



Quebec Region

ASSESSMENT OF THE QUEBEC NORTH SHORE (DIVISION 4S) HERRING STOCKS IN 2018



Atlantic herring (*Clupea harengus*). Photo from Nozères et al. (2010).

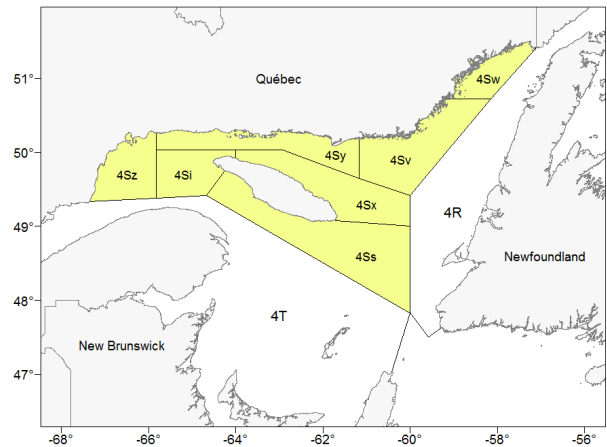


Figure 1. Map of unit areas of NAFO Division 4S (Quebec North Shore). Division 4S is defined by the coloured area.

Context:

Since 1992, the herring fishery on the Quebec North Shore (NAFO Division 4S) has been managed by a preventive Total Allowable Catch (TAC) of 4,000 t due to the lack of scientific information to establish a formal TAC. This TAC is assigned in whole to the different fishing fleets and to all catches, without distinction between the two spawning groups. Between 1984 and 2010, herring landings were, on average, 476 t per year. Catches have increased significantly since 2011 and are on average at 3,515 t.

A first series of acoustic surveys was conducted in 2009, 2010, 2011 and 2013 on the Lower North Shore of Quebec (unit area 4Sw). A second series of surveys that covers the entire coastal area of 4S began in 2016. This new time series could eventually be used to develop and implement an analytical assessment of the two herring spawning groups in the North Shore of Quebec, as well as establish limit reference points to define a strategic framework for the fishery based on the precautionary approach.

The last assessment of the two herring spawning stocks in Division 4S was in 2017. The Fisheries and Aquaculture Management Branch requested scientific advice on these stocks for the 2019 and 2020 fishing seasons. This science advisory report is from the March 15, 2019 meeting on the assessment of the Quebec North Shore (4S) herring stocks in 2018. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada Science Advisory Schedule](#) as they become available.

SUMMARY

- Despite a TAC of 4,000 t, herring landings on the North Shore of Quebec (4S) have decreased by 38% since 2016 to reach 2,501 t in 2018, their lowest level since 2011. Almost all landings came from the eastern end of unit area 4Sw.
- The decrease in landings is partly attributable to the new management measures put in place in 2017 and 2018, to poor weather conditions for fishing activities, and to an increased presence of herring at greater depths, which would have had the effect of reducing their availability to fishing gear.
- Since 2008, herring catches have been largely dominated by fall spawners.
- Unlike in 2016 and 2017 when catches of the fall spawning herring stock were dominated by fish older than 9 years, catches in 2018 were mainly composed of 5 to 9 years old fish. Catches of the spring spawning herring stock in 2017 and 2018 were mostly composed of 4- and 5-year old fish.
- Based on the age composition in the catches, no important recruitment has been observed since 2000 in fall spawners. A relatively large year-class appeared in spring spawners in 2013.
- An acoustic survey covering the entire 4S coastal zone was conducted for the second time in the fall of 2018. The biomass index was estimated at 2,473 t for spring spawners and 19,950 t for fall spawners. The total biomass index in 2018 was similar to that estimated in 2016.
- Unlike in 2016 when the highest biomasses were observed in the western part of 4S, the highest biomasses in 2018 were observed in 4Sw at the eastern end of the zone.
- Six acoustic surveys were conducted between 2009 and 2018 in the 4Sw unit area. After a significant decrease from 2010 to 2016, the biomass index for spring and fall spawners increased in 2018.
- Cohorts are mainly monitored in commercial fisheries catches. A limited spring fishery (May-June) would better track cohorts of the spring spawning herring stock.
- Given the understanding of the status and productivity of the stock, maintaining the TAC at status quo should allow to maintain or increase the stock.

INTRODUCTION

Species biology

Herring (*Clupea harengus*) is a pelagic fish present on both sides of the North Atlantic, as well as in the Baltic Sea. Its distribution in Canada extends from the coasts of Nova Scotia to the coasts of Labrador. Herring make long annual migrations in order to feed, spawn near the coast, and overwinter in deeper waters. The same herring return to the same feeding, spawning, and wintering sites year after year. This homing phenomenon is attributed to a learning behaviour with the recruitment of young year-classes in a population. At spawning, eggs attach themselves to the sea floor, forming a carpet of a few centimetres thick. Eggs are about 1 mm in diameter and hatch at 4 to 6 mm larvae in 10 to 30 days, depending on temperature. The herring larvae are pelagic and metamorphose into juveniles at a length of about 40-50 mm. Most herring reach sexual maturity at 4 years, at a total length of about 26 cm. The herring

populations of the North Shore of Quebec are characterized by two spawner groups. Spring herring generally spawn in April and May, and fall herring in August and September. Spring and fall spawner herring in the Quebec North Shore (NAFO Division 4S, Figure 1) are considered separate stocks and are assessed separately. Recent studies have confirmed genetic differentiation between these two spawner groups (Lamichhaney et al. 2017).

Overview of the fishery

Since 1992, the herring fishery on the Quebec North Shore (NAFO Division 4S) has been managed by a preventive Total Allowable Catch (TAC) of 4,000 t due to the lack of scientific information to establish a formal TAC. Despite a high number of herring licence holders in Division 4S (254 in 2017 and 253 in 2018), active licences only numbered 14 and 11 in 2017 and 2018, respectively. Purse seine, traps, and gillnets are the main fishing gear used on the North Shore of Quebec. There is no TAC distribution among the different types of fishing gear, and the fishing is competitive. Herring on the North Shore of Quebec is also used as fishing bait for snow crab, lobster, and groundfish fisheries. Following the recommendations in the previous Science Advisory Report, additional management measures were put in place to limit fishing effort in the eastern end of Division 4S and protect the spawning season of spring and fall spawners. These measures include a change to the authorized fishing period for purse seine licence holders.

ASSESSMENT

Commercial fishing

Herring catches on Quebec's North Shore have increased significantly since 2011 (Figure 2). Average annual landings went from 476 t for the 1984–2010 period, to 3,515 t for the 2011–2018 period. However, landings have decreased by 38% since 2016, reaching 2,501 t in 2018, their lowest level since 2011. This decrease in landings may be partly due to the management measures that were put in place in 2017 and 2018, as well as adverse weather conditions for fishing activities. This decrease could also be due to the increased presence of herring at greater depths. This phenomenon, which would reduce the availability of fish to fishing gear, was reported by members of the fishing industry and was also observed during the acoustic survey conducted by Fisheries and Oceans Canada (DFO) in the fall of 2018.

Since 1984, most herring catches on Quebec's North Shore have come from three unit areas, namely 4Sz of Division 4S West, and 4Sv and 4Sw of Division 4S East (Figure 2). Between 1984 and 2007, 55% of catches on average were from the west area (4Sw). Since 2008, more than 99% of the catches have been made in Division 4S East (4Sv et 4Sw). In 2017 and 2018, almost all landings of herring catches were made at the eastern end of unit area 4Sw (Figure 3).

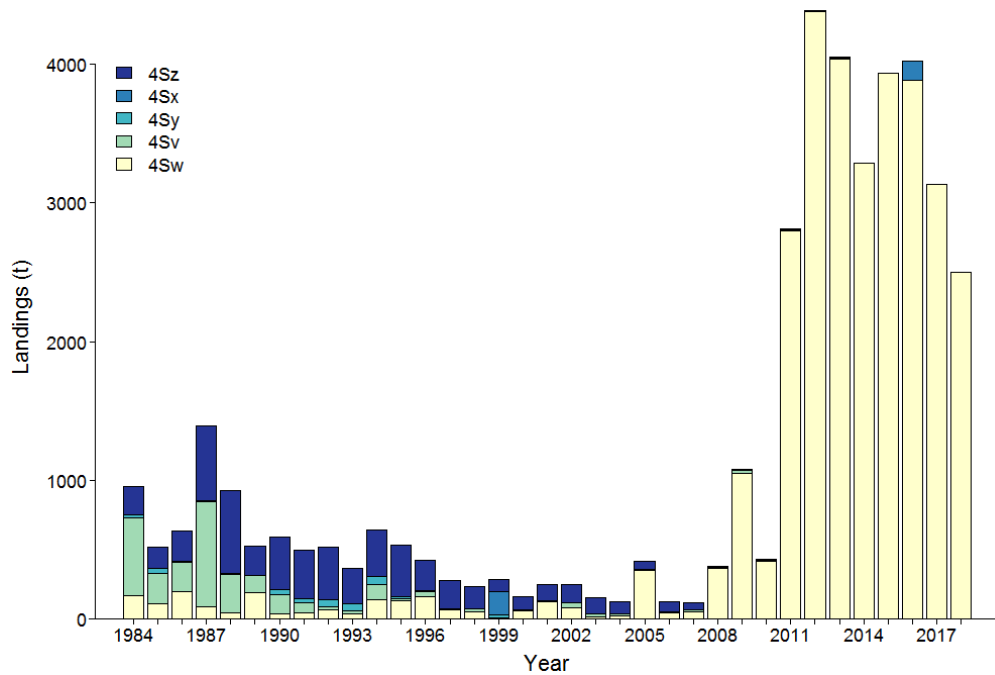


Figure 2. Herring cumulative commercial landings (tons) in the unit areas on the Quebec North Shore (NAFO Division 4S) from 1984 to 2018. Landings in 4Si and 4Ss are not presented because they have always been very low.

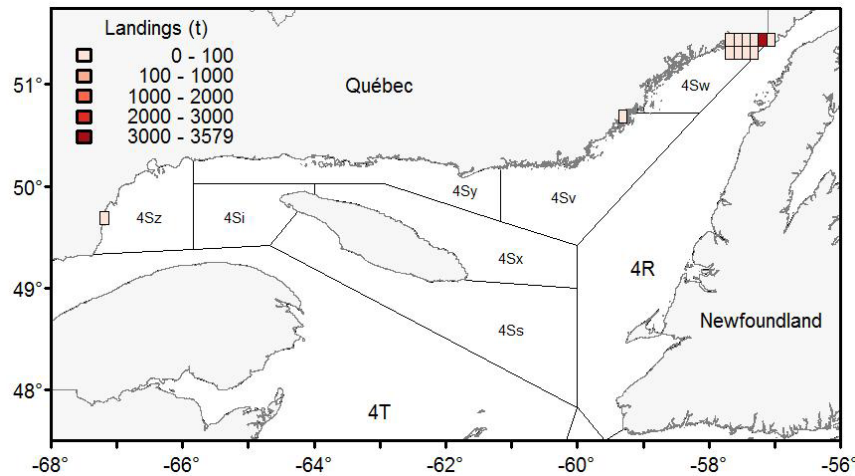


Figure 3. Spatial distribution of herring commercial catches on Quebec's North Shore (NAFO Division 4S) for 2017 and 2018 combined

From 1984 to 2008, most herring landings on the North Shore of Quebec were associated with the gillnet (Figure 4). As of 2008, net traps replaced gillnets in Division 4S East only. Since 2011, the purse seine has been used most often (Figure 4), with an annual average of 85% of herring catches; traps have been used in 14% of catches and gillnets in less than 1% of catches. In 2017 and 2018, over 98% of landings were with the purse seine.

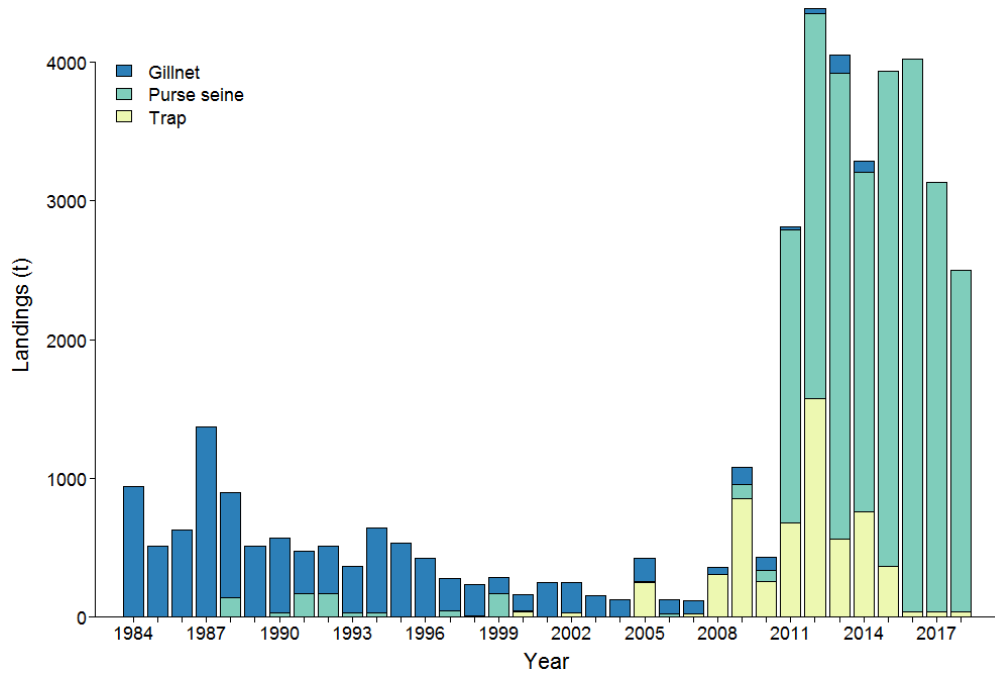


Figure 4. Herring cumulative commercial landings (tons) by fishing gear on the Quebec North Shore (NAFO Division 4S) from 1984 to 2018.

Between 1985 and 2007, spring spawners accounted for, on average, 65% of commercial herring landings (Figure 5). Since 2008, catches have been largely dominated by fall spawners. This change coincides with the shift in fishing effort from the western area—where fishing activities were concentrated in the spring—to the eastern end of the area, where activities take place mainly in the summer and fall.

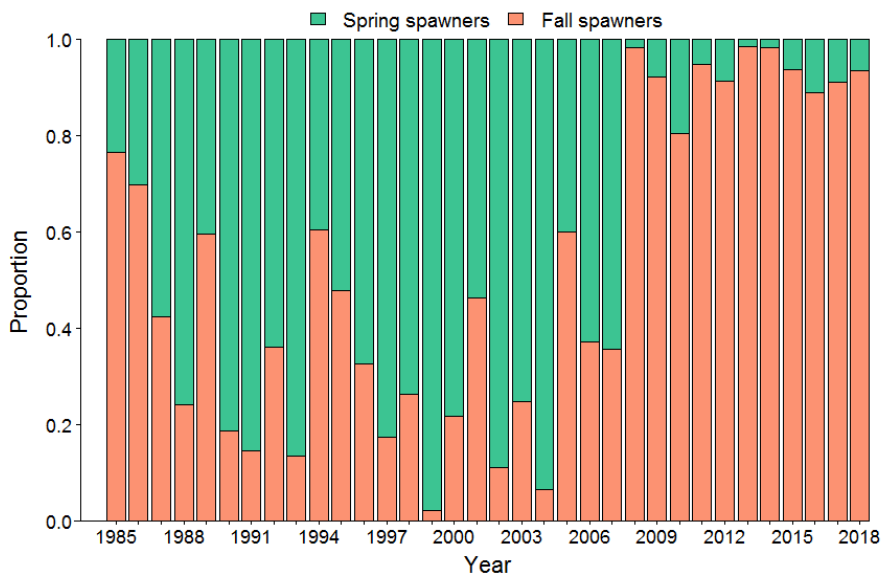


Figure 5. Annual proportion of spring and fall spawners in Quebec North Shore herring commercial catches (NAFO Division 4S) from 1985 to 2018.

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Biological Indicators

Annual catch-at-age composition indicates that the two herring spawning stocks of the Quebec North Shore are characterized by the occasional occurrence of dominant year-classes (Figures 6 and 7). In the fall spawners, the most recent year-class is that of 2005 and, to a lesser extent, that of 2008 (Figure 6B). However, no significant recruitment has been observed since 2000 in fall spawners (Figure 7). In spring spawners, an abundant year-class appeared in 2013 (Figures 6A and 7).

Whereas in 2016 and 2017, catches of herring from the fall spawning stock were dominated by fish over 9 years of age, the 2018 catches consisted mainly of fish between the ages of 5 and 9 (Figure 6B). Herring catches from the spring spawning stock in 2017 and 2018 consisted primarily of 4- and 5-year old fish (Figure 6A).

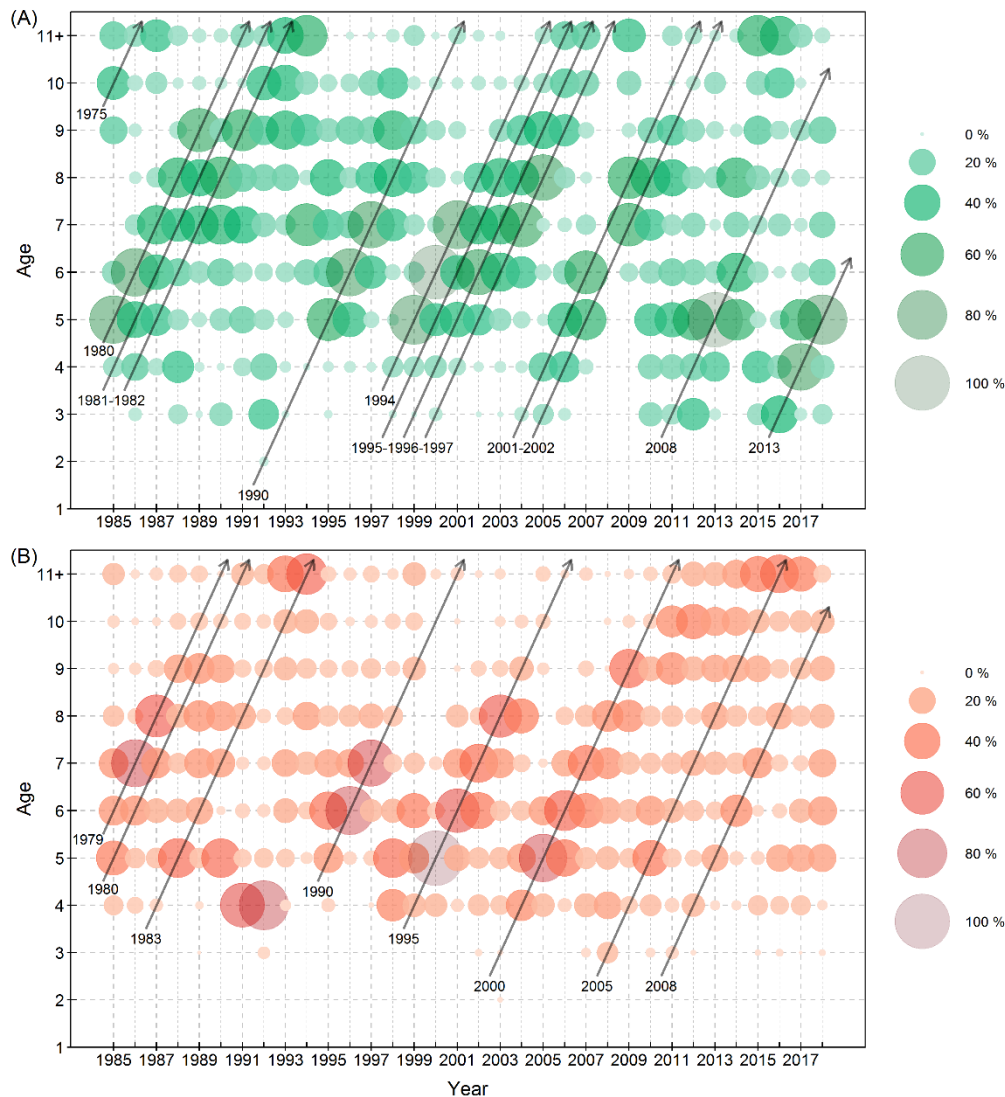


Figure 6. Annual catch-at-age composition (%) of herring, spring (A) and fall (B) spawners, on the North Shore of Quebec (NAFO Division 4S) from 1985 to 2018. Dominant year-classes are indicated with arrows.

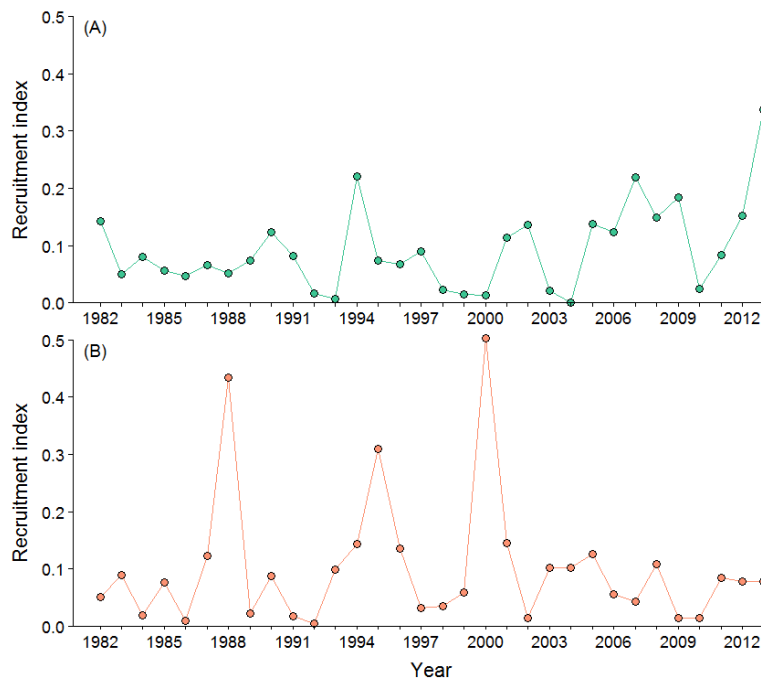


Figure 7. Recruitment index for spring (A) and fall (B) herring spawners for the 1982 to 2013 year-classes. The index is the proportion of age-4 fish in commercial landings on Quebec's North Shore (NAFO Division 4S).

The average total length of spring and fall spawners on Quebec's North Shore decreased significantly during the 1990s (Figure 8). Since the mid-2000s, average length has shown an upward trend for both herring spawning stocks, but it remains below the historical average (calculated for the 1981 to 2018 period) for fall spawners. For spring spawners, the average length has remained close to the historical average since 2012; however, it is below the series average in 2017 and 2018.

The condition (Fulton's K) of herring in the spring spawning stock has remained relatively stable since 1981, while the condition of herring in the fall spawning stock has declined slightly (Figure 9). Condition of herring in both spawning stocks was below the historical average in 2017 and 2018.

The sum of the annual anomalies (positive and negative, relative to the 1981-2018 average) of the main stock status indicators, namely the recruitment index (Figure 7), mean total length at age 6 (Figure 8), and Fulton's condition factor (Figure 9), was calculated for the spring and fall herring spawners on Quebec's North Shore. During the 1980s and early 1990s, most of the anomalies in the main stock status indicators for the spring and fall spawning stocks were positive (Figure 10). From the mid-1990s on, anomalies in these indicators remained predominantly negative in fall spawners, while in spring spawners, after a series of predominantly negative values during the 2000s, the anomalies fluctuated between positive and negative values. In 2017 and 2018, the anomalies of all three indicators were negative for both spawning stocks (Figure 10).

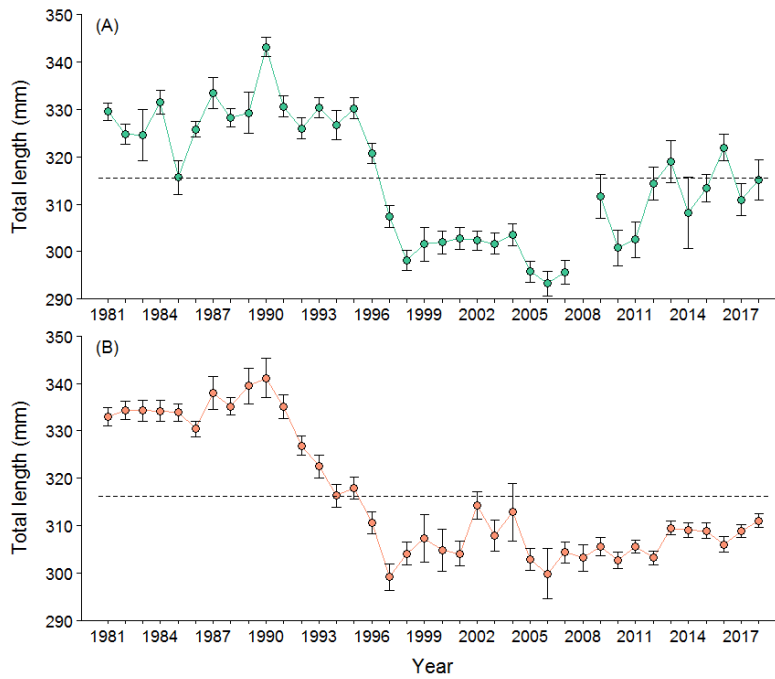


Figure 8. Total length (mm) at age 6 (with a 95% confidence interval) of spring (A) and fall (B) herring spawners on Quebec’s North Shore (NAFO Division 4S) from 1981 to 2018. The series has been standardized to take into account the fishing sector (east/west), fishing gear and month of capture. The dashed horizontal line indicates the series average.

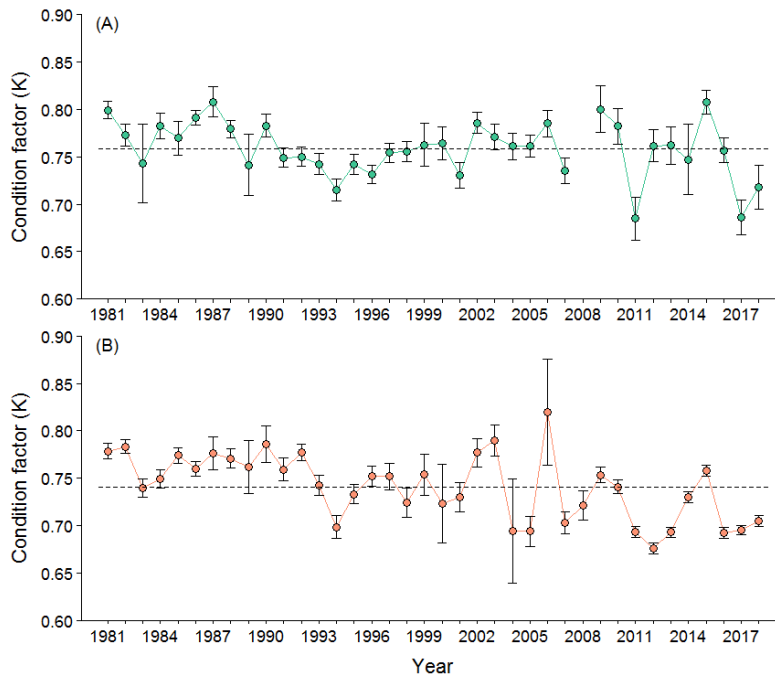


Figure 9. Fulton’s condition factor (with a 95% confidence interval) for spring (A) and fall (B) herring spawners on Quebec’s North Shore (NAFO Division 4S) from 1981 to 2018. The series has been standardized to take into account herring length, fishing sector (east/west), fishing gear and month of capture. The dashed horizontal line indicates the series average.

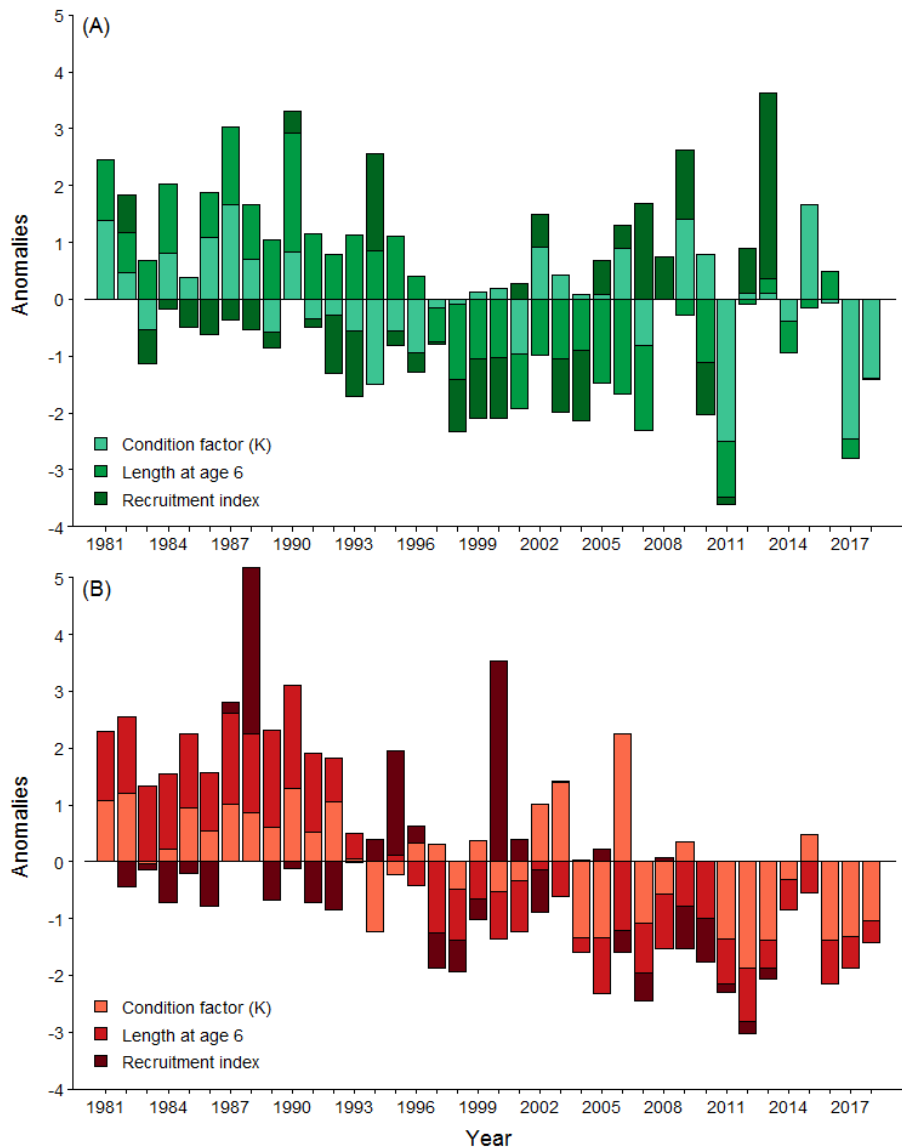


Figure 10. Sum of the annual standardized anomalies in the main indicators of stock status (Fulton's condition factor, average total length at age 6, and recruitment index) for spring (A) and fall (B) spawning herring stocks on Quebec's North Shore (NAFO Division 4S) from 1981 to 2018. .

Acoustic Surveys

A biennial acoustic survey covering the entire 4S inshore area was initiated in 2016. The 2018 survey was conducted from October 14 to November 9. Despite difficult weather conditions, the survey covered all strata except stratum 2 where only two out of seven transects were completed (Figure 11).

The biomass index was estimated at 2,473 t for spring spawners, compared with 19,950 t for fall spawners. The biomass index for fall spawners in 2018 is similar to that estimated in 2016 (19,325 t), while the index for spring spawners has almost tripled (752 t). Whereas in 2016, the highest biomass values were observed in the western part of the area, in 2018 the highest values were observed in unit area 4Sw (stratum 1) at the eastern end of the area (Figure 11).

Assessment of the Quebec North Shore (Division 4S) herring stocks in 2018

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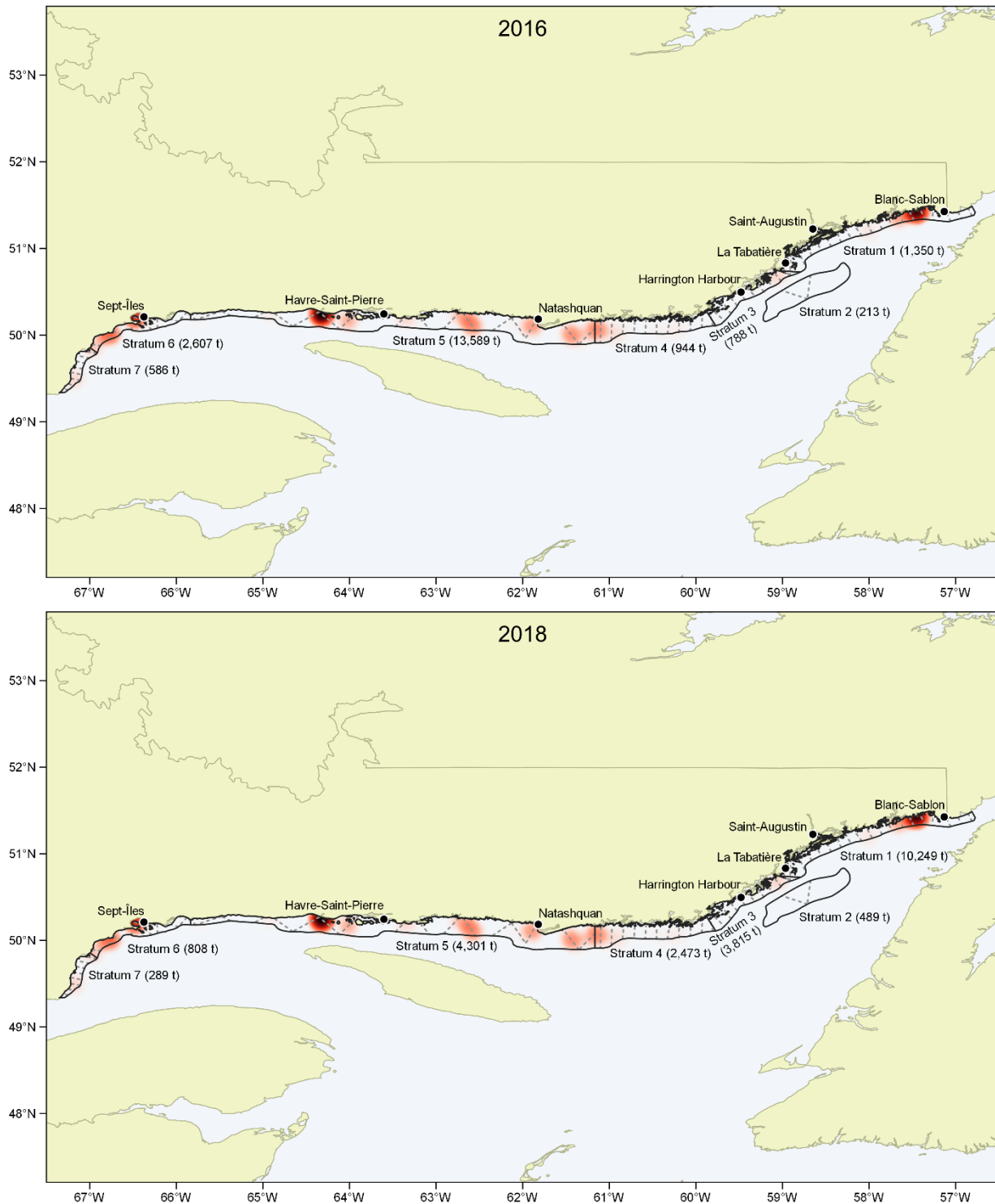


Figure 11. Herring density distribution (acoustic signal) along the Quebec North Shore in fall 2016 (upper panel) and 2018 (lower panel). Strata limits (black), completed transects (grey lines) and estimated biomass for each stratum are shown.

Four acoustic surveys were also conducted between 2009 and 2013 in unit area 4Sw located in the eastern part of the Lower North Shore of Quebec (Figure 1). The area covered by these

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surveys corresponds to stratum 1 from the 2016 and 2018 surveys (Figure 11). The biomass index of spring spawners in unit area 4Sw fell between 2009 and 2016 from 2,562 t to 35 t, and then increased to 1,130 t in 2018 (Figure 12A). After a significant decrease from 27,087 t in 2010 to 1,518 t in 2016, the biomass index for fall spawners increased to 9,119 t in 2018 (Figure 12B). The proportion of spring spawners in the biomass index of unit area 4Sw increased from 4% in 2016 to 11% in 2018, a level comparable to that of 2009.

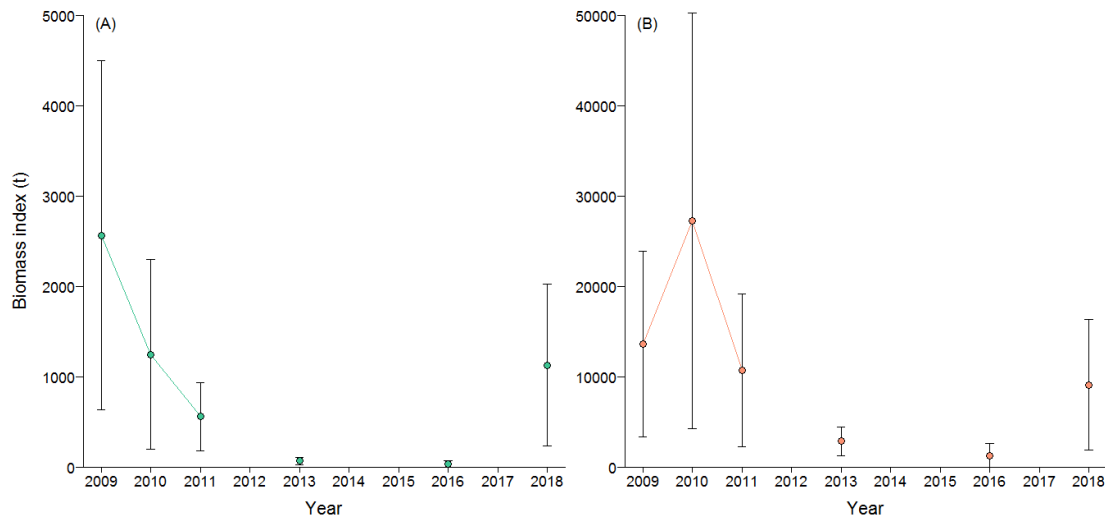


Figure 12. Biomass index (tons, with 95% confidence interval) of the spring (A) and fall (B) herring spawning stocks in unit area 4Sw located in the eastern part of the Lower North Shore of Quebec from 2009 to 2018.

Environmental and Ecosystem Considerations

The variability in herring population recruitment in the Gulf of St. Lawrence is considered to be closely related to environmental conditions. Recent research has shown that herring recruitment on the west coast of Newfoundland and in the southern Gulf of St. Lawrence (NAFO Divisions 4R and 4T) is influenced by zooplankton dynamics (abundance and phenology) and, to a lesser extent, by abiotic environmental conditions (water temperature) (Brosset et al. 2019). These results suggest that changes in zooplankton abundance, species composition and phenology affect the productivity of herring stocks in the Gulf of St. Lawrence.

Statistical models were used to describe the potential effects of these environmental variations on herring recruitment on Quebec's North Shore. Results show that changes in abiotic and biotic environmental conditions (zooplankton) explain the recruitment trend observed in recent decades, accounting for 74% and 78% of the variability in recruitment of the spring and fall spawning stocks, respectively. In the case of spring spawners, good recruitment is associated with earlier spring warming and colder water temperatures in spring (Figure 13), suggesting that larval survival in this stock is dependent on the synchronization between their emergence period and peak abundance of their prey, as well as the predominance of zooplankton species typical of cold waters. In the case of fall spawners, good recruitment occurs when the plankton bloom is substantial and water temperatures are warmer in summer (Figure 14). Adequate food (zooplankton) during the larval period and faster larval growth due to warmer temperatures could improve larval survival in the fall spawning stock. Strong recruitment to the spring spawning stock is associated with colder-than-average environmental conditions, while strong recruitment to the fall spawning stock occurs when environmental conditions are slightly warmer than average. These results show that recruitment to the spring and fall spawning stocks is

favoured by different environmental conditions, which is consistent with the results obtained for the herring stocks in Divisions 4R and 4T (Brosset et al. 2019).

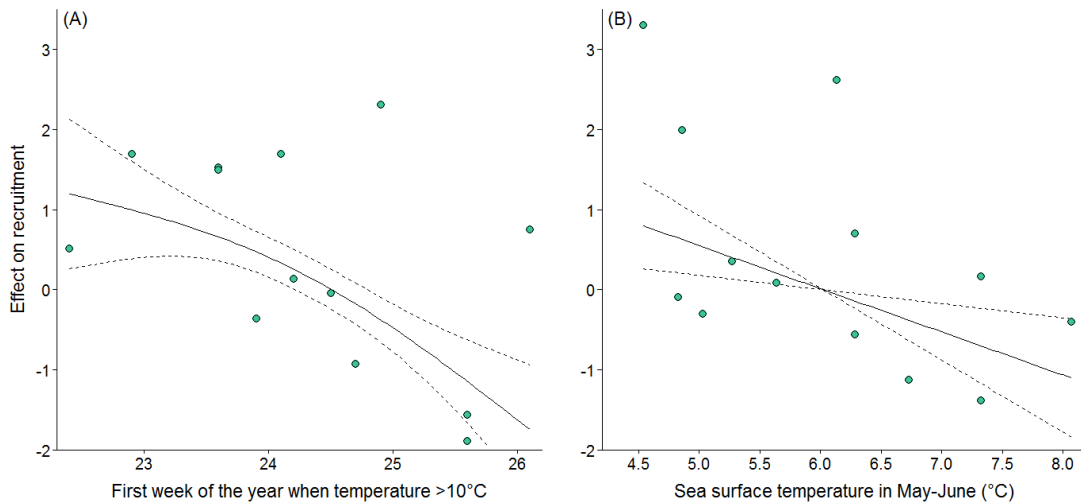


Figure 13. Effects of spring warming (A) and near-surface water temperature in May and June (B) on recruitment of spring herring spawners on Quebec's North Shore (NAFO Division 4S). Spring warming corresponds the first week of the year when the average weekly surface water temperature is above 10°C. The dashed lines indicate the 95% confidence intervals.

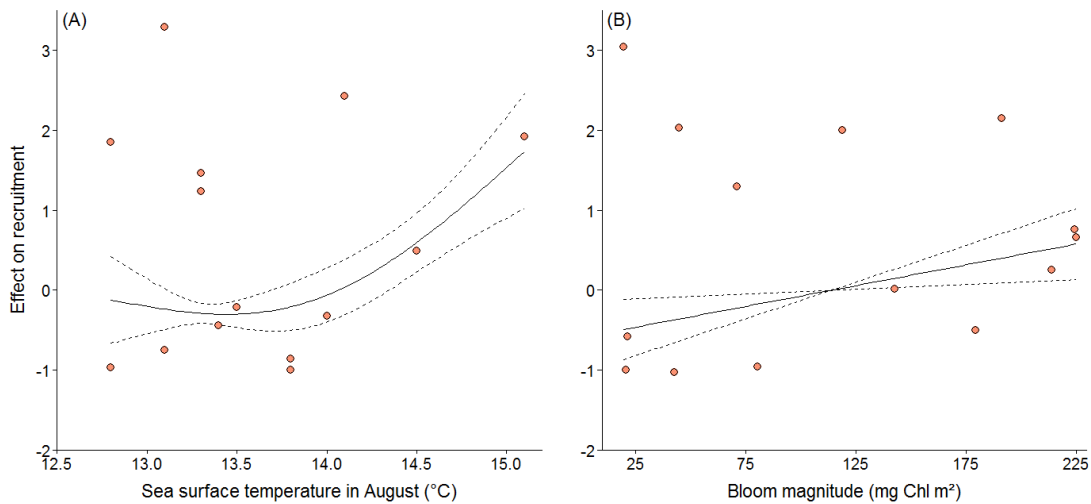


Figure 14. Effects of surface water temperature in August (A) and magnitude of the plankton bloom (B) on recruitment of fall herring spawners on Quebec's North Shore (NAFO Division 4S). The dashed lines indicate the 95% confidence intervals.

Sources of Uncertainty

The lack of information on herring population structure in the northern Gulf of St. Lawrence is the main source of uncertainty. Tagging studies have shown that exchanges occur between the herring stocks in Divisions 4R and 4S. However, the migration and mixing patterns of herring stocks in the northern Gulf are still poorly understood. Until more detailed information becomes available, the herring stocks in Divisions 4R and 4S are considered distinct populations and assessed separately.

The acoustic surveys have been conducted during similar periods, between mid-October and early November, to measure the abundance of herring when they gather near the coast to feed before undertaking their migration to wintering areas in deeper waters. However, the timing of this gathering near the coast and of winter migration may vary from year to year. As a result, the proportion of the stock that is sampled in the survey each year is unknown, which limits our ability to provide advice related to stock abundance. In addition, the proportion of spring spawners in the biomass index is probably underestimated, since they appear to leave the coast earlier than fall spawners to begin their winter migration.

Samples from the commercial fishery were used to convert the acoustic index to biomass because it was not possible to obtain fishery-independent samples. The use of commercial samples compromises the statistical independence of acoustic samples in relation to fishing data and adds uncertainty to the survey results. The representativeness of commercial samples for characterizing acoustic signals is unknown.

The assessment of herring stocks in Division 4S depends primarily on samples of herring obtained annually from the commercial fishery. Since fishing now takes place almost exclusively in the eastern part of 4S, few commercial samples come from the western area. It is therefore difficult to obtain a representative sample of Division 4S as a whole. In addition, the small number of spring spawners in the commercial samples for the 2008 to 2018 period made it impossible to reliably determine the catch-at-age composition for this stock. This uncertainty makes it difficult to track cohorts of spring spawners over this period.

CONCLUSIONS AND ADVICE

Herring landings on Quebec's North Shore decreased during the period from 2016 to 2018. This decrease in landings may be partly due to the management measures put in place in 2017 and 2018, adverse weather conditions for fishing activities, and the increased presence of herring at greater depths, which would reduce their availability to fishing gear.

Whereas a relatively large year-class was observed among spring spawners in 2013, no significant recruitment has been observed for fall spawners since 2000. Nevertheless, the current catch-at-age composition of fall herring spawners points to a diversified age structure.

Although biomass estimates involve a high degree of uncertainty, the results of the acoustic survey suggest that the abundance index for spring and fall herring spawners increased in 4Sw in 2018. Maintaining the status quo for the TAC should allow the stock to remain stable or increase.

In 2017 and 2018, in keeping with the recommendations provided in the previous science advisory report, management measures were put in place to reduce fishing effort in 4Sw during the spawning period for spring and fall spawners. However, since no fishing activity took place during the spawning period of spring spawners, this spawning component was under-represented in our samples, limiting our ability to provide advice concerning this stock. A restricted or limited spring (May-June) fishery would allow better monitoring of herring cohorts in the spring spawning stock.

The role that environmental conditions play in relation to variations in recruitment to the spring and fall spawning stock is being studied. The preliminary results of this research provide a better understanding of the influence that the environment has on herring recruitment on Quebec's North Shore. This information will eventually be incorporated into the stock assessment process to ensure that environmental changes are taken into account.

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To date, no analyses have been conducted to assess the effect of fishing pressure on stock dynamics for the two herring spawning stocks on Quebec's North Shore. Once the new acoustic survey time series for the entire 4S area is long enough, it will be possible to develop an analytical assessment of both herring spawning groups and establish limit reference points, in order to develop a strategic framework for the fishery based on the precautionary approach.

Monitoring Process for Interim Years

The assessment of herring stocks on Quebec's North Shore is carried out every two years. As part of the March 15, 2019 assessment, it was agreed that during the intervening year, DFO Science would not update any of the indicators.

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SOURCES OF INFORMATION

This science advisory report is from the March 15, 2019, meeting on the Assessment of the Quebec North Shore (4S) herring stocks in 2018. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada Science Advisory Schedule](#) as they become available.

- Brosset, P., Doniol-Valcroze, T., Swain, D. P., Lehoux, C., Van Beveren, E., Mbaye, B. C., Émond, K. and Plourde, S. 2019. Environmental variability controls recruitment but with different drivers among spawning components in Gulf of St. Lawrence herring stocks. *Fish. Oceanogr.*, 28: 1-17.
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