice based on the total SSB for the sGSL has also been overly optimistic.

Estimated changes in fully-recruited catchability to the gillnet fishery differed between regions (Fig. 30). Catchability was lowest and varied little over time in the North region. Catchability in the South region increased over time, primarily between 1995 and 2010. In this region, q since 2010 has been 3.5 times greater than q prior to 1995 but has started to decrease in recent years. Estimated catchability was greatest in the Middle region until the late 2000s when it was surpassed by catchability in the South region. In the Middle region, fully-recruited q was at its lowest around 1990, and then increased to a level about three times as high by late-2010s. Estimates of catchability at age are shown in Figure 31 for the fishery (i.e., the CPUE index) and Figure 32 for the experimental nets. Catchability to the experimental nets was highest in the Middle region and lowest in the North region. Catchability in the South was similar to the North at young ages and slightly greater than the North at older ages. The patterns in relative catchability between regions for the experimental nets resemble those for the gillnet fishery in 1986 (e.g., q relatively low in the South) and contrast those for the gillnet fishery in 2014 (e.g., q relatively high in the South) (Fig. 32). There is a tendency for catchability to decline with an increase in population biomass among these three regions, but most of the variation in q within the Middle and South regions is independent of stock biomass (Fig. 33). This suggests that much of the increase in q in these two regions is related to technological improvements and improved fishing tactics rather than density-dependent effects. The similarities in patterns in q-at-age between the experimental nets and the CPUE index in 1986 but not in 2014 (Fig. 32) is consistent with this suggestion.

Estimated SSB in the North region was at a high level from the mid-1980s to the early 1990s, and declined to a moderate level from the mid-1990s to the late 2000s (Fig. 34; Tables 24 and 25). Estimated SSB in this region declined continuously from 2012 to 2017, with the median estimate reaching its lowest levels since the early-1980s. In the Middle region, estimated SSB increased gradually from 1980 to the late 2000s, but has declined consistently from 2009 to 2017 to reach the lowest level since 1980 (Fig. 34; Tables 26 and 27). SSB in the South region was at a relatively high level from about the mid-1980s to the late 2000s. However, estimated SSB declined from 2009 to 2015. In 2016, SSB began to increase in the South region, however, uncertainty in this region is very high (Fig. 34; Tables 28 and 29). This may be because there is less extensive and less reliable information from Fisherman's Bank as they did not participate in the experimental net project and there is a high frequency in nil fishery catches from this area in recent years. Nil catches are not incorporated in the CPUE index. Thus, estimates of SSB in the South region may be biased high for recent years. Summed over the three regions, the MLE at the start of 2018 is 112,268 t (Table 30; 567.8 million herring, Table 31) and the MCMC median is 111,832 t (95% CI: 79,044 – 182,064). The estimated probabilities that the SSB is in the cautious zone (SSB was below the USR of 172,000 t) at the beginning of 2017 and 2018 are 98% and 97%, respectively (Fig. 35).

Estimated abundance of FS age 4 and older has declined in the North and Middle regions since 2013 and 2009 respectively (Fig. 36). To a large extent, this reflects drastic reductions in the recruitment of age 4 herring. In the South region, this abundance declined from 2004 to 2015

but has increased recently, however, uncertainty in the estimates for this region have been very high since 2016 (Fig. 36). In all three regions, estimated abundances of age 4 herring in the last four years (2015 to 2018) are among the lowest observed, comparable or lower than the low levels estimated for the late 1970s. The estimates for the start of 2018 are highly uncertain for the North and South regions. The 2018 estimates are based on single observations (age 3 catch rates in the experimental nets in 2017).

The three most recent estimates of recruitment rate (recruit abundance divided by the SSB producing them) were among the lowest observed in the North and Middle regions (the 2012 to 2014 cohorts in Figure 37). The estimates for these three cohorts were average in the South region, though these estimates were extremely uncertain (Fig. 37). Summed over all three regions, total recruitment rates for the 2012 to 2014 cohorts were among the lowest observed. In the previous assessment (Swain 2016a), the 2010 and 2011 cohorts were reported to be among the lowest observed. Nevertheless, in this assessment the values for the 2010 and 2011 cohorts are higher. This suggests that the most recent estimates of recruitment rate may be biased low.

Estimated fishing mortality for ages 5 to 10 (F5-10) declined in the North region since 2008, but in the Middle and South regions F5-10 remained relatively high and consistent until 2017 (Fig. 38). In the North region, F5-10 averaged 0.54 from 1995 to 2008, declining to an average of 0.20 for the period 2013 to 2017 (Table 32). In the Middle region, estimated F5-10 averaged 0.40 from 1995 to 2016, however, in 2017 F5-10 increased drastically to 0.95 (Table 33). In the South estimated F5-10 averaged 0.36 from 1996 to 2015 but then declined to an F5-10 of 0.10 (Table 34). The weighted average F5-10 over all three regions (weighted by regional abundance of 5 to 10 year olds) exceeded F0.1 (the reference level in the healthy zone above the USR) from 1994 to 2011 except in 2004 (Fig. 38, Table 35). It then declined to a level just below F0.1. Based on the population model, the probability that F5-10 exceeded F0.1 was 1.7% in 2016 and 20% in 2017.

The FS population trajectory with respect to spawning stock biomass and fishing mortality levels is shown in Figure 39. The stock was in the healthy zone (SSB > USR) in most years from 1984 to 2012 but has declined into the cautious zone (LRP < SSB < USR) since 2015. The fishing mortality rate exceeded the reference level in 18 of the 30 years in the 1984 to 2012 period.

5.3 FALL SPAWNER PROJECTIONS

The population model was projected forward to the start of 2020 during the MCMC sampling of the joint posterior distribution of the parameters. This takes into account uncertainties in the parameter estimates. Projection results depend strongly on what recruitment rates are realized in the projection years. No model estimates are available for abundances at age 2 in 2017 and ages 2 and 3 in 2018. When there is no direct information on the strength of cohorts appearing in projections, their strength is estimated based on the recruitment rates estimated for recent cohorts. This assumes that recruitment in the near future will be similar to that in the recent past. However, in our case, it appears that the most recent estimates of recruitment rate are biased low and would result in overly pessimistic projections. On the other hand, if we base recruitment in the projection on recruitment observed relatively far in the past, it becomes more likely that the stock was in different recruitment regimes. An intermediate recruitment regime was used in projections based on 2008 to 2012 cohorts, which have been observed five to nine times in the observed data. Recruitment rates were randomly selected from the 2008 to 2012 cohorts. This random selection was repeated in each of the 200,000 MCMC iterations. For each iteration, vectors of beginning of year weight-at-age in each region, weight-at-age in the fishery catch for each region, and partial recruitment at age to the fishery in each region were randomly

selected from the last five years. Projections were conducted at annual catch levels from 10,000 to 50,000 t in increments of 2,000 t.

Summed over all three regions, the median value of SSB at the start of 2020 was below the USR at all annual catch levels between 10,000 and 50,000 t (Figs. 40 and 41; Table 36). The probability that SSB would be below the USR at the start of 2020 increased from 90% at a catch of 10,000 t, to 99% at a catch of 50,000 t. At a catch of 20,000 t (the landings in 2017) in 2018 and 2019, this probability would be 94%. The probability that SSB would be below the LRP in 2020 ranged from 0% at 10,000 t to 17% at 50,000 t (Table 36). An increase in SSB by 5% or more by 2020 would only be likely (i.e., probability > 50%) at catches below 16,000 t whereas a decrease by 5% or more is probable at catches of 24,000 t and above.

At catch levels from 10,000 to 20,000 t in 2018 and 2019, the median value of weighted average F5-10 over all regions in 2019 was below 0.32 (Figs. 40 and 42; Table 36). The median increased from 0.13 at a catch of 10,000 t to 1.36 at a catch of 50,000 t. At a catch of 20,000 t (the landings in 2017), the median was 0.31 in 2019. The probability that F5-10 would be greater than 0.32 in 2019 was 0 at a catch of 10,000 t, increasing to 99.6% at a catch of 50,000 t. With a catch of 20,000 t in 2018 and 2019, this probability would be 46%.

6. DISCUSSIONS AND CONCLUSIONS

6.1 SPRING SPAWNERS

As with the previous assessment, this assessment used a model for SS that allowed catchability to the fishery to vary over time (Swain 2016a). Estimated catchability increased sharply in the 2000s, reaching a level in 2007 that was about 5.5 times the level in the 1990s. Estimated catchability has remained at this high level since then. The increase in fishery catchability (q) in the 2000s 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 (MacCall1990) 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, net saturation at high abundance may also contribute to increased catchability at low population size. Finally, catchability by fisheries is expected to increase over time due to technological improvements and improvements in fishing tactics.

The SS component trajectory with respect to spawning stock biomass and fishing mortality levels is shown in Figure 22. Estimated SSB of SS has been below the LRP (19,250 t) since 2004, the median SSB estimate at the start of 2018 is 12,446 t. Considering the uncertainty in model estimates, the probability that the SSB was above the LRP at the start of 2018 is 15%. Recruitment rates were high in the early 1980s but have been much lower since. Recruitment rates have been variable in recent cohorts. Recruitment rate was relatively low for the 2012 cohort and high for the 2013 cohort, though uncertainty in the 2013 estimate is very high. Estimated abundances of age-4 herring at the start of 2017 and 2018 were higher than those since 2005, though the uncertainty in these estimates is very high. The median estimate of SS (4+) abundance at the start of 2017 (the most recent full estimate) is about 20% of the average spawner abundance in 1985 to 1995. Exploitation rates (ages 6 to 8) were high (above the F0.1 removal rate reference level of F = 0.35) from 1999 to 2011 but declined to a lower level since 2012. Once a stock has declined out of the healthy zone, fishing at the maximum removal rate is not advised. This stock is estimated to have been below the healthy zone since 1999.

Despite large uncertainty in the projections, the probability that SSB will remain below the LRP at the start of 2020 was high, even with no catch (>80%). The probability that *F* (ages 6 to 8) will exceed 0.35 in 2019 is low (0%) with catches of 1,000 t or less, increasing up to 57% (low recruitment scenario) with catches of 2,500 t. At catches of 2,000 t (i.e., the spring TAC since 2009) all or most surplus production is being removed. At 2,000 t, the probability of an increase in SSB ranges from 0% (low recruitment scenario) to 19% (high recruitment scenario). Furthermore, at 2,000 t there is at most a 9% probability that SSB will exceed the LRP.

By 2027, the probability of exceeding the LRP was most favorable under the high recruitment scenarios and low catches (<1,500 t), however at the low recruitment scenarios even with no catch there was little chance (0.13) of SSB exceeding the LRP. Even under the high and mixed recruitment scenarios, there is little probability (0.11) of SSB exceeding the USR by 2027 with no catch, at low recruitment there is 0% chance. At 2,000 t, the probability of SSB exceeding the LRP by 2027 depends on the recruitment scenario, ranging from 2% at low recruitment to 38% at high recruitment. Furthermore at 2,000 t there is at most a 4% chance of reaching the USR by 2027.

6.2 FALL SPAWNERS

As with the previous assessment, this assessment used a model that treated FS as independent populations in three spawning regions and allowed catchability to the fishery to vary over time (Swain 2016a, b). As discussed in the SS assessment, catchability to fisheries is expected to change over time for a number of reasons. When estimates from all three regions are included, there was a weak tendency for catchability to increase as population size decreased, as expected from theory (e.g. Winters and Wheeler 1985). However, the variation in estimated *q* within the Middle and South regions was largely independent of population size. This lack of relationship and comparisons between estimated catchabilities to the fishery and the experimental nets suggest that increasing catchability to the fishery over time is due to technological improvements and improved fishing tactics.

The fall spawner component trajectory with respect to spawning stock biomass and fishing mortality levels is shown in Figure 39. Estimated SSB of FS was above the USR until 2013 but has declined since then. All three regions contributed to this overall decline. The median estimate of total SSB at the start of 2018 was well below the USR, though uncertainty in this estimate was high. The probabilities that total SSB was below the USR at the start of 2017 and 2018 were 98% and 99%, respectively. Exploitation rates (ages 5 to 10) were high (above the F0.1 removal rate reference level in the healthy zone of $F = 0.32$) from 1994 to 2011 but declined to a lower level since 2012. Once a stock has declined out of the healthy zone it is advised that fishing should be at rates which are less than the maximum removal rate (F0.1). Based on the projections, the probability of an increase of 5% or more in SSB by 2020 is 50% with catches of 16,000 t and 74% with catches of 10,000 t. The probability of a decrease by 5% or more is 20% with catches of 16,000 t and 50% with 24,000 t. With a catch of 20,000 t (the catch in 2017), the probability that total SSB (i.e., summed over regions) will be below the USR at the start of 2020 is 94%. With this catch in 2018 and 2019, the probability that *F* for ages 5 to 10 would exceed $F = 0.32$ in 2019 is 46%.

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 elevated 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 SS and FS assessments accounts for some of the effects listed above.

The commercial CPUE calculations are subject to uncertainty. The estimates are 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 new modelling approach considers the dynamics of FS herring in three regions. The dynamics are modelled independently among regions and assume closed populations after recruitment at age 2. 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 FS herring based on tagging studies. Nevertheless, elemental analyses of otolith structures did not detect region-specific differences among FS despite showing distinct differences between SS and FS 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 herring in bait fisheries are presently not accounted for in the assessments of either SS or FS 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 constitutes a source of uncertainty in the total fishing mortality.

Uncertainty in recruitment rate in both the SS and FS leads to uncertainty in projections as these are heavily reliant on the recruitment rate selected. In this assessment, we used various recruitment scenarios in the SS assessment to account for variation in recruitment rates among years. In the FS assessment, we used an intermediate recruitment rate as it appears that the most recent estimates of recruitment rate are biased low and would result in overly pessimistic projections.

The model assumes that natural mortality (M) was constant over time. Retrospective patterns from previous assessments indicated a change in dynamics over time which could be because of changes in catchability (q) or M. A model that incorporated time-varying change in q provided a better model fit to address non-stationarity in the stock compared to a model that varied M. This does not mean that M did not change but the current data and information used in the model only resolve one or the other. Future research should also consider whether M has changed in this ecosystem and what information could be used to incorporate this dynamic in the population model.

In the previous assessment, the FS abundances were declining and the estimate at the end of 2015 was just below the USR. In this assessment, the median of the 2014 and 2015 estimates are below the USR. The declining trend in status has continued into 2018. Given this decline in absolute level of abundance from the previous assessment, it is possible that the current

biomass values from the model are overestimated. This overestimation of the biomass will result in an underestimate of the risk of failing to achieve defined management objectives for different catch options for 2018 and 2019 although the extent of the bias is not known.

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TABLES

Table 1. Landings (t) of NAFO Div. 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 are also provided. Total catches highlighted in grey indicate years and stocks where the total catch exceeded the TAC.

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

Year	Spawning group	Spring fishery		Fall fishery		Annual 4T catch	Annual 4Vn catch	Total catch 4TVn	TAC 4TVn
		Fixed	Mobile	Fixed	Mobile				
	Total	11,881	4,818	44,791	9,104	70,594	0	70,594	79,000
2000	SS	14,586	10	706	2,324	17,626	0	17,626	16,500
	FS	1,596	538	49,676	6,373	58,183	0	58,183	71,000
	Total	16,182	548	50,382	8,697	75,809	0	75,809	87,500
2001	SS	9,938	459	736	2,986	14,119	0	14,119	12,500
	FS	659	638	44,786	7,285	53,368	0	53,368	60,500
	Total	10,597	1,097	45,522	10,271	67,487	0	67,487	73,000
2002	SS	8,142	420	673	704	9,939	0	9,939	8,000
	FS	966	464	41,290	10,898	53,618	0	53,618	51,500
	Total	9,108	884	41,963	11,602	63,557	0	63,557	59,500
2003	SS	8,458	41	37	449	8,985	0	8,985	11,000
	FS	608	60	47,766	12,779	61,213	0	61,213	62,000
	Total	9,066	101	47,803	13,228	70,198	0	70,198	73,000
2004	SS	7,671	21	122	410	8,224	0	8,224	13,500
	FS	374	31	35,904	7,090	43,399	0	43,399	73,000
	Total	8,045	52	36,026	7,500	51,623	0	51,623	86,500
2005	SS	3,571	0	14	1,084	4,669	0	4,669	11,000
	FS	925	0	51,715	7,756	60,396	0	60,396	70,000
	Total	4,496	0	51,729	8,840	65,065	0	65,065	81,000
2006	SS	1,409	0	293	745	2,447	0	2,447	9,000
	FS	1,257	0	47,630	4,409	53,296	0	53,296	68,800
	Total	2,666	0	47,923	5,154	55,743	0	55,743	77,800
2007	SS	1,734	0	10	2,414	4,158	0	4,158	5,000
	FS	496	0	43,161	4,426	48,083	0	48,083	68,800
	Total	2,230	0	43,171	6,840	52,241	0	52,241	73,800
2008	SS	1,503	0	35	1,473	3,011	0	3,011	2,500
	FS	187	0	38,831	2,738	41,756	0	41,756	68,800
	Total	1,690	0	38,866	4,211	44,767	0	44,767	71,300
2009	SS	1,256	0	70	519	1,845	0	1,845	2,500
	FS	94	0	44,780	1,939	46,813	0	46,813	65,000
	Total	1,350	0	44,850	2,458	48,658	0	48,658	67,500
2010	SS	769	5	2	595	1,371	0	1,371	2,000
	FS	386	297	42,458	4,154	47,295	0	47,295	65,000
	Total	1,155	302	42,460	4,749	48,666	0	48,666	67,000
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

Table 2a. Commercial herring fishery samples collected, number of fish processed for age (N), landings (t), and % TAC landed by gear type (fixed gear and mobile gear), and zone in the spring (April 1-June 30) and fall (July 1-December 31) herring fisheries of NAFO Div. 4T in 2016. These data are used to derive the 2016 catch-at-age and weight-at-age matrices for NAFO Div. 4T herring.

Gear type	Fishing season	Region	Specific area	Zone	Samples	N	Landings (t)	% TAC landed
Fixed	Spring	North	Gaspé (16A) spring	4Tp	1	26	12.2	65.7
Fixed	Spring	North	Chaleur (16B) April	4Tmn	3	81	61.0	80.6
Fixed	Spring	North	Chaleur (16B) May-June	4Tmn	4	102	140.0	
Fixed	Spring	Middle	West P.E.I. (16E) spring	4Tl	0	0	20.6	92.8
Fixed	Spring	Middle	Northumberland Strait (16E) spring	4Th	18	359	536.2	
Fixed	Spring	South	East P.E.I.	4Tgj	1	21	56.4	55.7
Fixed	Spring	South	Magdalen Islands (16D) fall	4Tf	0	0	0.5	2.2
Fixed	Fall	North	Gaspé (16A) fall	4Topq	1	32	14.4	47.3
Fixed	Fall	North	Chaleur (16B) July	4Tmn	3	68	115.9	100.6
Fixed	Fall	North	Chaleur (16B) August	4Tmn	8	197	7,066.1	100.4
Fixed	Fall	North	Chaleur (16B) September	4Tmn	7	173	5,293.2	
Fixed	Fall	Middle	Escuminac-West P.E.I. (16CE) August	4Tl	5	111	3,849.9	102.0
Fixed	Fall	Middle	Escuminac-West P.E.I. (16CE) September	4Tl	2	48	1,160.6	
Fixed	Fall	South	Magdalen Islands (16D) fall	4Tf	0	0	0	0
Fixed	Fall	South	Pictou (16F) fall	4Th	5	107	4,352.4	82.1
Fixed	Fall	South	East P.E.I. (16G) August	4Tgj	4	97	1,066.5	34.1
Fixed	Fall	South	East P.E.I. (16G) September	4Tgj	2	49	317.8	
Fixed	All	All	All areas	4T	64	1,471	24,063.9	85.4
Mobile	Spring	South	Spring Edge fishery – June*	4Tf	0	0	1120.0	22.4
Mobile	Fall	North	East of Grande-Anse (16B) September-October	4Tmn	2	57	421.1	8.1
Mobile	Fall	North	East of Grande-Anse (16B) November	4Tmn	9	272	350.0	
Mobile	All	All	All areas	4T	11	329	1,891.0	15.1

* Catch-at-age for the Edge fishery used samples collected in 4Tf during the multi-species bottom trawl survey.

Table 2b. Commercial herring fishery samples collected, number of fish processed for age (N), landings (t), and % TAC landed by gear type (fixed gear and mobile gear), and zone in the spring (April 1-June 30) and fall (July 1-December 31) herring fisheries in NAFO Div. 4T in 2017. These data are used to derive the 2017 catch-at-age and weight-at-age matrices for NAFO Div. 4T herring.

Gear type	Fishing season	Region	Specific area	Zone	Samples	N	Landings (t)	% TAC landed
Fixed	Spring	North	Gaspé (16A) spring	4Tp	0	0	18.8	77.7
Fixed	Spring	North	Chaleur (16B) April	4Tmn	6	167	72.0	99.6
Fixed	Spring	North	Chaleur (16B) May-June	4Tmn	7	200	276.7	
Fixed	Spring	Middle	West P.E.I. (16E) spring	4Tl	0	0	42.7	70.4
Fixed	Spring	Middle	Northumberland Strait (16E) spring	4Th	15	331	441.8	
Fixed	Spring	South	East P.E.I.	4Tgj	3	52	94.0	57.7
Fixed	Spring	South	Magdalen Islands (16D) fall	4Tf	0	0	0.1	2.3
Fixed	Fall	North	Gaspé (16A) fall	4Topq	1	27	6.2	15.7
Fixed	Fall	North	Chaleur (16B) July	4Tmn	2	49	148.8	121.4
Fixed	Fall	North	Chaleur (16B) August	4Tmn	10	246	7,002.2	94
Fixed	Fall	North	Chaleur (16B) September	4Tmn	5	133	4,526.4	
Fixed	Fall	Middle	Escuminac-West P.E.I. (16CE) August	4Tl	2	41	1,310.8	106.9
Fixed	Fall	Middle	Escuminac-West P.E.I. (16CE) September	4Tl	4	96	4,184.6	
Fixed	Fall	South	Magdalen Islands (16D) fall	4Tf	2	66	4.7	2.7
Fixed	Fall	South	Pictou (16F) fall	4Th	2	39	2,521.0	64.1
Fixed	Fall	South	East P.E.I. (16G) August	4Tgj	2	38	624.5	7.4
Fixed	Fall	South	East P.E.I. (16G) September	4Tgj	0	0	231.2	
Fixed	All	All	All areas	4T	64	1,573	21,774.6	75.8
Mobile	Spring	South	Spring Edge fishery – June*	4Tf	0	0	90.2	2.2
Mobile	Fall	North	East of Grande-Anse (16B) September-October	4Tmn	1	31	245.3	42.1
Mobile	Fall	North	East of Grande-Anse (16B) November	4Tmn	8	319	570.8	
Mobile	All	All	All areas	4T	9	350	906.3	26.2

* Catch-at-age for the Edge fishery used sampled collected in 4Tf during the multi-species bottom trawl survey.

Table 3a. Summary of 2016 Atlantic Herring Dockside Monitoring Program (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 of abundance from 2015 [scale 1 (poor) to 10 (excellent)].

Fishery season	Region	Telephone survey area	Source	Number of respondents	Net length (fathom)	Number of nets set	Percent 2⅝" mesh size	Comparison to previous year
Spring	South	1 - Magdalen Islands	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Spring	North	2- Quebec	DMP	-	-	-	-	-
			Phone	12	14.5	14.3	-	3.8
Spring	North	3- Acadian Peninsula	DMP	2	13.0	16.9	-	-
			Phone	2	16.0	18.8	-	6.0
Spring	Middle	4- Escuminac	DMP	3	15.0	24.6	-	-
			Phone	1	11.5	19.7	-	10.0
Spring	Middle	5- South east NB	DMP	36	14.4	23.6	-	-
			Phone	13	13.9	20.0	-	6.1
Spring	South	6- Nova Scotia	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Spring	South	7- East P.E.I.	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Spring	Middle	8- West P.E.I.	DMP	1	13.0	21.4	-	-
			Phone	5	15.1	20.0	-	4.8
Fall	South	1 - Magdalen Islands	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Fall	North	2- Quebec	DMP	-	-	-	-	-
			Phone	20	14.1	6.7	100	4.7
Fall	North	3- Acadian Peninsula	DMP	17	14.5	7.7	100	-
			Phone	33	13.9	7.9	100	5.3
Fall	Middle	4- Escuminac	DMP	12	15.0	8.2	100	-
			Phone	15	13.6	7.9	100	7.1
Fall	Middle	5- South east NB	DMP	1	15.0	5.6	100	-
			Phone	2	13.5	8.0	100	6.0
Fall	South	6- Nova Scotia	DMP	33	15.3	7.2	100	-
			Phone	33	14.8	7.1	100	3.5
Fall	South	7- East P.E.I.	DMP	46	14.0	8.6	100	-
			Phone	9	14.4	8.3	100	6.2
Fall	Middle	8- West P.E.I.	DMP	51	12.5	8.3	100	-
			Phone	10	13.2	6.3	100	5.6

Table 3b. Summary of 2017 Atlantic Herring Dockside Monitoring Program (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 of abundance from 2016 [scale 1 (poor) to 10 (excellent)].

Fishery season	Region	Telephone survey area	Source	Number of respondents	Net length (fathom)	Number of nets set	Percent 2⅝" mesh size	Comparison to previous year
Spring	South	1 - Magdalen Islands	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Spring	North	2- Quebec	DMP	1	13.0	21.4	-	-
			Phone	9	13.3	16.8	-	6.6
Spring	North	3- Acadian Peninsula	DMP	1	15.0	10.7	-	-
			Phone	5	13.0	17.1	-	5.7
Spring	Middle	4- Escuminac	DMP	1	13.0	21.4	-	-
			Phone	-	-	-	-	-
Spring	Middle	5- South east NB	DMP	32	13.7	22.0	-	-
			Phone	11	13.6	21.9	-	5.6
Spring	South	6- Nova Scotia	DMP	3	15.0	16.3	-	-
			Phone	-	-	-	-	-
Spring	South	7- East P.E.I.	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Spring	Middle	8- West P.E.I.	DMP	27	12.5	18.0	-	-
			Phone	7	13.3	21.4	-	6
Fall	South	1 - Magdalen Islands	DMP	-	-	-	-	-
			Phone	-	-	-	-	-
Fall	North	2- Quebec	DMP	-	-	-	-	-
			Phone	9	13.6	8.5	100	4.7
Fall	North	3- Acadian Peninsula	DMP	24	14.2	9.5	100	-
			Phone	31	13.7	8.0	100	4.1
Fall	Middle	4- Escuminac	DMP	21	14.9	9.1	100	-
			Phone	22	14.3	8.7	100	4.8
Fall	Middle	5- South east NB	DMP	1	15.0	9.6	100	-
			Phone	-	-	-	-	-
Fall	South	6- Nova Scotia	DMP	28	15.1	7.8	100	-
			Phone	23	14.3	6.5	100	2.2
Fall	South	7- East P.E.I.	DMP	32	14.2	9.1	100	-
			Phone	3	12.8	8.6	100	2.3
Fall	Middle	8- West P.E.I.	DMP	44	12.7	9.4	100	-
			Phone	8	13.8	8.5	100	4.6

Table 4. Spring spawner (SS) Atlantic Herring catch-at-age (number of fish in thousands) from the fixed gear fishery in NAFO Div. 4T. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	-	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	-	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	-	155	13,547	26,208	2,142	472	76	-	-	8	-	42,608
1984	16	39	3,377	12,083	7,529	409	59	14	7	4	-	23,538
1985	-	39	4,921	12,685	13,742	4,630	614	100	32	71	-	36,833
1986	-	11	2,712	13,905	12,357	10,348	2,783	391	20	233	349	43,109
1987	-	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	3,941	15,672	4,836	4,912	6,957	4,326	2,598	1,025	279	44,546
1990	-	128	1,925	7,387	4,109	2,178	2,532	3,928	1,827	733	306	25,053
1991	-	-	6,070	11,715	14,140	9,142	3,166	2,897	4,448	1,640	1,097	54,314
1992	-	-	2,160	30,046	11,543	7,579	3,460	1,593	1,956	1,423	2,263	62,023
1993	-	8	231	5,488	40,374	18,381	4,900	2,409	1,375	708	2,724	76,597
1994	-	-	2,061	5,847	24,642	48,553	9,048	3,595	1,221	438	1,032	96,438
1995	-	-	200	13,345	10,782	17,781	28,929	6,408	1,788	1,156	2,271	82,660
1996	-	-	416	1,682	48,104	9,123	14,154	9,414	3,102	590	1,087	87,672
1997	-	2	107	5,440	4,069	37,818	6,961	4,149	3,938	1,015	179	63,678
1998	-	-	785	7,744	15,786	2,264	29,871	3,421	2,449	1,966	875	65,159
1999	-	89	1,724	6,599	9,410	10,297	2,255	16,045	2,583	1,342	1,155	51,499
2000	-	12	2,141	11,977	15,975	15,248	7,568	4,457	11,675	2,912	1,756	73,722
2001	-	-	910	11,316	13,082	9,859	4,920	3,360	1,387	6,593	1,735	53,163
2002	-	1	2,509	7,044	18,352	7,626	3,608	2,075	1,152	1,052	1,214	44,633
2003	-	-	285	10,766	11,071	12,832	3,925	2,483	998	686	759	43,803
2004	-	21	1,607	2,606	15,101	5,400	8,500	3,223	1,164	413	1,005	39,040
2005	-	-	72	3,639	3,209	5,784	2,561	2,023	566	125	174	18,153
2006	-	1	720	1,299	4,653	1,652	528	285	387	28	73	9,626
2007	-	1	864	2,037	1,563	2,323	1,738	803	196	149	110	9,784
2008	-	71	177	2,812	3,111	1,139	1,261	269	52	23	12	8,928
2009	-	23	411	1,060	2,445	3,033	344	349	91	6	14	7,775
2010	-	-	144	1,107	860	1,559	766	366	358	4	13	5,177
2011	-	-	25	116	885	812	1,102	512	782	287	5	4,526
2012	-	-	153	400	400	609	671	340	225	186	84	3,068
2013	-	-	16	303	963	1,157	1,492	1,141	814	50	39	5,974
2014	-	-	1	17	454	773	868	1,080	561	222	67	4,041
2015	-	-	0	103	157	783	1,195	535	396	76	41	3,287
2016	-	-	28	26	649	1,067	1,653	773	338	102	21	4,657
2017	-	6	88	703	746	1,977	1,617	1,207	276	49	3	6,673

Table 5. Spring spawner (SS) Atlantic Herring mean weight-at-age (kg) from the fixed gear fishery in NAFO Div. 4T. A dash indicates no fish of that age were sampled in that year.

	Age (years)										
Year	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	0.170	0.181	0.195	0.211	0.203
2017	-	0.125	0.148	0.138	0.150	0.176	0.177	0.186	0.185	0.198	0.212

Table 6a. Fall spawner (FS) Atlantic Herring catch-at-age (number of fish in thousands) from the fixed gear fishery in NAFO Div. 4T for the North region. A dash indicates no fish of that age were sampled in that year.

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

Table 6b. Fall spawner (FS) Atlantic Herring catch-at-age (number of fish in thousands) from the fixed gear fishery in NAFO Div. 4T for the Middle region. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	-	-	38	601	749	220	442	2,005	9	59	1,139	5,262
1979	-	-	144	3,673	2,048	831	205	100	209	18	161	7,389
1980	-	-	424	964	2,283	579	271	225	282	107	96	5,232
1981	-	-	974	6,224	1,910	1,150	460	629	31	83	238	11,699
1982	-	-	29	1,653	1,559	210	139	116	-	-	31	3,737
1983	-	-	255	3,998	1,482	1,578	351	130	-	-	-	7,794
1984	-	-	41	1,908	2,723	937	1,001	315	77	11	6	7,019
1985	-	-	11	235	1,370	1,010	562	536	200	41	1	3,964
1986	-	-	47	1,600	1,328	2,455	1,120	435	200	27	46	7,257
1987	-	-	298	934	1,761	1,532	3,059	289	267	298	19	8,457
1988	-	-	817	3,091	2,817	2,473	1,135	1,189	886	15	0	12,424
1989	-	-	16	772	1,431	1,274	694	428	378	171	139	5,303
1990	-	-	219	1,923	1,390	1,508	2,655	548	382	298	64	8,987
1991	-	-	17	5,973	1,617	1,332	1,749	2,066	1,271	585	1,335	15,945
1992	-	-	12	3,880	9,415	1,284	534	304	220	106	249	16,004
1993	-	-	-	350	6,612	8,298	1,417	597	415	470	716	18,875
1994	-	-	-	850	1,373	6,909	9,293	1,134	359	439	741	21,099
1995	-	-	-	214	10,009	3,408	12,249	10,646	1,363	243	4,272	42,403
1996	-	-	-	3,414	2,107	12,096	1,046	3,144	3,605	833	869	27,113
1997	-	-	285	4,835	10,979	1,980	4,125	782	938	1,026	639	25,588
1998	-	-	23	5,113	4,301	8,730	1,761	3,286	596	1,293	2,229	27,331
1999	-	-	-	9,710	12,903	5,104	3,222	1,303	2,854	278	1,330	36,703
2000	-	-	13	11,054	21,136	7,789	2,516	1,394	414	369	165	44,850
2001	-	-	383	5,519	13,582	9,633	2,919	630	208	-	293	33,167
2002	-	-	275	9,081	8,110	7,172	6,937	1,245	172	146	217	33,356
2003	-	-	123	5,648	11,842	5,541	3,737	3,739	839	110	156	31,735
2004	-	-	15	5,579	10,122	7,144	5,096	4,523	2,652	920	175	36,227
2005	-	-	-	2,355	14,518	11,757	3,536	3,046	2,099	895	66	38,273
2006	-	-	-	1,697	7,740	13,789	5,094	2,598	1,949	1,544	523	34,935
2007	-	-	193	1,197	3,429	9,509	9,811	3,736	1,509	733	454	30,572
2008	-	-	1,426	12,175	2,575	4,491	5,326	8,515	1,536	1,451	332	37,826
2009	-	-	101	8,185	14,543	3,368	7,438	3,578	1,245	530	245	39,232
2010	-	-	8	1,529	11,467	17,000	4,954	4,333	2,473	1,154	644	43,562
2011	-	-	-	405	2,089	12,157	15,610	2,973	2,237	2,101	631	38,202
2012	-	-	7	147	1,935	8,679	11,646	8,142	925	526	443	32,450
2013	-	-	7	590	1,125	7,042	10,527	6,451	2,488	201	43	28,474
2014	-	-	-	-	3,452	2,161	7,389	8,144	1,536	755	-	23,436
2015	-	-	-	165	1,052	10,058	4,474	7,592	2,987	1,060	-	27,388
2016	-	-	18	279	1,227	7,869	6,459	3,603	1,610	570	-	21,634
2017	-	-	25	128	1,032	3,573	6,651	8,169	4,645	638	23	24,884

Table 6c. Fall spawner (FS) Atlantic Herring catch-at-age (number of fish in thousands) from the fixed gear fishery in NAFO Div. 4T for the South region. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	-	41	1,988	1,390	632	154	75	119	22	-	13	4,434
1979	-	16	267	4,634	2,198	773	263	292	175	52	205	8,875
1980	-	38	4,404	1,939	2,352	294	923	129	164	154	77	10,473
1981	-	42	1,158	5,336	2,185	1,049	531	310	88	99	24	10,823
1982	-	-	353	7,029	3,634	3,226	2,345	819	332	81	37	17,856
1983	-	-	467	7,485	5,047	3,237	1,011	1,266	477	47	161	19,198
1984	-	-	397	15,010	5,562	4,586	2,288	703	381	110	23	29,060
1985	-	-	89	3,442	15,465	6,385	3,221	2,234	509	333	29	31,707
1986	-	383	871	20,436	5,745	12,065	3,350	1,635	487	106	164	45,244
1987	-	-	1,083	11,141	12,821	6,139	14,100	6,213	4,292	1,851	1,323	58,963
1988	-	-	377	4,361	16,703	9,665	4,750	6,641	3,036	985	665	47,183
1989	-	-	33	1,355	2,076	8,332	4,204	1,803	2,446	622	300	21,171
1990	-	-	875	6,772	6,732	7,712	36,015	9,853	4,322	4,591	2,472	79,345
1991	-	-	11	4,956	1,670	1,339	1,201	3,899	1,365	840	1,190	16,471
1992	-	-	-	1,335	7,461	1,081	631	1,510	3,338	1,241	1,316	17,913
1993	-	-	-	302	3,227	3,902	982	405	586	485	1,123	11,013
1994	-	-	-	1,463	310	10,000	13,800	1,873	2,460	5,256	8,730	43,892
1995	-	-	1	341	7,908	2,733	12,171	10,381	2,759	3,036	7,345	46,675
1996	-	-	4	3,477	2,082	13,644	4,899	11,411	10,891	2,781	8,448	57,637
1997	-	-	454	3,780	22,567	2,027	8,585	1,488	3,105	2,920	2,597	47,521
1998	-	-	-	9,390	4,415	15,711	3,964	8,891	1,751	3,429	4,223	51,773
1999	-	-	89	8,880	32,161	4,365	9,706	1,899	3,102	1,152	1,593	62,949
2000	-	-	77	8,101	31,645	18,887	3,076	3,685	715	1,148	717	68,050
2001	-	-	56	1,816	22,486	21,033	13,536	1,991	1,593	433	824	63,767
2002	-	-	-	17,708	7,514	16,987	14,117	4,249	1,072	926	547	63,120
2003	-	-	61	5,076	41,894	6,513	13,669	8,690	1,700	262	381	78,246
2004	-	-	-	4,823	11,135	24,502	4,842	4,452	2,175	600	312	52,840
2005	-	-	3	424	12,345	20,406	31,839	6,051	6,169	1,732	385	79,354
2006	-	-	51	2,825	7,738	20,291	20,875	15,511	5,119	2,721	760	75,890
2007	-	-	492	206	9,238	13,512	24,751	15,374	4,948	2,939	938	72,397
2008	-	-	292	4,858	1,774	6,585	12,063	15,009	6,873	3,646	2,818	53,919
2009	-	-	411	2,398	20,654	10,345	20,617	6,815	3,615	5,240	2,610	72,705
2010	-	-	-	2,080	8,754	32,103	8,352	10,398	6,809	3,819	2,439	74,754
2011	-	-	1	312	7,530	7,478	25,275	8,102	4,030	2,350	4,185	59,263
2012	-	-	-	24	1,199	12,938	14,639	15,613	1,662	476	1,603	48,156
2013	-	-	15	341	1,025	9,166	19,571	7,271	3,448	110	108	41,054
2014	-	-	-	173	2,842	2,276	8,971	15,942	3,504	1,700	58	35,466
2015	-	-	-	-	1,653	7,979	4,406	12,483	3,358	1,923	208	32,011
2016	-	-	10	305	3,417	10,631	5,826	4,287	1,947	570	39	27,032
2017	-	-	-	368	298	3,692	7,499	2,659	989	208	19	15,732

Table 7a. Fall spawner (FS) Atlantic Herring mean weight-at-age (kg) from the fixed gear fishery in NAFO Div. 4T for the North region. A dash indicates no fish of that age were sampled in that year.

	Age (years)										
Year	1	2	3	4	5	6	7	8	9	10	11+
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

Table 7b. Fall spawner (FS) Atlantic Herring mean weight-at-age (kg) from the fixed gear fishery in NAFO Div. 4T for the Middle region. A dash indicates no fish of that age were sampled in that year.

	Age (years)										
Year	1	2	3	4	5	6	7	8	9	10	11+
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
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	0.220	0.226	0.232	0.240	0.247	0.259	-
2017	-	-	0.134	0.174	0.200	0.212	0.213	0.225	0.234	0.251	0.289

Table 7c. Fall spawner (FS) Atlantic Herring mean weight-at-age (kg) from the fixed gear fishery in NAFO Div. 4T for the South region. A dash indicates no fish of that age were sampled in that year.

	Age (years)										
Year	1	2	3	4	5	6	7	8	9	10	11+
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
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	-	-	0.120	0.161	0.208	0.206	0.214	0.220	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

Table 8. Spring spawner (SS) Atlantic Herring catch-at-age (number of fish in thousands) from the mobile gear fishery in NAFO Div. 4T. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
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	-	362	1,105	939	9	881	347	699	264	417	7	5,031
1982	-	2,343	3,816	400	53	10	89	165	210	2	19	7,109
1983	-	1,349	8,017	3,838	449	1	65	71	89	-	-	13,878
1984	-	619	1,831	4,190	2,901	291	-	71	41	-	-	9,943
1985	601	1,132	4,581	2,451	3,085	1,153	77	-	-	-	294	13,373
1986	-	4,194	3,982	9,551	7,647	7,410	3,070	212	514	-	60	36,640
1987	-	1,476	1,977	2,945	10,495	7,260	7,060	3,696	-	-	93	35,002
1988	2,710	6,291	2,125	1,546	2,730	11,772	9,514	5,399	2,434	-	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	-	52	4,057	2,255	3,477	5,930	2,435	1,349	647	166	1,251	21,620
1995	-	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	-	71	-	-	7,340
2006	61	236	898	521	1,825	620	138	24	6	5	-	4,333
2007	524	3,651	3,605	2,396	1,786	2,368	700	256	15	-	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	-	173	38	3,358
2010	-	116	406	941	506	713	634	74	8	-	1	3,398
2011	19	629	814	669	682	577	576	73	106	356	23	4,525
2012	-	17	404	454	279	237	169	9	33	-	21	1,624
2013	1	124	282	831	1,120	703	621	442	41	-	18	4,185
2014	-	489	191	714	309	656	372	213	-	37	82	3,063
2015	-	564	560	206	270	554	864	457	190	22	17	3,704
2016	-	271	495	138	91	41	114	38	86	-	-	1275
2017	2	102	101	140	18	2	5	1	0	-	-	421

Table 9. Spring spawner (SS) Atlantic Herring mean weight-at-age (kg) from the mobile gear fishery in NAFO Div. 4T. A dash indicates no fish of that age were sampled in that year.

	Age (years)										
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	-	-

Table 10a. Fall spawner (FS) Atlantic Herring catch-at-age (number of fish in thousands) from the mobile gear fishery in NAFO Div. 4T for the North region. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	-	79	4,054	12,822	17,080	2,899	2,891	10,421	1,050	511	11,781	63,149
1979	155	5,920	8,880	6,475	4,166	3,064	1,118	687	1,783	263	2,633	32,916
1980	139	2,317	17,087	4,629	1,872	678	734	373	452	307	492	28,976
1981	1	33	292	344	31	9	13	1	5	-	-	728
1982	-	1,014	8,857	3,562	6,916	830	131	153	103	25	260	21,854
1983	-	9	242	291	112	175	31	7	10	1	4	882
1984	-	378	1,020	4,581	4,736	2,610	1,705	367	84	10	37	15,528
1985	-	331	1,904	2,489	7,414	6,556	2,955	2,205	1,837	574	-	26,263
1986	-	272	2,098	2,483	3,109	5,959	3,521	1,564	1,614	208	218	21,336
1987	-	1,622	3,350	2,275	1,030	1,329	3,638	3,869	865	864	371	19,214
1988	97	3,900	2,467	2,731	3,207	1,539	3,197	2,786	1,060	1,384	1,608	23,976
1989	-	828	1,073	2,202	4,390	4,541	1,899	2,252	2,706	1,557	1,182	22,630
1990	-	71	4,463	3,357	3,653	2,019	1,981	1,549	2,084	988	296	20,461
1991	-	-	5,138	18,139	4,009	1,188	1,942	1,452	382	712	2,282	35,246
1992	-	44	586	5,067	12,734	2,263	1,385	957	1,158	935	4,768	30,479
1993	-	311	4,383	2,693	4,587	7,513	2,282	1,874	1,767	2,377	3,285	31,072
1994	-	-	275	6,305	2,091	4,865	6,027	921	415	403	697	22,542
1995	-	-	1,861	3,547	19,016	6,060	8,390	8,584	1,916	596	2,084	52,351
1996	-	359	2,684	10,407	2,556	8,340	2,346	1,813	1,446	438	403	30,510
1997	-	362	4,079	5,423	6,371	1,235	2,540	477	923	557	419	21,800
1998	-	51	1,489	2,898	2,848	1,690	469	1,778	108	455	144	11,879
1999	-	690	7,217	10,835	5,770	2,761	1,239	767	490	183	112	30,065
2000	-	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	-	21	23,166
2002	-	76	1,363	7,505	6,378	4,178	4,009	975	321	346	217	25,367
2003	-	-	4,531	9,687	5,600	3,695	3,219	3,961	960	549	318	32,520
2004	-	71	2,533	8,511	3,204	1,537	741	344	333	40	-	17,314
2005	-	802	3,145	9,147	7,649	1,800	240	100	159	42	38	23,122
2006	-	800	1,966	3,218	7,747	5,366	1,417	493	315	239	54	21,616
2007	-	1,491	14,991	4,688	2,787	2,987	1,571	390	81	3	12	29,000
2008	-	1,385	8,080	5,566	1,678	834	607	771	3	24	-	18,948
2009	-	179	4,648	5,917	2,313	295	211	51	5	0	-	13,618
2010	11	6	1,811	6,112	10,088	6,857	1,258	684	203	90	-	27,119
2011	-	1,177	749	2,101	2,304	2,477	1,015	368	8	59	6	10,263
2012	-	42	379	314	931	641	410	9	-	9	-	2,734
2013	17	527	447	2,904	1,833	2,390	1,318	499	241	18	5	10,200
2014	-	36	1,783	597	2,690	1,304	1,585	944	456	94	-	9,488
2015	-	229	1,252	375	282	1,544	162	625	407	290	-	5,166
2016	-	19	336	1,087	654	656	806	344	148	60	-	4,126
2017	-	112	102	84	53	8	3	1	-	-	-	362

Table 10b. Fall spawner (FS) Atlantic Herring catch-at-age (number of fish in thousands) from the mobile gear fishery in NAFO Div. 4T for the Middle region. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	-	20	948	4,808	1,863	538	633	1,578	197	59	1,753	12,277
1979	-	-	-	-	-	3,097	745	2,065	1,754	1,313	7,202	17,887
1980	8	135	1,022	284	137	53	48	24	29	20	30	1,784
1981	-	5	44	52	5	1	2	-	1	-	-	110
1982	-	4	31	12	24	3	-	1	-	-	1	77
1983	-	207	5,327	6,407	2,466	3,865	672	156	209	28	85	19,422
1984	-	20	54	242	251	138	90	19	4	1	2	820
1985	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-	-	-	-	-
1987	-	2	3	2	1	1	3	4	1	1	-	18
1988	-	-	-	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	3	24	369	127	122	102	121	70	23	30	956
1997	-	-	-	-	-	-	-	-	-	-	-	-
1998	-	-	61	283	567	1,695	152	140	141	36-	427	3,848
1999	-	-	-	-	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-	-	-	-
2002	-	-	320	464	288	464	190	64	-	-	3	1,795
2003	-	-	-	-	-	-	-	-	-	-	-	-
2004	-	-	-	-	-	-	-	-	-	-	-	-
2005	-	154	1,321	8,673	7,234	3,128	988	583	515	229	116	22,941
2006	-	1	28	192	574	85	30	15	-	-	-	926
2007	-	-	176	238	37	322	118	87	19	31	8	1,036
2008	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-	-	-	-	-	-
2014	-	-	-	-	-	-	-	-	-	-	-	-
2015	-	-	-	-	-	-	-	-	-	-	-	-
2016	-	-	-	-	-	-	-	-	-	-	-	-
2017	-	-	-	-	-	-	-	-	-	-	-	-

Table 10c. Fall spawner (FS) Atlantic Herring catch-at-age (number of fish in thousands) from the mobile gear fishery in NAFO Div. 4T for the South region. A dash indicates no fish of that age were sampled in that year.

	Age (years)											
Year	1	2	3	4	5	6	7	8	9	10	11+	total
1978	-	1,252	16,405	5,700	2,552	899	1,528	3,024	597	698	4,256	37,472
1979	1	31	84	597	780	1,071	215	489	313	83	2,055	6,239
1980	3	493	23,229	10,890	19,861	9,562	4,078	1,396	2,103	1,419	1,328	74,471
1981	17	1,081	9,675	11,391	1,040	287	432	30	181	-	-	24,134
1982	-	-	-	11	22	8	4	2	1	-	2	47
1983	-	5	139	167	64	101	18	4	5	1	2	506
1984	-	-	1	2	1	1	1	-	-	-	-	5
1985	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	74	426	135	6	7	5	1	-	-	-	366
1987	-	9	19	13	6	8	21	22	5	5	2	110
1988	1	50	32	35	42	20	41	36	14	18	21	310
1989	-	-	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-	-	-
1992	-	-	76	341	619	738	657	485	536	395	100	3,367
1993	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	13	2,188	1,578	5,388	7,248	775	1,388	962	2,032	21,042
1995	-	22	505	251	1,389	367	1,402	1,762	114	347	402	6,262
1996	-	28	6	2,463	3,060	2,247	1,637	1,285	578	369	649	12,636
1997	-	66	799	889	3,491	1,199	2,075	422	457	231	497	10,712
1998	-	-	3	16	113	349	116	490	91	273	697	2,177
1999	-	23	846	2,005	3,480	2,109	4,730	2,132	1,738	460	1,233	18,756
2000	-	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	-	954	2,799	6,060	4,530	4,663	3,411	870	232	455	174	24,148
2003	-	201	4,034	5,966	6,382	3,697	4,609	3,633	1,543	303	357	30,726
2004	-	448	2,059	6,792	3,471	2,984	2,191	1,801	1,445	467	333	21,992
2005	-	-	-	-	-	-	-	-	-	-	-	-
2006	-	240	360	260	420	381	129	10	15	3	-	1,817
2007	-	-	70	95	15	128	47	34	8	12	3	411
2008	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	64	928	516	342	38	21	5	-	1	1,914
2011	-	-	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	40	211	413	149	333	56	5	7	1214
2013	-	18	-	1,502	2,107	3,489	5,125	2,162	1,870	202	98	16,575
2014	-	-	-	496	2,895	1,691	2,199	1,972	990	263	-	10,505
2015	-	-	61	359	554	3,343	1,306	1,279	724	176	-	7,856
2016	-	694	1,810	1,392	1,880	-	-	-	-	-	-	5,776
2017	-	105	100	56	112	142	29	8	15	-	-	584

Table 11. Fall spawner (FS) Atlantic Herring weight-at-age (kg) from the mobile gear fishery in NAFO Div. 4T, fishing regions combined. A dash indicates no fish of that age were sampled in that year.

	Age (years)										
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	-	-

Table 12. Percent of annual fishing days with no gillnet catch of Atlantic Herring as reported from the telephone survey for the main fishing areas in the spring and fall fisheries in NAFO Div. 4T.

Year	Spring fishery	Fall fishery
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

Table 13. Results of the multiplicative general linear model applied to the fishery catch-per-unit-effort data for the Atlantic Herring spring spawners (NAFO Div. 4T) and fall spawners (by fishing region in NAFO Div. 4T).

Spawner group	Area	R^2	F_{year}	P_{year}	F_{week}	P_{week}	F_{area}	P_{area}
Spring	Div. 4T	0.44	22.3	<0.0001	18.9	<0.0001	51.8	<0.0001
Fall	North region	0.57	3.3	<0.0001	18.4	<0.0001	-	-
Fall	Middle region	0.68	6.2	<0.0001	13.2	<0.0001	-	-
Fall	South region	0.52	4.5	<0.0001	13.1	<0.0001	-	-

Table 14. Spring spawner (SS) Atlantic Herring fixed gear age-disaggregated mean catch-per-unit-effort values (number per net-haul) for NAFO Div. 4T.

	Age (years)							
Year	4	5	6	7	8	9	10	11
1990	116.1	64.6	34.2	39.8	61.7	28.7	11.5	116.1
1991	186.5	225.1	145.5	50.4	46.1	70.8	26.1	186.5
1992	551.2	211.8	139.0	63.5	29.2	35.9	26.1	551.2
1993	61.1	449.2	204.5	54.5	26.8	15.3	7.9	61.1
1994	46.9	197.8	389.8	72.6	28.9	9.8	3.5	46.9
1995	131.3	106.1	175.0	284.7	63.1	17.6	11.4	131.3
1996	14.8	422.5	80.1	124.3	82.7	27.2	5.2	14.8
1997	74.4	55.6	517.2	95.2	56.7	53.9	13.9	74.4
1998	77.0	157.0	22.5	297.2	34.0	24.4	19.6	77.0
1999	72.2	102.9	112.6	24.7	175.4	28.2	14.7	72.2
2000	103.9	138.5	132.2	65.6	38.7	101.3	25.3	103.9
2001	110.0	127.2	95.8	47.8	32.7	13.5	64.1	110.0
2002	70.4	183.3	76.2	36.0	20.7	11.5	10.5	70.4
2003	133.6	137.4	159.2	48.7	30.8	12.4	8.5	133.6
2004	24.2	140.4	50.2	79.0	30.0	10.8	3.8	24.2
2005	65.7	57.9	104.4	46.2	36.5	10.2	2.3	65.7
2006	58.7	210.3	74.6	23.8	12.9	17.5	1.3	58.7
2007	94.4	72.4	107.6	80.5	37.2	9.1	6.9	94.4
2008	147.7	163.5	59.9	66.2	14.1	2.8	1.2	147.7
2009	86.1	198.7	246.5	27.9	28.4	7.4	0.5	86.1
2010	55.5	43.1	78.1	38.4	18.3	18.0	0.2	55.5
2011	7.8	59.3	54.5	73.9	34.3	52.5	19.3	7.8
2012	49.2	49.1	74.8	82.5	41.8	27.6	22.9	49.2
2013	38.1	121.1	145.5	187.7	143.5	102.4	6.3	38.1
2014	2.5	66.7	113.6	127.5	158.7	82.4	32.6	2.5
2015	14.9	22.6	113.0	172.4	77.2	57.2	11.0	14.9
2016	2.0	48.9	80.4	124.5	58.3	25.5	7.7	2.0
2017	81.3	86.2	228.5	186.8	139.5	31.9	5.7	81.3

Table 15a. Fall spawner (FS) Atlantic Herring fixed gear age-disaggregated mean catch-per-unit-effort values (number per net-haul) from the North region of NAFO Div. 4T.

	Age (years)							
Year	4	5	6	7	8	9	10	11
1986	105.6	103.6	233.4	163.5	77.5	35.4	4.8	8.2
1987	188.4	113.7	103.2	153.9	70.5	42.7	18.7	5.9
1988	110.6	190.0	72.9	64.7	59.2	31.5	15.3	14.9
1989	181.9	296.9	317.2	154.3	70.7	88.9	39.8	31.8
1990	69.0	63.0	97.8	103.8	39.2	27.5	28.9	20.8
1991	486.1	123.6	91.2	135.3	129.5	41.7	26.0	42.5
1992	74.3	450.7	128.9	75.1	81.8	71.9	34.7	65.4
1993	30.5	313.4	363.5	51.0	28.5	29.4	8.3	10.6
1994	40.7	65.5	196.2	296.1	56.4	43.8	20.1	33.6
1995	17.8	129.6	60.0	144.8	153.7	26.9	17.2	18.8
1996	83.4	100.9	135.7	29.8	56.7	61.8	8.8	10.2
1997	91.4	315.0	97.1	86.5	16.7	28.9	25.9	7.5
1998	57.0	156.2	149.1	37.3	35.6	5.1	8.3	15.0
1999	123.5	148.6	184.9	65.7	13.0	8.3	2.3	3.2
2000	153.7	501.5	133.4	56.2	30.8	6.0	4.4	2.0
2001	146.3	185.0	190.6	29.1	13.1	3.6	1.1	1.5
2002	188.7	206.4	144.8	77.8	20.3	6.1	4.2	1.7
2003	83.0	174.6	117.2	82.7	98.7	24.7	10.8	6.8
2004	210.1	156.8	76.1	46.1	35.8	24.5	5.6	3.8
2005	47.5	530.8	211.5	81.5	44.9	27.0	19.1	1.7
2006	16.2	100.4	97.4	14.5	4.1	7.8	3.0	1.6
2007	35.1	103.9	236.3	162.5	34.7	6.5	6.0	3.8
2008	65.7	41.8	66.7	54.1	52.3	6.3	2.1	3.1
2009	117.7	200.9	55.3	54.6	31.9	8.9	1.6	1.3
2010	17.7	151.4	130.6	45.2	30.2	23.7	9.7	1.1
2011	8.0	31.0	130.0	117.7	13.4	15.2	13.8	3.8
2012	1.1	60.6	124.2	185.1	82.8	16.5	19.3	6.7
2013	9.1	77.5	249.8	179.2	92.1	19.8	1.6	0.9
2014	1.6	80.0	176.4	440.2	202.7	137.1	1.8	1.1
2015	2.3	69.0	489.9	364.3	439.1	136.5	21.7	5.8
2016	19.5	80.5	219.1	271.3	189.1	61.5	28.9	5.0
2017	7.8	73.8	111.3	200.3	232.4	81.3	29.0	5.1

Table 15b. Fall spawner (FS) Atlantic Herring fixed gear age-disaggregated mean catch-per-unit-effort values (number per net-haul) from the Middle region of NAFO Div. 4T.

	Age (years)							
Year	4	5	6	7	8	9	10	11
1986	133.4	110.7	204.8	93.4	36.2	16.7	2.2	3.8
1987	80.2	151.2	131.5	262.7	24.8	22.9	25.6	1.6
1988	69.2	63.1	55.4	25.4	26.6	19.8	0.3	0.0
1989	23.8	44.1	39.3	21.4	13.2	11.7	5.3	4.3
1990	47.4	34.3	37.2	65.5	13.5	9.4	7.3	1.6
1991	156.3	42.3	34.8	45.8	54.0	33.3	15.3	34.9
1992	104.6	253.8	34.6	14.4	8.2	5.9	2.9	6.7
1993	9.7	182.9	229.5	39.2	16.5	11.5	13.0	19.8
1994	14.3	23.1	116.0	156.1	19.1	6.0	7.4	12.5
1995	2.7	126.8	43.2	155.2	134.9	17.3	3.1	54.1
1996	61.8	38.1	219.0	18.9	56.9	65.3	15.1	15.7
1997	126.5	287.3	51.8	107.9	20.5	24.5	26.8	16.7
1998	54.0	45.4	92.2	18.6	34.7	6.3	13.7	23.6
1999	119.5	158.8	62.8	39.7	16.0	35.1	3.4	16.4
2000	202.5	387.2	142.7	46.1	25.5	7.6	6.8	3.0
2001	108.1	266.1	188.7	57.2	12.3	4.1	0.0	5.7
2002	146.9	131.2	116.0	112.2	20.2	2.8	2.4	3.5
2003	85.4	179.1	83.8	56.5	56.6	12.7	1.7	2.4
2004	127.2	230.8	162.9	116.2	103.1	60.5	21.0	4.0
2005	54.3	334.8	271.2	81.5	70.3	48.4	20.6	1.5
2006	47.7	217.6	387.7	143.2	73.0	54.8	43.4	14.7
2007	51.4	147.1	408.0	420.9	160.3	64.7	31.4	19.5
2008	320.3	67.7	118.2	140.1	224.0	40.4	38.2	8.7
2009	154.8	275.0	63.7	140.7	67.7	23.5	10.0	4.6
2010	12.8	96.4	142.9	41.6	36.4	20.8	9.7	5.4
2011	4.4	22.9	133.3	171.2	32.6	24.5	23.0	6.9
2012	2.3	30.9	138.4	185.8	129.9	14.8	8.4	7.1
2013	17.0	32.4	202.8	303.2	185.8	71.7	5.8	1.2
2014	0.0	48.0	30.1	102.9	113.4	21.4	10.5	0.0
2015	7.0	44.7	427.5	190.2	322.7	126.9	45.1	0.0
2016	18.1	79.8	511.7	420.0	234.3	104.7	37.0	0.0
2017	2.2	17.4	60.1	111.9	137.4	78.1	10.7	0.4

Table 15c. Fall spawner (FS) Atlantic Herring fixed gear age-disaggregated mean catch-per-unit-effort values (number per net-haul) from the South region of NAFO Div. 4T.

	Age (years)							
Year	4	5	6	7	8	9	10	11
1986	476.4	133.9	281.3	78.1	38.1	11.4	2.5	3.8
1987	129.7	149.3	71.5	164.2	72.4	50.0	21.6	15.4
1988	59.7	228.5	132.2	65.0	90.8	41.5	13.5	9.1
1989	106.3	162.9	653.6	329.8	141.5	191.9	48.8	23.5
1990	109.4	108.7	124.6	581.8	159.2	69.8	74.2	39.9
1991	352.2	118.7	95.1	85.3	277.0	97.0	59.7	84.6
1992	99.2	554.3	80.3	46.9	112.2	248.0	92.2	97.7
1993	29.9	318.7	385.3	97.0	40.0	57.9	47.9	110.9
1994	34.9	7.4	238.4	329.0	44.6	58.7	125.3	208.1
1995	4.0	93.0	32.1	143.1	122.0	32.4	35.7	86.3
1996	44.0	26.4	172.8	62.0	144.5	137.9	35.2	107.0
1997	123.7	738.4	66.3	280.9	48.7	101.6	95.5	85.0
1998	120.0	56.4	200.7	50.6	113.6	22.4	43.8	53.9
1999	149.1	540.0	73.3	163.0	31.9	52.1	19.3	26.8
2000	118.2	461.6	275.5	44.9	53.8	10.4	16.7	10.5
2001	37.8	467.8	437.6	281.6	41.4	33.1	9.0	17.1
2002	379.0	160.8	363.5	302.1	90.9	22.9	19.8	11.7
2003	99.7	823.0	127.9	268.5	170.7	33.4	5.1	7.5
2004	111.3	257.1	565.7	111.8	102.8	50.2	13.8	7.2
2005	9.8	286.5	473.5	738.8	140.4	143.1	40.2	8.9
2006	75.6	207.0	542.8	558.4	414.9	136.9	72.8	20.3
2007	7.9	355.6	520.1	952.7	591.7	190.4	113.1	36.1
2008	127.3	46.5	172.6	316.2	393.4	180.2	95.6	73.9
2009	53.9	464.6	232.7	463.7	153.3	81.3	117.9	58.7
2010	47.9	201.6	739.3	192.3	239.5	156.8	87.9	56.2
2011	7.3	175.3	174.1	588.5	188.6	93.8	54.7	97.4
2012	0.3	12.9	138.7	156.9	167.3	17.8	5.1	17.2
2013	9.0	27.0	242.0	516.7	192.0	91.0	2.9	2.9
2014	5.4	88.9	71.2	280.7	498.8	109.7	53.2	1.8
2015	0.0	55.7	268.8	148.4	420.5	113.1	64.8	7.0
2016	2.4	26.5	82.5	45.2	33.3	15.1	4.4	0.3
2017	9.1	7.4	91.6	186.1	66.0	24.6	5.2	0.5

Table 16. Spring spawner (A; upper table) and fall spawner (B; lower table) Atlantic Herring catch-at-age (t) from the fishery-independent acoustic survey in NAFO area 4Tmno.

A) Spring spawner

	Age (years)								
Year	2	3	4	5	6	7	8	9	10
1994	2,548	231,972	100,087	109,649	104,274	28,059	6,389	7,213	1,020
1995	47,487	7,754	77,137	21,658	25,176	21,107	5,123	777	74
1996	329,625	141,573	16,362	184,895	48,108	28,881	30,565	7,998	3,685
1997	152,575	77,940	79,051	11,238	84,978	5,522	12,953	14,800	2,648
1998	156,808	30,320	31,992	19,716	5,616	38,121	6,423	5,438	3,585
1999	242,560	109,082	56,090	19,836	6,278	3,667	18,015	2,748	1,380
2000	22,189	31,065	25,435	9,748	8,553	1,647	10,009	2,155	448
2001	90,891	14,967	8,107	5,733	3,180	1,844	2,784	500	440
2002	93,282	27,633	8,130	11,464	3,494	5,132	1,684	271	123
2003	246,067	41,734	57,654	26,041	17,349	5,255	1,878	4,847	3,520
2004	234,180	62,439	9,350	10,956	556	0	0	0	0
2005	141,882	144,933	34,193	1,674	3,269	746	292	0	0
2006	100,680	39,313	24,601	26,314	2,909	885	572	257	338
2007	49,662	39,444	8,005	12,402	8,158	1,172	1,456	0	0
2008	71,227	25,129	7,599	9,225	5,760	3,091	2,294	532	0
2009	47,329	39,979	16,153	7,849	2,438	1,224	1,773	0	0
2010	37,884	67,713	73,493	8,786	8,469	8,824	2,433	1,517	0
2011	20,724	39,960	14,878	16,259	10,973	4,135	106	3,538	104
2012	14,686	114,169	29,857	9,938	7,663	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

B) Fall spawner

	Age (years)								
Year	2	3	4	5	6	7	8	9	10
1994	2,157	4,442	201,387	61,956	33,090	17,255	2,309	0	12
1995	13,032	23,475	12,114	53,149	11,242	20,081	27,312	2,836	1,218
1996	276,748	252,685	203,250	33,855	120,199	32,473	27,034	11,945	3,000
1997	234,294	383,392	238,795	115,422	16,301	45,770	15,375	14,487	6,536
1998	73,765	198,123	111,466	55,623	39,509	9,352	27,410	3,700	6,706
1999	60,387	324,854	231,521	103,094	69,001	82,058	34,684	30,955	11,048
2000	69,467	152,924	237,946	197,059	83,604	30,623	32,789	22,338	9,798
2001	130,503	430,404	119,003	55,365	38,311	11,522	14,404	10,217	3,448
2002	265,715	65,241	75,331	58,918	69,961	46,733	11,739	2,050	4,002
2003	57,267	418,553	236,960	221,303	85,138	135,135	133,900	56,418	21,343
2004	61,447	92,757	104,324	41,493	36,813	47,659	14,412	17,158	5,750
2005	41,546	148,749	357,945	187,039	69,267	14,900	5,769	5,923	2,600
2006	650,349	192,892	96,550	134,037	187,250	88,038	40,814	38,326	13,275
2007	146,879	306,699	71,436	34,344	42,814	34,105	3,974	1,952	1,419
2008	163,627	155,365	98,998	20,089	11,055	10,437	7,404	2,007	467
2009	102,976	169,918	96,964	50,109	6,429	2,552	1,186	421	160
2010	36,518	153,077	248,399	270,706	132,936	6,744	7,318	1,353	213
2011	29,046	42,618	88,110	68,688	51,739	22,620	4,808	2,908	1,077
2012	306	289,119	159,440	122,634	69,157	29,580	3,985	4,268	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

Table 17. Mean standardized age-disaggregated annual catch per unit effort (number per hour) of Atlantic Herring derived from the experimental gillnets in the fall fishery in North, Middle, and South regions of NAFO Div. 4T. A dash indicates no data were available for that region and year.

		Age (years)								
Region	Year	2	3	4	5	6	7	8	9	10
North	2002	0.0	5.7	34.5	28.5	15.2	9.4	1.4	0.4	0.3
North	2003	0.0	6.2	11.0	6.1	4.6	3.5	2.9	0.7	0.6
North	2004	0.1	1.5	20.6	7.5	2.6	1.2	1.2	1.0	0.2
North	2005	0.0	0.0	8.8	17.1	5.1	2.3	1.2	0.8	0.4
North	2006	0.0	0.6	13.9	36.5	25.2	5.2	1.2	1.8	0.6
North	2007	-	-	-	-	-	-	-	-	-
North	2008	0.4	16.1	108.0	20.0	13.0	16.2	11.2	2.1	1.2
North	2009	0.6	18.0	78.1	63.7	12.0	11.0	7.4	2.5	0.5
North	2010	0.0	8.6	41.2	69.7	32.7	4.0	3.1	2.0	0.9
North	2011	0.0	0.0	13.9	30.1	35.2	18.8	3.8	2.5	1.7
North	2012	-	-	-	-	-	-	-	-	-
North	2013	0.0	0.9	32.8	31.5	65.4	48.1	24.0	6.0	1.1
North	2014	-	-	-	-	-	-	-	-	-
North	2015	0.0	0.6	10.7	9.9	49.4	23.3	26.6	11.7	2.3
North	2016	0.0	0.9	10.4	16.6	41.3	41.5	24.8	8.0	3.0
North	2017	0.0	0.3	5.7	21.3	12.1	15.3	10.9	3.8	1.0
Middle	2002	-	-	-	-	-	-	-	-	-
Middle	2003	1.0	26.1	70.7	53.2	21.0	22.8	15.3	2.9	1.0
Middle	2004	0.0	11.2	66.8	44.3	16.6	7.2	6.6	3.5	1.0
Middle	2005	0.4	8.7	45.9	67.1	34.8	12.0	7.3	5.9	2.1
Middle	2006	0.1	3.9	20.7	39.9	53.2	23.1	9.8	6.2	5.0
Middle	2007	0.2	10.9	8.5	13.9	20.8	21.7	8.5	2.9	2.0
Middle	2008	1.0	15.6	100.1	15.4	13.1	12.9	12.7	3.2	1.8
Middle	2009	0.1	45.9	155.8	140.4	24.6	28.2	16.1	5.8	2.0
Middle	2010	0.0	0.1	1.4	3.9	5.7	1.2	1.5	1.9	0.9
Middle	2011	0.0	0.8	18.5	25.3	44.5	41.7	9.2	7.0	5.6
Middle	2012	0.5	10.9	7.6	24.7	31.2	37.5	24.1	2.1	1.1
Middle	2013	0.3	5.5	82.8	18.4	56.2	49.6	30.9	10.6	0.6
Middle	2014	0.0	0.0	0.7	16.3	8.5	17.8	12.8	3.8	0.8
Middle	2015	0.3	2.5	14.2	15.7	101.7	23.7	28.8	11.1	3.1
Middle	2016	0.0	2.3	41.0	15.6	70.9	42.9	23.4	10.1	2.9
Middle	2017	0.0	0.2	1.6	8.4	9.2	23.2	1.3	0.0	0.0
South	2002	0.0	10.0	50.0	7.6	9.2	6.7	2.4	0.4	0.1
South	2003	0.6	13.3	27.9	67.7	11.6	16.7	11.7	3.5	0.6
South	2004	0.1	7.5	26.9	18.4	25.1	4.9	5.1	2.3	0.7
South	2005	0.1	7.3	9.0	15.8	15.3	20.1	3.5	3.7	1.1
South	2006	0.0	1.7	31.1	19.1	37.3	41.9	24.2	7.2	3.9
South	2007	1.2	45.3	8.0	17.1	13.4	19.3	16.1	6.3	1.8
South	2008	0.2	9.6	49.1	4.0	10.5	9.1	10.1	6.0	2.9
South	2009	0.4	10.9	18.4	43.2	6.7	10.5	4.4	2.9	1.5
South	2010	0.1	0.4	11.1	4.3	9.1	1.2	2.1	1.1	0.9
South	2011	0.0	0.6	21.3	40.2	16.5	24.8	2.2	2.6	1.2
South	2012	0.1	3.2	2.0	5.6	9.3	3.8	4.2	0.6	0.2
South	2013	0.0	0.3	10.3	5.3	17.1	19.3	7.1	2.6	0.1
South	2014	0.0	0.0	2.2	26.4	13.2	29.0	25.5	5.4	2.2
South	2015	0.2	1.2	5.5	25.7	72.8	27.1	36.6	21.5	5.4
South	2016	0.1	2.5	44.9	29.6	119.6	49.0	58.1	13.6	3.0
South	2017	0.0	1.1	34.5	41.9	47.4	46.6	11.1	5.1	0.2

Table 18a. Relative selectivity-at-age (proportion) of Atlantic Herring in the NAFO Div. 4T commercial fixed gear fishery for the 2⅝ inches gillnet mesh as calculated from the experimental gillnet data.

Mesh size (inches)	Year	Age (years)								
		2	3	4	5	6	7	8	9	10
2⅝	1986	0.190	0.491	0.647	0.851	0.956	0.933	0.866	0.818	0.585
2⅝	1987	0.107	0.583	0.653	0.848	0.945	0.936	0.863	0.802	0.764
2⅝	1988	0.121	0.490	0.719	0.870	0.942	0.932	0.889	0.823	0.785
2⅝	1989	0.120	0.569	0.724	0.927	0.969	0.944	0.866	0.822	0.745
2⅝	1990	0.294	0.332	0.656	0.854	0.939	0.921	0.846	0.758	0.731
2⅝	1991	0.133	0.432	0.554	0.777	0.933	0.938	0.899	0.815	0.735
2⅝	1992	0.139	0.310	0.489	0.730	0.906	0.933	0.871	0.834	0.759
2⅝	1993	0.146	0.217	0.521	0.677	0.856	0.927	0.886	0.841	0.798
2⅝	1994	0.121	0.121	0.387	0.653	0.816	0.932	0.957	0.880	0.833
2⅝	1995	0.159	0.465	0.384	0.554	0.721	0.867	0.946	0.897	0.831
2⅝	1996	0.165	0.219	0.434	0.637	0.718	0.847	0.918	0.944	0.851
2⅝	1997	0.048	0.145	0.330	0.580	0.779	0.868	0.955	0.949	0.932
2⅝	1998	0.021	0.172	0.382	0.549	0.743	0.883	0.937	0.945	0.925
2⅝	1999	0.365	0.092	0.337	0.563	0.656	0.829	0.924	0.947	0.918
2⅝	2000	0.011	0.100	0.344	0.524	0.714	0.818	0.925	0.932	0.947
2⅝	2001	0.006	0.075	0.328	0.516	0.670	0.814	0.909	0.967	0.935
2⅝	2002	0.002	0.152	0.310	0.483	0.621	0.762	0.880	0.953	0.957
2⅝	2003	0.057	0.231	0.310	0.462	0.621	0.757	0.851	0.922	0.931
2⅝	2004	0.008	0.109	0.300	0.454	0.609	0.729	0.861	0.920	0.946
2⅝	2005	0.001	0.065	0.259	0.458	0.568	0.671	0.820	0.889	0.922
2⅝	2006	0.700	0.137	0.276	0.430	0.591	0.690	0.799	0.909	0.933
2⅝	2007	0.030	0.057	0.286	0.412	0.572	0.702	0.778	0.849	0.919
2⅝	2008	0.011	0.041	0.203	0.409	0.558	0.683	0.772	0.818	0.895
2⅝	2009	0.027	0.089	0.233	0.343	0.542	0.680	0.781	0.851	0.874
2⅝	2010	0.001	0.032	0.163	0.348	0.413	0.616	0.681	0.765	0.833
2⅝	2011	0.625	0.036	0.116	0.285	0.449	0.489	0.694	0.752	0.829
2⅝	2012	0.000	0.063	0.102	0.230	0.370	0.516	0.569	0.734	0.838
2⅝	2013	0.927	0.042	0.108	0.271	0.377	0.477	0.580	0.633	0.774
2⅝	2014	0.970	0.059	0.198	0.282	0.382	0.427	0.508	0.600	0.650
2⅝	2015	0.009	0.076	0.162	0.326	0.363	0.490	0.544	0.634	0.692
2⅝	2016	0.003	0.092	0.215	0.358	0.468	0.555	0.613	0.697	0.756
2⅝	2017	0.794	0.075	0.260	0.340	0.470	0.560	0.634	0.697	0.807

Table 18b. Relative selectivity-at-age (proportion) of Atlantic Herring in the NAFO Div. 4T commercial fixed gear fishery for the 2¾" inches gillnet mesh as calculated from the experimental gillnet data.

Mesh size		Age (years)								
(inches)	Year	2	3	4	5	6	7	8	9	10
2¾	1986	0.080	0.277	0.404	0.639	0.828	0.938	0.891	0.917	0.842
2¾	1987	0.016	0.351	0.411	0.623	0.826	0.919	0.955	0.943	0.928
2¾	1988	0.046	0.281	0.479	0.655	0.823	0.910	0.965	0.964	0.945
2¾	1989	0.041	0.332	0.493	0.768	0.867	0.948	0.958	0.946	0.922
2¾	1990	0.138	0.174	0.418	0.642	0.882	0.956	0.962	0.936	0.928
2¾	1991	0.066	0.232	0.322	0.541	0.786	0.919	0.963	0.951	0.922
2¾	1992	0.078	0.146	0.271	0.484	0.720	0.879	0.967	0.964	0.937
2¾	1993	0.090	0.094	0.300	0.429	0.632	0.789	0.902	0.957	0.931
2¾	1994	0.046	0.046	0.199	0.406	0.576	0.754	0.904	0.963	0.961
2¾	1995	0.115	0.249	0.197	0.321	0.480	0.666	0.801	0.907	0.945
2¾	1996	0.127	0.095	0.234	0.393	0.473	0.629	0.759	0.875	0.956
2¾	1997	0.016	0.059	0.164	0.347	0.539	0.649	0.831	0.870	0.933
2¾	1998	0.006	0.075	0.196	0.320	0.498	0.684	0.787	0.891	0.946
2¾	1999	0.640	0.034	0.168	0.330	0.416	0.604	0.753	0.840	0.925
2¾	2000	0.003	0.039	0.172	0.299	0.467	0.592	0.754	0.801	0.907
2¾	2001	0.002	0.028	0.162	0.292	0.423	0.581	0.713	0.841	0.889
2¾	2002	0.000	0.067	0.151	0.268	0.380	0.520	0.669	0.806	0.835
2¾	2003	0.019	0.112	0.152	0.253	0.380	0.513	0.632	0.749	0.839
2¾	2004	0.002	0.043	0.145	0.247	0.371	0.489	0.646	0.746	0.842
2¾	2005	0.000	0.024	0.123	0.250	0.337	0.428	0.597	0.697	0.764
2¾	2006	0.932	0.055	0.132	0.231	0.358	0.450	0.568	0.733	0.788
2¾	2007	0.010	0.020	0.137	0.217	0.341	0.460	0.543	0.644	0.756
2¾	2008	0.004	0.015	0.090	0.218	0.331	0.443	0.536	0.591	0.701
2¾	2009	0.009	0.035	0.107	0.173	0.321	0.444	0.548	0.648	0.671
2¾	2010	0.000	0.010	0.071	0.176	0.219	0.387	0.452	0.537	0.618
2¾	2011	0.824	0.022	0.047	0.141	0.247	0.276	0.467	0.526	0.619
2¾	2012	0.000	0.025	0.039	0.104	0.191	0.295	0.337	0.501	0.621
2¾	2013	0.997	0.014	0.044	0.129	0.195	0.264	0.342	0.388	0.537
2¾	2014	0.949	0.021	0.085	0.137	0.197	0.228	0.287	0.360	0.404
2¾	2015	0.002	0.028	0.067	0.162	0.184	0.276	0.315	0.391	0.446
2¾	2016	0.000	0.035	0.098	0.181	0.259	0.327	0.374	0.450	0.512
2¾	2017	0.936	0.027	0.129	0.172	0.263	0.331	0.393	0.453	0.586

Table 19. Multi-species trawl survey abundance index (median number per tow) of fall spawner Atlantic Herring from the southern Gulf of St. Lawrence, NAFO Div. 4T. The values represent the median from the Monte Carlo Markov Chain (MCMC) posterior distributions for each year and age.

	Age (years)										
Year	1	2	3	4	5	6	7	8	9	10	11+
1994	1.25	1.16	1.78	6.40	2.48	2.02	2.03	0.43	0.46	0.50	0.71
1995	1.65	1.63	5.50	2.78	9.18	2.08	1.93	1.55	0.29	0.19	0.35
1996	4.13	0.86	0.27	0.76	0.21	0.74	0.27	0.32	0.19	0.05	0.10
1997	5.39	8.28	2.57	1.43	3.20	1.03	1.97	0.53	0.55	0.27	0.33
1998	8.42	2.20	0.55	1.82	0.58	0.93	0.31	0.56	0.11	0.14	0.19
1999	32.97	15.76	3.87	3.46	2.36	0.67	0.76	0.32	0.27	0.14	0.18
2000	10.54	5.99	3.62	5.61	3.19	1.17	0.25	0.48	0.16	0.14	0.03
2001	4.73	19.59	11.36	4.21	3.19	1.95	0.76	0.28	0.19	0.06	0.16
2002	17.93	20.82	8.38	10.57	2.83	2.12	1.56	0.44	0.30	0.09	0.08
2003	7.98	1.73	3.36	9.45	11.13	3.57	2.96	2.08	0.33	0.11	0.20
2004	1.94	1.46	3.68	7.08	4.69	3.85	2.44	1.84	1.02	0.20	0.29
2005	2.92	1.37	3.99	13.14	14.02	5.27	2.00	1.62	0.70	0.66	0.21
2006	12.51	4.22	1.29	3.53	2.36	3.35	1.60	1.03	0.11	0.06	0.06
2007	10.18	30.00	40.16	5.74	6.88	5.71	6.94	3.27	2.01	0.54	0.60
2008	27.43	9.05	9.63	9.18	1.34	2.62	3.50	2.59	1.91	0.86	1.43
2009	1.15	9.80	14.13	10.64	7.69	1.91	1.66	0.83	0.93	0.04	0.26
2010	2.10	24.03	34.28	65.87	42.91	36.44	4.12	3.79	3.22	2.37	1.14
2011	6.84	29.50	4.41	18.39	19.16	11.17	6.82	2.45	0.66	0.73	0.34
2012	1.76	17.08	128.28	40.77	60.70	43.83	21.83	10.16	2.11	0.56	0.49
2013	1.24	2.01	3.57	15.27	5.56	6.13	4.88	2.73	0.23	0.07	0.16
2014	41.57	15.28	2.19	2.98	13.12	2.62	1.81	1.47	0.01	0.01	0.03
2015	5.56	10.49	16.97	8.35	9.31	16.28	4.67	6.15	2.55	0.56	0.16
2016	0.19	2.77	5.68	9.99	2.50	4.47	2.74	0.63	0.49	0.13	0.10
2017	35.83	2.92	0.81	2.92	2.65	1.15	1.45	0.34	0.09	0.04	0.03

Table 20. Maximum likelihood estimates (MLEs) of beginning of year spring spawner Atlantic Herring biomass (t) for NAFO Div. 4T. Shading indicates values that are not directly estimated by the model. These values are calculated using the average of the five most recent estimates of recruitment rate (recruits/SSB). Note that MLEs may differ slightly from the MCMC medians reported in the text.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	6,687	5,110	35,034	6,975	7,016	3,328	2,017	1,245	7,516	2,309	65,441
1979	14,357	5,281	3,791	21,214	5,203	4,698	2,302	1,523	750	6,090	45,570
1980	7,929	9,031	3,312	2,346	9,148	3,408	1,857	1,269	796	671	22,806
1981	30,958	5,639	5,129	1,618	1,401	3,279	483	260	302	564	13,037
1982	37,609	29,085	3,066	3,469	1,170	687	2,001	133	35	255	10,816
1983	35,992	36,267	22,714	1,980	2,720	941	355	1,637	7	0	30,355
1984	31,629	35,908	32,710	15,055	1,278	2,415	811	264	1,328	3	53,863
1985	15,944	41,718	33,869	29,349	11,790	1,012	2,164	636	271	1,052	80,142
1986	11,170	17,641	44,990	30,010	24,315	9,913	700	1,679	497	1,034	113,139
1987	19,570	11,444	16,645	36,576	23,879	17,686	7,112	388	1,213	1,035	104,535
1988	13,882	16,887	10,666	13,747	26,886	16,707	11,201	3,915	44	1,674	84,841
1989	26,007	17,882	15,321	8,228	10,069	17,756	10,041	6,441	2,215	585	70,656
1990	89,884	28,537	19,439	11,336	6,368	6,596	10,128	5,883	3,820	1,604	65,176
1991	34,305	70,625	25,595	14,528	8,044	4,333	4,458	5,389	3,365	3,873	69,586
1992	16,711	28,424	56,286	19,387	8,840	4,214	2,597	2,538	2,845	4,268	100,974
1993	51,803	17,399	24,789	42,633	13,915	5,384	2,568	1,630	1,337	4,309	96,565
1994	9,628	58,231	16,552	20,638	29,383	7,706	3,070	1,401	663	2,786	82,199
1995	11,234	8,184	58,962	13,873	13,651	15,996	4,441	1,510	727	2,011	111,171
1996	11,629	14,500	7,415	48,242	9,717	7,864	6,584	1,966	597	779	83,164
1997	12,892	12,561	14,733	6,364	33,066	6,199	3,694	3,238	854	576	68,723
1998	10,515	11,952	11,998	11,315	4,473	21,054	3,905	1,985	1,506	773	57,009
1999	14,966	11,206	11,092	9,393	7,131	3,610	11,941	2,611	1,049	1,054	47,880
2000	8,362	15,118	10,637	8,639	6,481	4,102	2,577	6,267	1,383	894	40,978
2001	8,931	7,441	13,957	7,478	4,784	2,683	1,933	1,130	2,555	724	35,244
2002	2,612	8,533	6,206	10,296	4,093	2,227	1,108	855	586	705	26,077
2003	4,321	2,782	7,409	4,438	5,934	2,175	1,092	460	442	501	22,451
2004	2,584	4,919	2,599	4,947	2,050	2,829	1,053	400	154	406	14,438
2005	4,023	2,706	4,743	1,912	1,910	790	724	214	81	122	10,496
2006	3,349	3,607	2,348	3,412	1,216	597	175	169	41	86	8,044
2007	2,845	3,544	3,247	1,847	2,037	653	371	84	50	76	8,365
2008	3,728	2,365	2,912	2,295	1,132	1,004	125	101	24	22	7,616
2009	3,325	2,889	1,986	2,040	1,257	664	479	29	52	18	6,525
2010	3,296	2,999	2,317	1,551	1,391	576	450	341	4	12	6,642
2011	1,826	2,991	2,499	1,802	1,116	845	260	315	202	9	7,048
2012	1,517	2,306	2,728	2,143	1,278	743	393	100	79	42	7,505
2013	2,505	1,888	2,427	2,443	1,925	962	498	264	35	45	8,600
2014	1,704	2,620	2,001	2,079	1,876	1,422	505	158	74	43	8,159
2015	6,664	1,589	2,490	1,701	1,733	1,417	1,018	206	32	21	8,618
2016	3,269	6,382	1,478	2,144	1,423	1,231	848	681	61	12	7,879
2017	3,983	3,478	5,918	1,353	1,876	1,083	767	563	497	36	12,094
2018	3,642	3,673	3,058	5,285	1,122	1,320	670	448	443	458	12,804

Table 21. Maximum likelihood estimates (MLEs) of beginning of year spring spawner Atlantic Herring abundance (number in thousands) for NAFO Div. 4T. Shading indicates values that are not directly estimated by the model. These values are calculated using the average of the five most recent estimates of recruitment rate (recruits/SSB). Note that MLEs may differ slightly from the MCMC medians reported in the text.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	59,170	35,988	164,577	30,126	27,365	11,498	6,794	3,745	20,517	6,243	270,864
1979	81,125	34,988	20,762	90,219	20,976	16,347	7,656	4,682	2,225	16,704	179,571
1980	53,117	53,237	17,974	10,418	35,062	13,079	6,410	4,234	2,254	1,899	91,331
1981	212,214	33,310	25,833	7,099	4,722	10,730	1,690	847	953	1,441	53,316
1982	299,199	173,024	15,682	13,939	4,061	1,832	5,736	398	92	649	42,389
1983	270,946	242,652	116,993	8,718	10,473	2,936	1,150	4,264	20	0	144,554
1984	333,673	220,473	179,221	68,793	4,813	8,148	2,278	878	3,411	9	267,549
1985	133,220	272,594	175,806	132,060	46,929	3,310	6,617	1,788	676	2,796	369,982
1986	89,066	108,014	214,604	130,287	92,960	33,212	2,088	5,327	1,435	2,514	482,427
1987	130,069	69,126	82,394	154,559	88,655	60,131	21,923	1,168	3,880	2,655	415,366
1988	159,156	105,149	53,699	59,248	99,044	55,793	34,206	10,981	128	4,574	317,673
1989	213,017	124,132	80,980	36,900	37,639	57,404	30,909	18,455	5,968	1,629	269,885
1990	514,505	174,019	95,384	47,775	24,378	22,197	31,522	17,629	10,724	4,556	254,165
1991	241,786	416,445	135,097	64,866	31,603	15,621	14,541	17,044	10,131	10,624	299,526
1992	161,634	196,309	326,998	97,286	38,034	16,537	9,356	8,406	9,166	12,769	518,552
1993	557,561	131,558	156,238	234,018	66,140	22,097	9,795	5,825	4,420	13,763	512,296
1994	67,911	453,691	105,359	116,928	150,412	35,276	12,279	4,988	2,372	8,954	436,567
1995	134,922	55,554	365,926	78,952	70,460	74,340	18,584	5,629	2,410	6,679	622,980
1996	115,686	109,184	43,870	272,154	49,719	37,347	28,149	7,991	2,101	2,633	443,963
1997	110,918	94,368	86,361	33,571	169,411	29,286	16,043	12,866	3,439	1,908	352,884
1998	109,945	90,432	75,896	62,685	22,700	97,804	16,908	7,976	5,720	2,759	292,448
1999	141,419	89,746	72,612	53,421	35,779	16,352	51,703	10,354	4,033	3,840	248,094
2000	67,173	114,104	69,358	49,137	32,531	18,702	10,519	25,318	5,277	3,270	214,111
2001	84,398	53,799	88,551	42,656	24,586	12,240	8,228	4,359	9,871	2,702	193,193
2002	28,595	65,255	39,870	57,949	20,948	10,311	4,602	3,336	2,152	2,552	141,719
2003	51,628	22,739	48,337	25,353	30,336	10,146	4,718	1,819	1,662	1,786	124,157
2004	26,649	42,081	17,770	29,117	10,575	13,117	4,555	1,643	597	1,477	78,852
2005	36,099	21,359	32,258	11,813	10,068	3,727	3,010	870	309	430	62,486
2006	34,641	27,917	15,742	20,824	6,559	2,811	744	675	152	336	47,843
2007	26,458	28,148	21,397	11,248	11,237	3,334	1,703	333	203	304	49,759
2008	30,214	18,373	19,022	13,530	6,204	5,005	580	454	86	88	44,970
2009	30,220	21,541	13,181	12,356	7,203	3,530	2,277	117	241	71	38,975
2010	31,850	24,323	15,760	9,632	7,763	3,034	2,184	1,534	16	52	39,975
2011	27,658	25,972	19,417	11,059	6,656	4,317	1,233	1,393	927	40	45,041
2012	22,488	22,077	20,506	15,189	7,643	4,200	2,032	487	353	199	50,609
2013	28,297	18,396	17,572	16,018	11,823	5,495	2,683	1,350	169	193	55,302
2014	18,595	23,055	14,792	13,363	11,238	8,005	2,607	790	347	201	51,343
2015	69,241	14,783	18,703	11,451	10,253	7,914	5,438	982	152	89	54,980
2016	36,176	56,181	11,597	15,033	8,990	7,189	4,629	3,559	283	59	51,340
2017	38,208	29,254	45,525	9,346	11,641	6,361	4,298	3,060	2,531	170	82,933
2018	34,932	30,897	23,519	36,512	6,963	7,749	3,752	2,435	2,257	2,164	85,350

Table 22. Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) by age of spring spawner Atlantic Herring from NAFO Div. 4T. No estimates (na) are available for the 2014 and 2015 year-classes. F6-8 is the abundance-weighted average F for ages 6 to 8 years.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	F6-8
1978	0.325	0.350	0.401	0.162	0.315	0.207	0.172	0.320	0.271	0.271	0.275
1979	0.221	0.466	0.490	0.745	0.272	0.736	0.392	0.531	2.099	2.099	0.584
1980	0.267	0.523	0.729	0.591	0.984	1.846	1.824	1.291	0.859	0.859	1.613
1981	0.004	0.553	0.417	0.359	0.747	0.426	1.246	2.016	1.105	1.105	0.741
1982	0.009	0.191	0.387	0.086	0.124	0.265	0.097	2.805	10.145	10.145	0.188
1983	0.006	0.103	0.331	0.394	0.051	0.054	0.070	0.023	0.612	0.612	0.054
1984	0.002	0.026	0.105	0.182	0.174	0.008	0.042	0.062	0.001	0.001	0.125
1985	0.010	0.039	0.100	0.151	0.146	0.260	0.017	0.020	0.123	0.123	0.169
1986	0.053	0.071	0.128	0.185	0.236	0.215	0.381	0.117	0.197	0.197	0.262
1987	0.013	0.053	0.130	0.245	0.263	0.364	0.491	2.014	0.157	0.157	0.377
1988	0.049	0.061	0.175	0.254	0.345	0.391	0.417	0.410	0.860	0.860	0.393
1989	0.002	0.063	0.328	0.215	0.328	0.399	0.361	0.343	0.311	0.311	0.356
1990	0.011	0.053	0.186	0.213	0.245	0.223	0.415	0.354	0.163	0.163	0.266
1991	0.008	0.042	0.128	0.334	0.448	0.313	0.348	0.420	0.286	0.286	0.398
1992	0.006	0.028	0.135	0.186	0.343	0.324	0.274	0.443	0.266	0.266	0.333
1993	0.006	0.022	0.090	0.242	0.429	0.388	0.475	0.699	0.508	0.508	0.414
1994	0.001	0.015	0.089	0.307	0.505	0.441	0.580	0.527	0.328	0.328	0.512
1995	0.012	0.036	0.096	0.262	0.435	0.771	0.644	0.785	1.039	1.039	0.509
1996	0.004	0.034	0.068	0.274	0.329	0.645	0.583	0.643	0.709	0.709	0.593
1997	0.004	0.018	0.120	0.191	0.349	0.349	0.499	0.611	0.462	0.462	0.435
1998	0.003	0.019	0.151	0.361	0.128	0.437	0.290	0.482	0.592	0.592	0.267
1999	0.015	0.058	0.191	0.296	0.449	0.241	0.514	0.474	0.679	0.679	0.393
2000	0.022	0.054	0.286	0.492	0.777	0.621	0.681	0.742	0.952	0.952	0.710
2001	0.057	0.100	0.224	0.511	0.669	0.778	0.703	0.506	1.395	1.395	0.700
2002	0.029	0.100	0.253	0.447	0.525	0.582	0.728	0.497	0.768	0.768	0.587
2003	0.004	0.047	0.307	0.674	0.638	0.601	0.855	0.914	0.648	0.648	0.693
2004	0.021	0.066	0.208	0.862	0.843	1.272	1.455	1.471	1.374	1.374	1.125
2005	0.057	0.105	0.238	0.388	1.076	1.412	1.296	1.547	0.586	0.586	1.179
2006	0.008	0.066	0.136	0.417	0.477	0.301	0.605	1.000	0.272	0.272	0.416
2007	0.165	0.192	0.258	0.395	0.609	1.548	1.121	1.153	1.552	1.552	0.965
2008	0.138	0.132	0.231	0.430	0.364	0.588	1.404	0.433	0.697	0.697	0.609
2009	0.017	0.112	0.114	0.265	0.665	0.280	0.195	1.812	1.589	1.589	0.436
2010	0.004	0.025	0.154	0.170	0.387	0.700	0.250	0.304	0.334	0.334	0.449
2011	0.025	0.036	0.046	0.169	0.260	0.553	0.728	1.172	1.383	1.383	0.434
2012	0.001	0.028	0.047	0.051	0.130	0.248	0.209	0.858	0.852	0.852	0.187
2013	0.005	0.018	0.074	0.154	0.190	0.546	1.022	1.158	0.389	0.389	0.534
2014	0.029	0.009	0.056	0.065	0.151	0.187	0.777	1.448	1.615	1.615	0.346
2015	0.009	0.043	0.018	0.042	0.155	0.336	0.224	1.044	1.210	1.210	0.226
2016	na	0.010	0.016	0.056	0.146	0.314	0.214	0.141	0.500	0.500	0.236
2017	na	na	0.021	0.094	0.207	0.328	0.368	0.105	0.022	0.022	0.252

Table 23. Probabilities of various population states of spring spawning Atlantic Herring from NAFO Div. 4T at the beginning of 2019 and 2020 (for SSB) or 2018 and 2019 (for F) based on projections under various recruitment scenarios (1 – high recruitment, 2 – low recruitment, 3 – mixed recruitment) and at different levels of annual catch. The abbreviation "na" signifies not examined.

(1) High recruitment scenario

Population		Catch option (t)						
state	Year	0	500	1,000	1,500	2,000	2,500	3,000
SSB increasing	2018	0.91	0.80	0.63	0.44	0.28	0.16	na
	2019	0.80	0.66	0.49	0.32	0.19	0.10	na
SSB > LRP	2019	0.16	0.15	0.13	0.12	0.11	0.10	na
	2020	0.20	0.17	0.14	0.11	0.09	0.08	na
	2027	0.87	0.75	0.63	0.50	0.38	0.29	0.21
SSB > USR	2019	0.00	0.00	0.00	0.00	0.00	0.00	na
	2020	0.00	0.00	0.00	0.00	0.00	0.00	na
	2027	0.11	0.08	0.06	0.05	0.04	0.03	0.02
F_{6-8} > 0.35	2018	0.00	0.00	0.00	0.04	0.22	0.48	0.71
	2019	0.00	0.00	0.00	0.03	0.18	0.39	0.60
	2027	0.00	0.00	0.01	0.10	0.30	0.51	0.69

(2) Low recruitment scenario

Population		Catch option (t)						
state	Year	0	500	1,000	1,500	2,000	2,500	3,000
SSB increasing	2018	0.53	0.25	0.08	0.01	0.00	0.00	na
	2019	0.39	0.18	0.05	0.01	0.00	0.00	na
SSB > LRP	2019	0.07	0.06	0.06	0.05	0.05	0.05	na
	2020	0.06	0.05	0.04	0.03	0.03	0.02	na
	2027	0.13	0.07	0.04	0.03	0.02	0.01	0.01
SSB > USR	2019	0.00	0.00	0.00	0.00	0.00	0.00	na
	2020	0.00	0.00	0.00	0.00	0.00	0.00	na
	2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F_{6-8} > 0.35	2018	0.00	0.00	0.00	0.06	0.31	0.58	0.78
	2019	0.00	0.00	0.00	0.09	0.33	0.57	0.74
	2027	0.00	0.00	0.29	0.73	0.91	0.96	0.98

(3) Mixed recruitment scenario

Population		Catch option (t)						
state	Year	0	500	1,000	1,500	2,000	2,500	3,000
SSB increasing	2018	0.68	0.52	0.37	0.23	0.13	0.07	na
	2019	0.58	0.43	0.28	0.17	0.10	0.05	na
SSB > LRP	2019	0.11	0.10	0.09	0.08	0.07	0.07	na
	2020	0.12	0.10	0.08	0.07	0.06	0.05	na
	2027	0.54	0.40	0.28	0.19	0.12	0.09	0.06
SSB > USR	2019	0.00	0.00	0.00	0.00	0.00	0.00	na
	2020	0.00	0.00	0.00	0.00	0.00	0.00	na
	2027	0.02	0.01	0.01	0.01	0.01	0.01	0.00
F_{6-8} > 0.35	2018	0.00	0.00	0.00	0.05	0.26	0.53	0.75
	2019	0.00	0.00	0.00	0.06	0.26	0.49	0.68
	2027	0.00	0.00	0.07	0.35	0.62	0.79	0.90

Table 24. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring biomass (t) in the North region for NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	15,556	9,491	6,235	7,593	1,982	2,063	6,156	650	249	7,442	32,368
1979	25,421	11,342	9,123	2,374	2,257	731	1,008	1,197	254	1,409	18,354
1980	13,376	29,932	8,017	6,746	739	835	260	469	264	307	17,638
1981	48,087	22,588	31,138	7,137	5,524	428	210	85	235	153	44,910
1982	27,213	42,676	28,277	29,139	6,411	5,009	304	93	55	281	69,571
1983	16,017	43,096	40,399	24,468	21,735	4,905	4,250	119	19	119	96,015
1984	16,648	26,263	57,138	38,888	21,412	16,514	3,965	3,500	60	70	141,546
1985	22,048	24,611	31,682	55,839	32,972	17,520	12,989	3,078	2,896	19	156,994
1986	19,382	37,235	30,880	29,982	46,745	26,033	12,966	8,762	1,289	2,067	158,724
1987	17,638	32,805	50,080	27,670	25,763	33,833	16,609	8,080	5,704	2,097	169,835
1988	13,218	19,608	38,904	43,963	20,571	18,265	21,774	9,562	4,454	4,813	162,307
1989	46,410	19,415	22,995	31,897	33,072	15,255	12,238	14,936	6,318	5,118	141,829
1990	33,535	70,137	25,180	21,360	22,741	22,329	9,619	8,270	9,886	6,995	126,380
1991	8,624	36,436	83,772	20,949	14,797	13,518	11,990	4,984	4,242	9,806	164,059
1992	13,805	10,532	39,069	70,206	15,649	10,958	8,434	7,033	3,138	8,855	163,343
1993	6,218	20,323	11,546	37,450	51,490	10,393	7,228	4,726	3,465	4,983	131,281
1994	15,470	9,166	27,793	11,950	28,637	37,488	7,522	5,149	2,758	4,864	126,161
1995	14,455	20,453	12,100	26,421	8,310	16,599	18,614	3,692	2,087	3,191	91,014
1996	13,155	18,445	26,170	11,417	14,848	3,447	5,750	6,087	1,157	1,416	70,293
1997	21,261	17,523	22,522	24,011	6,986	7,139	1,446	2,231	2,176	913	67,425
1998	14,866	31,071	20,146	21,084	13,546	3,600	3,510	703	815	1,234	64,638
1999	11,233	20,665	41,603	17,892	13,611	6,227	1,523	1,200	339	412	82,808
2000	10,607	17,537	26,212	39,853	10,176	4,700	2,513	552	533	273	84,812
2001	10,083	14,968	23,504	23,665	23,040	5,003	2,278	1,078	244	359	79,171
2002	30,666	16,601	19,567	20,101	14,899	12,998	3,106	1,360	716	399	73,146
2003	22,560	41,949	21,533	15,679	11,910	8,496	8,263	1,836	897	569	69,184
2004	13,499	28,659	49,477	16,904	7,301	5,599	3,530	2,324	328	223	85,685
2005	7,472	15,880	31,548	42,935	11,018	3,965	3,390	1,828	1,071	120	95,874
2006	21,493	10,295	18,749	29,854	26,174	4,525	1,317	1,699	745	371	83,434
2007	30,958	28,300	12,332	17,709	19,654	13,525	2,284	622	564	380	67,069
2008	18,007	27,257	34,814	9,708	10,707	8,259	5,986	635	272	387	70,767
2009	38,337	28,551	48,957	32,405	8,815	8,541	5,373	1,500	161	134	105,886
2010	19,213	40,534	24,210	32,176	18,621	4,304	3,805	2,566	849	102	86,633
2011	27,171	20,271	42,175	22,431	21,758	10,298	1,691	1,836	1,089	320	101,596
2012	13,908	25,581	19,874	41,829	19,748	13,212	3,824	750	800	298	100,335
2013	8,603	13,541	29,818	21,722	38,051	14,049	6,012	848	108	58	110,664
2014	9,684	8,444	15,129	31,791	20,379	29,004	7,999	2,884	187	69	107,441
2015	3,977	8,534	8,891	16,241	30,363	16,178	19,916	4,349	677	153	96,767
2016	1,733	4,543	10,562	9,592	15,586	22,502	10,598	12,894	2,345	384	84,464
2017	na	1,849	4,835	11,375	8,653	10,679	15,521	6,235	10,222	1,863	69,384
2018	na	na	2,265	4,691	9,888	6,148	6,106	9,858	4,143	9,651	52,748

Table 25. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring abundance (number in thousands) in the North region for NAFO Div. 4T. Shading and "na "indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	72,572	55,308	28,765	31,005	6,742	7,369	18,237	2,042	846	18,551	113,557
1979	248,738	59,346	41,431	9,111	8,068	2,480	3,065	3,350	693	3,903	72,100
1980	185,673	198,304	40,439	25,160	2,463	2,754	808	1,319	698	755	74,398
1981	295,718	149,900	144,198	27,615	17,428	1,201	586	216	577	352	192,175
1982	404,469	242,063	118,886	106,172	20,021	13,726	756	231	124	618	260,535
1983	223,551	330,235	188,632	89,050	70,083	14,071	10,822	302	42	263	373,264
1984	208,304	183,020	270,066	145,839	69,424	49,110	10,574	8,481	152	140	553,786
1985	348,914	170,204	148,513	210,267	108,990	51,364	35,847	7,824	6,766	40	569,611
1986	257,463	285,367	137,542	116,748	153,621	75,962	34,979	22,944	3,130	4,715	549,641
1987	176,312	210,547	231,187	101,426	84,008	100,671	45,226	20,687	14,342	4,946	602,493
1988	188,727	142,873	162,806	165,375	68,932	55,633	61,350	25,414	11,232	11,830	562,573
1989	638,641	150,995	114,609	117,788	110,132	46,458	35,060	40,743	16,146	12,652	493,588
1990	336,427	522,127	122,400	80,917	74,677	67,065	27,089	22,436	25,593	16,829	437,006
1991	112,729	275,366	421,327	84,797	51,666	41,832	34,589	13,786	11,590	24,686	684,273
1992	258,911	92,294	220,692	302,705	59,232	36,373	25,316	20,141	8,728	23,363	696,549
1993	110,243	211,938	75,025	170,561	202,750	36,859	22,935	13,789	10,111	13,763	545,794
1994	238,263	89,978	169,488	57,145	116,527	137,218	25,034	15,364	7,930	13,324	542,029
1995	208,911	195,073	73,420	127,167	35,435	62,731	64,322	11,550	5,919	8,709	389,253
1996	179,081	171,042	158,011	53,939	65,600	13,705	20,087	19,778	3,342	3,689	338,150
1997	400,842	146,295	137,614	108,496	28,024	27,694	5,059	7,096	6,483	2,422	322,887
1998	255,915	327,854	115,762	99,759	55,634	13,375	12,863	2,266	2,478	3,513	305,649
1999	219,778	209,479	267,046	84,274	57,576	23,578	5,412	4,093	1,054	1,216	444,249
2000	184,630	179,315	164,833	191,032	42,477	18,326	8,811	1,892	1,727	812	429,911
2001	189,674	150,446	142,170	111,571	97,010	19,067	8,165	3,618	754	1,073	383,427
2002	443,850	154,213	116,750	91,708	60,833	49,064	10,890	4,406	2,253	1,115	337,019
2003	318,921	363,324	124,837	69,722	48,489	31,426	28,685	5,984	2,705	1,663	313,511
2004	186,446	261,110	293,160	83,064	30,299	21,766	12,560	7,755	1,017	650	450,271
2005	123,947	152,585	211,490	210,908	49,182	15,701	12,468	6,347	3,568	382	510,046
2006	346,886	100,754	122,086	160,360	115,372	18,681	4,969	5,858	2,501	1,201	431,028
2007	374,615	283,283	80,711	91,557	90,364	56,766	9,137	2,241	1,915	1,231	333,923
2008	270,256	305,362	218,376	57,206	58,717	40,267	23,740	2,610	912	1,270	403,098
2009	473,644	220,016	242,350	157,167	34,796	30,544	18,839	5,759	562	472	490,488
2010	250,371	387,625	175,457	172,713	91,948	18,698	15,415	9,893	3,184	352	487,660
2011	363,388	204,982	315,725	135,320	108,333	48,480	7,079	7,246	4,179	1,119	627,481
2012	179,499	296,454	167,148	255,100	102,949	62,436	17,187	3,009	3,120	1,079	612,027
2013	112,711	146,924	242,365	136,425	200,247	67,826	27,235	3,660	407	218	678,382
2014	127,107	91,804	119,887	194,858	101,918	135,655	35,676	12,284	756	236	601,269
2015	51,876	104,035	73,556	97,534	153,093	73,421	87,641	18,311	2,939	584	507,080
2016	24,110	42,265	84,046	59,802	77,177	106,768	47,207	55,816	9,860	1,667	442,341
2017	na	19,723	34,279	66,666	43,569	49,549	70,528	27,100	41,890	7,362	340,945
2018	na	na	16,055	27,491	49,787	28,524	27,745	42,847	16,978	38,128	247,554

Table 26. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring biomass (t) in the Middle region for NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	762	2,668	2,353	2,273	695	1,249	2,303	729	154	5,268	15,023
1979	3,308	1,502	1,927	1,129	1,615	432	956	947	530	2,872	10,406
1980	1,739	4,966	1,699	1,536	616	405	110	223	168	161	4,918
1981	2,124	3,443	5,385	1,407	811	375	266	15	70	185	8,514
1982	3,978	7,792	4,318	3,689	815	341	169	15	0	76	9,423
1983	1,766	8,054	5,158	2,912	2,801	643	254	91	9	45	11,915
1984	1,122	3,444	7,690	2,835	1,539	905	248	102	6	3	13,328
1985	1,944	7,257	4,711	7,889	2,114	1,202	501	106	55	1	16,578
1986	3,958	7,050	4,127	3,571	6,778	1,719	939	256	17	30	17,436
1987	853	7,160	6,096	3,889	2,467	5,099	1,010	612	110	9	19,292
1988	1,487	3,062	7,546	6,395	3,680	2,065	4,093	834	394	8	25,014
1989	9,112	6,703	2,327	5,314	5,416	2,649	1,688	3,210	467	349	21,418
1990	7,834	20,732	5,530	1,983	4,278	4,315	1,947	1,253	2,465	568	22,339
1991	1,363	13,795	23,600	4,589	1,348	3,464	2,838	1,481	982	2,393	40,695
1992	7,056	3,345	14,263	18,714	3,619	773	2,324	1,698	806	2,108	44,304
1993	1,973	9,255	3,479	12,101	14,115	2,660	542	1,792	1,333	2,153	38,175
1994	4,969	1,130	8,988	2,637	9,155	10,268	1,926	297	1,437	2,591	37,299
1995	2,099	4,843	3,063	10,390	2,049	6,419	6,444	1,471	149	2,957	32,942
1996	4,263	3,571	10,337	2,762	8,258	1,178	2,613	2,838	942	1,064	29,991
1997	9,879	9,268	5,442	8,084	1,883	4,106	730	1,368	1,394	1,072	24,079
1998	8,547	10,573	10,753	4,045	4,701	1,182	2,481	409	891	1,523	25,984
1999	6,401	7,470	18,413	8,520	2,570	1,685	562	1,273	141	688	33,852
2000	4,250	4,441	15,749	14,896	4,769	1,113	656	131	353	190	37,857
2001	5,378	10,906	10,403	11,832	8,792	2,351	362	190	0	288	34,219
2002	7,990	11,272	13,596	8,954	7,570	5,628	1,291	151	104	166	37,461
2003	5,043	18,842	14,615	10,111	6,370	4,919	3,139	768	85	126	40,133
2004	5,652	13,381	22,043	11,981	6,308	4,170	3,339	1,650	412	92	49,995
2005	2,573	4,995	10,981	17,728	8,277	3,813	2,316	1,679	638	117	45,549
2006	8,145	4,184	8,994	9,954	11,274	3,922	2,219	1,051	718	249	38,381
2007	12,000	20,732	6,937	7,604	7,802	6,747	2,165	1,220	351	228	33,053
2008	6,313	9,605	16,768	3,865	5,166	3,741	2,737	814	594	149	33,834
2009	6,645	13,037	15,531	18,277	4,587	4,810	3,306	1,078	396	189	48,174
2010	4,012	8,225	11,972	12,832	12,305	2,587	2,070	1,550	514	283	44,113
2011	6,386	4,410	9,293	10,747	9,326	7,328	1,088	797	708	227	39,513
2012	5,004	6,766	4,617	8,610	8,996	5,497	2,983	294	154	135	31,286
2013	2,050	5,656	8,299	5,147	7,153	6,049	2,348	851	51	12	29,910
2014	1,439	2,248	6,421	8,629	4,713	5,042	3,220	698	211	0	28,935
2015	501	1,577	2,548	6,598	7,773	3,687	3,200	971	259	0	25,037
2016	102	555	1,835	3,222	6,658	5,050	2,298	1,221	184	0	20,468
2017	na	147	700	2,072	2,509	3,865	2,945	1,145	688	25	13,949
2018	na	na	185	706	1,719	1,390	1,925	788	4	451	7,169

Table 27. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring abundance (number in thousands) in the Middle region for NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	11,901	14,212	11,515	9,872	2,542	4,784	7,050	2,031	523	12,761	51,079
1979	36,328	9,726	10,747	4,598	5,737	1,401	2,950	2,577	1,478	8,170	37,658
1980	24,575	29,743	7,833	5,506	1,935	1,224	307	507	384	381	18,078
1981	39,261	19,999	23,046	5,290	2,345	1,018	716	34	139	399	32,986
1982	66,009	32,140	15,455	13,233	2,616	893	420	40	0	156	32,813
1983	26,630	54,040	26,260	11,152	9,407	1,949	606	239	32	99	49,745
1984	33,036	21,615	39,212	12,188	5,593	2,864	685	241	14	10	60,807
1985	45,616	27,030	17,612	30,164	7,307	3,612	1,368	262	125	2	60,452
1986	40,120	37,347	22,120	14,207	23,460	5,073	2,451	641	39	67	68,057
1987	15,952	32,848	30,535	16,668	10,434	16,994	3,146	1,616	345	22	79,760
1988	36,767	13,059	26,621	24,155	12,058	7,162	11,157	2,312	1,082	24	84,571
1989	153,736	30,102	9,955	19,010	17,237	7,648	4,841	8,063	1,100	891	68,744
1990	102,306	125,869	24,631	7,454	14,273	12,963	5,636	3,578	6,260	1,351	76,145
1991	23,193	83,761	102,854	18,432	4,852	10,326	8,226	4,120	2,585	5,904	157,299
1992	94,363	18,989	68,563	78,821	13,632	2,777	6,879	4,879	2,233	5,225	183,007
1993	21,736	77,258	15,536	52,633	56,048	10,003	1,793	5,358	3,796	5,785	150,952
1994	70,475	17,796	63,253	12,404	37,134	38,414	6,914	933	4,012	6,776	169,839
1995	41,776	57,700	14,570	51,020	8,917	24,186	23,099	4,639	442	7,769	134,641
1996	77,727	34,203	47,241	11,736	32,766	4,250	8,881	9,405	2,575	2,705	119,559
1997	138,473	63,635	27,982	35,266	7,598	15,885	2,449	4,347	4,411	2,749	100,687
1998	114,699	113,372	51,843	18,557	19,024	4,443	9,300	1,304	2,716	4,366	111,551
1999	82,391	93,908	92,746	37,580	10,821	6,296	1,928	4,545	412	1,973	156,302
2000	98,158	67,456	76,885	67,181	19,203	4,303	2,283	426	1,191	530	172,003
2001	109,685	80,365	55,217	52,992	36,043	8,754	1,287	632	0	930	155,855
2002	161,735	89,802	65,451	40,232	31,184	20,858	4,550	492	331	499	163,597
2003	112,083	132,417	72,986	44,989	25,385	18,670	10,688	2,550	249	352	175,869
2004	73,267	91,766	108,303	54,662	26,197	15,801	11,923	5,400	1,336	255	223,875
2005	46,418	59,986	75,118	83,636	35,644	15,033	8,366	5,712	2,055	334	225,898
2006	182,041	37,865	47,920	51,568	48,936	15,870	8,249	3,606	2,342	793	179,284
2007	138,150	149,041	30,976	37,527	34,734	27,609	8,398	4,410	1,217	737	145,609
2008	107,825	113,107	121,691	24,066	27,599	19,612	13,710	3,462	2,241	512	212,892
2009	88,808	88,280	91,317	88,656	17,382	18,553	11,274	3,671	1,462	675	232,989
2010	54,654	72,709	72,186	67,383	59,491	11,201	8,534	6,021	1,890	1,056	227,762
2011	92,650	44,747	59,522	57,721	44,845	33,446	4,744	3,125	2,717	816	206,936
2012	69,121	75,856	36,635	48,367	45,372	25,799	13,447	1,247	585	493	171,945
2013	28,635	56,592	62,099	29,861	37,853	29,338	10,719	3,781	207	44	173,902
2014	20,275	23,444	46,327	50,309	23,433	24,654	14,589	3,048	893	0	163,253
2015	6,989	16,600	19,195	37,929	38,942	16,930	14,542	4,109	1,084	0	132,731
2016	1,875	5,722	13,591	15,566	30,105	22,847	9,843	5,141	731	0	97,824
2017	na	1,535	4,669	10,876	11,638	17,579	12,907	4,832	2,765	98	65,363
2018	na	na	1,235	3,707	7,973	6,322	8,437	3,325	17	1,750	32,767

Table 28. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring biomass (t) in the South region for NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	3,886	8,966	4,819	3,217	1,147	1,780	1,866	282	442	3,419	16,971
1979	14,473	5,518	9,917	4,577	2,471	986	1,287	866	83	1,392	21,580
1980	8,666	11,599	5,850	9,447	3,749	1,807	773	926	625	558	23,736
1981	10,575	11,771	9,156	3,725	4,016	1,121	315	218	99	25	18,677
1982	16,076	15,734	12,726	7,686	3,318	3,769	797	180	107	61	28,646
1983	8,545	26,511	18,742	11,088	5,936	1,832	2,257	357	29	97	40,339
1984	15,540	14,446	34,554	15,948	8,428	4,241	1,313	1,494	144	35	66,155
1985	16,966	26,277	18,288	30,807	13,309	6,353	3,130	930	1,177	106	74,099
1986	15,434	28,211	34,072	16,292	24,475	10,134	4,641	1,975	596	847	93,032
1987	7,397	19,690	37,621	28,222	13,443	18,313	7,835	3,429	1,484	1,178	111,523
1988	5,292	11,981	20,627	36,027	23,335	10,562	12,080	4,819	1,492	1,063	110,005
1989	16,752	7,784	14,105	17,027	29,015	18,093	7,888	8,380	3,019	1,570	99,098
1990	16,249	26,590	10,120	12,595	15,481	23,654	14,587	6,250	6,237	3,439	92,363
1991	4,611	20,875	33,370	8,743	9,782	12,053	9,413	9,324	3,712	5,525	91,921
1992	7,388	6,615	23,044	30,071	7,267	7,790	9,625	6,433	7,114	6,534	97,880
1993	3,470	15,484	6,898	21,914	24,148	5,567	6,358	7,514	4,101	10,395	86,895
1994	17,934	4,323	17,614	6,448	18,625	19,410	4,561	5,317	6,181	11,061	89,217
1995	3,471	11,519	5,496	17,072	5,217	12,536	11,495	3,414	3,411	8,701	67,341
1996	15,247	5,467	14,050	5,869	14,630	4,484	8,077	7,051	2,077	6,523	62,761
1997	20,105	21,566	7,383	20,015	4,621	9,658	2,416	3,655	2,885	3,165	53,797
1998	14,881	20,861	26,947	6,970	13,227	3,684	5,969	1,653	2,109	3,075	63,635
1999	9,061	21,297	26,716	25,138	5,354	7,866	2,171	2,661	888	1,605	72,400
2000	25,156	13,027	27,389	30,167	14,795	3,226	3,322	792	941	733	81,365
2001	17,140	33,936	16,438	26,879	20,072	8,295	1,948	1,760	434	731	76,556
2002	19,723	26,688	44,639	17,194	19,461	12,118	3,427	824	821	454	98,938
2003	10,561	24,140	32,417	43,623	13,545	11,995	6,227	1,582	349	473	110,211
2004	8,335	13,152	28,096	29,658	28,139	9,342	6,055	2,189	491	308	104,278
2005	5,611	15,957	16,363	28,261	24,961	18,416	6,566	3,676	961	229	99,433
2006	17,431	7,751	19,941	17,521	23,961	17,695	8,703	4,286	1,537	455	94,098
2007	13,500	25,832	9,061	16,320	13,627	15,979	10,112	3,692	2,290	744	71,824
2008	20,804	10,072	22,607	8,275	9,841	6,983	6,196	4,454	1,889	1,529	61,776
2009	13,678	15,715	23,142	35,802	10,289	12,352	6,302	4,499	2,823	1,334	96,542
2010	6,259	12,360	21,335	15,545	22,962	5,448	4,388	3,023	2,406	1,560	76,667
2011	11,864	5,730	12,755	18,965	11,617	13,290	2,823	1,291	885	1,659	63,284
2012	9,714	10,799	5,655	13,350	16,078	8,408	6,116	559	153	508	50,828
2013	8,866	8,996	11,308	5,557	12,171	11,801	4,244	1,933	88	64	47,165
2014	15,688	8,130	9,961	10,199	4,822	8,656	5,541	1,713	545	11	41,448
2015	15,336	14,398	8,514	9,230	8,943	3,650	5,416	1,300	522	69	37,645
2016	4,766	12,716	15,932	8,596	8,807	6,357	2,197	2,123	287	20	44,317
2017	na	5,828	15,399	15,292	7,889	5,772	4,467	1,083	1,472	128	51,502
2018	na	na	7,421	14,962	15,457	5,811	3,448	3,269	748	1,235	52,351

Table 29. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring abundance (number in thousands) in the South region for NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	52,189	88,501	34,284	15,658	5,462	6,865	6,599	976	1,481	9,058	80,384
1979	116,150	41,561	55,915	21,692	9,956	3,525	4,180	2,597	250	4,194	102,308
1980	101,420	95,053	33,710	41,063	15,077	6,491	2,455	2,720	1,687	1,507	104,709
1981	125,089	82,556	53,020	16,114	13,842	3,615	920	657	247	59	88,473
1982	240,733	101,400	57,832	28,404	10,291	10,129	2,095	448	297	141	109,637
1983	119,472	197,096	82,700	41,004	19,961	5,525	6,180	980	74	251	156,675
1984	233,891	97,811	160,821	60,809	28,966	13,338	3,598	3,918	373	78	271,900
1985	269,554	191,494	79,721	118,133	44,770	19,585	8,860	2,313	2,864	249	276,495
1986	131,629	220,692	156,702	62,163	82,785	30,903	13,135	5,247	1,436	2,223	354,594
1987	92,943	107,356	179,516	109,762	45,709	56,905	22,277	9,279	3,856	2,752	430,056
1988	74,774	76,087	86,900	136,911	78,305	31,886	33,901	12,640	3,760	2,572	386,876
1989	236,078	61,174	61,925	67,180	97,004	55,384	21,790	21,749	7,609	3,668	336,308
1990	181,250	193,284	50,055	49,476	53,128	71,906	41,553	16,214	15,602	8,400	306,335
1991	59,779	148,395	157,457	34,881	34,443	36,551	26,757	25,164	9,393	13,312	337,958
1992	165,316	48,943	121,485	124,441	27,050	26,991	28,841	18,395	19,371	16,759	383,334
1993	56,387	135,349	40,002	97,950	94,593	20,506	20,936	21,813	11,576	26,829	334,205
1994	183,848	46,166	110,815	32,478	77,282	73,924	15,902	16,775	17,330	29,991	374,497
1995	66,485	150,522	37,786	87,432	24,887	49,430	41,628	10,636	10,275	23,531	285,604
1996	224,224	54,413	122,780	30,402	63,202	17,582	28,281	23,182	6,129	17,699	309,256
1997	277,503	183,554	44,541	95,163	20,263	37,467	8,542	11,813	8,750	8,593	235,131
1998	259,886	227,140	149,150	32,259	54,513	13,685	21,105	5,277	6,476	8,606	291,070
1999	167,914	212,777	185,964	113,627	22,332	30,218	7,542	8,898	2,670	4,681	375,931
2000	421,368	137,456	173,362	142,432	61,058	12,472	11,857	2,586	2,976	2,079	408,820
2001	301,761	344,774	110,730	131,256	86,483	32,139	7,116	5,994	1,400	2,323	377,441
2002	288,178	246,310	276,607	86,458	83,093	47,719	12,489	2,856	2,734	1,427	513,382
2003	160,911	235,079	199,134	205,032	59,936	48,583	23,370	5,646	1,174	1,532	544,406
2004	159,274	131,561	188,768	153,073	124,472	39,881	23,409	8,156	1,739	1,052	540,549
2005	93,135	129,998	105,854	144,070	112,157	77,195	26,321	13,549	3,443	766	483,354
2006	297,413	76,253	106,430	86,282	106,821	73,462	34,723	16,110	5,583	1,558	430,969
2007	150,047	243,284	62,059	84,353	63,287	68,859	41,290	14,562	8,585	2,738	345,733
2008	214,899	122,848	198,677	50,538	60,722	39,549	34,161	20,007	7,481	5,782	416,916
2009	156,191	175,944	100,315	158,276	39,776	43,779	21,556	14,556	10,220	5,091	393,569
2010	68,443	127,879	143,680	79,966	110,976	23,273	17,438	11,536	8,669	5,539	401,077
2011	129,043	56,036	104,640	114,919	57,116	61,738	11,538	5,024	3,392	6,039	364,406
2012	107,555	105,651	45,878	85,390	87,295	40,025	27,937	2,292	582	1,947	291,346
2013	97,173	88,058	86,500	37,504	68,638	59,447	19,525	8,694	365	241	280,914
2014	172,074	79,542	72,083	69,157	27,881	44,807	26,583	7,569	2,398	44	250,522
2015	168,692	140,883	65,123	58,413	51,447	19,254	26,649	5,920	2,304	287	229,397
2016	81,011	138,114	115,290	52,994	45,832	31,940	10,637	9,554	1,240	84	267,570
2017	na	65,699	111,435	92,859	38,613	27,967	20,907	4,873	6,071	539	303,263
2018	na	na	53,702	90,853	75,652	28,156	16,137	14,714	3,086	5,208	287,507

Table 30. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring biomass (t) in NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	20,204	21,125	13,406	13,083	3,823	5,092	10,324	1,661	844	16,128	64,362
1979	43,202	18,361	20,967	8,079	6,343	2,149	3,251	3,010	867	5,673	50,341
1980	23,781	46,498	15,567	17,730	5,104	3,047	1,143	1,618	1,057	1,026	46,292
1981	60,786	37,803	45,679	12,269	10,351	1,925	791	318	404	364	72,101
1982	47,267	66,202	45,322	40,514	10,544	9,120	1,271	288	162	418	107,639
1983	26,328	77,661	64,300	38,469	30,473	7,380	6,761	568	57	261	148,268
1984	33,309	44,153	99,382	57,671	31,379	21,660	5,525	5,096	209	108	221,029
1985	40,958	58,145	54,681	94,534	48,395	25,074	16,620	4,114	4,128	126	247,670
1986	38,774	72,496	69,078	49,846	77,998	37,886	18,545	10,993	1,902	2,945	269,193
1987	25,888	59,656	93,797	59,781	41,673	57,245	25,454	12,121	7,297	3,284	300,651
1988	19,998	34,650	67,077	86,385	47,586	30,892	37,947	15,216	6,340	5,884	297,327
1989	72,274	33,902	39,427	54,238	67,503	35,996	21,814	26,526	9,804	7,037	262,346
1990	57,618	117,459	40,830	35,939	42,500	50,298	26,153	15,773	18,588	11,001	241,083
1991	14,597	71,106	140,742	34,281	25,927	29,035	24,241	15,789	8,936	17,724	296,675
1992	28,249	20,492	76,377	118,991	26,535	19,522	20,384	15,164	11,058	17,497	305,527
1993	11,660	45,062	21,922	71,465	89,753	18,620	14,128	14,033	8,898	17,531	256,351
1994	38,374	14,618	54,395	21,036	56,416	67,166	14,008	10,763	10,377	18,517	252,677
1995	20,024	36,816	20,658	53,884	15,576	35,554	36,553	8,576	5,647	14,849	191,297
1996	32,666	27,483	50,557	20,047	37,735	9,109	16,441	15,976	4,177	9,003	163,045
1997	51,244	48,357	35,347	52,109	13,491	20,903	4,591	7,255	6,455	5,150	145,301
1998	38,295	62,504	57,846	32,099	31,474	8,466	11,960	2,766	3,815	5,833	154,257
1999	26,694	49,432	86,732	51,550	21,535	15,779	4,256	5,134	1,369	2,706	189,060
2000	40,013	35,004	69,350	84,916	29,741	9,038	6,490	1,475	1,827	1,196	204,034
2001	32,601	59,810	50,345	62,376	51,904	15,649	4,589	3,028	678	1,378	189,947
2002	58,378	54,561	77,802	46,249	41,930	30,743	7,823	2,336	1,641	1,020	209,545
2003	38,164	84,931	68,566	69,412	31,825	25,410	17,630	4,186	1,331	1,168	219,528
2004	27,485	55,193	99,616	58,543	41,748	19,111	12,924	6,163	1,231	623	239,958
2005	15,656	36,832	58,892	88,924	44,255	26,194	12,271	7,183	2,671	466	240,856
2006	47,069	22,230	47,684	57,328	61,410	26,142	12,238	7,035	2,999	1,075	215,913
2007	56,458	74,863	28,329	41,633	41,083	36,251	14,561	5,534	3,204	1,352	171,946
2008	45,125	46,934	74,189	21,848	25,714	18,983	14,920	5,903	2,754	2,065	166,376
2009	58,659	57,304	87,630	86,484	23,691	25,702	14,981	7,078	3,380	1,657	250,603
2010	29,485	61,118	57,517	60,553	53,889	12,340	10,263	7,138	3,770	1,945	207,413
2011	45,421	30,411	64,222	52,143	42,701	30,915	5,602	3,923	2,683	2,206	204,394
2012	28,626	43,145	30,146	63,788	44,822	27,117	12,923	1,604	1,107	941	182,449
2013	19,519	28,193	49,425	32,425	57,375	31,899	12,603	3,631	246	133	187,739
2014	26,811	18,822	31,511	50,619	29,914	42,702	16,760	5,296	943	80	177,823
2015	19,814	24,509	19,952	32,070	47,079	23,516	28,532	6,619	1,458	222	159,449
2016	6,601	17,814	28,329	21,410	31,050	33,910	15,094	16,238	2,815	404	149,249
2017	na	7,825	20,935	28,739	19,051	20,316	22,933	8,463	12,382	2,017	134,835
2018	na	na	9,871	20,359	27,064	13,349	11,479	13,915	4,895	11,337	112,268

Table 31. Maximum likelihood estimates (MLEs) of beginning of year fall spawner Atlantic Herring abundance (number in thousands) in NAFO Div. 4T. Shading and "na" indicates cohorts that cannot yet be estimated by the model.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	4+
1978	136,662	158,021	74,564	56,536	14,747	19,018	31,886	5,049	2,850	40,370	245,020
1979	401,216	110,633	108,093	35,401	23,760	7,405	10,195	8,525	2,421	16,267	212,067
1980	311,668	323,100	81,982	71,728	19,475	10,470	3,570	4,546	2,769	2,643	197,184
1981	460,068	252,455	220,264	49,018	33,616	5,834	2,222	907	963	810	313,634
1982	711,211	375,603	192,172	147,809	32,928	24,748	3,271	719	422	914	402,984
1983	369,653	581,371	297,592	141,206	99,451	21,544	17,608	1,521	148	613	579,685
1984	475,231	302,446	470,099	218,836	103,983	65,312	14,856	12,640	539	228	886,493
1985	664,084	388,728	245,846	358,564	161,067	74,561	46,075	10,400	9,755	291	906,558
1986	429,212	543,406	316,364	193,118	259,866	111,938	50,565	28,832	4,605	7,004	972,293
1987	285,207	350,751	441,238	227,856	140,151	174,570	70,649	31,582	18,543	7,719	1,112,309
1988	300,267	232,019	276,327	326,441	159,296	94,681	106,408	40,367	16,074	14,426	1,034,020
1989	1,028,455	242,271	186,489	203,978	224,374	109,490	61,691	70,554	24,855	17,210	898,640
1990	619,983	841,280	197,086	137,847	142,078	151,934	74,278	42,228	47,454	26,581	819,486
1991	195,701	507,522	681,638	138,109	90,961	88,709	69,572	43,070	23,569	43,902	1,179,530
1992	518,590	160,226	410,740	505,967	99,914	66,141	61,036	43,414	30,331	45,347	1,262,889
1993	188,366	424,545	130,563	321,144	353,391	67,368	45,664	40,960	25,483	46,377	1,030,950
1994	492,586	153,940	343,556	102,027	230,942	249,557	47,850	33,072	29,271	50,091	1,086,366
1995	317,172	403,295	125,776	265,618	69,240	136,346	129,049	26,825	16,636	40,009	809,498
1996	481,032	259,659	328,032	96,077	161,567	35,537	57,249	52,365	12,046	24,092	766,965
1997	816,818	393,484	210,137	238,925	55,885	81,045	16,050	23,256	19,644	13,764	658,705
1998	630,500	668,366	316,755	150,574	129,170	31,503	43,268	8,846	11,669	16,485	708,270
1999	470,083	516,164	545,756	235,482	90,728	60,092	14,882	17,536	4,136	7,871	976,482
2000	704,156	384,227	415,080	400,645	122,738	35,101	22,951	4,904	5,894	3,422	1,010,734
2001	601,120	575,585	308,117	295,819	219,537	59,960	16,568	10,243	2,154	4,326	916,723
2002	893,763	490,325	458,808	218,398	175,109	117,641	27,929	7,754	5,318	3,040	1,013,998
2003	591,915	730,820	396,957	319,743	133,810	98,679	62,743	14,179	4,128	3,547	1,033,786
2004	418,987	484,437	590,231	290,799	180,968	77,447	47,892	21,311	4,091	1,957	1,214,695
2005	263,500	342,569	392,462	438,614	196,983	107,929	47,155	25,608	9,067	1,482	1,219,298
2006	826,340	214,872	276,436	298,210	271,129	108,013	47,941	25,574	10,427	3,552	1,041,280
2007	662,812	675,608	173,746	213,437	188,385	153,234	58,825	21,213	11,717	4,706	825,264
2008	592,980	541,317	538,744	131,810	147,038	99,427	71,611	26,079	10,634	7,564	1,032,906
2009	718,643	484,240	433,982	404,099	91,954	92,876	51,668	23,987	12,244	6,237	1,117,046
2010	373,468	588,213	391,323	320,062	262,416	53,172	41,387	27,450	13,743	6,946	1,116,499
2011	585,081	305,765	479,887	307,960	210,294	143,664	23,361	15,395	10,288	7,973	1,198,822
2012	356,175	477,961	249,661	388,857	235,616	128,259	58,571	6,548	4,286	3,518	1,075,317
2013	238,518	291,574	390,964	203,790	306,738	156,611	57,479	16,135	978	503	1,133,197
2014	319,456	194,790	238,297	314,323	153,232	205,116	76,848	22,900	4,047	280	1,015,044
2015	227,557	261,518	157,874	193,876	243,482	109,605	128,832	28,340	6,327	871	869,208
2016	106,996	186,101	212,926	128,362	153,113	161,555	67,687	70,511	11,831	1,751	807,735
2017	na	86,957	150,383	170,400	93,819	95,095	104,342	36,805	50,726	8,000	709,571
2018	na	na	70,992	122,051	133,412	63,002	52,319	60,887	20,081	45,086	567,829

Table 32. Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) by age of fall spawner Atlantic Herring in the North region of NAFO Div. 4T. F5-10 is the abundance-weighted average F for ages 5 to 10 years. No estimates ("na") are available for the shaded cell.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.0012	0.0889	0.950	1.146	0.800	0.677	1.494	0.881	1.403	1.403	1.150
1979	0.0266	0.1836	0.299	1.108	0.875	0.921	0.643	1.369	1.606	1.606	1.013
1980	0.0140	0.1186	0.181	0.167	0.518	1.348	1.117	0.626	1.217	1.217	0.355
1981	0.0002	0.0318	0.106	0.122	0.039	0.263	0.730	0.354	0.209	0.209	0.104
1982	0.0028	0.0494	0.089	0.215	0.153	0.038	0.719	1.497	0.836	0.836	0.195
1983	0.0000	0.0011	0.057	0.049	0.156	0.086	0.044	0.482	0.581	0.581	0.093
1984	0.0020	0.0089	0.050	0.091	0.101	0.115	0.101	0.026	1.788	1.788	0.097
1985	0.0010	0.0131	0.041	0.114	0.161	0.184	0.246	0.716	0.167	0.167	0.158
1986	0.0012	0.0106	0.105	0.129	0.223	0.319	0.325	0.270	0.261	0.261	0.225
1987	0.0103	0.0571	0.135	0.186	0.212	0.295	0.376	0.411	0.289	0.289	0.262
1988	0.0231	0.0204	0.124	0.207	0.195	0.262	0.209	0.254	0.400	0.400	0.221
1989	0.0014	0.0100	0.148	0.256	0.296	0.339	0.246	0.265	0.337	0.337	0.282
1990	0.0003	0.0145	0.167	0.249	0.380	0.462	0.475	0.460	0.341	0.341	0.374
1991	0.0000	0.0213	0.131	0.159	0.151	0.302	0.341	0.257	0.240	0.240	0.218
1992	0.0002	0.0072	0.058	0.201	0.274	0.261	0.408	0.489	0.647	0.647	0.248
1993	0.0031	0.0235	0.072	0.181	0.190	0.187	0.201	0.353	0.383	0.383	0.196
1994	0.0000	0.0034	0.087	0.278	0.419	0.558	0.574	0.754	0.692	0.692	0.481
1995	0.0000	0.0107	0.108	0.462	0.750	0.939	0.979	1.040	1.178	1.178	0.736
1996	0.0022	0.0175	0.176	0.455	0.662	0.797	0.841	0.915	0.866	0.866	0.662
1997	0.0010	0.0341	0.122	0.468	0.540	0.567	0.603	0.852	0.730	0.730	0.522
1998	0.0002	0.0051	0.117	0.350	0.658	0.705	0.945	0.565	1.395	1.395	0.525
1999	0.0035	0.0397	0.135	0.485	0.945	0.784	0.851	0.663	0.828	0.828	0.693
2000	0.0048	0.0321	0.190	0.478	0.601	0.608	0.690	0.720	0.662	0.662	0.517
2001	0.0070	0.0536	0.238	0.407	0.482	0.360	0.417	0.274	0.294	0.294	0.431
2002	0.0002	0.0113	0.316	0.437	0.460	0.337	0.399	0.288	0.506	0.506	0.417
2003	0.0000	0.0146	0.207	0.633	0.601	0.717	1.108	1.572	1.705	1.705	0.757
2004	0.0004	0.0108	0.129	0.324	0.457	0.357	0.483	0.576	1.274	1.274	0.386
2005	0.0072	0.0230	0.077	0.403	0.768	0.951	0.555	0.731	0.991	0.991	0.513
2006	0.0025	0.0218	0.088	0.374	0.509	0.515	0.596	0.918	0.901	0.901	0.451
2007	0.0044	0.0602	0.144	0.244	0.608	0.672	1.053	0.698	0.707	0.707	0.508
2008	0.0057	0.0311	0.129	0.297	0.454	0.560	1.216	1.335	1.332	1.332	0.544
2009	0.0004	0.0263	0.139	0.336	0.421	0.484	0.444	0.393	0.878	0.878	0.377
2010	0.0000	0.0052	0.060	0.266	0.440	0.771	0.555	0.662	0.951	0.951	0.382
2011	0.0036	0.0040	0.013	0.073	0.351	0.837	0.655	0.643	1.391	1.391	0.334
2012	0.0003	0.0014	0.003	0.042	0.217	0.630	1.347	1.801	2.760	2.760	0.247
2013	0.0052	0.0034	0.018	0.092	0.189	0.442	0.596	1.378	0.773	0.773	0.234
2014	0.0003	0.0216	0.006	0.041	0.128	0.237	0.467	1.230	0.329	0.329	0.177
2015	0.0049	0.0134	0.007	0.034	0.160	0.242	0.251	0.419	0.548	0.548	0.178
2016	0.0008	0.0094	0.032	0.117	0.243	0.215	0.355	0.087	0.248	0.248	0.204
2017	na	0.0057	0.021	0.092	0.224	0.380	0.298	0.268	0.056	0.056	0.218

Table 33. Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) by age of fall spawner Atlantic Herring in the Middle region of NAFO Div. 4T. F5-10 is the abundance-weighted average F for ages 5 to 10 years. No estimates ("na") are available for the shaded cell.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.002	0.080	0.718	0.343	0.396	0.283	0.806	0.118	0.286	0.286	0.441
1979	0.000	0.016	0.469	0.666	1.344	1.317	1.560	1.704	3.032	3.032	1.392
1980	0.006	0.055	0.193	0.654	0.442	0.337	2.010	1.095	0.451	0.451	0.630
1981	0.000	0.058	0.355	0.504	0.765	0.684	2.691	4.247	1.039	1.039	0.773
1982	0.000	0.002	0.126	0.141	0.094	0.188	0.363	0.010	0.252	0.252	0.142
1983	0.009	0.121	0.568	0.490	0.989	0.846	0.720	2.636	2.426	2.426	0.751
1984	0.001	0.005	0.062	0.312	0.237	0.539	0.759	0.460	2.334	2.334	0.340
1985	0.000	0.000	0.015	0.051	0.165	0.188	0.558	1.712	0.442	0.442	0.110
1986	0.000	0.001	0.083	0.109	0.122	0.278	0.217	0.419	1.371	1.371	0.146
1987	0.000	0.010	0.034	0.124	0.176	0.221	0.108	0.201	2.538	2.538	0.187
1988	0.000	0.071	0.137	0.137	0.255	0.192	0.125	0.543	0.016	0.016	0.180
1989	0.000	0.001	0.089	0.087	0.085	0.105	0.102	0.053	0.188	0.188	0.087
1990	0.000	0.002	0.090	0.229	0.124	0.255	0.113	0.125	0.054	0.054	0.163
1991	0.000	0.000	0.066	0.102	0.358	0.206	0.322	0.413	0.285	0.285	0.223
1992	0.000	0.001	0.064	0.141	0.110	0.237	0.050	0.051	0.054	0.054	0.128
1993	0.000	0.000	0.025	0.149	0.178	0.169	0.454	0.089	0.146	0.146	0.165
1994	0.000	0.000	0.015	0.130	0.229	0.309	0.199	0.546	0.128	0.128	0.244
1995	0.000	0.000	0.016	0.243	0.541	0.802	0.699	0.389	0.911	0.911	0.489
1996	0.000	0.001	0.092	0.235	0.524	0.351	0.514	0.557	0.453	0.453	0.465
1997	0.000	0.005	0.211	0.417	0.337	0.335	0.430	0.270	0.295	0.295	0.374
1998	0.000	0.001	0.122	0.339	0.906	0.635	0.516	0.952	1.078	1.078	0.638
1999	0.000	0.000	0.122	0.471	0.722	0.814	1.309	1.140	1.303	1.303	0.632
2000	0.000	0.000	0.172	0.423	0.586	1.007	1.085	7.002	0.416	0.416	0.528
2001	0.000	0.005	0.117	0.330	0.347	0.454	0.761	0.447	0.423	0.423	0.353
2002	0.000	0.007	0.175	0.260	0.313	0.469	0.379	0.482	0.657	0.657	0.330
2003	0.000	0.001	0.089	0.341	0.274	0.248	0.483	0.447	0.659	0.659	0.326
2004	0.000	0.000	0.058	0.228	0.355	0.436	0.536	0.766	1.361	1.361	0.355
2005	0.004	0.025	0.176	0.336	0.609	0.400	0.642	0.691	0.902	0.902	0.445
2006	0.000	0.001	0.044	0.195	0.372	0.436	0.426	0.887	1.248	1.248	0.343
2007	0.000	0.003	0.052	0.107	0.372	0.500	0.686	0.477	1.139	1.139	0.351
2008	0.000	0.014	0.117	0.125	0.197	0.354	1.118	0.662	1.206	1.206	0.394
2009	0.000	0.001	0.104	0.199	0.239	0.577	0.427	0.464	0.505	0.505	0.282
2010	0.000	0.000	0.024	0.207	0.376	0.659	0.805	0.596	1.084	1.084	0.364
2011	0.000	0.000	0.008	0.041	0.353	0.711	1.136	1.476	1.770	1.770	0.387
2012	0.000	0.000	0.004	0.045	0.236	0.678	1.069	1.598	2.996	2.996	0.360
2013	0.000	0.000	0.011	0.042	0.229	0.499	1.058	1.243	7.605	7.605	0.377
2014	0.000	0.000	0.000	0.056	0.125	0.328	1.067	0.833	8.875	8.875	0.341
2015	0.000	0.000	0.010	0.031	0.333	0.342	0.840	1.526	8.842	8.842	0.423
2016	0.000	0.003	0.023	0.091	0.338	0.371	0.512	0.420	1.806	1.806	0.339
2017	na	0.018	0.031	0.110	0.410	0.534	1.156	5.477	0.292	0.292	0.950

Table 34. Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) by age of fall spawner Atlantic Herring in the South region of NAFO Div. 4T. F5-10 is the abundance-weighted average F for ages 5 to 10 years. No estimates ("na") are available for the shaded cell.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.028	0.259	0.258	0.253	0.238	0.296	0.732	1.161	0.721	0.721	0.387
1979	0.000	0.009	0.109	0.164	0.228	0.162	0.230	0.231	0.882	0.882	0.194
1980	0.006	0.384	0.538	0.887	1.228	1.754	1.119	2.199	3.788	3.788	1.172
1981	0.010	0.156	0.424	0.248	0.112	0.346	0.519	0.592	0.577	0.577	0.221
1982	0.000	0.004	0.144	0.153	0.422	0.294	0.559	1.604	0.359	0.359	0.264
1983	0.000	0.003	0.107	0.148	0.203	0.229	0.256	0.768	1.222	1.222	0.187
1984	0.000	0.004	0.108	0.106	0.191	0.209	0.242	0.113	0.393	0.393	0.146
1985	0.000	0.001	0.049	0.156	0.171	0.199	0.324	0.277	0.137	0.137	0.172
1986	0.004	0.007	0.156	0.107	0.175	0.127	0.147	0.108	0.085	0.085	0.142
1987	0.000	0.011	0.071	0.138	0.160	0.318	0.367	0.703	0.744	0.744	0.234
1988	0.001	0.006	0.057	0.145	0.146	0.181	0.244	0.308	0.346	0.346	0.170
1989	0.000	0.001	0.024	0.035	0.099	0.087	0.096	0.132	0.094	0.094	0.083
1990	0.000	0.005	0.161	0.162	0.174	0.789	0.302	0.346	0.389	0.389	0.396
1991	0.000	0.000	0.035	0.054	0.044	0.037	0.175	0.062	0.104	0.104	0.071
1992	0.000	0.002	0.015	0.074	0.077	0.054	0.079	0.263	0.098	0.098	0.089
1993	0.000	0.000	0.008	0.037	0.047	0.054	0.022	0.030	0.047	0.047	0.040
1994	0.000	0.000	0.037	0.066	0.247	0.374	0.202	0.290	0.499	0.499	0.281
1995	0.000	0.004	0.017	0.125	0.147	0.358	0.385	0.351	0.447	0.447	0.253
1996	0.000	0.000	0.055	0.206	0.323	0.522	0.673	0.774	0.820	0.820	0.461
1997	0.000	0.008	0.123	0.357	0.192	0.374	0.282	0.401	0.501	0.501	0.348
1998	0.000	0.000	0.072	0.168	0.390	0.396	0.664	0.481	0.970	0.970	0.412
1999	0.000	0.005	0.067	0.421	0.383	0.736	0.871	0.895	1.063	1.063	0.518
2000	0.001	0.016	0.078	0.299	0.442	0.361	0.482	0.413	0.578	0.578	0.354
2001	0.003	0.020	0.047	0.257	0.395	0.745	0.713	0.585	0.759	0.759	0.384
2002	0.004	0.013	0.099	0.166	0.337	0.514	0.594	0.689	0.799	0.799	0.333
2003	0.001	0.019	0.063	0.299	0.207	0.530	0.853	0.978	0.745	0.745	0.366
2004	0.003	0.017	0.070	0.111	0.278	0.216	0.347	0.662	1.093	1.093	0.216
2005	0.000	0.000	0.004	0.099	0.223	0.599	0.291	0.687	0.794	0.794	0.279
2006	0.001	0.006	0.032	0.110	0.239	0.376	0.669	0.429	0.759	0.759	0.300
2007	0.000	0.003	0.005	0.129	0.270	0.501	0.525	0.466	0.472	0.472	0.338
2008	0.000	0.003	0.027	0.039	0.127	0.407	0.653	0.472	0.757	0.757	0.298
2009	0.000	0.003	0.027	0.155	0.336	0.720	0.425	0.318	0.817	0.817	0.318
2010	0.000	0.001	0.023	0.137	0.386	0.502	1.044	1.024	0.656	0.656	0.402
2011	0.000	0.000	0.003	0.075	0.156	0.593	1.416	1.956	1.378	1.378	0.335
2012	0.000	0.000	0.002	0.018	0.184	0.518	0.967	1.639	2.149	2.149	0.289
2013	0.000	0.000	0.024	0.096	0.226	0.605	0.748	1.088	2.413	2.413	0.412
2014	0.000	0.000	0.010	0.096	0.170	0.320	1.302	0.989	1.943	1.943	0.406
2015	0.000	0.000	0.006	0.043	0.277	0.393	0.826	1.364	3.233	3.233	0.377
2016	0.009	0.015	0.016	0.117	0.294	0.224	0.581	0.253	0.697	0.697	0.238
2017	na	0.002	0.004	0.005	0.116	0.350	0.151	0.257	0.039	0.039	0.101

Table 35. Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) by age of fall spawner Atlantic Herring in NAFO Div. 4T. F5-10 is the abundance-weighted average F for ages 5 to 10 years. No estimates ("na") are available for the shaded cell.

	Age (years)										
Year	2	3	4	5	6	7	8	9	10	11+	F5-10
1978	0.011	0.183	0.596	0.759	0.522	0.441	1.185	0.628	0.844	0.897	0.747
1979	0.017	0.103	0.217	0.472	0.717	0.635	0.739	1.124	2.402	2.135	0.564
1980	0.011	0.191	0.329	0.617	1.060	1.481	1.195	1.619	2.677	2.572	0.676
1981	0.003	0.074	0.209	0.205	0.120	0.388	1.275	0.671	0.423	0.644	0.213
1982	0.002	0.033	0.108	0.197	0.232	0.148	0.571	1.482	0.499	0.663	0.161
1983	0.001	0.013	0.116	0.112	0.244	0.191	0.141	1.005	1.300	1.142	0.145
1984	0.001	0.007	0.071	0.108	0.134	0.153	0.165	0.061	0.838	1.331	0.096
1985	0.001	0.006	0.041	0.122	0.164	0.188	0.270	0.643	0.162	0.143	0.127
1986	0.002	0.008	0.129	0.121	0.198	0.264	0.274	0.244	0.216	0.216	0.173
1987	0.006	0.039	0.102	0.158	0.193	0.295	0.361	0.486	0.425	0.457	0.191
1988	0.015	0.019	0.104	0.175	0.175	0.229	0.211	0.287	0.362	0.390	0.175
1989	0.001	0.006	0.104	0.167	0.195	0.196	0.182	0.200	0.256	0.278	0.173
1990	0.000	0.010	0.156	0.217	0.277	0.599	0.351	0.388	0.319	0.342	0.314
1991	0.000	0.012	0.099	0.125	0.121	0.182	0.275	0.158	0.191	0.205	0.128
1992	0.000	0.005	0.046	0.160	0.198	0.176	0.212	0.344	0.252	0.375	0.146
1993	0.002	0.012	0.047	0.132	0.150	0.144	0.128	0.147	0.195	0.159	0.131
1994	0.000	0.002	0.058	0.193	0.331	0.465	0.396	0.513	0.500	0.500	0.283
1995	0.000	0.007	0.070	0.309	0.506	0.704	0.737	0.654	0.719	0.696	0.463
1996	0.001	0.012	0.119	0.349	0.502	0.607	0.707	0.789	0.754	0.786	0.371
1997	0.001	0.017	0.134	0.416	0.386	0.432	0.406	0.514	0.530	0.500	0.334
1998	0.000	0.003	0.097	0.309	0.582	0.561	0.716	0.572	1.085	1.089	0.334
1999	0.002	0.018	0.110	0.452	0.780	0.763	0.920	0.904	1.027	1.087	0.333
2000	0.002	0.021	0.140	0.405	0.519	0.569	0.622	1.105	0.569	0.572	0.326
2001	0.004	0.027	0.148	0.327	0.425	0.580	0.571	0.466	0.596	0.571	0.315
2002	0.001	0.011	0.165	0.297	0.375	0.432	0.483	0.448	0.666	0.668	0.276
2003	0.000	0.014	0.113	0.378	0.363	0.536	0.906	1.133	1.369	1.186	0.339
2004	0.001	0.011	0.097	0.194	0.319	0.300	0.429	0.657	1.225	1.188	0.195
2005	0.004	0.015	0.076	0.291	0.429	0.622	0.423	0.699	0.896	0.869	0.292
2006	0.001	0.012	0.059	0.266	0.378	0.409	0.620	0.606	0.903	0.916	0.288
2007	0.002	0.027	0.078	0.174	0.451	0.564	0.630	0.493	0.580	0.638	0.339
2008	0.003	0.021	0.089	0.167	0.271	0.458	0.929	0.583	0.901	0.884	0.245
2009	0.000	0.013	0.106	0.235	0.350	0.614	0.433	0.358	0.782	0.788	0.247
2010	0.000	0.004	0.040	0.221	0.403	0.630	0.813	0.800	0.783	0.736	0.266
2011	0.002	0.003	0.010	0.068	0.298	0.703	1.129	1.240	1.487	1.420	0.218
2012	0.000	0.001	0.003	0.037	0.209	0.605	1.102	1.706	2.709	2.455	0.221
2013	0.003	0.002	0.018	0.085	0.203	0.515	0.734	1.190	2.828	2.159	0.205
2014	0.000	0.010	0.006	0.056	0.135	0.266	0.870	1.098	3.171	0.588	0.196
2015	0.001	0.006	0.007	0.036	0.213	0.284	0.436	0.777	2.947	1.433	0.218
2016	0.007	0.013	0.023	0.114	0.277	0.239	0.413	0.134	0.392	0.270	0.177
2017	na	0.003	0.009	0.046	0.202	0.400	0.375	0.950	0.067	0.058	0.203

Table 36a. Projections of fall spawning Atlantic Herring biomass (kt) in NAFO Div. 4T and biomass relative to population status objectives, expressed as probabilities, for various annual catch levels in 2018 and 2019. The same catch is assumed for 2018 and 2019. Spawning stock biomass (SSB) is the beginning-of-year median estimate from MCMC sampling. LRP is the limit reference point (58,000 t of SSB) and USR is the upper stock reference (172,000 t of SSB).

Catch	Projected SSB (kt)		Probability SSB < USR		Probability SSB < LRP		Probability SSB > SSB_{2018}		Probability 5% increase in SSB		Probability 5% decrease in SSB	
(kt)	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
10	121.8	128.3	0.937	0.899	0.000	0.000	0.756	0.859	0.601	0.741	0.050	0.061
12	120.1	125.3	0.941	0.909	0.000	0.001	0.711	0.804	0.556	0.664	0.115	0.102
14	118.3	122.2	0.947	0.919	0.000	0.001	0.664	0.734	0.503	0.580	0.176	0.151
16	116.6	119.2	0.949	0.929	0.000	0.002	0.617	0.653	0.454	0.498	0.228	0.204
18	115.0	116.2	0.953	0.936	0.001	0.004	0.570	0.573	0.398	0.417	0.271	0.275
20	113.3	113.3	0.955	0.943	0.001	0.006	0.524	0.496	0.345	0.346	0.317	0.351
22	111.7	110.5	0.958	0.950	0.002	0.010	0.474	0.421	0.298	0.285	0.361	0.428
24	110.1	107.7	0.960	0.955	0.003	0.016	0.426	0.353	0.247	0.230	0.409	0.503
26	108.5	104.9	0.962	0.962	0.004	0.020	0.373	0.290	0.203	0.186	0.451	0.575
28	106.9	102.3	0.965	0.964	0.006	0.028	0.327	0.236	0.165	0.150	0.496	0.636
30	105.4	99.6	0.966	0.966	0.007	0.035	0.279	0.194	0.127	0.119	0.546	0.699
32	103.9	97.1	0.967	0.970	0.010	0.044	0.237	0.159	0.099	0.090	0.590	0.750
34	102.4	94.7	0.969	0.972	0.012	0.052	0.196	0.126	0.076	0.070	0.636	0.793
36	100.9	92.4	0.970	0.975	0.014	0.062	0.162	0.101	0.060	0.057	0.681	0.828
38	99.5	90.3	0.971	0.977	0.017	0.075	0.128	0.080	0.045	0.043	0.722	0.858
40	98.1	88.2	0.972	0.978	0.021	0.088	0.102	0.066	0.034	0.035	0.760	0.883
42	96.7	86.2	0.974	0.980	0.025	0.103	0.080	0.052	0.028	0.029	0.799	0.907
44	95.5	84.4	0.975	0.981	0.030	0.121	0.064	0.041	0.024	0.022	0.830	0.922
46	94.1	82.6	0.976	0.983	0.034	0.140	0.052	0.035	0.019	0.018	0.860	0.934
48	92.9	80.8	0.977	0.984	0.039	0.157	0.041	0.029	0.017	0.014	0.885	0.947
50	91.8	79.1	0.979	0.986	0.044	0.174	0.033	0.022	0.013	0.011	0.906	0.956

Table 36b. Projections of fall spawning Atlantic Herring fishing mortality rates (F5-10) and probability of exceeding the removal rate reference (F0.1 = 0.32) for various annual catch levels in 2018 and 2019. F5-10 is the average instantaneous rate of fishing mortality for ages 5 to 10 years and values shown are the median estimates based on MCMC sampling.

Catch	Average F5-10		Probability F5-10 > 0.32	
(kt)	2018	2019	2018	2019
10	0.104	0.125	0.000	0.000
12	0.129	0.159	0.000	0.003
14	0.154	0.194	0.000	0.026
16	0.181	0.231	0.005	0.111
18	0.209	0.269	0.028	0.263
20	0.238	0.311	0.096	0.461
22	0.267	0.355	0.224	0.625
24	0.298	0.402	0.389	0.754
26	0.330	0.454	0.546	0.840
28	0.362	0.510	0.690	0.897
30	0.395	0.569	0.794	0.930
32	0.430	0.634	0.874	0.953
34	0.465	0.703	0.930	0.967
36	0.501	0.776	0.961	0.976
38	0.538	0.851	0.981	0.981
40	0.576	0.930	0.988	0.986
42	0.615	1.012	0.993	0.990
44	0.655	1.097	0.996	0.992
46	0.694	1.180	0.997	0.994
48	0.734	1.267	0.998	0.996
50	0.775	1.355	0.998	0.996

FIGURES

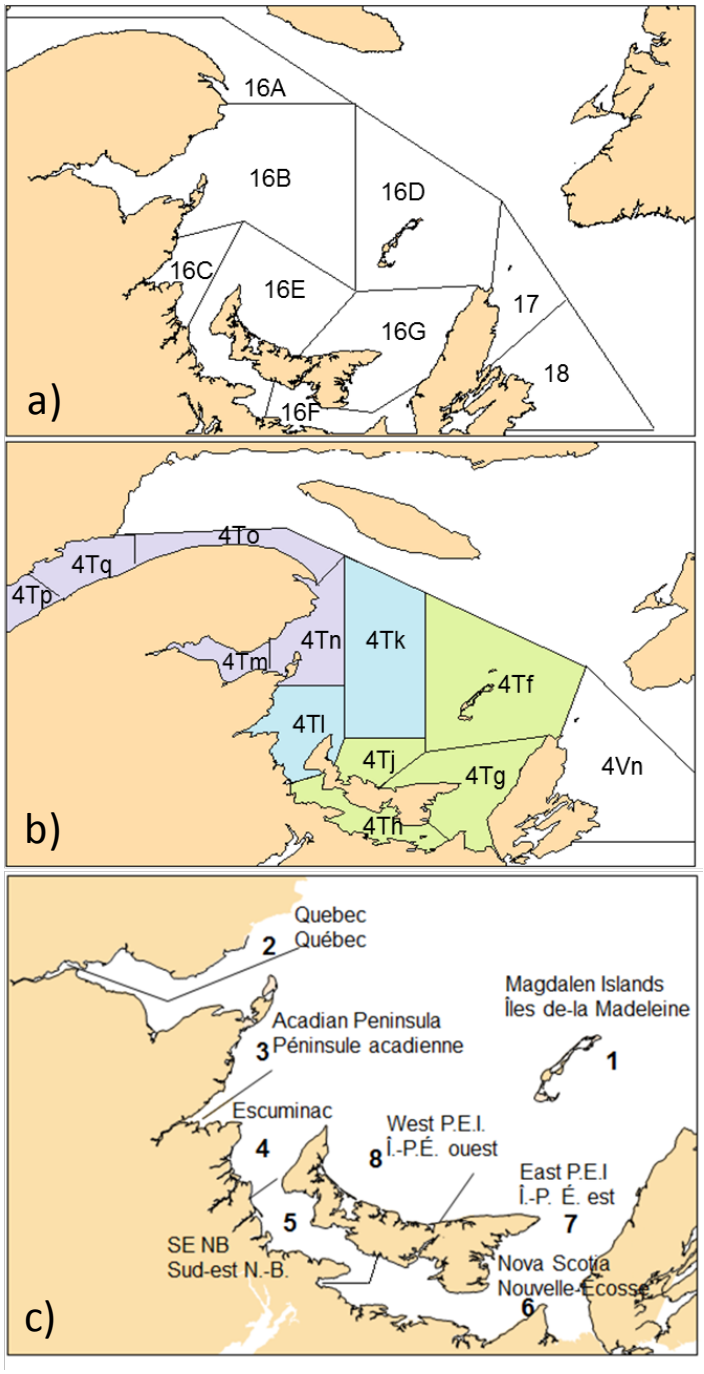

Figure 1. Southern Gulf of St. Lawrence herring fishery management zones (a - upper panel), Northwest Atlantic Fisheries Organization (NAFO) divisions 4T and 4Vn, where purple represents the North region, blue = Middle region, and green = South region (b - middle panel), and geographic areas used in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

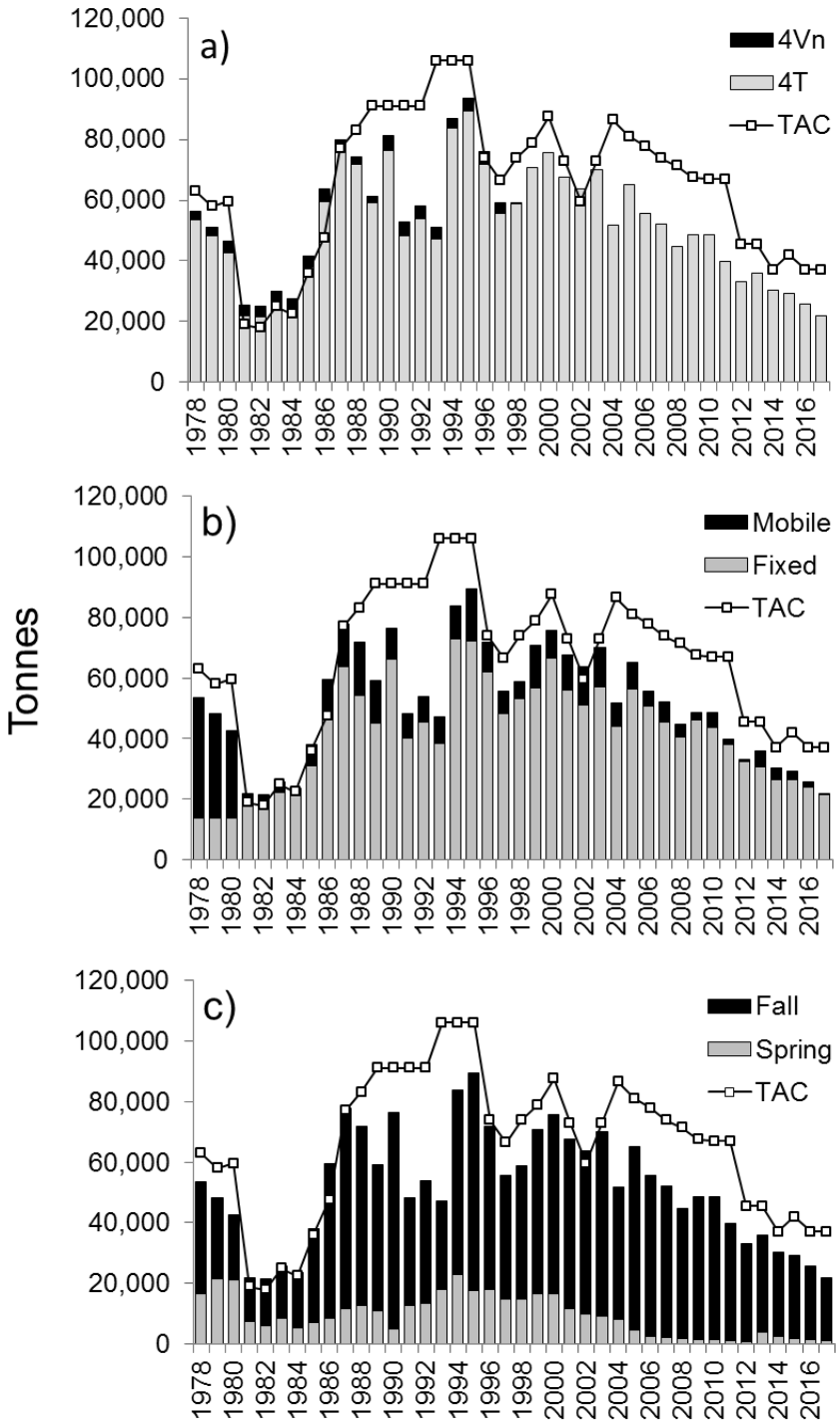

Figure 2. Reported landings (t) of southern Gulf of St. Lawrence Atlantic Herring (spring and fall spawners combined) by NAFO division (a - upper panel), by gear fleet (b - middle panel), and by fishing season (c - lower panel), 1978 to 2017. In all panels, the corresponding annual total allowable catch (TAC; t) is shown. For landings by season, the landings in Div. 4Vn were attributed to the fall fishing season. Data for 2016 and 2017 are preliminary.

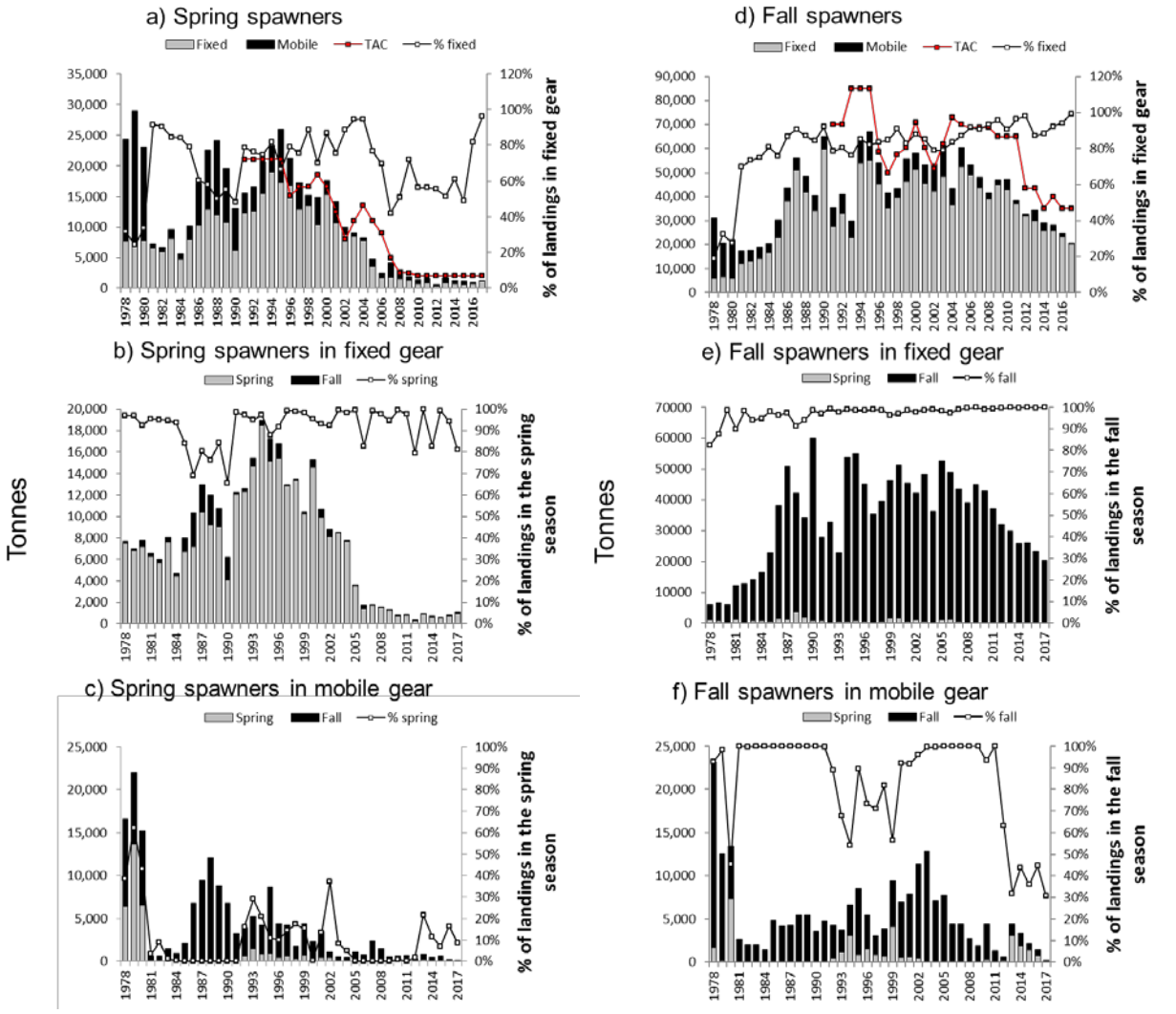

Figure 3. Estimated landings (t) of the spring spawner component (SS) (left column) and fall spawner component (FS) (right column) of Atlantic Herring from the southern Gulf of St. Lawrence, 1978 to 2017. The upper row (panels a, d) shows the estimated landings by gear type and the proportion of the landings attributed to the fixed gear fleet by spawner component. Also shown in these panels is the TAC for the spawner component (red symbols) for 1991 to 2017. The middle row (panels b, e) shows the estimated landings of herring in the fixed gear fleet that occurred in the spring fishery season (panel b) and the fall fishery season (panel e) as well as the proportion of herring landed in the corresponding fishing season. The lower row (panels c, f) shows the estimated landings of herring in the mobile gear fleet that occurred in the spring fishery season (panel c) and the fall fishery season (panel f) as well as the proportion of herring landed in the corresponding fishing season. For the mobile gear landings by season, the landings in NAFO Div. 4Vn were attributed to the fall fishing season. Data for 2016 and 2017 are preliminary.

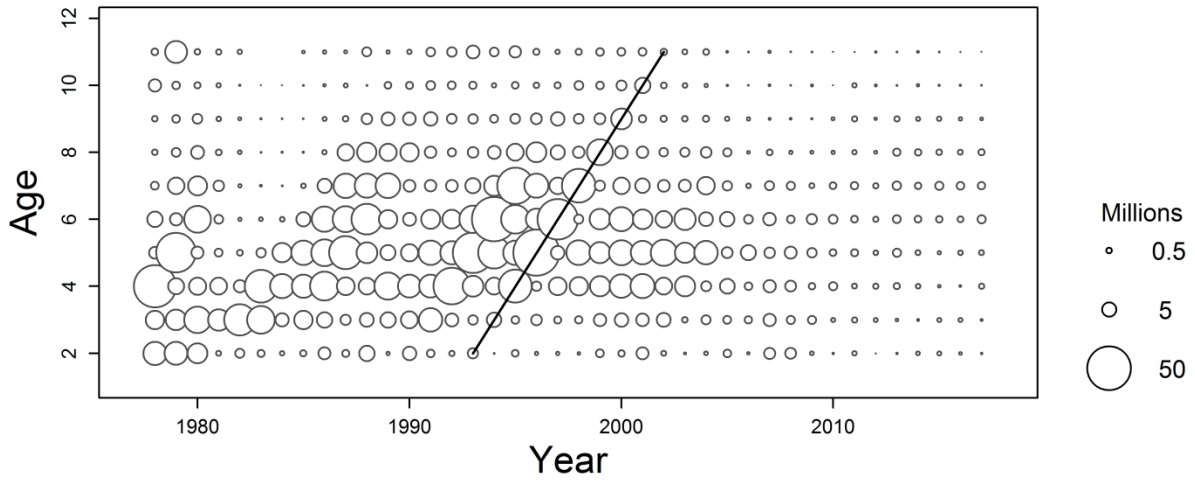

Figure 4. Catch-at-age (number of fish) of the spring spawner component of Atlantic Herring from the fishery, all gears combined, in NAFO Div. 4T for 1978 to 2017. The size of the bubble is proportional to the catch numbers by age and year. The diagonal line represents the most recent strong year-class (1991).

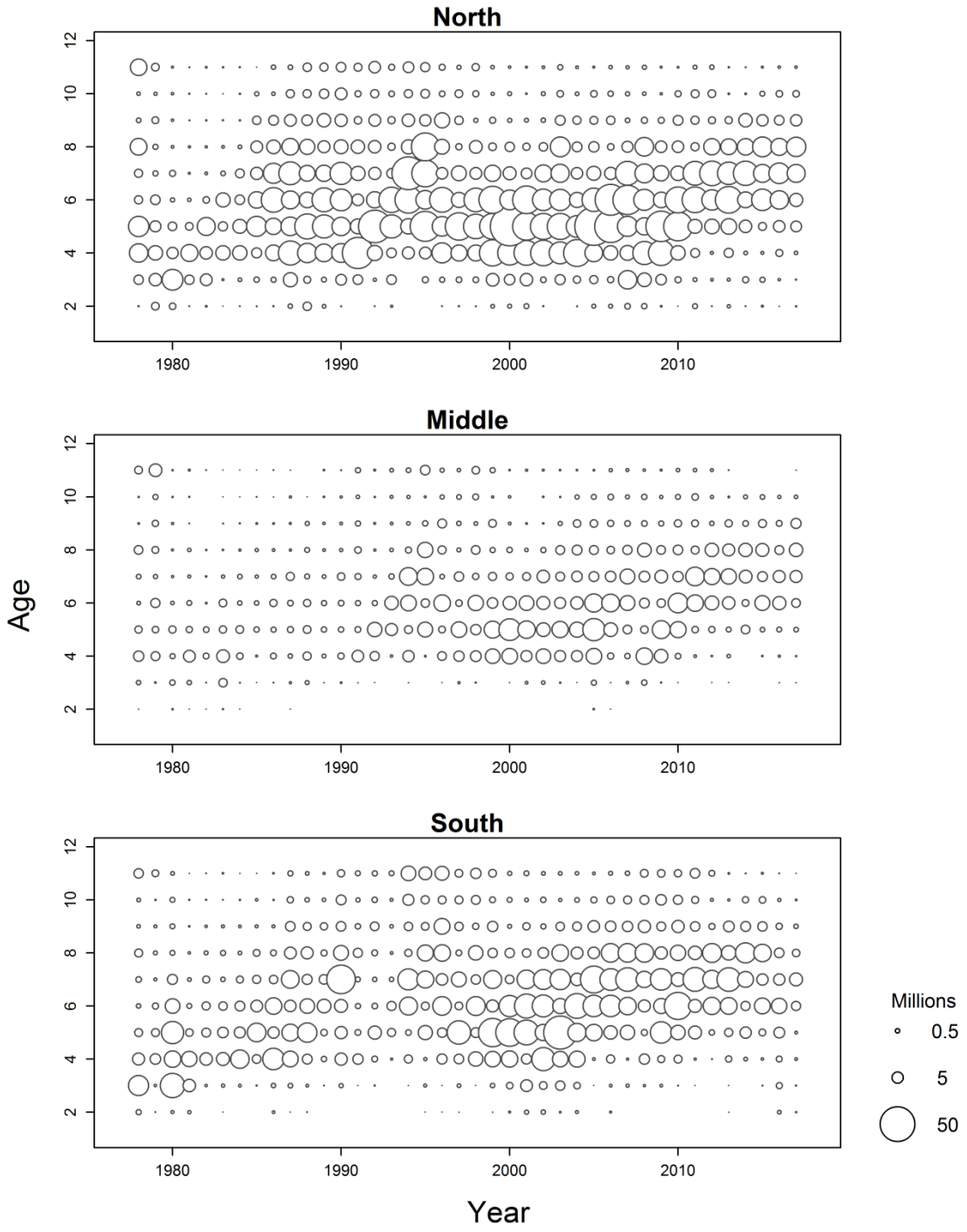

Figure 5. Bubble plots of fishery catch-at-age (number of fish) of thje fall spawner component of Atlantic Herring, by region (upper panel North, middle panel Middle, lower panel South) for mobile gear and fixed gear combined, in NAFO Div. 4T for 1978 to 2017. The size of the bubble is proportional to 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.

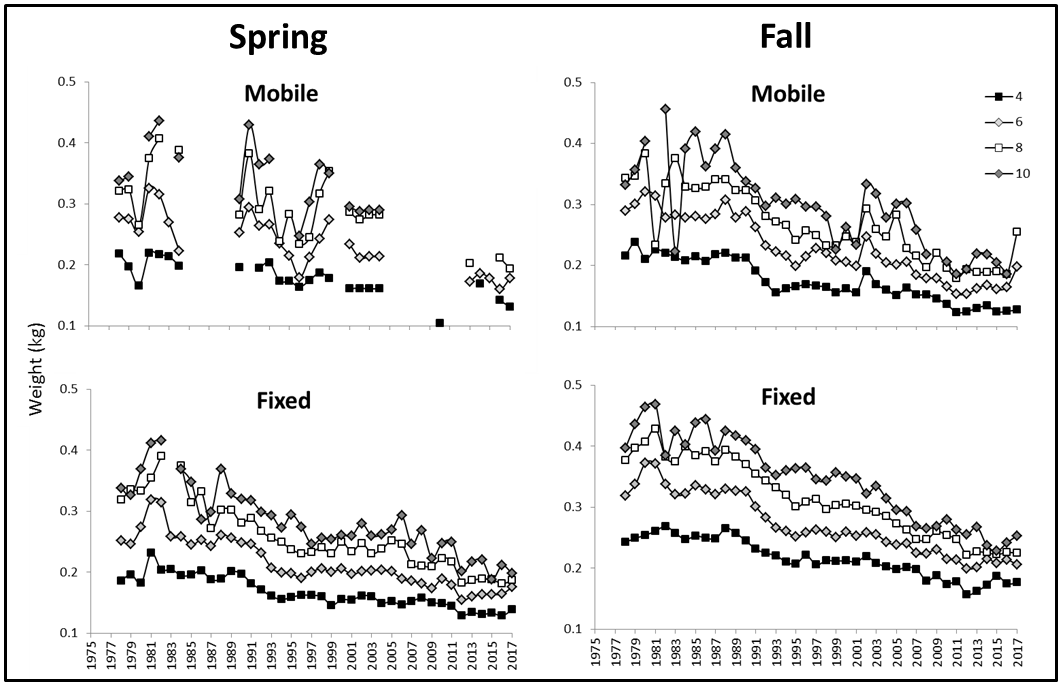

Figure 6. Mean weight (kg) of Atlantic Herring for ages 4, 6, 8, and 10 of spring spawners (left panels) sampled from catches in the spring season and fall spawners (right panels) sampled from catches in the fall season from mobile (upper panels) and fixed (lower panels) commercial gears, in NAFO Div. 4T for 1978 to 2017.

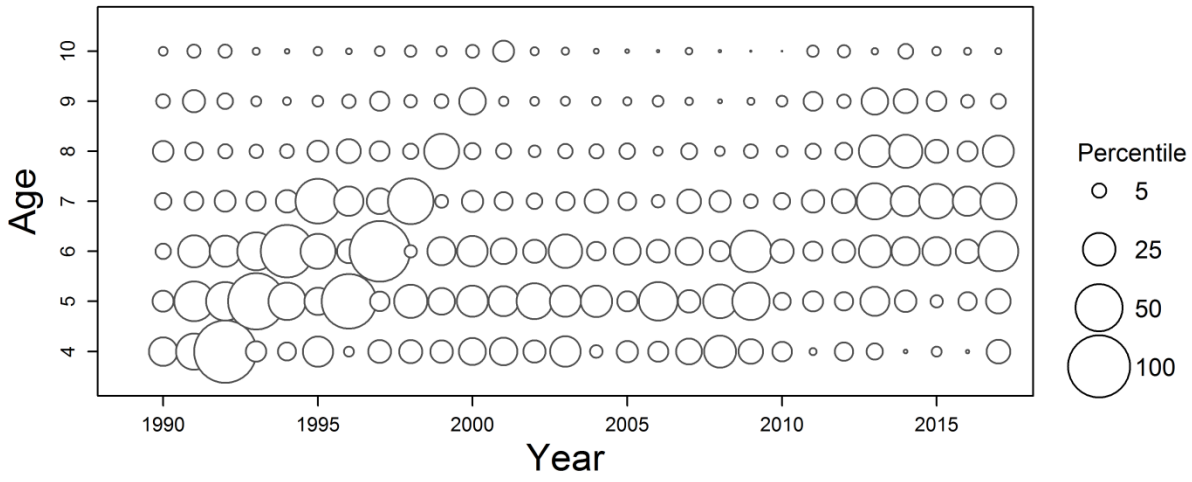

Figure 7. Bubble plot of spring spawner Atlantic Herring fixed gear catch-per-unit-effort values (number per net-haul per trip) at age from NAFO Div. 4T for 1990 to 2017. The size of the bubble is proportional to the maximum CPUE index value.

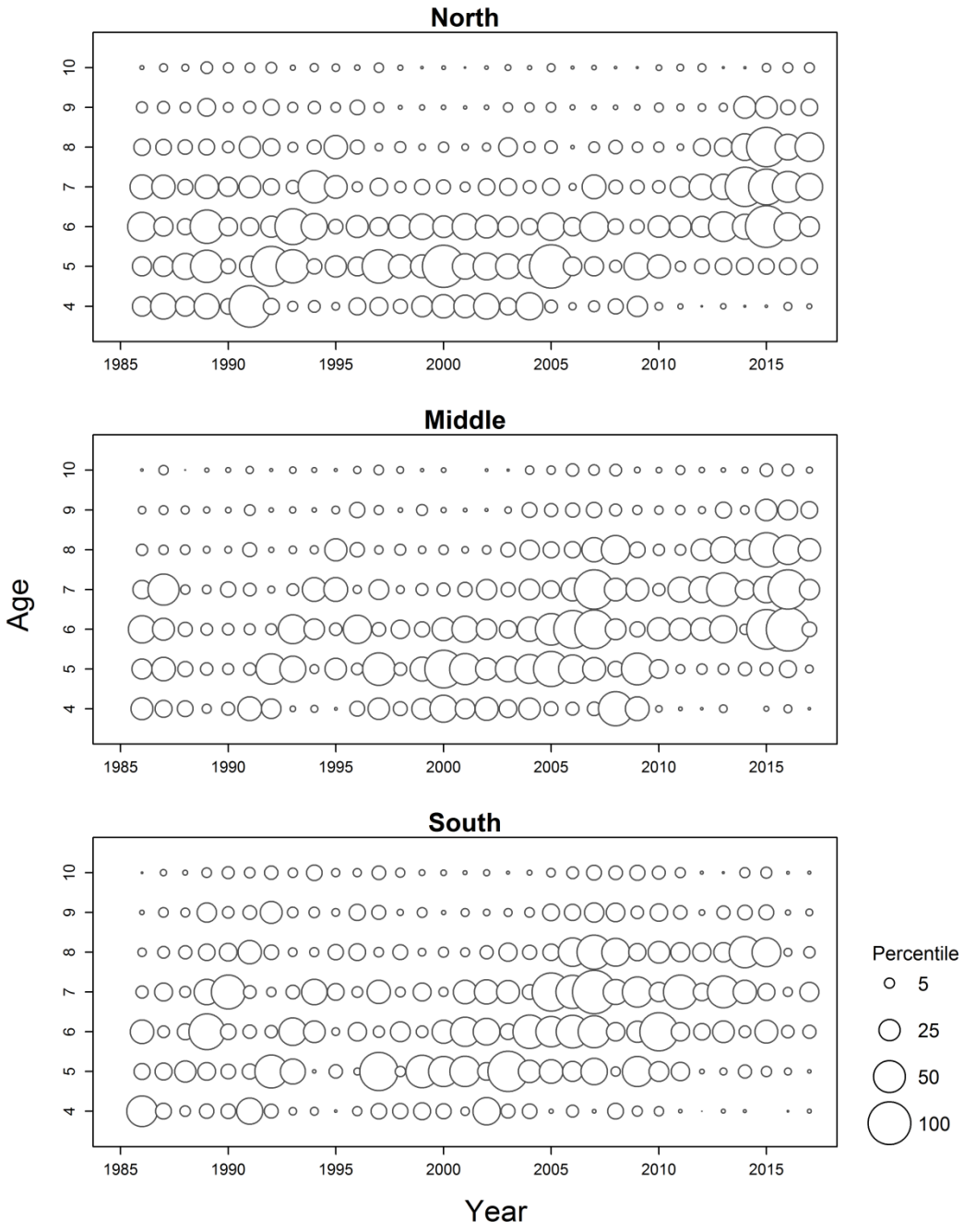

Figure 8. Fixed gear age-disaggregated catch-per-unit-effort indices (number per net-haul per trip) of fall spawner (FS) Atlantic Herring by region (upper panel North, middle panel Middle, and lower panel South), from NAFO Div. 4T for 1986 to 2017. The size of the bubble is proportional to the maximum CPUE index value.

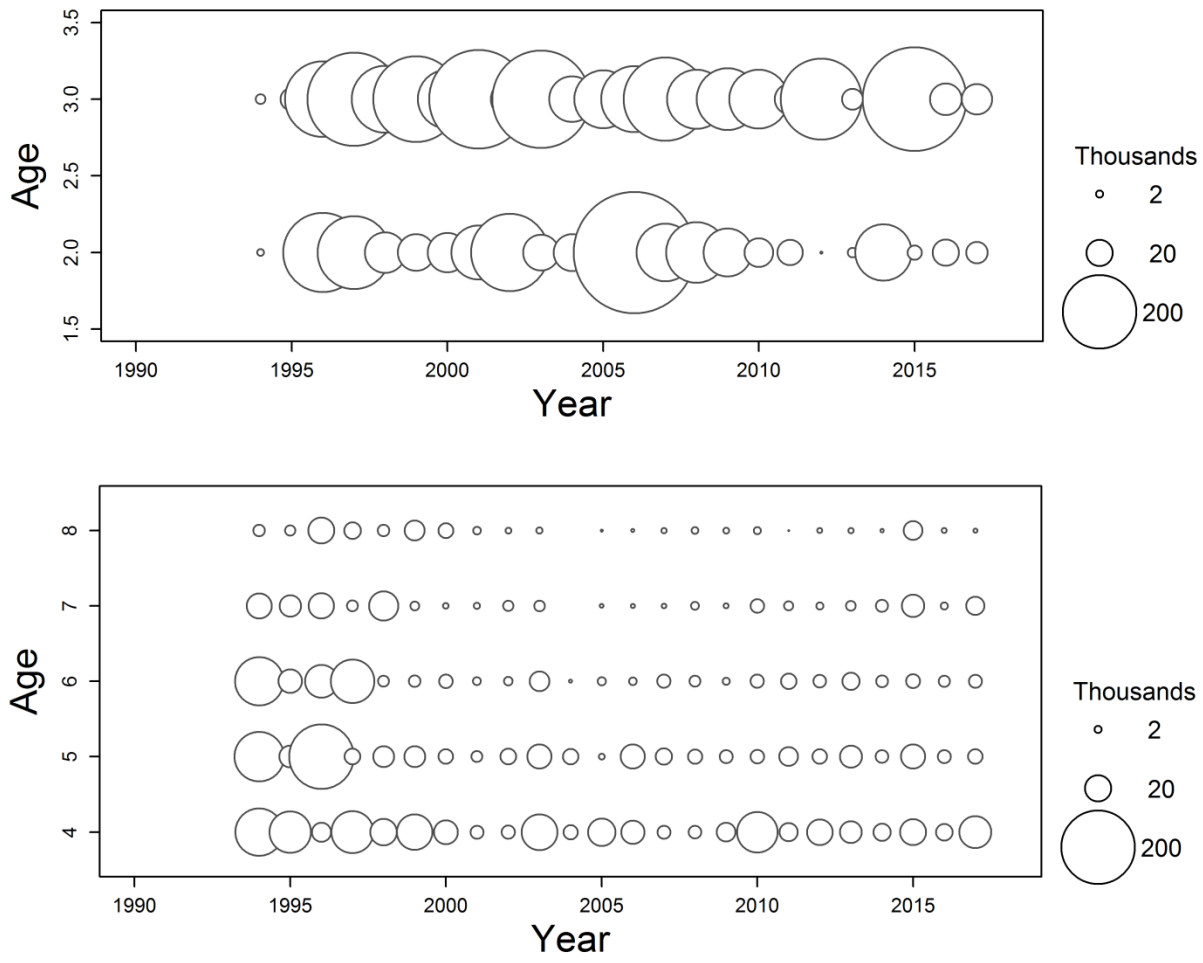

Figure 9. Bubble plot of the fisheries-independent acoustic survey abundance-at-age indices (number of fish) for fall spawner (upper panel; ages 2 and 3) and spring spawner (lower panel; ages 4 to 8) Atlantic Herring for NAFO Div. 4T from 1994 to 2017.

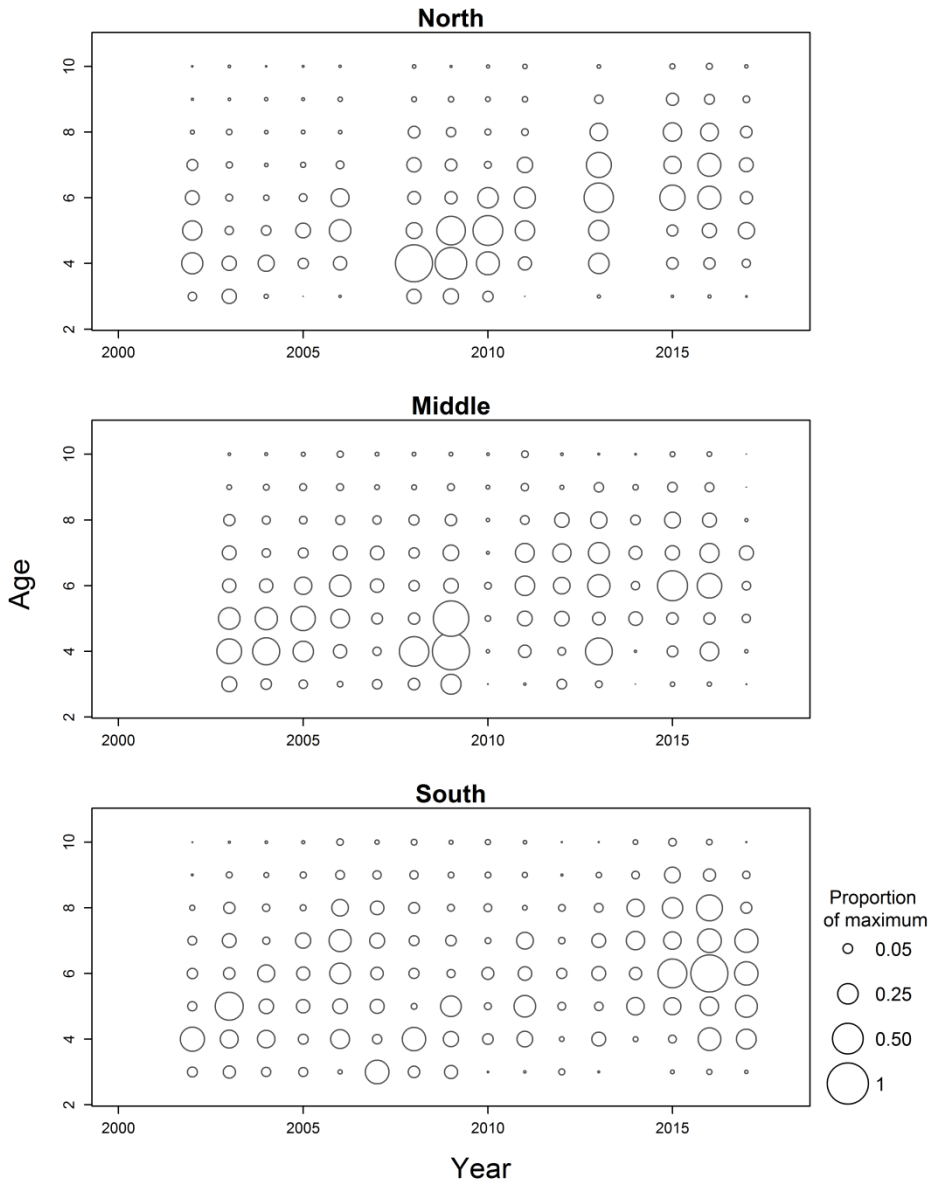

Figure 10. Bubble plots of the experimental gillnet catch-at-age indices (numbers per hour) of fall spawner Atlantic Herring by region (upper panel North, middle panel Middle, and lower panel South) for NAFO Div. 4T from 2002 to 2017. The size of the bubble is proportional to the maximum CPUE index value.

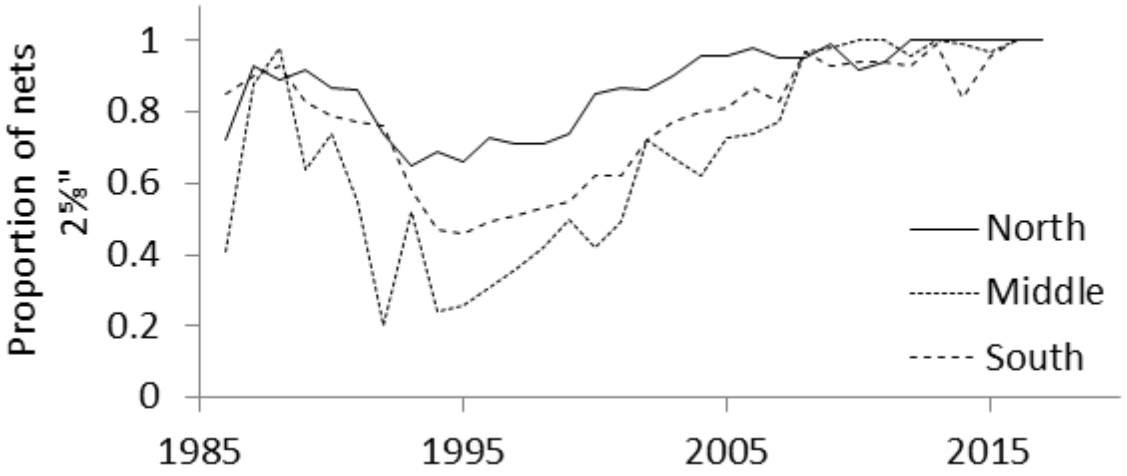

Figure 11. Variations in the proportions of gillnets with mesh sizes $2^{5}/_{8}$ inches used in the fall fixed gear fishery of AtlanticHherring by region for NAFO Div. 4T from 1986 to 2017. It is assumed that all other nets used were of mesh size 2¾.

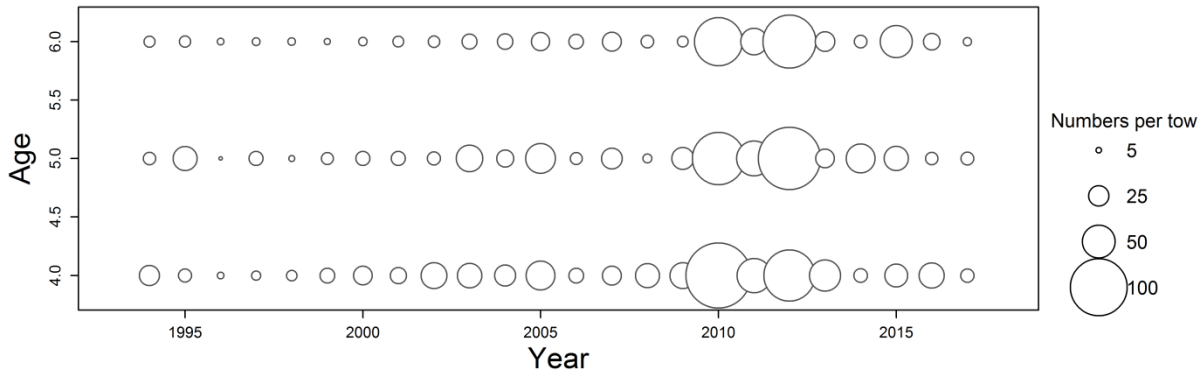

Figure 12. Multispecies bottom trawl survey abundance index (number of fish per standardized tow) for fall spawning Atlantic Herring of ages 4 to 6 years for NAFO Div. 4T from 1994 to 2017.

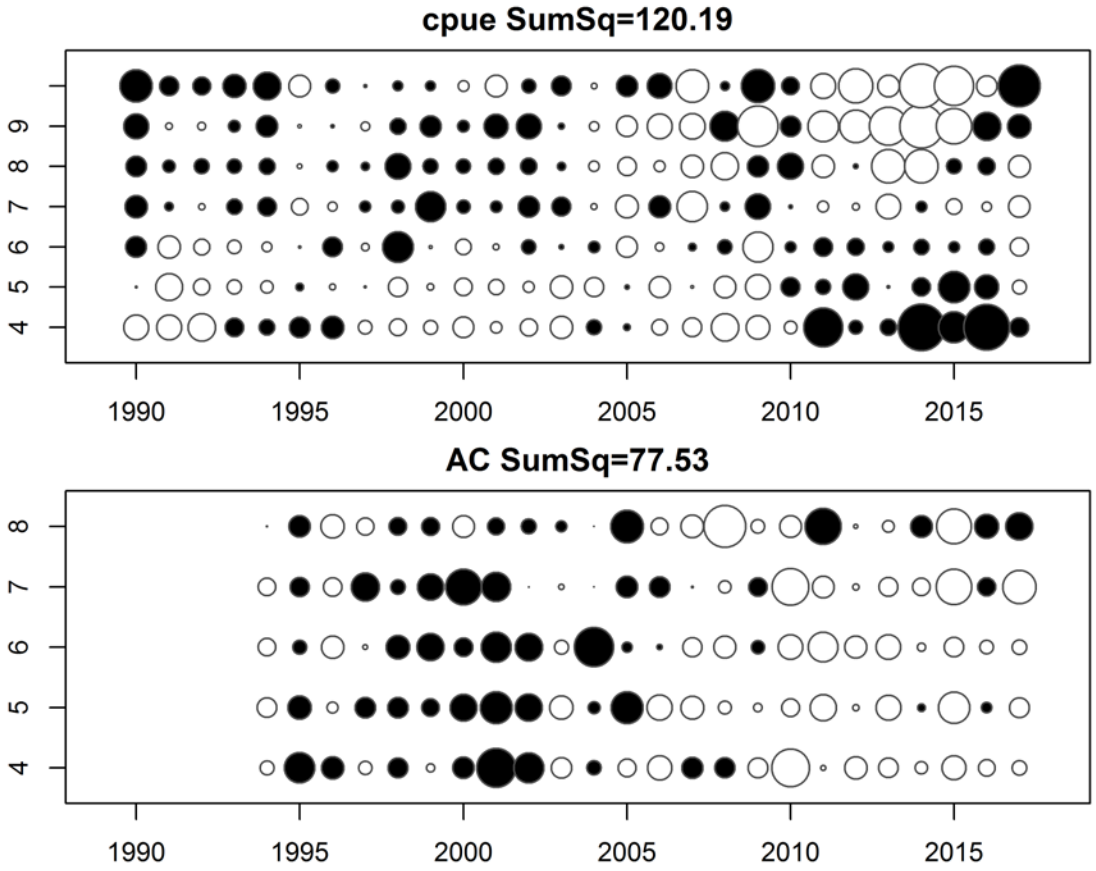

Figure 13. Residuals (observed – predicted indices) for population models of spring spawner Atlantic Herring in NAFO Div. 4T. The upper panel shows residuals for the CPUE index and the bottom panel shows residuals for the acoustic index. Rows are for ages and columns are for years. Circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted) and white circles indicate positive residuals.

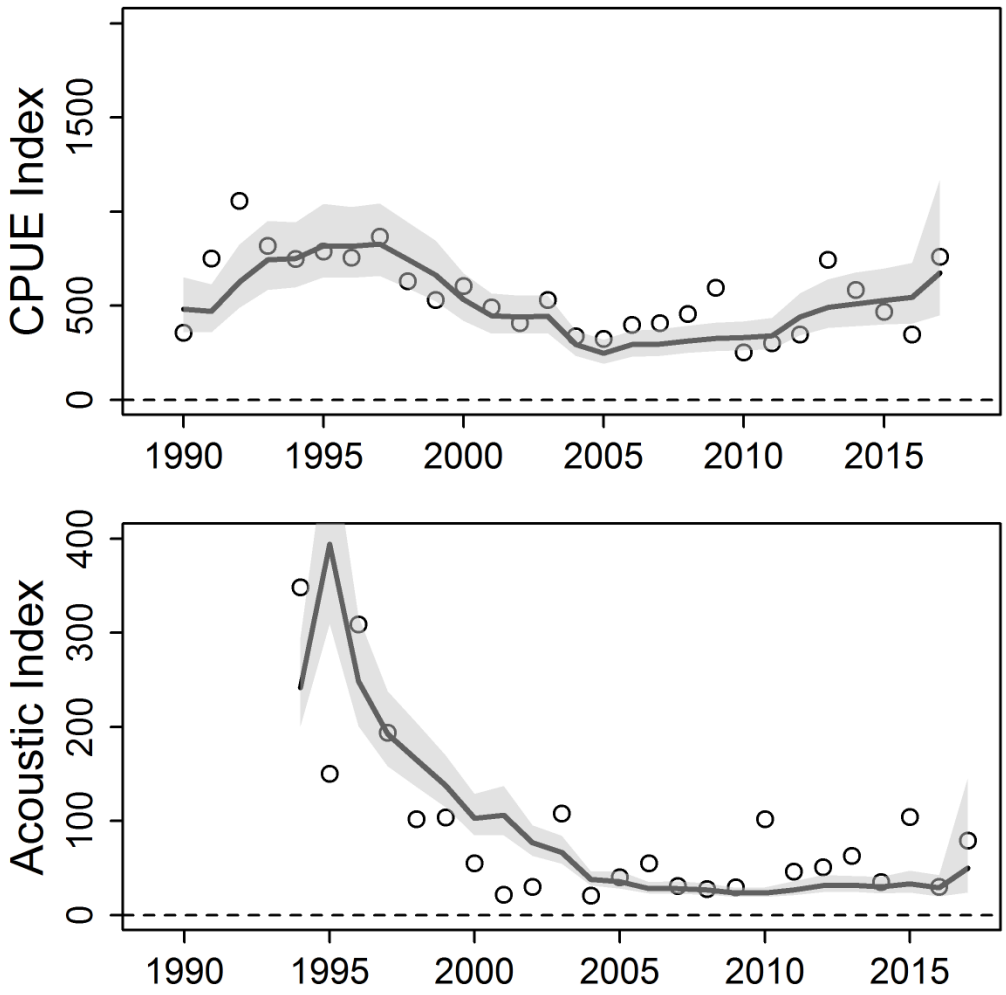

Figure 14. Observed (circles) and predicted (lines and shading) age-aggregated CPUE (upper panels) and acoustic (lower panels) indices for the model of spring spawner Atlantic Herring in NAFO Div. 4T. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

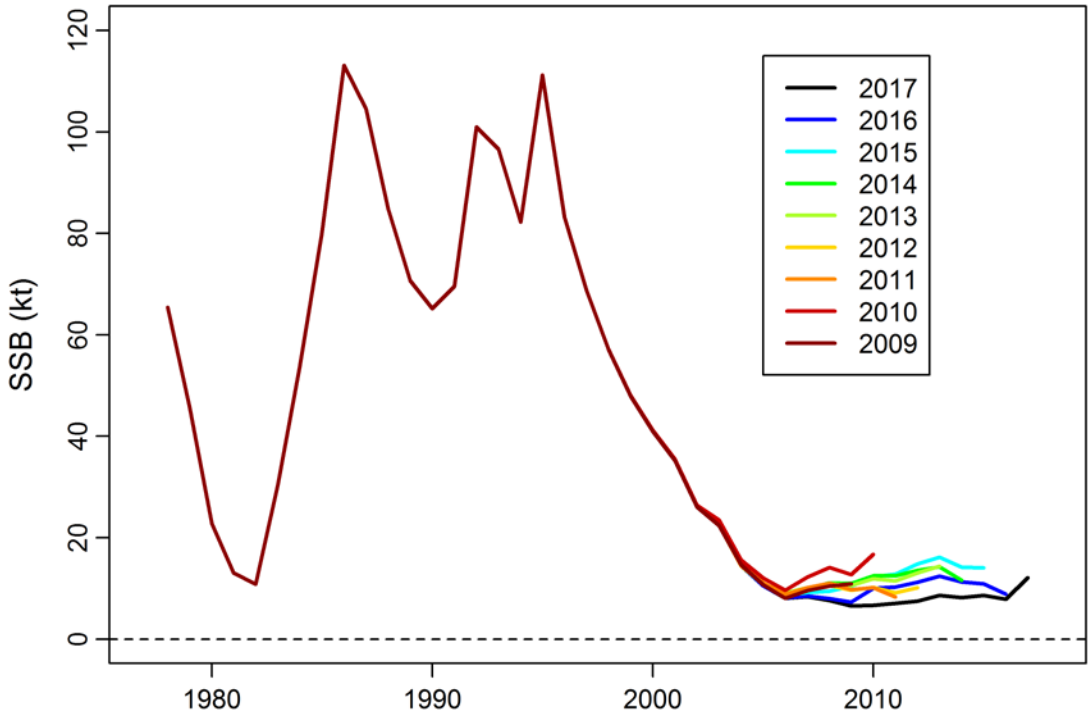

Figure 15. Retrospective patterns in estimated spawning stock biomass (SSB, kt) of ages 5 to 10 for spring spawner Atlantic Herring in NAFO Div. 4T.

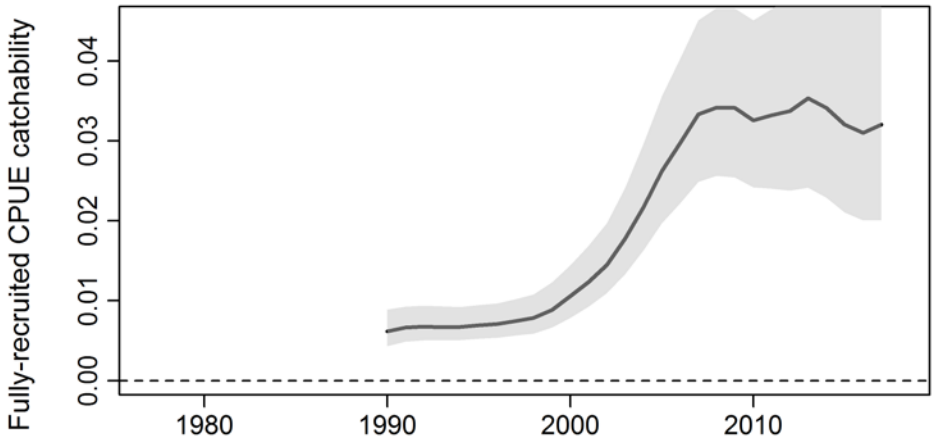

Figure 16. Estimated fully-recruited catchability to the CPUE index for spring spawner Atlantic Herring for NAFO Div. 4T. Lines show the median estimates and shading their 95% confidence interval based on MCMC sampling.

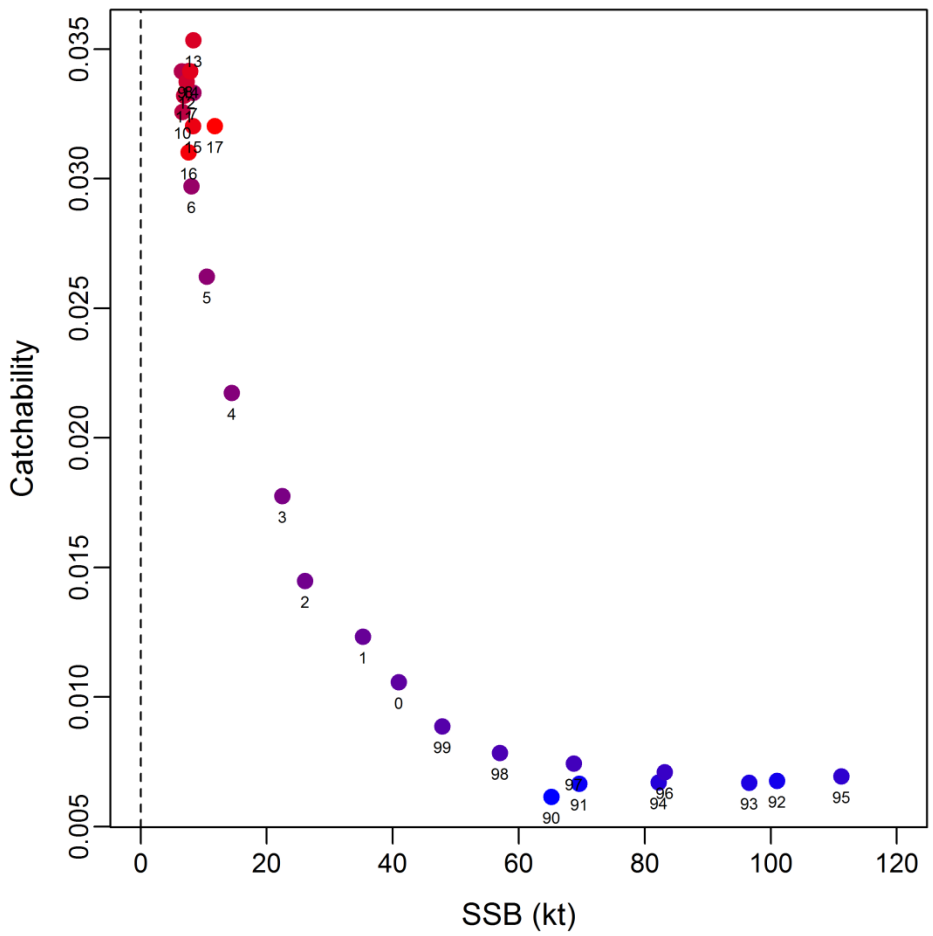

Figure 17. Fully-recruited catchability of Atlantic Herring to the spring gillnet fishery in relation to estimated spring spawner spawning stock biomass (SSB) for NAFO Div. 4T.

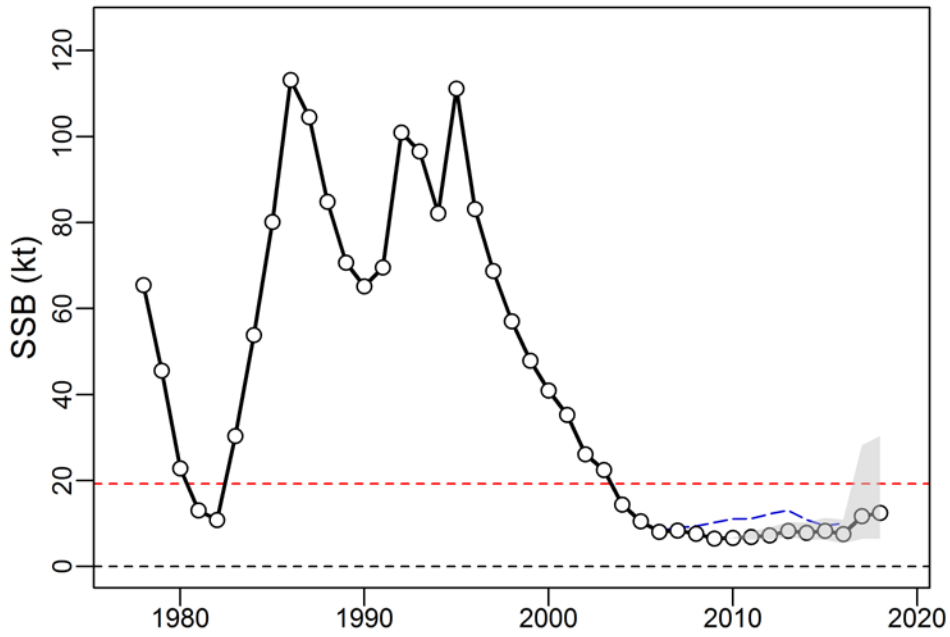

Figure 18. Estimated spawning stock biomass (SSB, kt) of the spring spawner component of Atlantic Herring in NAFO Div. 4T. Circles show the maximum likelihood estimates (MLEs). The solid line is the median MCMC estimate and shading its 95% confidence interval. The red dashed horizontal line is the Limit Reference Point (19,250 t of SSB). The blue dashed line shows the estimates from the 2016 assessment.

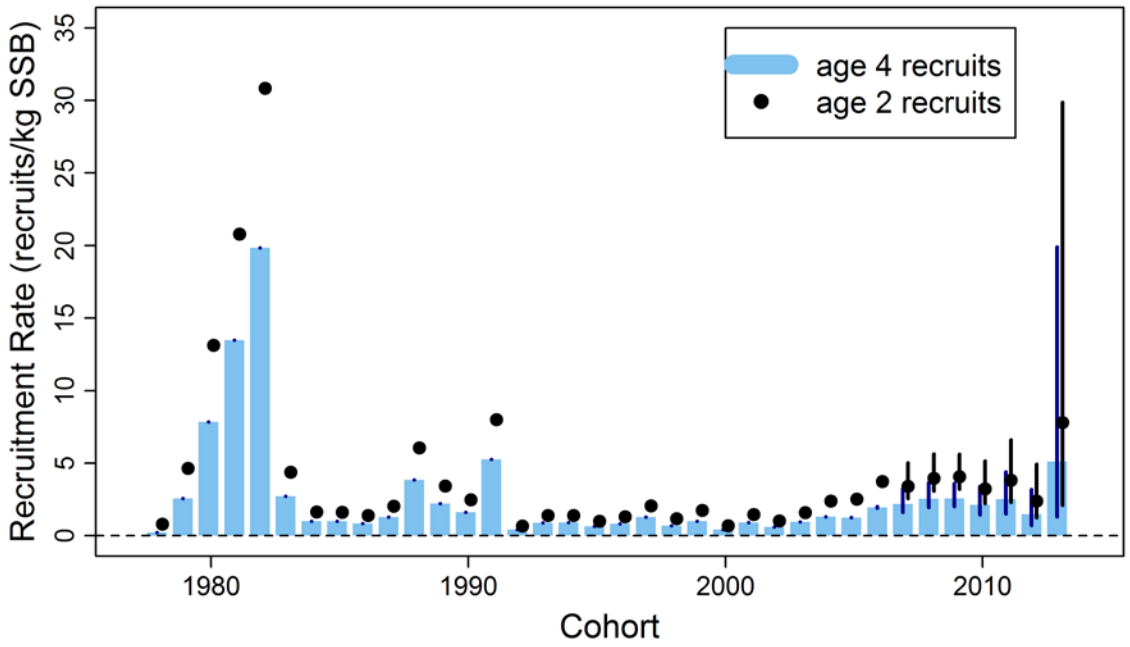

Figure 19. Recruitment rates for age 2 (circles) and age 4 (bars) recruits for the 1978 to 2013 cohorts of spring spawner Atlantic Herring in NAFO Div. 4T. Vertical lines indicate 95% confidence intervals.

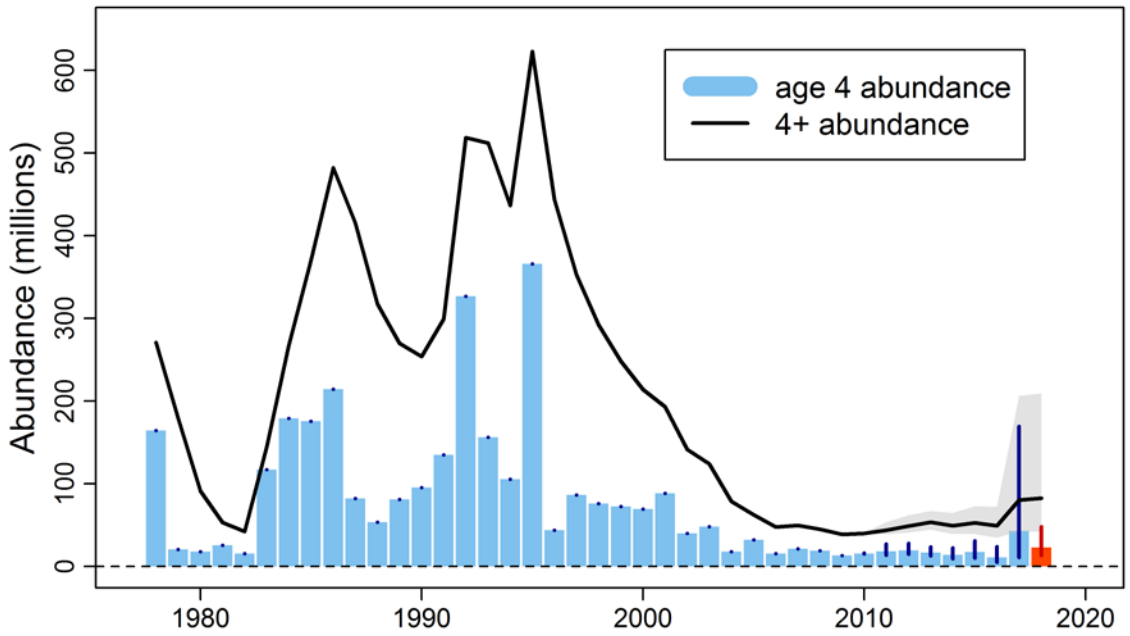

Figure 20. Estimated beginning-of-year abundance (millions) of 4 year old (blue bars) and 4 years and older (line) Atlantic Herring spring spawners in NAFO Div. 4T. Bars and the line show the median MCMC estimate and vertical lines or shading its 95% confidence interval. Age-4 abundance in 2018 (the red bar) was estimated assuming the recruitment rate for this cohort was the average of the rates for the preceding five cohorts.

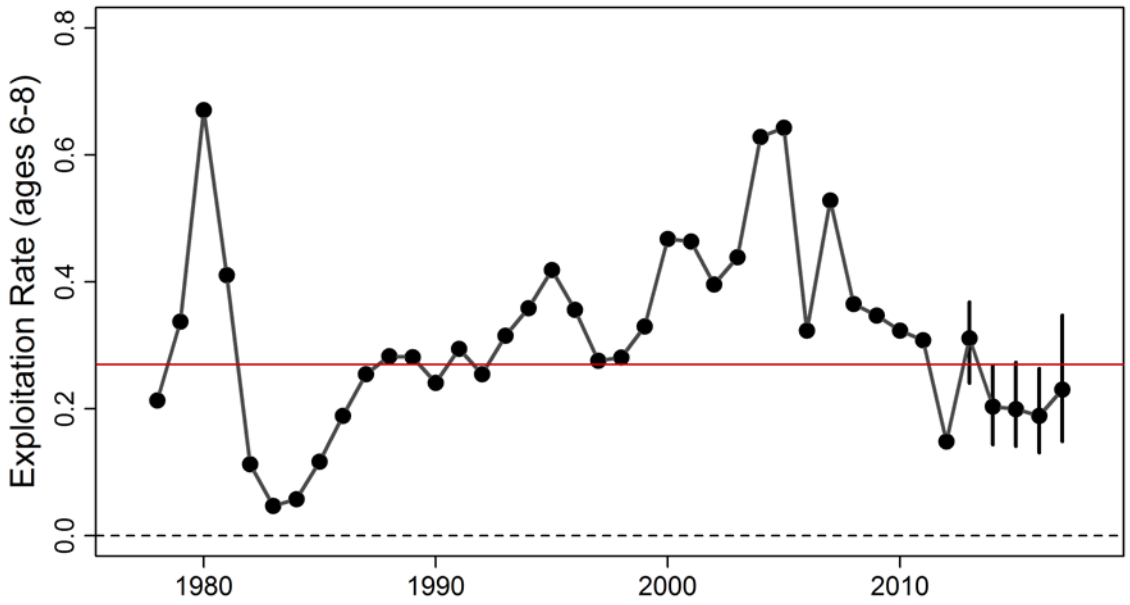

Figure 21. Estimated exploitation rate of spring-spawning Atlantic Herring aged 6 to 8 years in NAFO Div. 4T. Circles are the median estimates based on MCMC sampling and vertical lines their 95% confidence intervals. The red horizontal line shows the reference level (F0.1 = 0.35) exploitation rate (0.295).

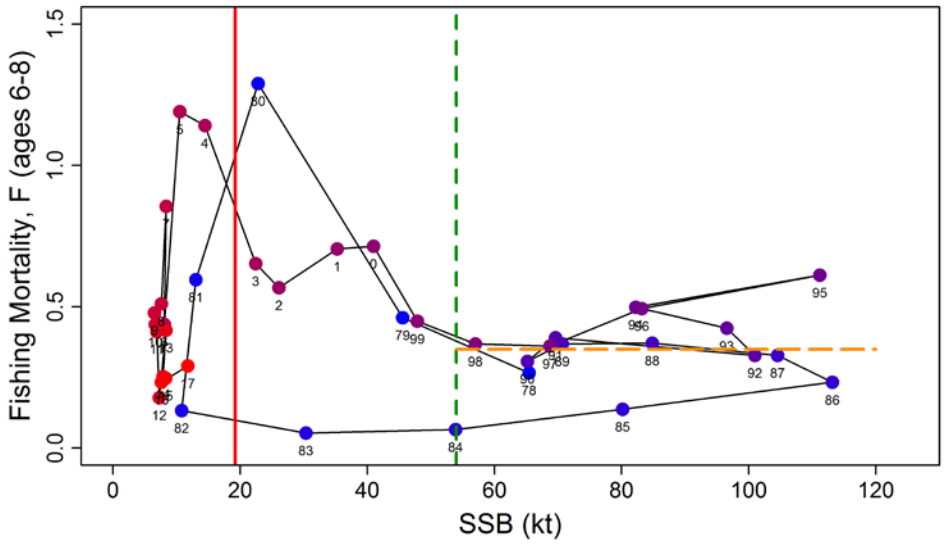

Figure 22. The population trajectory of the NAFO Div. 4T spring spawner Atlantic Herring expressed as the estimated spawning stock biomass (SSB) relative to the estimated fishing mortality rates for ages 6 to 8 years. The solid red vertical line is the Limit Reference Point (LRP; SSB = 19,250 t), the green dashed vertical line is the Upper Stock Reference (USR; SSB = 54,000 t), and the orange dashed horizontal line is the removal rate reference (F0.1 = 0.35) in the healthy zone when SSB > USR. Point labels are years (83 = 1983, 0 = 2000). Colour coding is from blue in the 1970s and early 1980s to red in the 2000s.

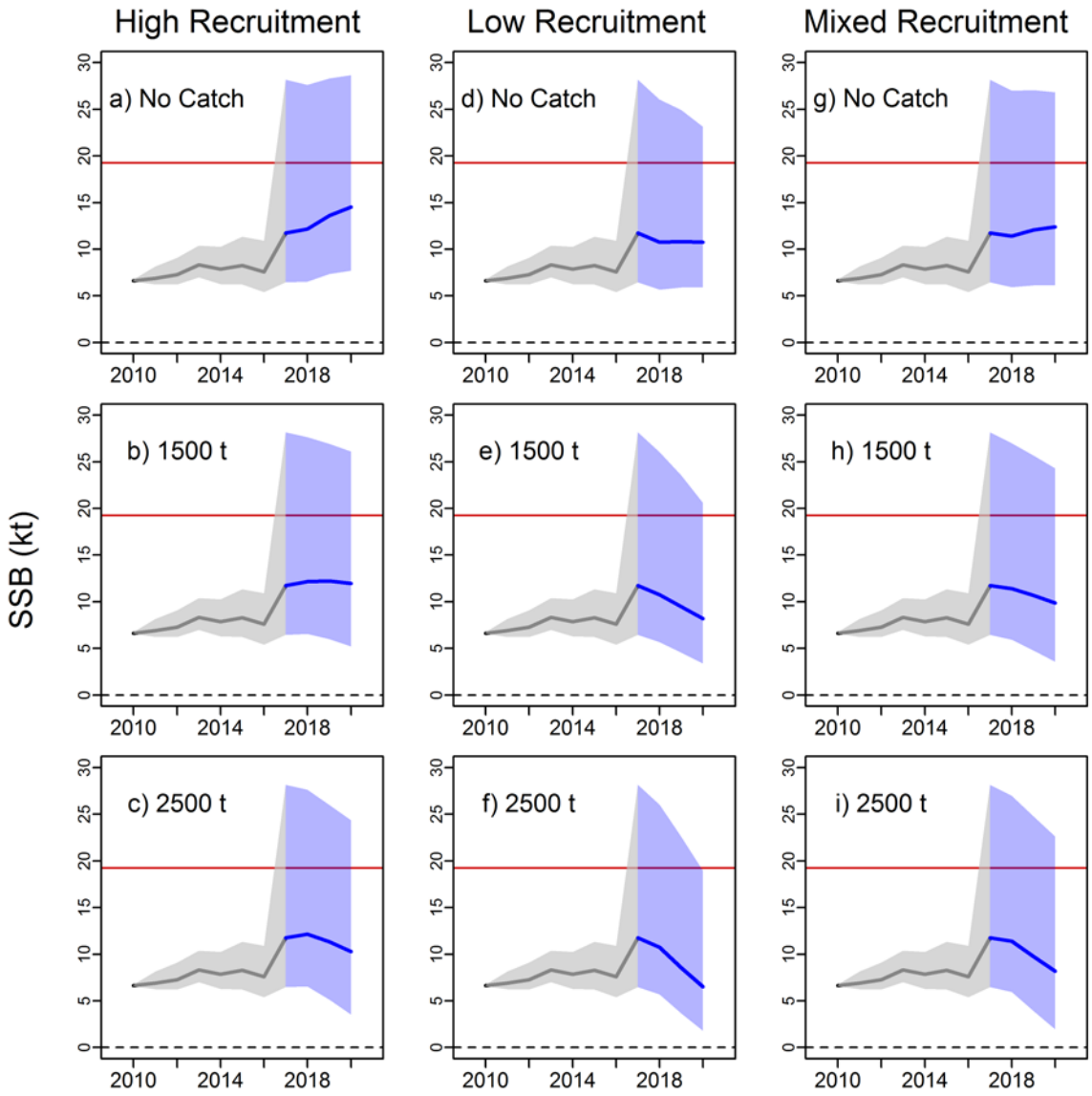

Figure 23. Projected spawning stock biomass (SSB in kt) of spring spawner Atlantic Herring in NAFO Div. 4T for three recruitment scenarios (columns) and three catch levels (rows) in 2018 and 2019. Lines show the median estimates of the beginning-of-year SSB and shading the 95% confidence intervals of these estimates (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period. The red horizontal line is the limit reference point (LRP).

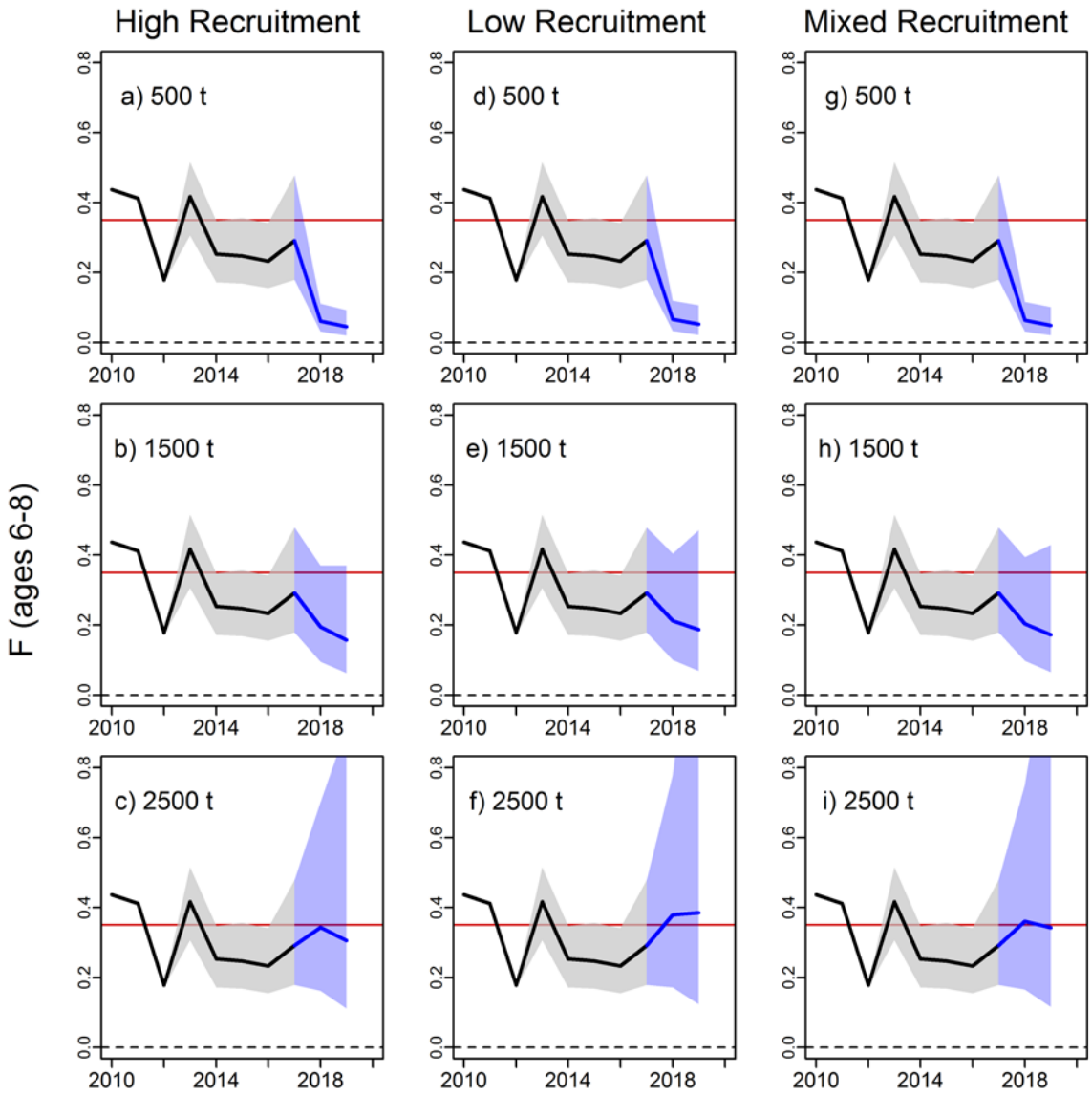

Figure 24. Projected ages 6 to 8 fishing mortality rate (F) of spring spawner Atlantic Herring in NAFO Div. 4T for three recruitment scenarios (columns) and three catch levels (rows) in 2018 and 2019. Lines show the median estimates and shading their 95% confidence intervals (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period. The red horizontal line is the removal rate reference level (F0.1) corresponding to F = 0.35.

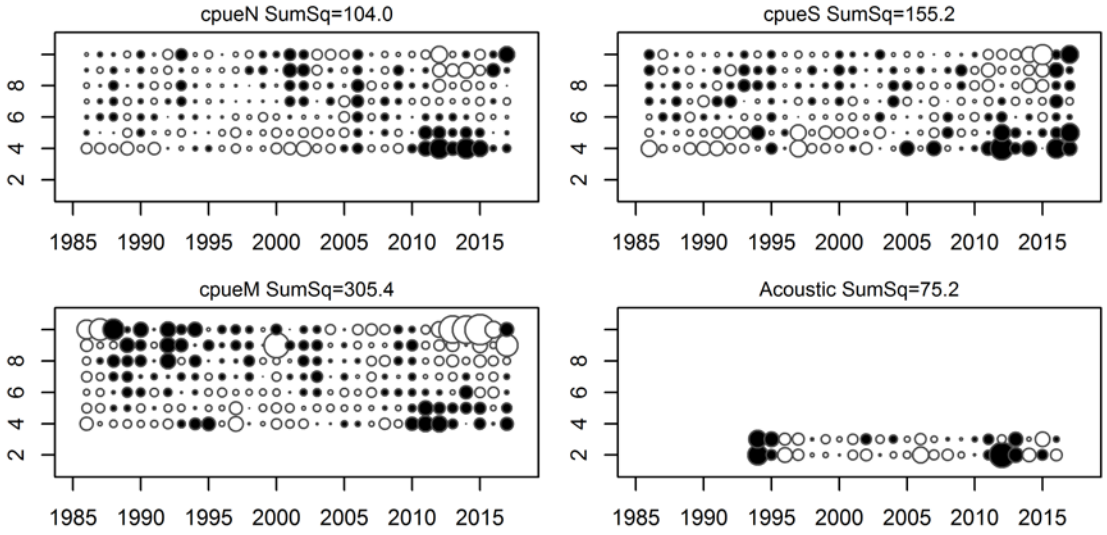

Figure 25. Commercial gillnet CPUE index residuals (observed – predicted indices) by region (cpueN = North; cpueM = Middle; cpueS = South) and residuals between predicted and observed indices from the acoustic survey (Acoustic, all regions combined) for fall spawner Atlantic Herring in NAFO Div. 4T. Rows are for ages and columns are for years. The circle radius is proportional to the absolute value of the residuals. Black circles indicate negative residuals (i.e., observed < predicted) and white circles indicate positive residuals.

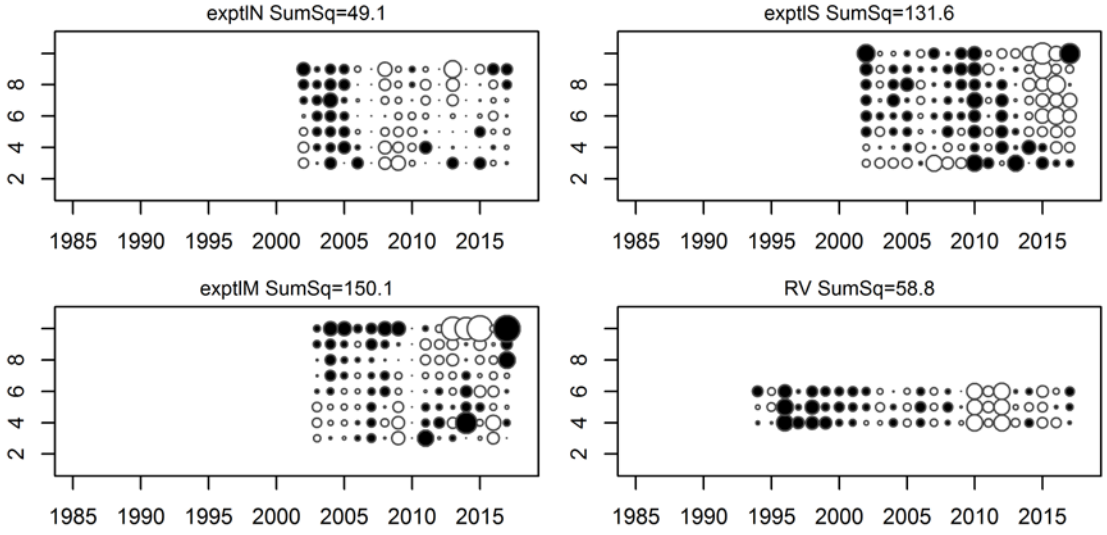

Figure 26. Experimental gillnet index residuals (observed – predicted indices) by region (exptlN = North; exptlM = Middle; exptlS = South), and residuals between predicted and observed indices from the RV survey (RV, all regions combined) for fall spawner Atlantic Herring in NAFO Div. 4T. Rows are for ages and columns are for years. The circle radius is proportional to the absolute value of residuals. Black circles indicate negative residuals (i.e., observed < predicted) and white circles indicate positive residuals.

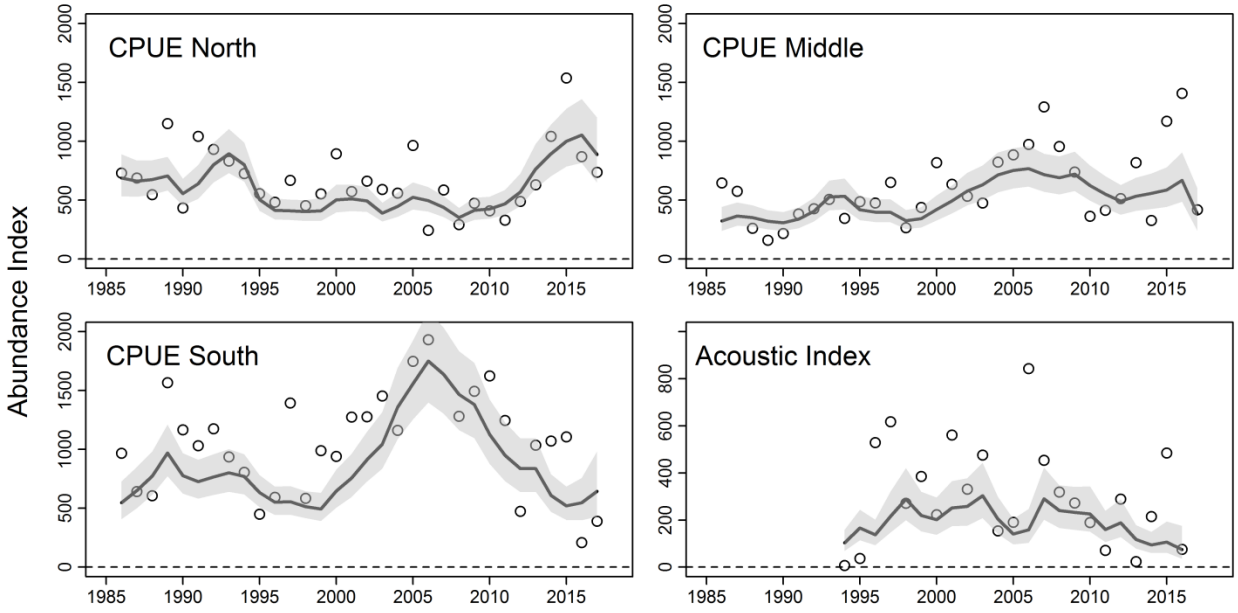

Figure 27. Observed (circles) and predicted (lines and shading) age-aggregated commercial gillnet CPUE indices by region (CPUE North, CPUE Middle, CPUE South) and acoustic indices (Acoustic, all regions combined) for fall spawner Atlantic Herring in NAFO Div. 4T. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

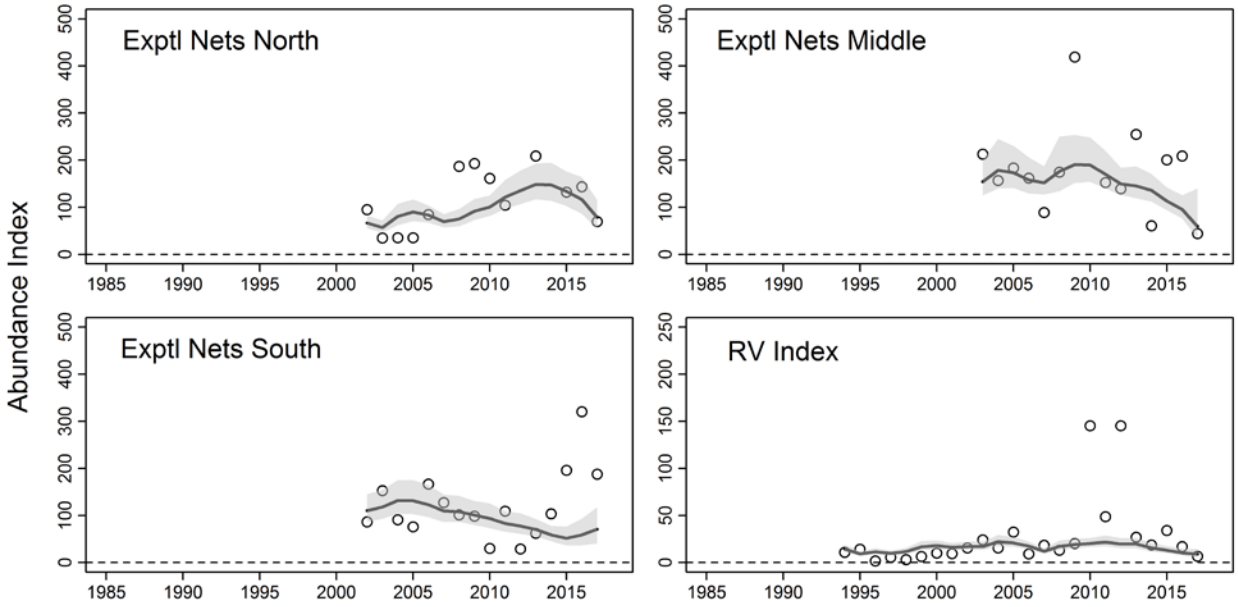

Figure 28. Observed (circles) and predicted (lines and shading) age-aggregated experimental gillnet indices by region (North, Middle, South) and RV indices (RV, all regions combined) for fall spawner Atlantic Herring in NAFO Div. 4T. The lines show the median predicted indices and the shading the 95% confidence intervals of the predictions based on MCMC sampling.

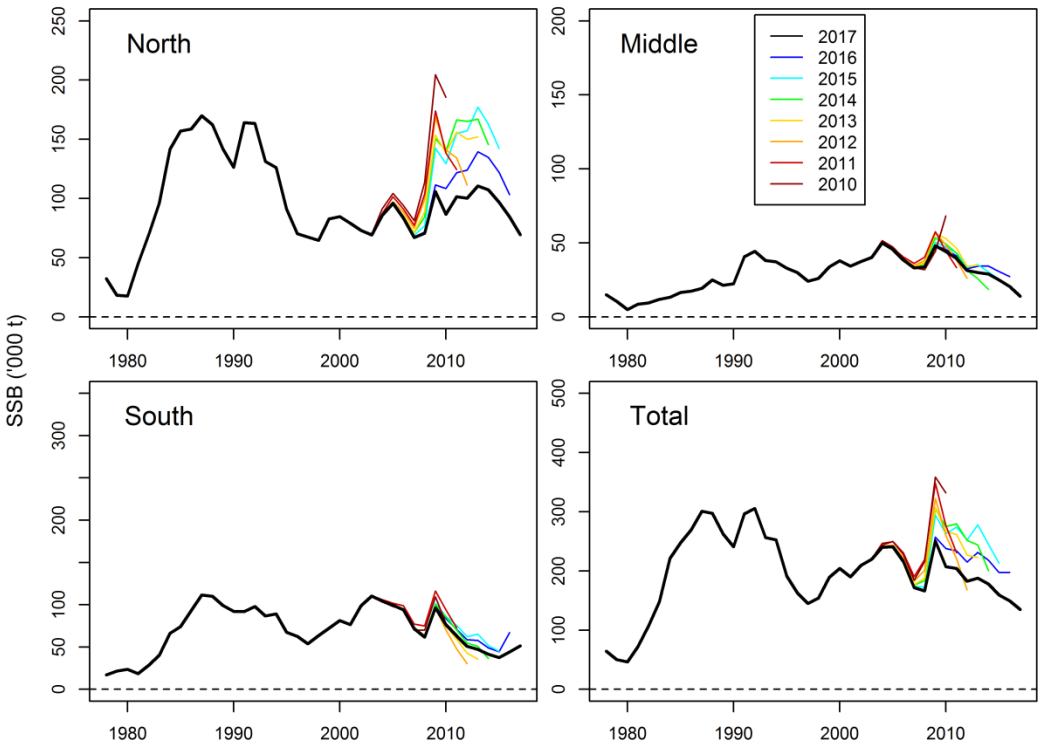

Figure 29. Retrospective patterns in spawning stock biomass (SSB) of fall spawner Atlantic Herring within the three regions (North, Middle, South) and overall (Total) in NAFO Div. 4T.

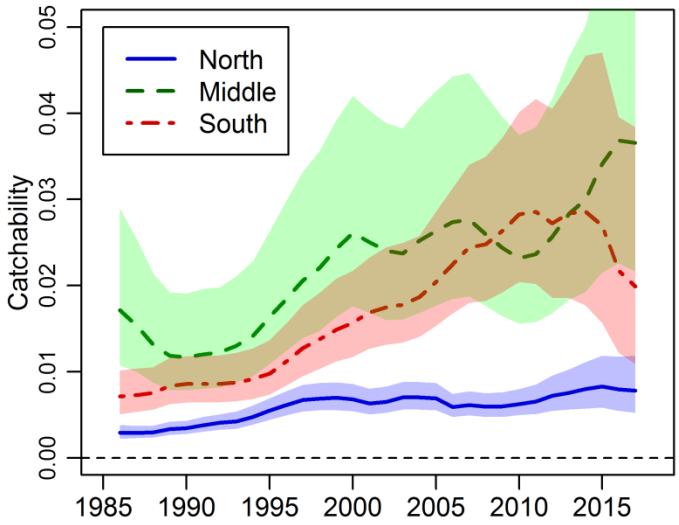

Figure 30. Estimated fully-recruited catchability of fall spawner Atlantic Herring for the commercial gillnet CPUE index by region (North, Middle, South) in NAFO Div. 4T. Lines show the median estimates and shading their 95% confidence intervals based on MCMC sampling.

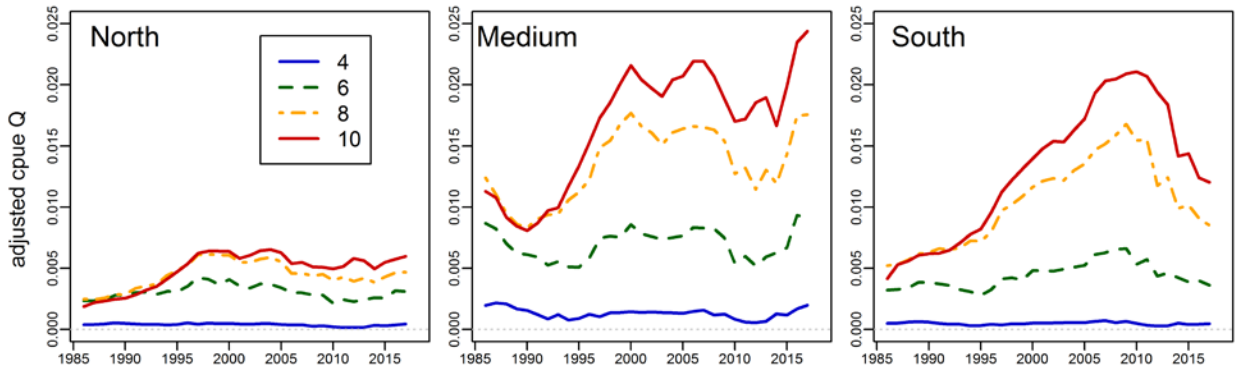

Figure 31. Estimated adjusted catchability (q) at age to the gillnet fishery in three regions (North, Middle and South) for fall spawner Atlantic Herring in NAFO Div. 4T. The adjusted catchability takes into account changes in mesh size and length at age as well as the changes over time in fully recruited q.

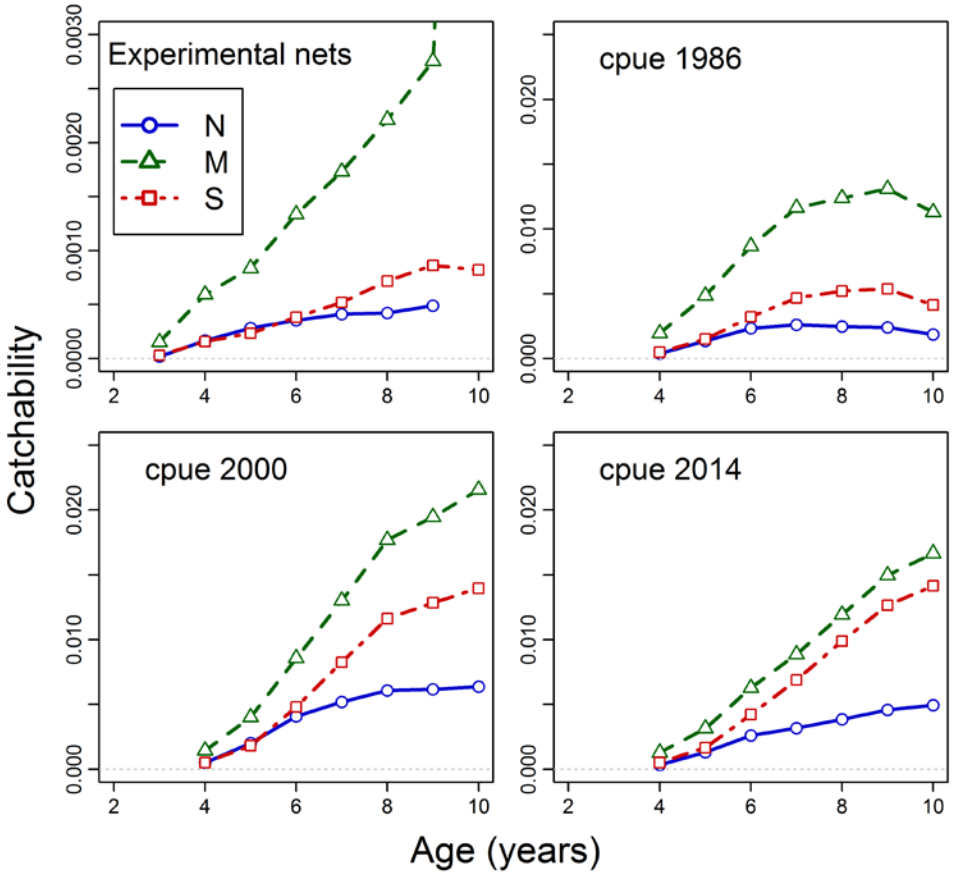

Figure 32. Catchability (q) at age to the experimental gillnets by region (upper left panel) compared to q-at-age in the commercial gillnet fishery in selected years (1986, upper right panel; 2000, lower left panel; and 2014, lower right panel) for fall spawner Atlantic Herring in NAFO Div. 4T.

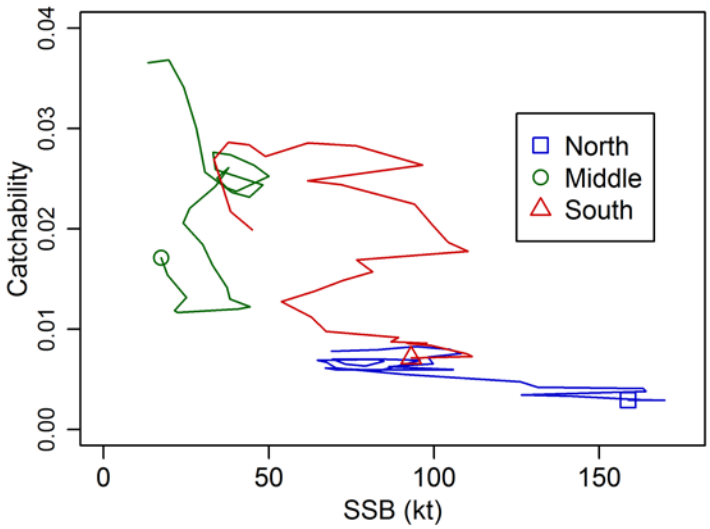

Figure 33. Fully-recruited catchability (q) in relation to spawning stock biomass (SSB, kt) of fall spawner Atlantic Herring for the three regions in NAFO Div. 4T. For each region, the marker denotes the first year in the 1986 to 2017 time series.

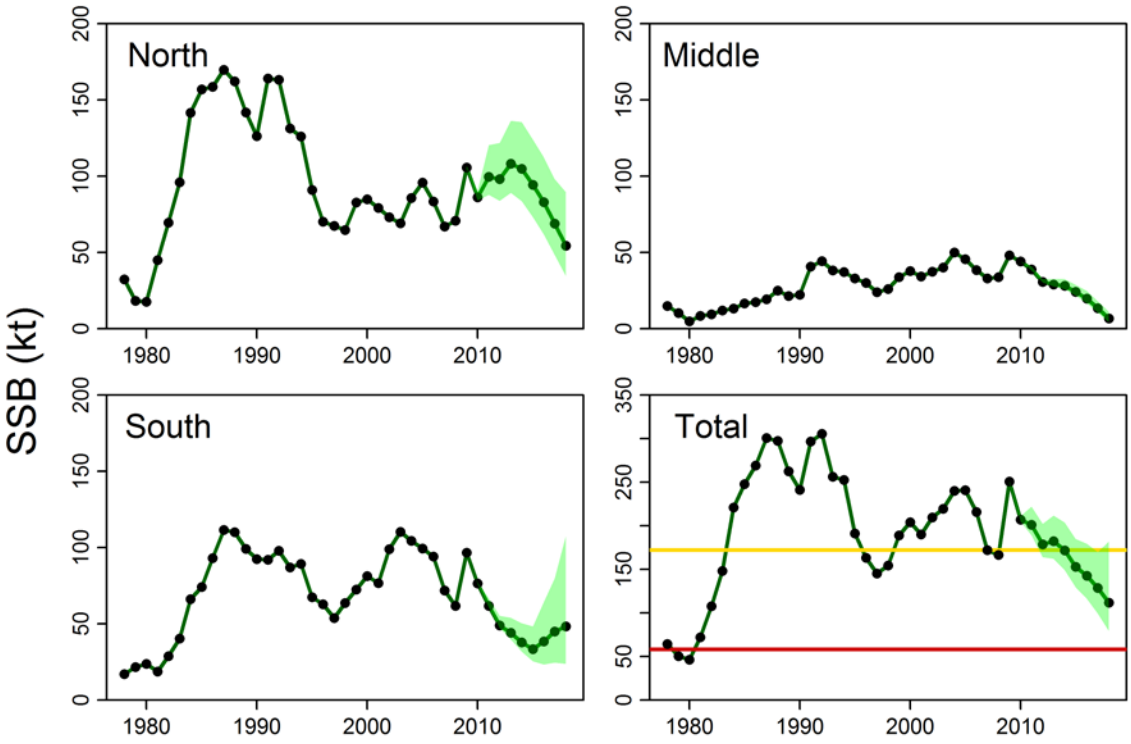

Figure 34. Estimated spawning stock biomass (SSB, kt) of fall spawner Atlantic Herring by region (North, Middle, South) and summed over regions (Total) in NAFO Div. 4T. The line and circles show the median estimates and the shading their 95% confidence intervals. In the lower right panel, the upper horizontal line is the upper stock reference level (USR) and the lower horizontal line is the limit reference point (LRP).

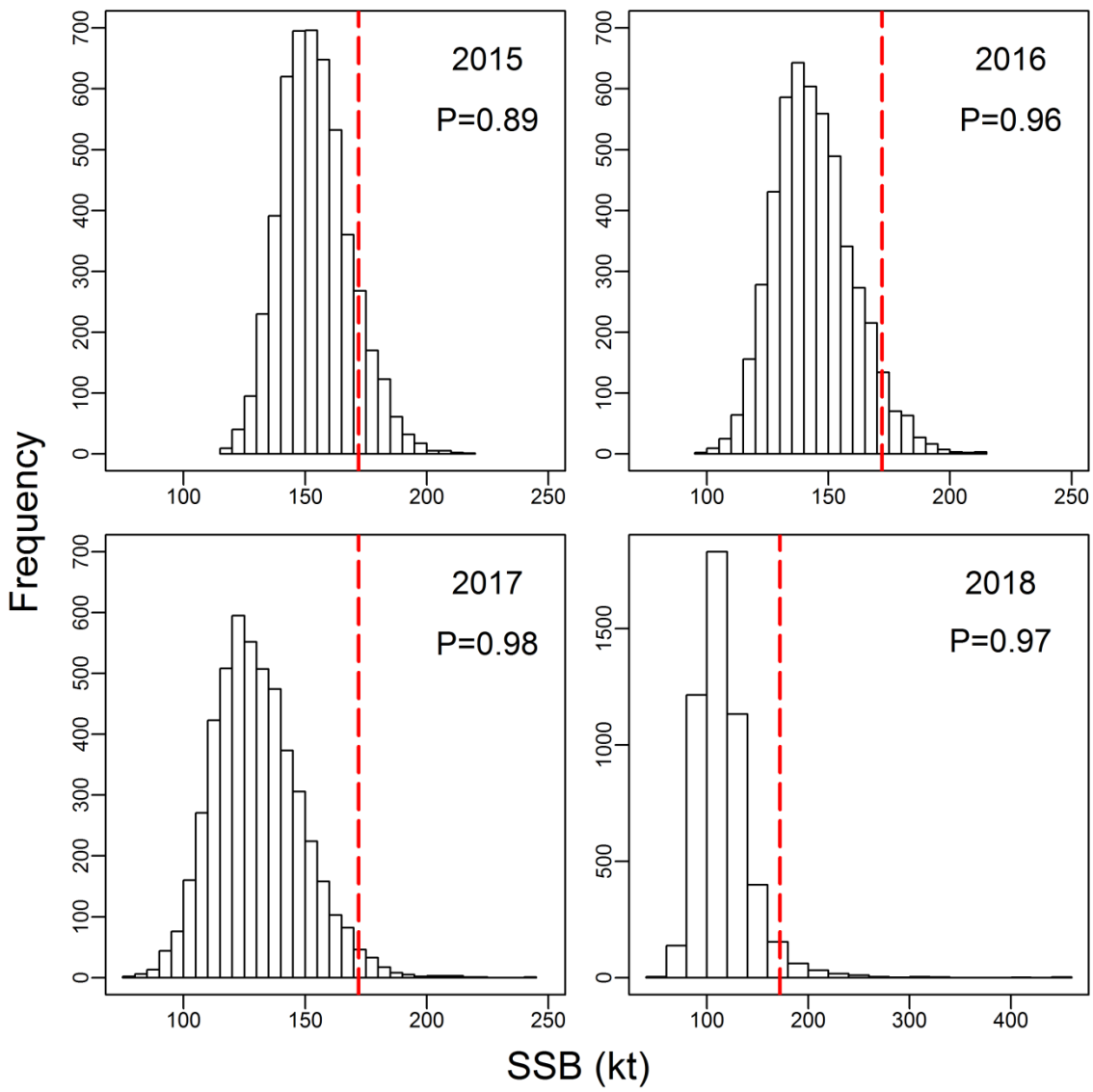

Figure 35. Posterior distributions of estimated total spawning stock biomass (SSB, kt) of fall spawner Atlantic Herring in NAFO Div. 4T at the start of 2015 to 2018 based on MCMC sampling. In each panel, the dashed vertical line shows the Upper Stock Reference (USR = 172,000) and p is the probability that the SSB will not be in the healthy zone (SSB < USR).

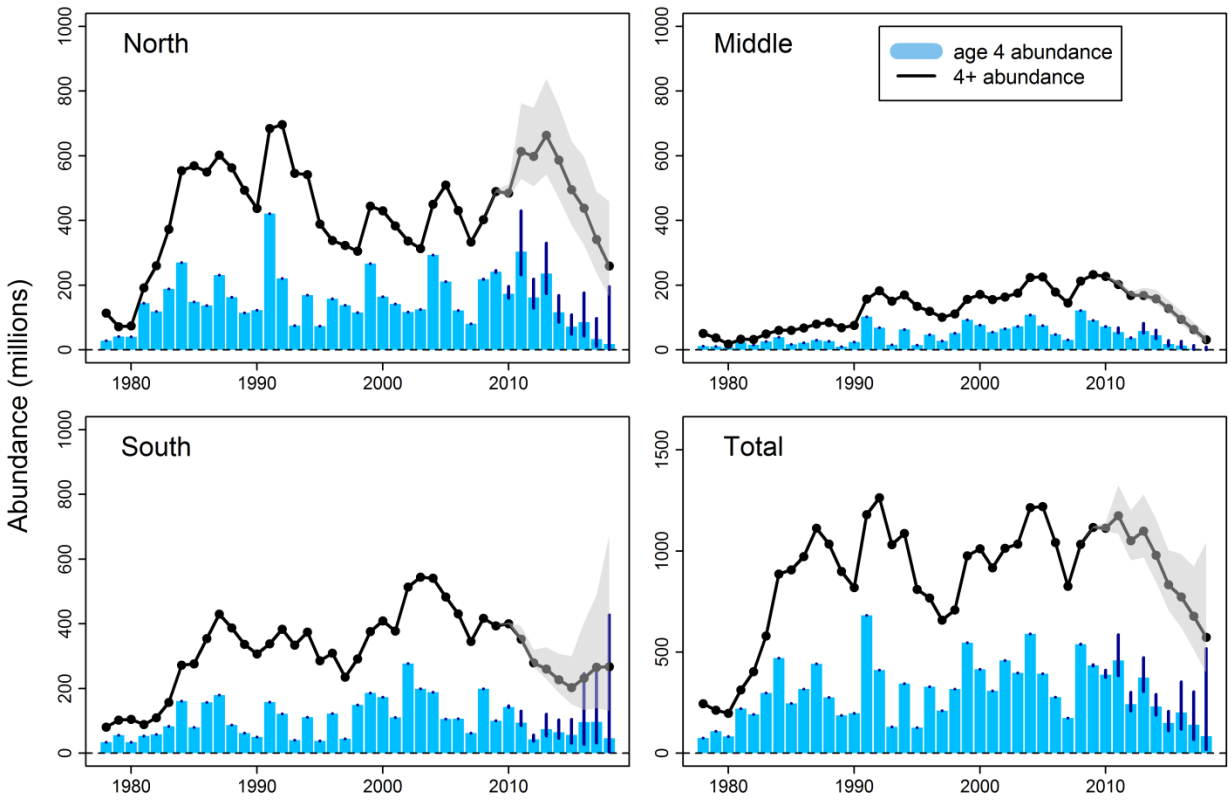

Figure 36. Estimated abundance (millions) of age 4 (histograms) and age 4+ (circle symbols and lines) fall spawner Atlantic Hrring in the three regions (North, Middle, South) and summed over regions (Total) of NAFO Div. 4T. Line and circles (age 4+) and bars (age 4) show the median estimates and shading or vertical lines show the 95% confidence intervals.

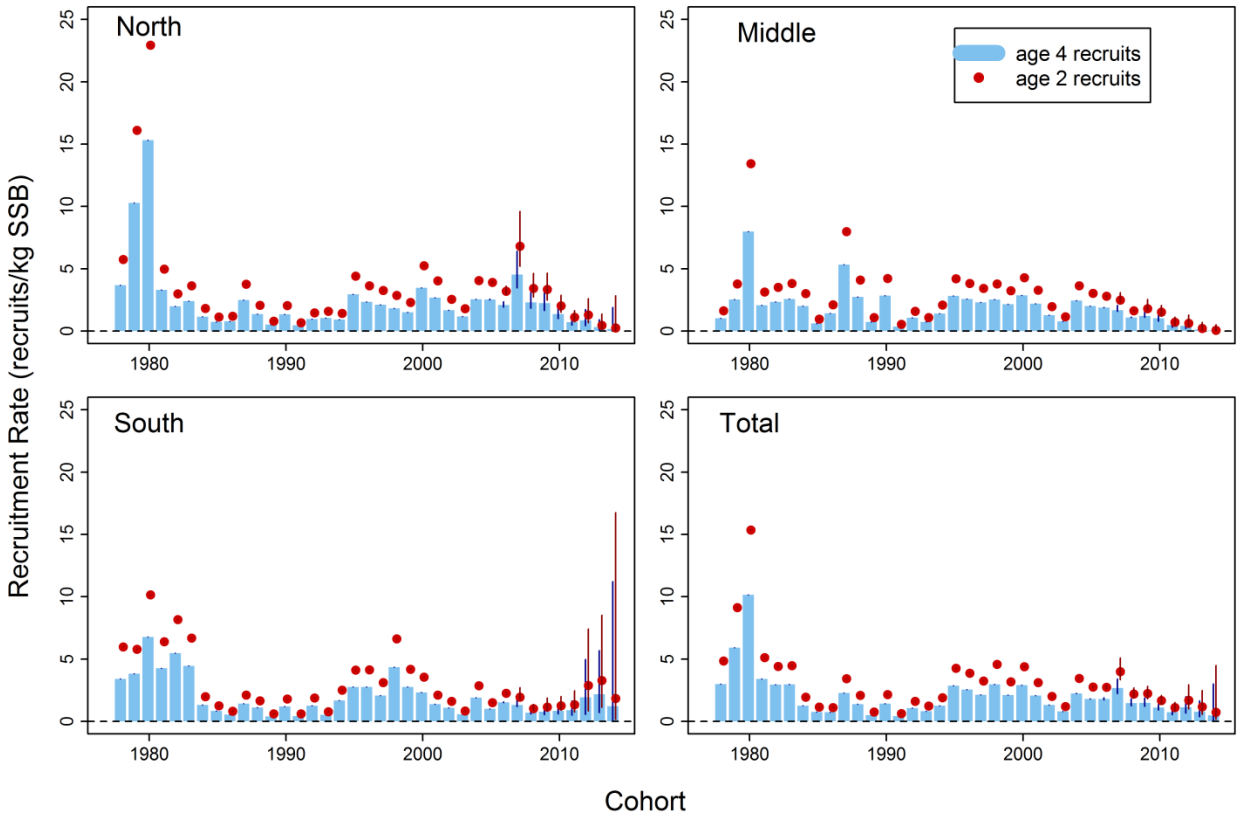

Figure 37. Estimated recruitment rate (recruits per kg of SSB) at age 2 (circles) and at age 4 (bars) of fall spawner Atlantic Herring in the three regions (North, Middle, South) and summed over regions (Total) of NAFO Div. 4T. Line and circles (age 4+) and bars (age 4) show the median estimates and shading or vertical lines show the 95% confidence intervals.

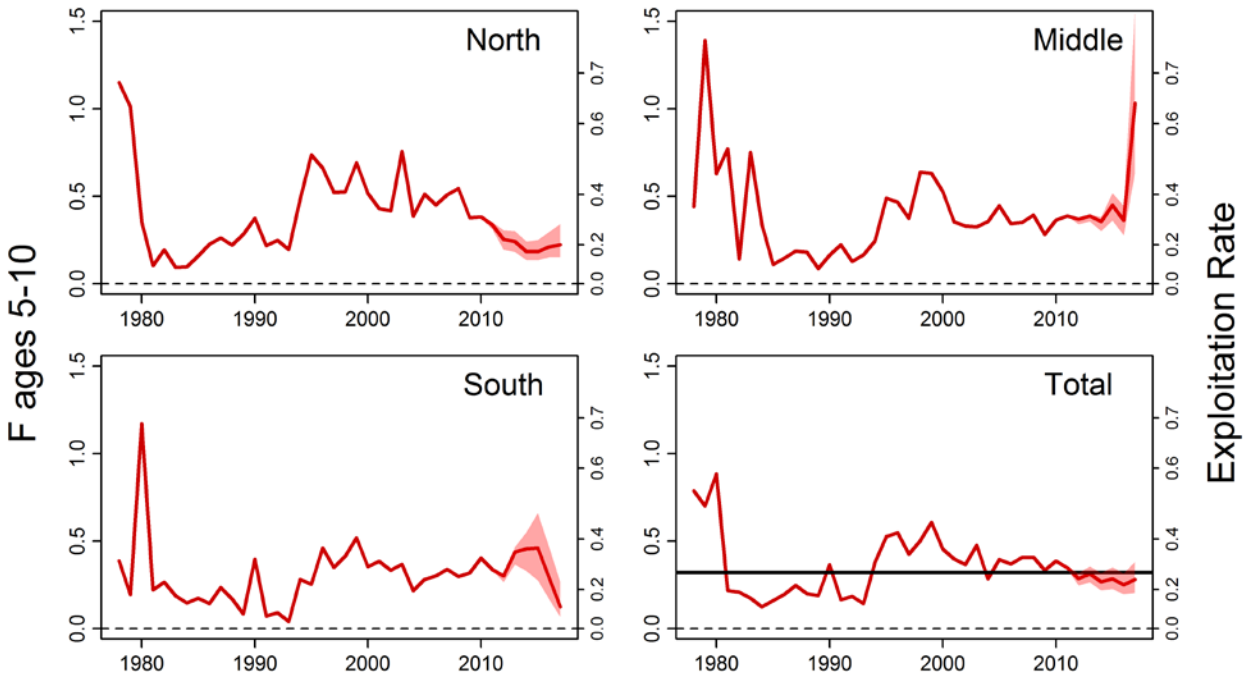

Figure 38. Estimated ages 5 to 10 instantaneous fishing mortality rate (F, left axes; annual exploitation rate right axes) of fall spawner Atlantic Herring in the three regions (North, Middle, South) and averaged over regions (Total; weighted by regional abundance at ages 5-10 years) in NAFO Div. 4T. Lines show the median estimates and shading their 95% confidence intervals. In the lower right panel, the horizontal line shows the reference removal rate (F0.1; F = 0.32) that applies in the healthy zone.

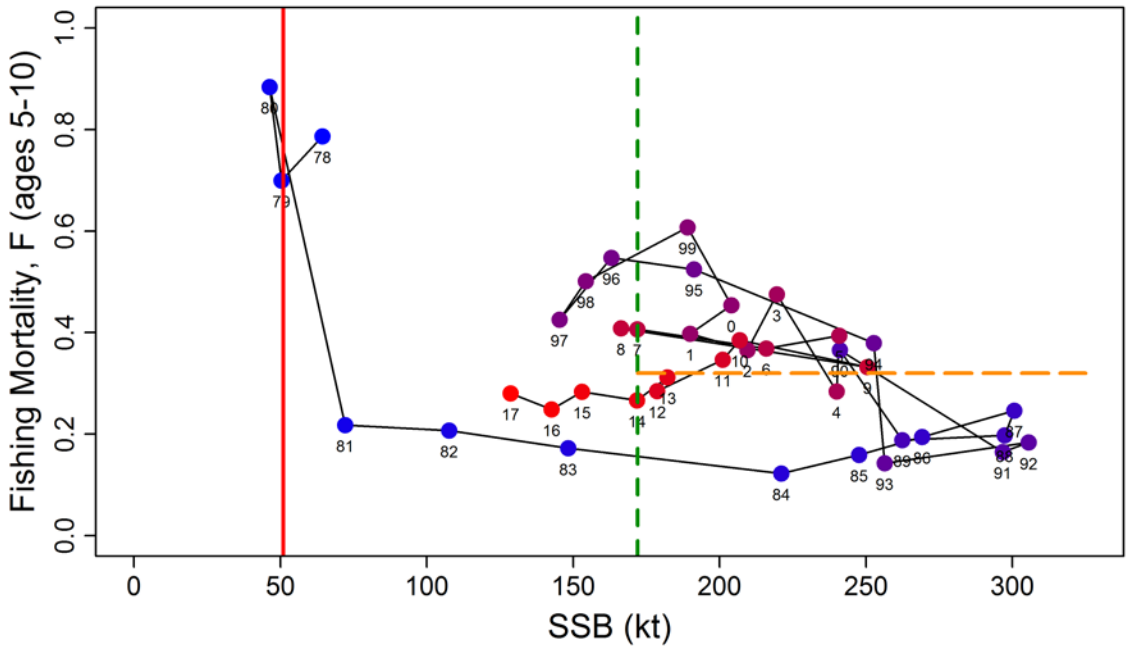

Figure 39. Population trajectory of the fall spawner component of Atlantic Herring in NAFO Div. 4T expressed as the spawning stock biomass (SSB) relative to the fishing mortality rates for ages 6 to 8 years. The solid red vertical line is the LRP (58,000 t), the green dashed vertical line is the Upper Stock Reference (USR = 172,000 t), and the orange dashed horizontal line is the removal rate reference (F0.1; F = 0.32). Point labels are years (83 = 1983, 0 = 2000). Colour coding is from blue in the 1970s and early 1980s to red in the 2000s.

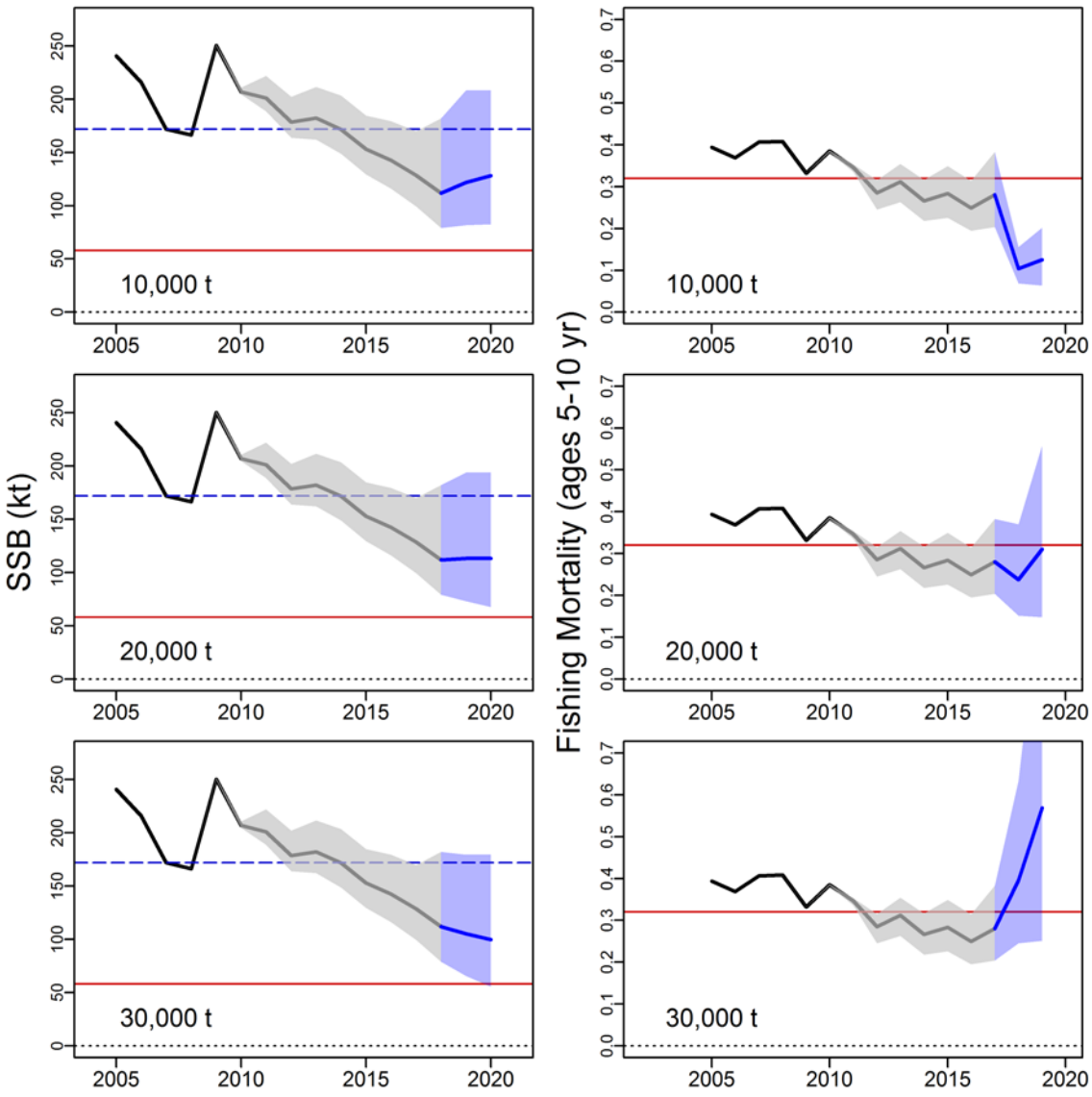

Figure 40. Estimated and projected spawning stock biomass (SSB in kt; left column) and ages 5 to 10 fishing mortality rate (F) (right column) of fall spawner Atlantic Herring in NAFO Div. 4T for three annual catch levels (rows) in 2018 and 2019. Lines show the median estimates of the beginning-of-year SSB or the median estimates of F in the year whereas shading shows the 95% confidence intervals of these estimates (based on MCMC sampling). Black and grey indicate the historical period and blue the projection period. In the left column, the blue horizontal dashed line is the upper stock reference (USR) and the red horizontal line is the limit reference point (LRP). In the right column, the red horizontal line is the removal rate reference level (F0.1; F = 0.32).

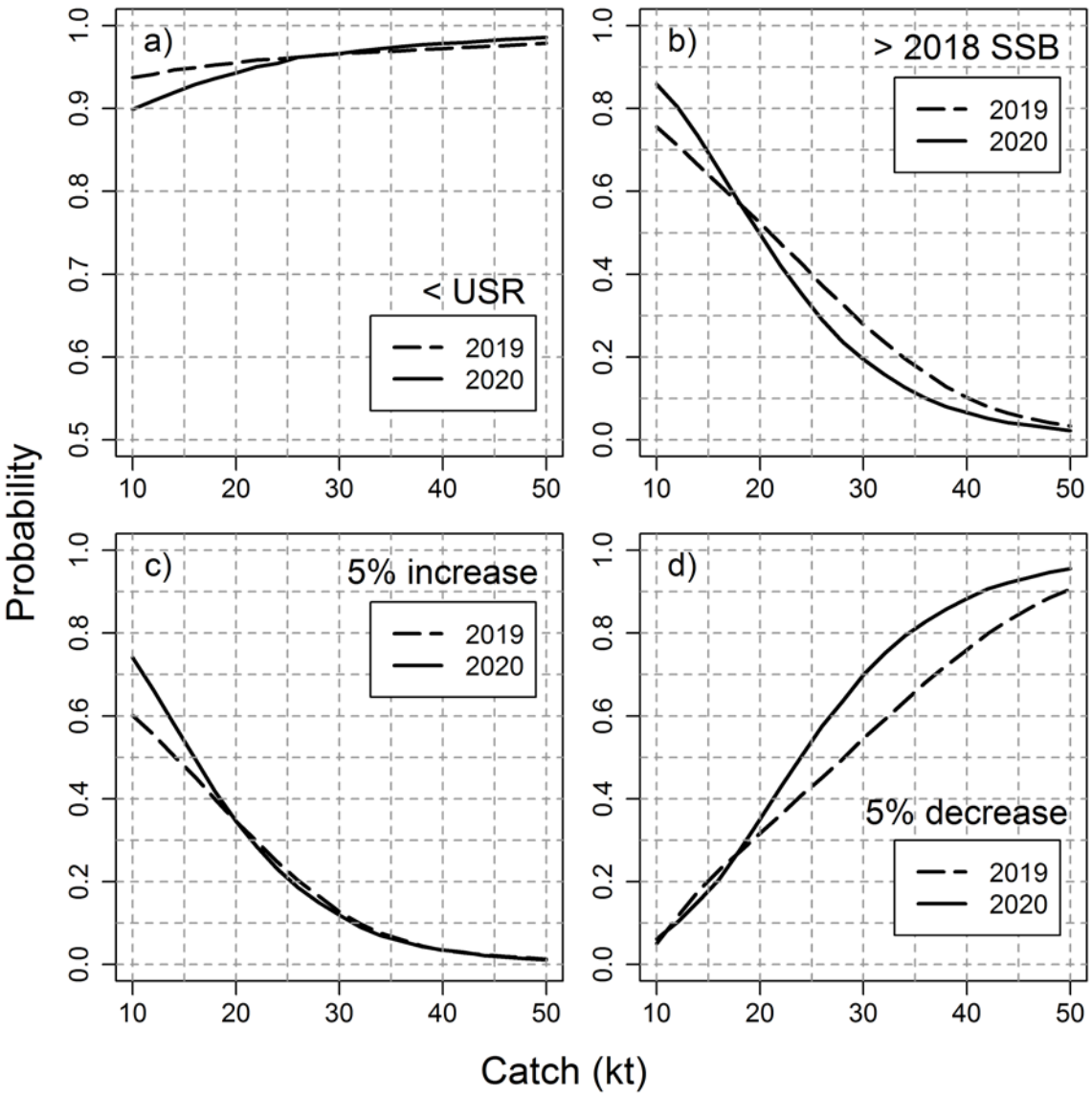

Figure 41. Profiles of the estimated probabilities of the projected spawning stock biomass (SSB) of fall-spawning Atlantic Herring at the start of 2019 and 2020 relative to stock status indicators for increasing levels of annual catch from 10,000 t to 50,000 t in 2018 and 2019. The stock status indicators are: a) the probability that SSB will be less than the USR at the start of 2019 (dashed line) and 2020 (solid line) (top left panel); b) the probability that SSB will be below the 2018 level (top right panel); c) the probability of a 5% increase above the 2018 level (lower left panel); d) the probability of a 5% decrease below the 2018 level (lower right panel).

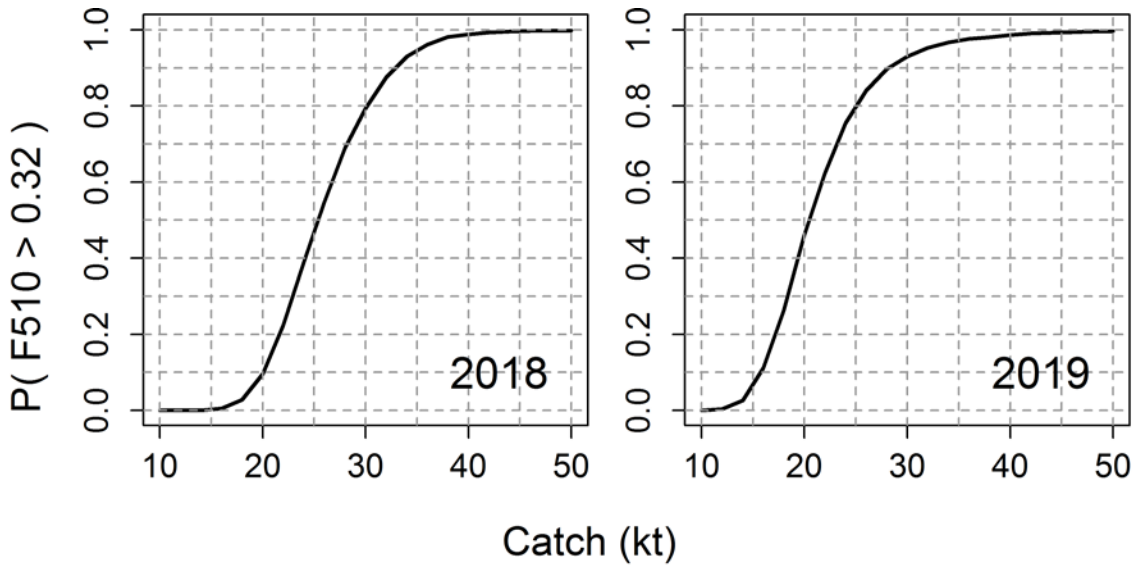

Figure 42. Probability profiles that the average fishing mortality rates for ages 5 to 10 (F5-10) in 2018 and 2019 will be greater than the reference removal rate (F0.1; F = 0.32) at various annual catch levels of 10,000 t to 50,000 t for fall spawner Atlantic Herring in NAFO Div. 4T.

APPENDICES

APPENDIX A. AGE READING CONSISTENCY TEST

A new reader was trained in 2015 to become the primary reader who aged the 2016 and 2017 otoliths. A new secondary reader was also trained in 2017.

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. Results are presented for the primary and secondary reader.

The results show an overall agreement of 86% and a coefficient of variation (CV) of 3.8% for the primary reader and an agreement of 85% (3.7% CV) for the secondary reader (Fig. A1). The CV is considered to be a more robust measure of the precision of age determination (Campana et al. 1995). Based on the reading bias plot, there was no bias present, and age determination is more variable for older (9+) herring (Fig. A1).

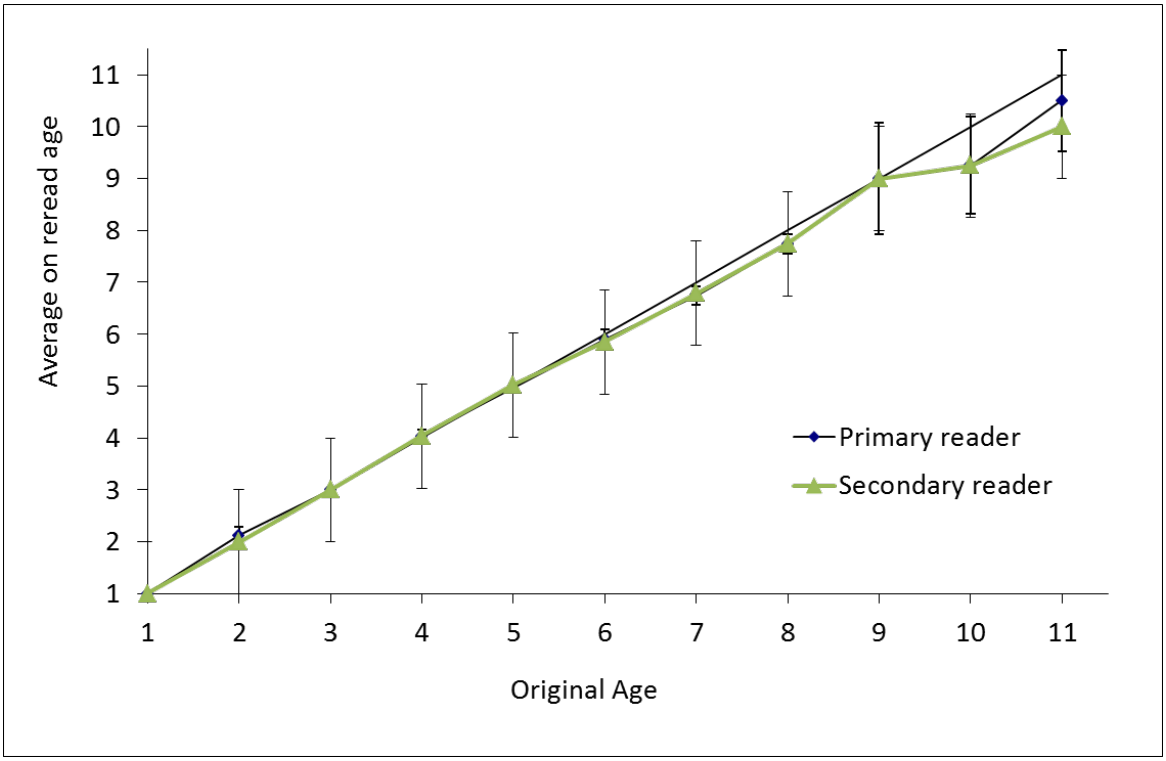

Figure A1. Comparison of Atlantic Herring ages in NAFO Div. 4T obtained during the validation test with the original ages assigned. Bars indicate 95% confidence intervals. Straight line indicates original ages.

APPENDIX B. FISHERY-INDEPENDENT ACOUSTIC SURVEY RESULTS

The 2015 to 2017 acoustic surveys were carried out in the 4Tmno areas (i.e., Chaleurs-Miscou; Fig. B1) and the biomass of herring were estimated to be 157,373 t; 63,493; and 69,023 respectively. The distribution of herring in the area can also be seen in Fig. B1 and Table B1. The 2015 acoustic biomass index of the Chaleurs-Miscou area for the combined spring (SS) and fall (FS) spawner groups was among the similar to the highest seen in the history of the survey; however the biomasses in 2016 and 2017 were similar to values observed since 2006, and are near the lowest value of the time series (Fig. B2).

Midwater trawl samples were made where herring densities were greatest. 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 B1a. Atlantic Herring biomass densities and estimates by stratum and area from the fishery-independent acoustic surveys conducted in 2015 in NAFO Div. 4T.

Area	Stratum	Mean target strength (dB kg^{-1})	Stratum area (km^2)	Mean backscatter (dB m^{-2})	Density (kg m^{-2})	Biomass (t)	Std. Error (t)	Std. Error (%)
Gaspé	Rivière au Renard	-34.70	124.6	-48.47	0.0421	5,241	2,542	48.5
	Cap Bon Ami	-34.70	69.0	0.00	0.0000	0	0	0
	Malbaie	-34.39	95.6	-48.70	0.0371	3,545	516	14.6
	Anse à Beaufils	-34.39	96.0	-50.46	0.0248	2,377	805	33.9
Chaleur	Grande Rivière	-34.67	106.4	-48.45	0.0419	4,458	2,677	60.0
	Newport	-34.67	124.9	-45.64	0.0800	9,995	8,733	87.4
	Shigawake	-35.20	265.6	-47.16	0.0636	16,897	6,076	36.0
	New Carlisle	-34.11	169.0	-46.80	0.0537	9,082	2,734	30.1
	New Richmond	-34.11	111.6	-60.65	0.0022	247	278	112.5
	Belledune	-34.24	266.0	-49.39	0.0305	8,114	2,748	33.9
	Nepisiguit	-34.57	211.3	-50.12	0.0279	5,885	9,226	156.8
	Maisonnette	-34.57	145.0	-46.23	0.0683	9,902	1,917	19.4
Miscou	West Miscou	-34.57	330.5	-45.79	0.0756	24,970	3,364	13.5
	North Miscou	-34.60	295.7	-55.82	0.0075	2,232	1,633	73.2
	Miscou NW	-34.60	444.0	-47.25	0.0542	24,084	14,310	59.4
	Miscou NE	-34.60	352.8	-47.77	0.0481	16,970	6,664	39.3
	Miscou SW	-34.80	552.2	-58.64	0.0041	2,284	1,189	52.1
	Miscou SE	-34.80	521.3	-51.52	0.0213	11,091	4,028	36.3
All	All		4,281.5			157,373		

Table B1b. Atlantic Herring biomass densities and estimates by stratum and area from the fishery-independent acoustic surveys conducted in 2016 in NAFO Div. 4T.

Area	Stratum	Mean target strength (dB kg^{-1})	Stratum area (km^2)	Mean backscatter (dB m^{-2})	Density (kg m^{-2})	Biomass (t)	Std. Error (t)	Std. Error (%)
Gaspé	Rivière au Renard	-34.81	124.6	-48.70	0.0407	5,077	859	16.9
	Cap Bon Ami	-34.81	69.0	-57.66	0.0052	357	343	96.1
	Malbaie	-34.81	95.6	-75.01	0.0001	9	9	100.6
	Anse à Beaufils	-34.81	96.0	-51.44	0.0217	2,085	750	36.0
Chaleur	Grande Rivière	-34.81	106.4	-53.01	0.0151	1,609	568	35.3
	Newport	-35.07	124.9	-58.37	0.0047	584	384	65.8
	Shigawake	-35.07	265.6	-51.49	0.0228	6,056	2,784	46.0
	New Carlisle	-34.64	169.0	-56.23	0.0069	1,173	702	59.9
	New Richmond	-34.64	111.6	-62.44	0.0017	185	125	67.7
	Belledune	-34.67	266.0	-55.85	0.0076	2,026	660	32.6
	Nepisiguit	-34.67	211.3	-47.75	0.0492	10,401	4,494	43.2
	Maisonnette	-34.55	145.0	-51.03	0.0225	3,257	475	14.6
Miscou	West Miscou	-34.71	330.5	-52.81	0.0155	5,113	2,333	45.6
	North Miscou	-34.60	295.7	-56.83	0.0060	1,767	2,384	134.9
	Miscou NW	-35.01	444.0	-47.92	0.0244	10,846	4,463	41.1
	Miscou NE	-35.01	352.8	-52.86	0.0164	5,797	1,520	26.2
	Miscou SW	-34.22	552.2	-57.31	0.0093	5,146	829	16.1
	Miscou SE	-34.22	521.3	-58.37	0.0038	2,004	862	43.0
All	All		4,281.5			63,493		

Table B1c. Atlantic Herring biomass densities and estimates by stratum and area from the fishery-independent acoustic surveys conducted in 2017 in NAFO Div. 4T.

Area	Stratum	Mean target strength (dB kg^{-1})	Stratum area (km^2)	Mean backscatter (dB m^{-2})	Density (kg m^{-2})	Biomass (t)	Std. Error (t)	Std. Error (%)
Gaspé	Rivière au Renard	-34.81	124.6	-57.65	0.0053	657	375	57.0
	Cap Bon Ami	-34.81	69.0	0.00	0.0000	0	0	0.0
	Malbaie	-34.81	95.6	0.00	0.0000	0	0	0.0
	Anse à Beaufils	-34.81	96.0	0.00	0.0000	0	0	0.0
Chaleur	Grande Rivière	-34.81	106.4	-63.06	0.0015	161	121	74.9
	Newport	-35.07	124.9	-58.06	0.0048	599	242	40.4
	Shigawake	-35.07	265.6	-52.05	0.0192	5,088	1,647	32.4
	New Carlisle	-34.64	169.0	-49.84	0.0315	5,322	1,240	23.3
	New Richmond	-34.64	111.6	-58.97	0.0039	430	175	40.6
	Belledune	-34.67	266.0	-49.36	0.0332	8,826	3,305	37.4
	Nepisiguit	-34.67	211.3	-48.25	0.0422	8,921	820	9.2
	Maisonnette	-34.55	145.0	-51.02	0.0249	3,606	494	13.7
Miscou	West Miscou	-34.71	330.5	-53.39	0.0144	4,746	1,570	33.1
	North Miscou	-34.60	295.7	-56.49	0.0067	1,992	1,435	72.0
	Miscou NW	-35.01	444.0	-48.47	0.0472	20,958	8,097	38.6
	Miscou NE	-35.01	352.8	-62.49	0.0017	597	241	40.4
	Miscou SW	-34.22	552.2	-57.94	0.0094	5,210	1,826	35.0
	Miscou SE	-34.22	521.3	-59.36	0.0037	1,910	1,040	54.4
All	All		4,281.5			69,023		

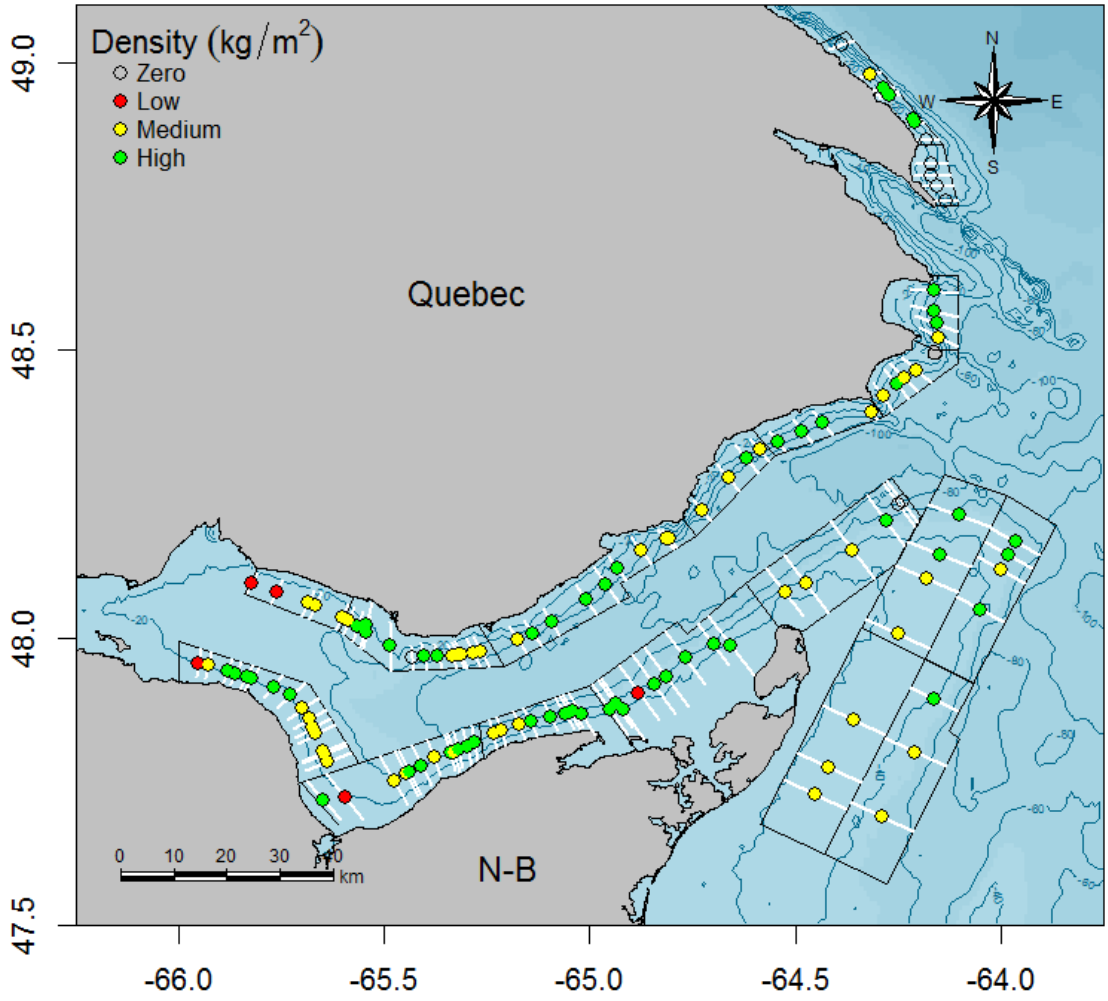

Figure B1. Surveyed transects covered during the 2015 acoustic surveys (whites lines) and Atlantic Herring biomass density by transect (colored circles, kg/m^2).

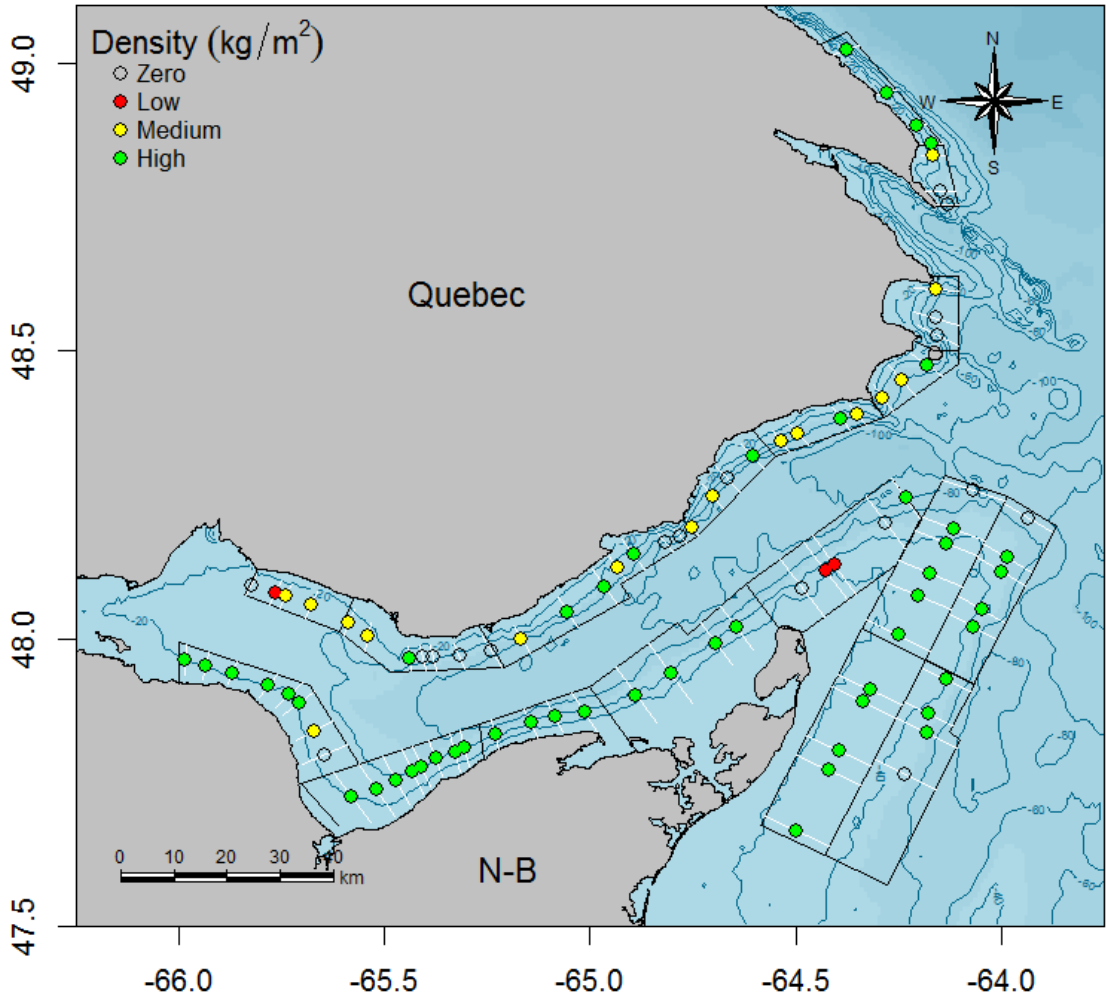

Figure B2. Surveyed transects covered during the 2016 acoustic surveys (whites lines) and Atlantic Herring biomass density by transect (colored circles, kg/m^2).

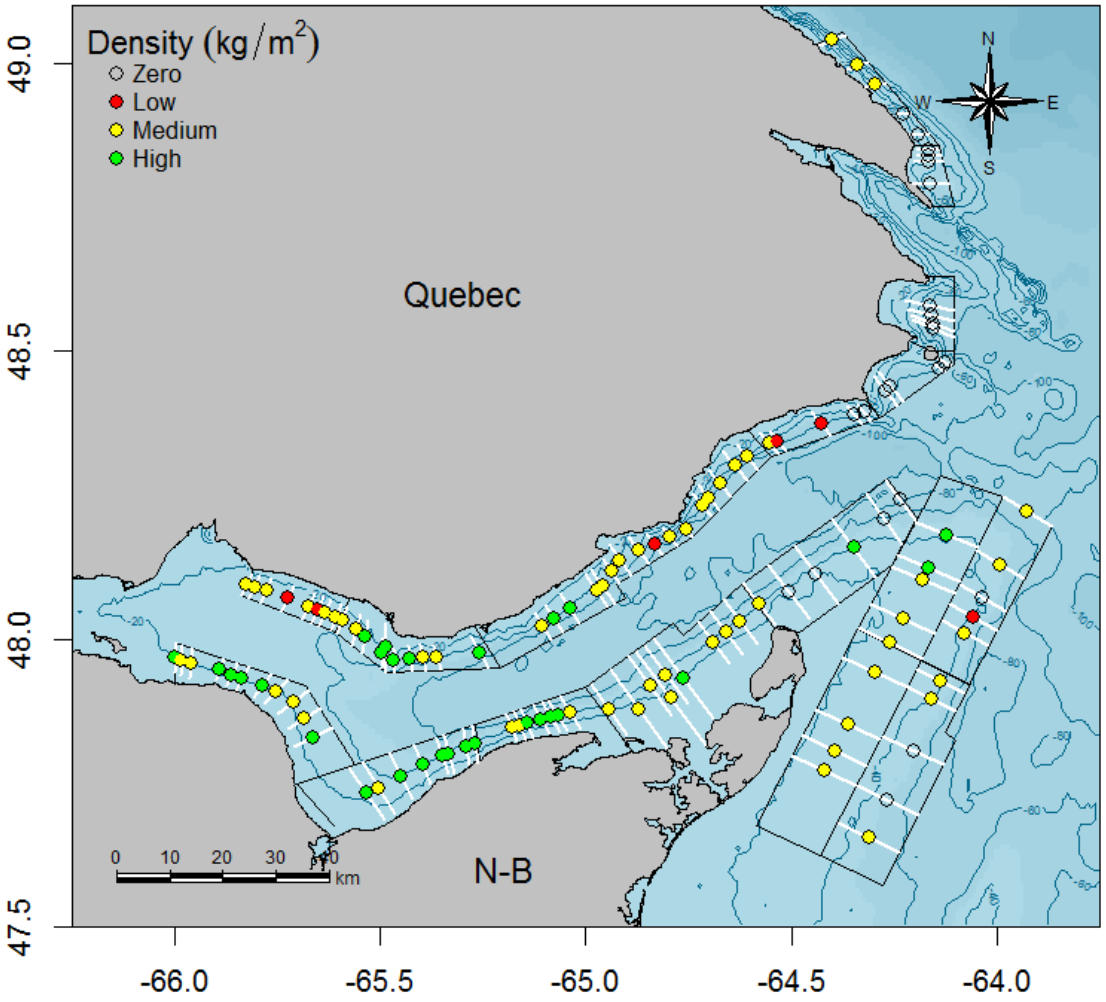

Figure B3. Surveyed transects covered during the 2017 acoustic surveys (whites lines) and Atlantic Herring biomass density by transect (colored circles, kg/m^2).

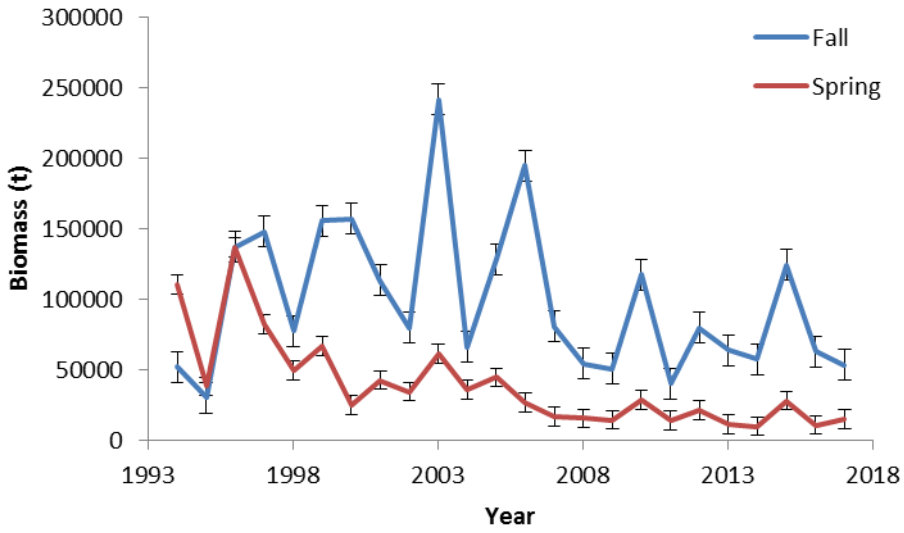

Figure B4. Acoustic survey biomass index (mean; ± 1 S.E.) of spring (red) and fall (blue) spawner Atlantic Herring from all strata of Chaleurs-Miscou in NAFO Div. 4T, 1994 to 2017.

APPENDIX C. SPAWNING GROUND ACOUSTIC SURVEY RESULTS

The spawning ground acoustic survey was first conducted in 2015, and has been every 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 (Fig. C1). Strata were defined on 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 within strata at a minimum of 400 m apart (Fig. C2).

Each fishing association selected one or two fish harvesters to conduct the acoustic surveys to quantify the biomass of fish schools using a hull-mounted 120 KHz single beam transducer Acoustic data from fishing vessels have been used to analyze 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 prior and following the fishing season and during the weekend fishing closure where possible. Escuminac and West PEI regions did not have week-end fishing closures for the years covered by this study, so sampling was only possible before and after the fishing season. For 2017 and 2018, these regions should have weekend closures, allowing a complete sampling grid. Size and age frequency data to convert the acoustic data into biomass estimates were obtained from the experimental gillnet surveys. Nightly acoustic data were processed and analyzed for each region in order to obtain a nightly biomass estimate (Table C1 to C3), as described in Claytor and Clay (2001).

Figure C3 shows the mean nightly biomass per spawning ground for every year. Some regions/years show great variations in nightly fish biomass (Miscou and Gaspé 2016, Escuminac 2015). As not every sampling trip has been undertaken for different regions/years, the presence or absence of samples in the beginning or the end of the season will have a great impact on the mean. Escuminac and West PEI regions are especially sensible to this, as only two trips can be done per year in these regions. 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 (Tables C1 to C4 for details). Gaspé (except 2017, harvester's boat sank), Miscou and Pictou regions show good coverage of the sampling season with almost five samples every year (Table C4).

The results show lower nightly biomass for every year in the West PEI and East PEI regions. Pictou region shows intermediate nightly biomass when compared to all regions, with a descending trend from 2015 to 2017. For the Escuminac region, biomass can reach high levels as in 2015 with 15,238 t, but other years do not show such high biomasses. Again, the low sampling effort on this spawning bed cannot allow an adequate characterization of the biomass for the whole spawning season. The Gaspé region shows intermediate biomasses for 2015 and 2017 (only one survey in 2017), but elevated biomass in 2016. The Miscou region shows the same trend as Gaspé, with the highest mean nightly biomass of all the sGSL in 2016.

For this survey to be included in the assessment, surveys need to be consistent across regions and conscientiously carried out. Weekend closures in West PEI and Escuminac for the next years will help acquiring more samples from these spawning beds. Also, the beginning of the sampling season could be moved to earlier dates, as the first sampling dates generally show the highest biomasses with a descending trend until the end of the fishing season. Earlier sampling

would allow a better estimation of the spawner biomass throughout the complete spawning season.

Table C1. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2015.

Herring Fishing Area	Region	Spawning Bed	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	Gaspé	15/08/2015	-36.11	38.7	-52.80	3.08E-02	1168	1064
16B	North	Gaspé	22/08/2015	-36.11	38.7	-48.60	1.67E-01	4501	3981
16B	North	Gaspé	29/08/2015	-36.11	38.7	-56.60	1.96E-02	954	847
16B	North	Gaspé	04/09/2015	-36.11	38.7	-52.86	5.34E-02	1728	1494
16B	North	Gaspé	12/09/2015	-36.11	38.7	-51.99	3.21E-02	1320	746
16B	North	Miscou	22/08/2015	-36.32	386.9	-68.18	5.57E-03	1029	676
16B	North	Miscou	29/08/2015	-36.32	386.9	-56.79	2.45E-02	6797	3623
16B	North	Miscou	04/09/2015	-36.32	386.9	-61.26	2.47E-02	4565	1459
16B	North	Miscou	10/09/2015	-36.32	386.9	-57.80	1.36E-02	2529	1546
16B	North	Miscou	13/09/2015	-36.32	386.9	-58.16	1.56E-02	2190	1438
16C	Middle	Escuminac	20/08/2015	-35.84	145.5	-52.15	4.82E-01	15238	11834
16C	Middle	Escuminac	07/10/2015	-35.84	145.5	-70.52	3.42E-04	41	39
16E	Middle	West PEI	20/08/2015	-35.97	111.3	0.00	0.00E+00	0	0
16E	Middle	West PEI	21/09/2015	-35.97	111.3	-14.14	2.19E-03	775	300
16F	South	Pictou	04/09/2015	-35.67	127.3	-40.17	5.42E-01	7583	6335
16F	South	Pictou	11/09/2015	-35.67	127.3	-55.56	1.55E-02	504	399
16F	South	Pictou	18/09/2015	-35.67	127.3	-47.83	7.84E-01	11239	7874
16F	South	Pictou	25/09/2015	-35.67	127.3	-43.71	1.12E-02	1319	980
16F	South	Pictou	12/10/2015	-35.67	127.3	-29.29	2.98E-02	2559	1698
16G	South	East PEI	-	-	56.1	-	-	-	-

Table C2. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2016.

Herring Fishing Area	Region	Spawning Bed	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	Gaspé	21/08/2016	-35.84	38.7	-63.79	2.87E-03	84	80
16B	North	Gaspé	29/08/2016	-35.84	38.7	-14.35	6.35E-02	3240	2875
16B	North	Gaspé	03/09/2016	-35.84	38.7	-52.80	3.26E-01	15265	12448
16B	North	Gaspé	10/09/2016	-35.84	38.7	-48.31	5.56E-01	15410	15360
16B	North	Gaspé	15/09/2016	-35.84	38.7	-51.90	2.85E-02	1006	757
16B	North	Miscou	09/08/2016	-36.05	386.9	-51.31	3.01E-02	5626	3470
16B	North	Miscou	15/08/2016	-36.05	386.9	-47.63	1.57E-01	29247	11652
16B	North	Miscou	19/08/2016	-36.05	386.9	-35.02	1.81E-02	2448	1875
16B	North	Miscou	27/08/2016	-36.05	386.9	-62.75	2.73E-02	5701	3516
16B	North	Miscou	13/09/2016	-36.05	386.9	-24.54	2.49E-02	5210	3412
16C	Middle	Escuminac	14/08/2016	-36.11	145.5	-57.23	2.91E-02	6203	5141
16C	Middle	Escuminac	08/09/2016	-36.11	145.5	-61.73	3.12E-03	390	227
16E	Middle	West PEI	03/09/2016	-39.9	111.3	-52.64	1.19E-03	307	305
16F	South	Pictou	06/09/2016	-35.67	127.3	-43.88	4.37E-02	1099	546
16F	South	Pictou	16/09/2016	-35.67	127.3	-40.76	6.67E-02	5435	5481
16F	South	Pictou	23/09/2016	-35.67	127.3	-50.16	3.55E-02	1169	650
16F	South	Pictou	30/09/2016	-35.67	127.3	-32.59	2.25E-02	4129	2867
16F	South	Pictou	20/10/2016	-35.67	127.3	0.00	0.00E+00	0	0
16G	South	East PEI	10/09/2016	-35.66	56.1	-47.50	6.64E-02	3337	2311
16G	South	East PEI	24/09/2016	-35.66	56.1	-25.90	1.22E-02	762	679
16G	South	East PEI	20/10/2016	-35.66	56.1	0.00	0.00E+00	0	0

Table C3. Atlantic Herring biomass densities and estimates by spawning ground from the spawning ground acoustic surveys conducted in 2017.

Herring Fishing Area	Region	Spawning Bed	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	Gaspé	18/08/2017	-35.84	38.7	-49.07	6.18E-02	1920	1632
16B	North	Miscou	17/08/2017	-36.78	386.9	-59.31	1.69E-02	6730	6563
16B	North	Miscou	29/08/2017	-36.78	386.9	-44.13	1.36E-03	425	333
16B	North	Miscou	11/09/2017	-36.78	386.9	-58.15	1.17E-02	5560	4321
16B	North	Miscou	18/09/2017	-36.78	386.9	-30.83	2.30E-02	7960	5460
16C	Middle	Escuminac	24/08/2017	-35.89	145.5	-55.48	3.92E-02	2360	1731
16E	Middle	West PEI	24/08/2017	-35.89	111.3	-44.30	1.03E-02	2811	0
16E	Middle	West PEI	27/09/2017	-35.89	111.3	-34.13	3.37E-02	1235	1437
16F	South	Pictou	08/09/2017	-35.64	127.3	-42.05	1.72E-01	6557	3732
16F	South	Pictou	15/09/2017	-35.64	127.3	-11.04	2.23E-03	27	29
16F	South	Pictou	22/09/2017	-35.64	127.3	-45.88	3.81E-02	894	858
16F	South	Pictou	09/10/2017	-35.64	127.3	-12.83	2.82E-04	46	53
16G	South	East PEI	22/09/2017	-35.82	56.1	-55.37	1.18E-02	627	569
16G	South	East PEI	30/09/2017	-35.82	56.1	-51.77	9.82E-02	3310	3626
16G	South	East PEI	13/10/2017	-35.82	56.1	0.00	0.00E+00	0	0
16G	South	East PEI	22/10/2017	-35.82	56.1	-27.63	5.68E-03	356	227
16G	South	East PEI	28/10/2017	-35.82	56.1	0.00	0.00E+00	0	0

Table C4. Number of individual acoustic sampling trips per year and region from the spawning ground acoustic surveys.

Region	2015	2016	2017
Gaspé	5	5	1
Miscou	5	5	4
Escuminac	2	2	1
West PEI	2	1	2
Pictou	5	5	4
East PEI	0	3	5
Total	19	21	17

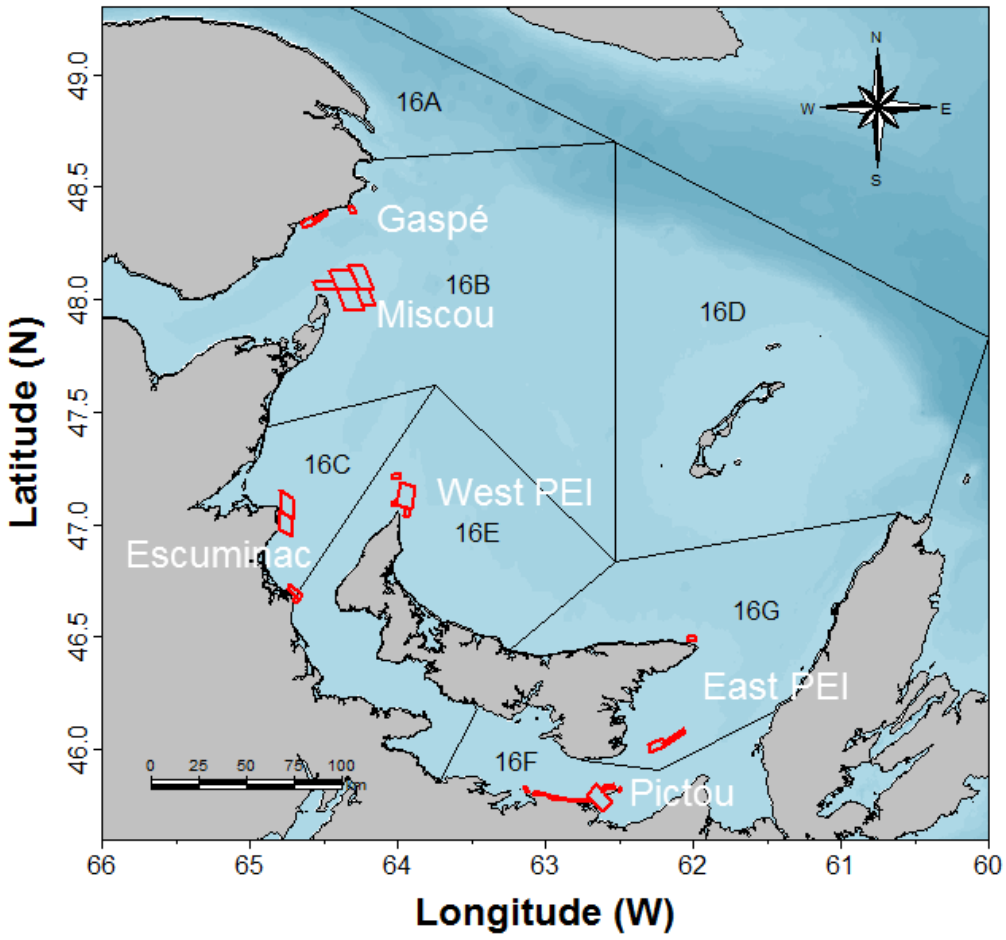

Figure C1. Fall spawner Atlantic Herring spawning grounds surveyed during the industry spawning ground acoustic survey.

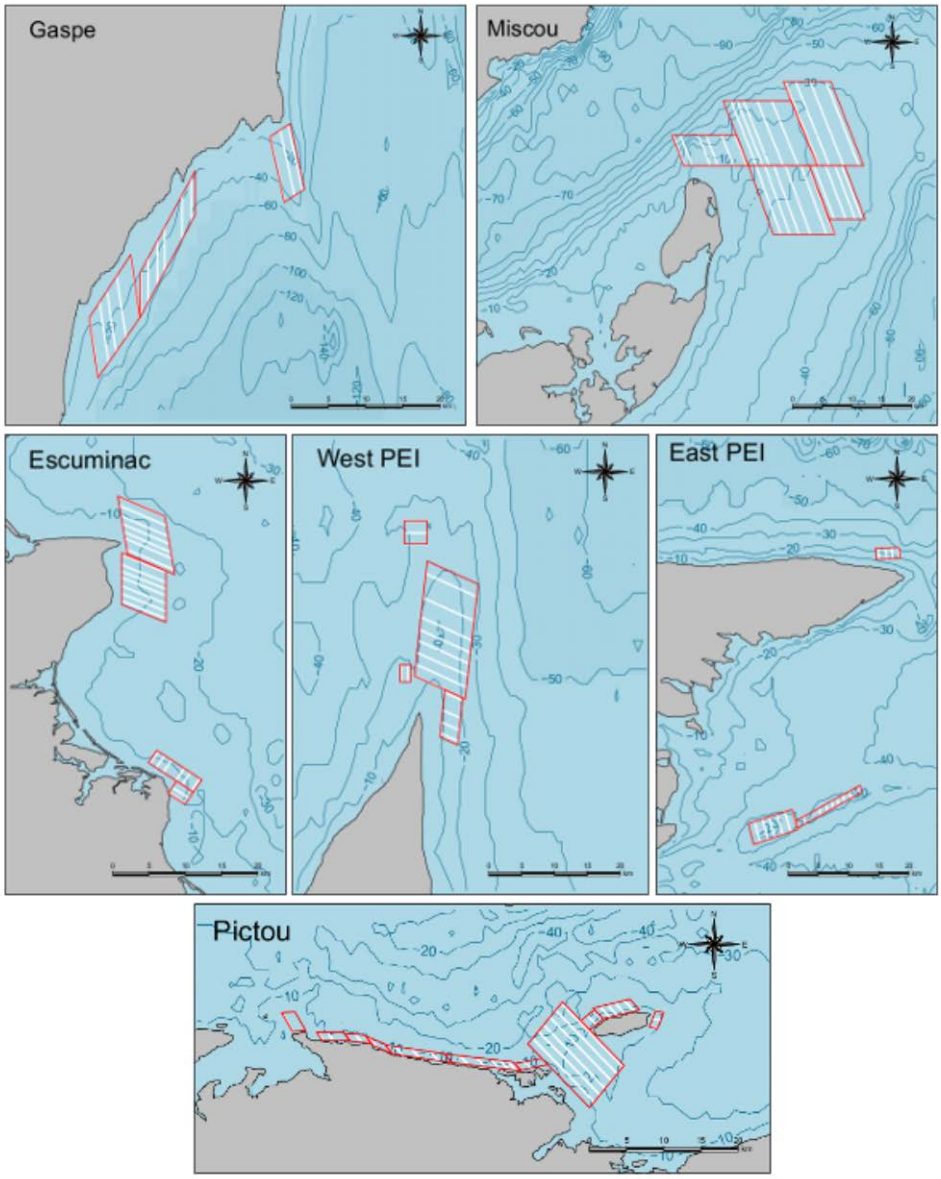

Figure C2. Surveyed transects covered during the Atlantic Herring spawning ground acoustic surveys (white lines).

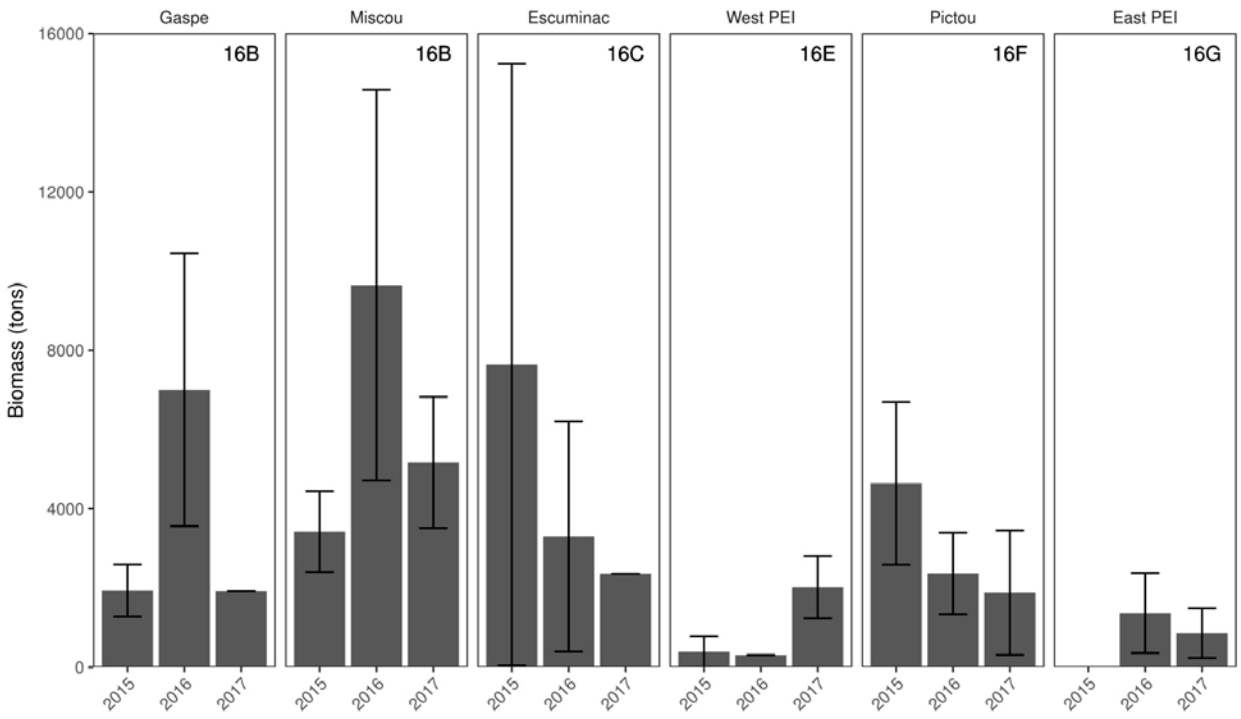

Figure C3. Nightly Atlantic Herring biomass estimates (t; mean plus one standard error bar) by spawning ground from the spawning ground acoustic surveys during August to October, 2015 to 2017.

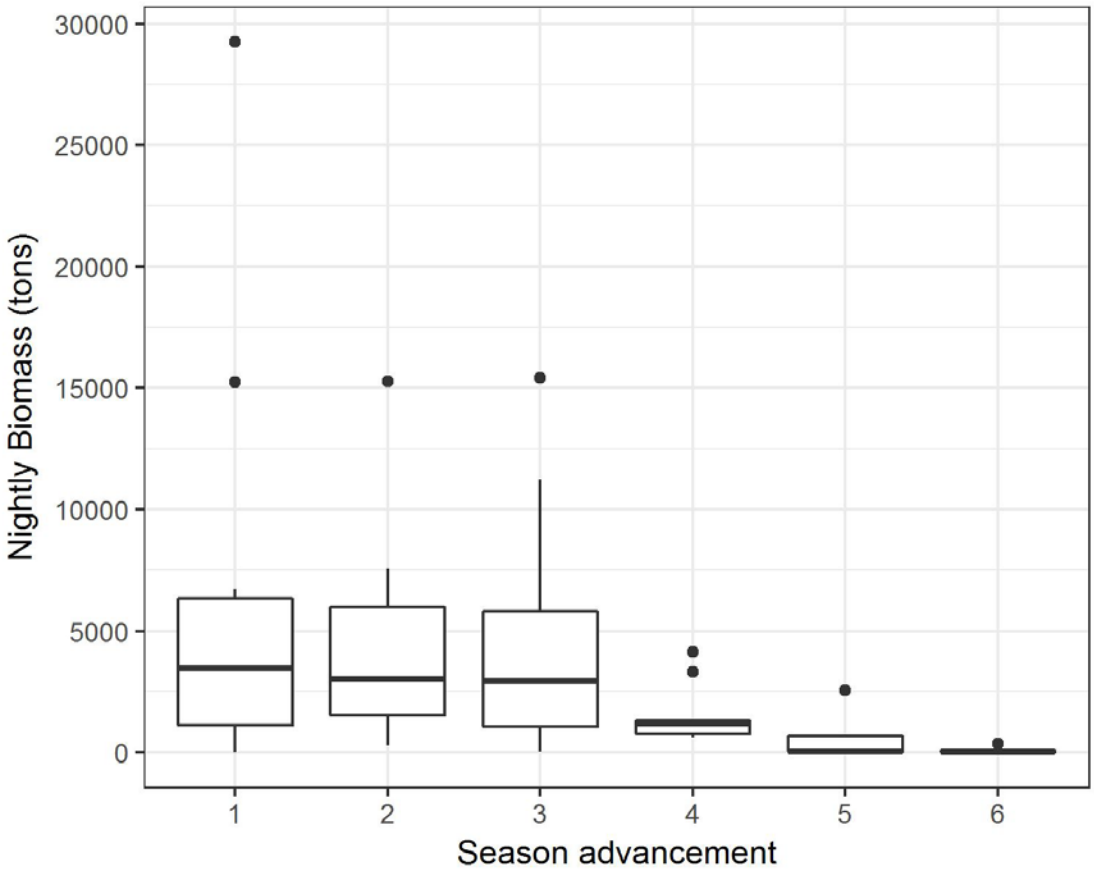

Figure C4. Season advancement expressed as the nightly Atlantic Herring biomass (t) (whole survey period estimate divided in six equal periods of 13 days) during August to October, from the spawning ground acoustic surveys conducted during 2015 to 2017.

APPENDIX D. MULTISPECIES BOTTOM-TRAWL SURVEY RESULTS

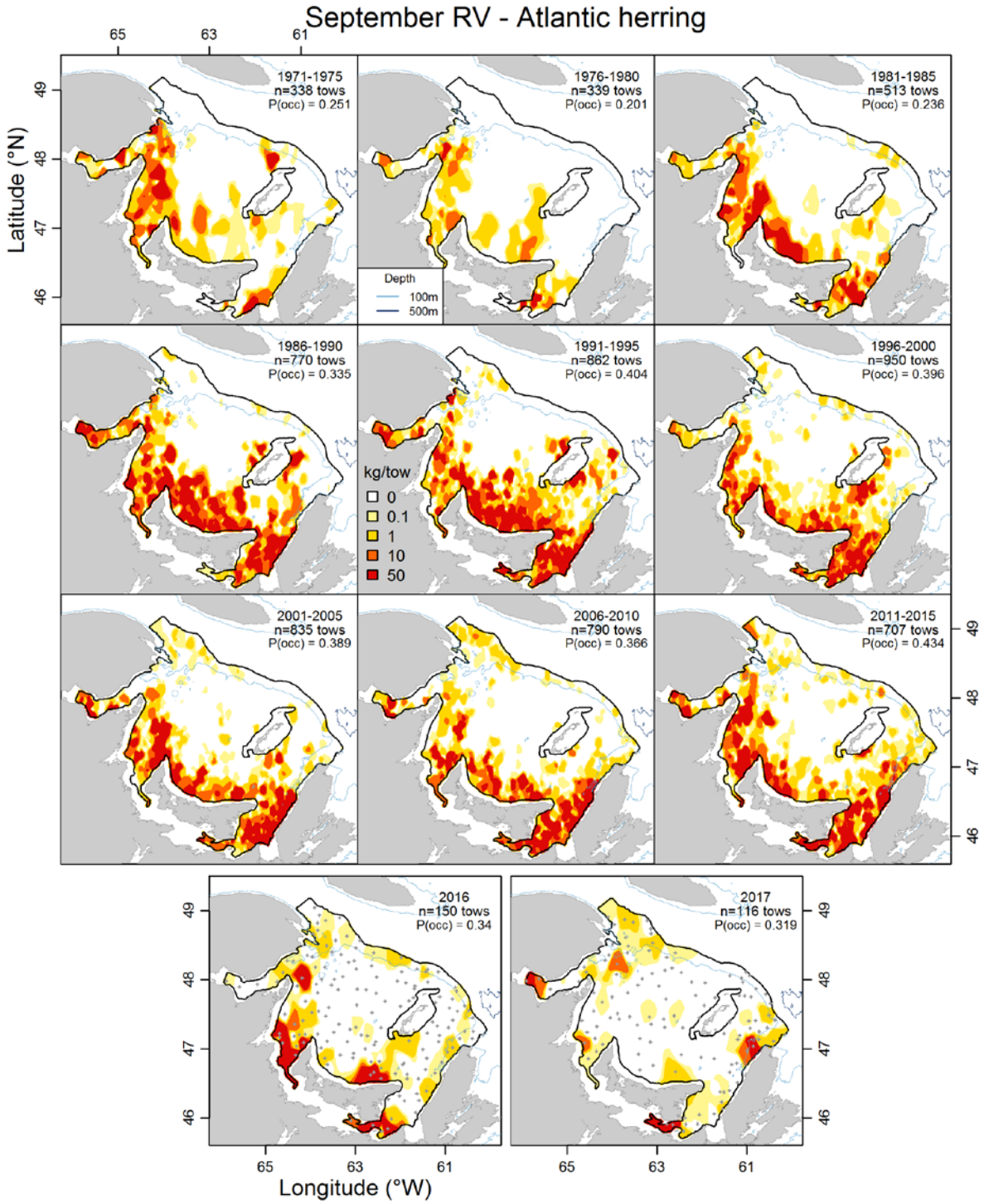

Figure D1. Spatial distribution of Atlantic Herring catches (number per tow) from the September multispecies bottom-trawl survey in the southern Gulf of St. Lawrence. The dots indicate the location of fishing sets.

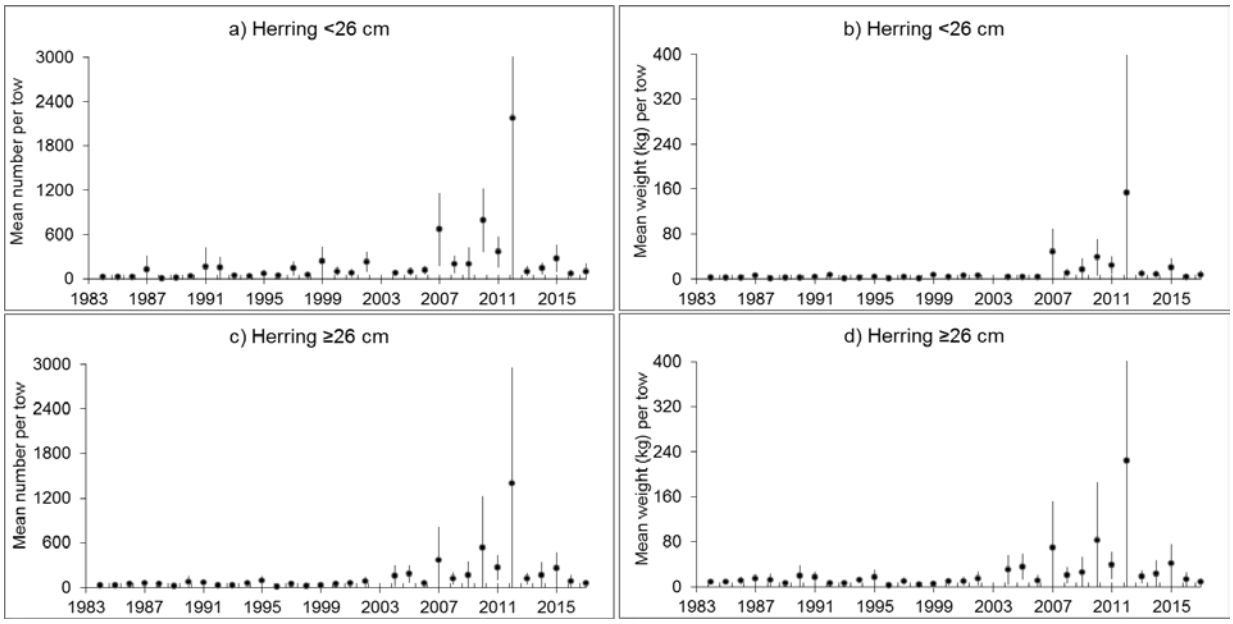

Figure D2. Abundance indices (mean, approximate 95% confidence limits, i.e. ± 2 standard errors, as vertical lines) expressed as number per tow (left column) and weight (kg) per tow (right column) of Atlantic Herring <26 cm in length (top row) and ≥ 26 cm (bottom row) from catches in the September multispecies bottom-trawl surveys in the southern Gulf of St. Lawrence.