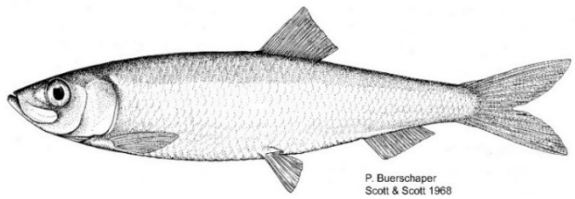
Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Quebec Region

Canadian Science Advisory Secretariat
Science Advisory Report 2021/037

ASSESSMENT OF THE QUEBEC NORTH SHORE (DIVISION 4S) HERRING STOCKS IN 2020



Atlantic herring (Clupea harengus)

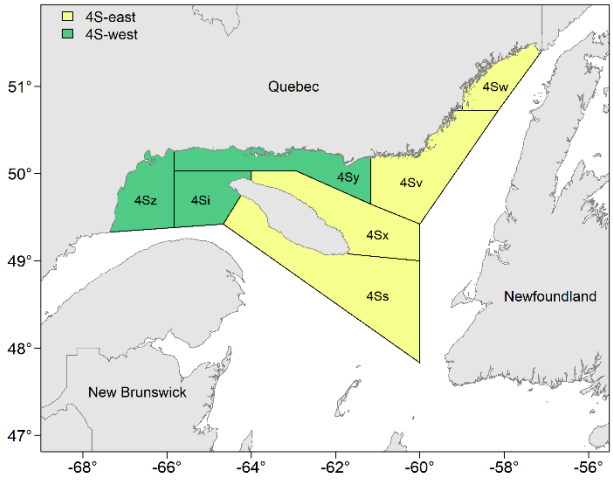


Figure 1. Map of unit areas of NAFO Division 4S. Unit areas belonging to the eastern (4Ss, 4Sv, 4Sw, and 4Sz) and western (4Si, 4Sy, and 4Sz) sectors of Division 4S are shown.

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. In 2019, the preventive TAC was increased to 4,500 t, while a maximum catch level of 4,000 t was maintained in Subdivision 4Sw to encourage the dispersion of fishing effort. 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 for the 2011-2018 period. Almost all of the catch comes from the purse seine fishery in the eastern end of Subdivision 4Sw.

Since 2009, eight fall acoustic surveys were conducted in unit area 4Sw. A second series of summer acoustic surveys has been initiated in 2019 in 4Sw. The data collected from these surveys are used to calculate biomass indices for the two spawning stocks, which, together with data from the commercial fishery, are the main source of information used to assess the stock status of herring on Quebec's North Shore.

The last assessment of the two herring spawning stocks in Division 4S was in 2019. The Fisheries and Aquaculture Management Branch requested scientific advice on these stocks for the 2021 and 2022 fishing seasons. This science advisory report is from the May 4-5, 2021 regional advisory meeting on the assessment of the Quebec North Shore (4S) herring stocks in 2020. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Landings of herring from the North Shore of Quebec have been decreasing since 2017 to reach 1,482 t (or 33% of the TAC) in 2020, their lowest level since 2011. Almost all landings came from the eastern end of unit area 4Sw. This decrease is in part attributable to a decrease in fishing effort.
- The proportion of the spring spawning stock in landings increased from an average of 7% for the period 2008-2019 to 28% in 2020. The herring catches of the spring spawning stock in 2019 and 2020 were mainly composed of small fish of the 2017 year-class, and to a lesser extent of fish of the 2013 year-class. These observations are consistent with those of the herring stock in 4R.
- Catches of the fall spawning herring stock in 2019 and 2020 consisted mainly of fish aged 11 years and over. A new year-class (2016) was also observed in 2020.
- The acoustic index of the spring spawning stock biomass in unit area 4Sw has been increasing since 2018, while the fall spawning stock biomass index has remained relatively stable.
- The annual condition of spring and fall spawners is favoured by early spring environmental conditions and the high abundance of *Calanus finmarchicus* and *C. hyperboreus*.
- The sum of the anomalies of three indicators of stock productivity (size at age 6, condition and proportion of ages 3 to 5) is positive in 2020 for the spring spawning stock and has remained mostly negative for the fall spawning stock since 2009.
- Evidence available up to 2020 (commercial catches at age, abundance of young fish) indicates that current catch levels are not expected to pose a significant short-term risk to herring stocks in 4S.

INTRODUCTION

Species biology

Herring (*Clupea harengus*) is a pelagic fish present on both sides of the North Atlantic. In the Northwest Atlantic, the range of herring extends from the coast of Labrador to Cape Hatteras in North Carolina. Herring stocks have a complex structure that remains largely unknown. Each stock consists of several populations that use temporally and spatially distinct spawning areas (Melvin et al. 2009; Stephenson et al. 2009). Every year, herring undertake migrations between feeding, spawning and overwintering areas. During these migrations, different populations (either from the same or adjacent stocks) mix during the feeding and overwintering periods, only to separate again into their individual components in the breeding season. The same herring return to the same spawning sites year after year. This homing phenomenon is attributed to a learning behaviour with the recruitment of young year-classes in a population (McQuinn 1997).

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 between 2 and 4 years (Wheeler et al. 2009). The herring populations of the North Shore of Quebec (NAFO Division 4S; Figure 1) 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 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 commercial fishery

Since 1992, the herring fishery on the Quebec North Shore has been managed by a preventive Total Allowable Catch (TAC) of 4,000 t due to the lack of scientific information on stock structure to establish a formal TAC. In 2019, the TAC was increased to 4,500 t, while a maximum catch level of 4,000 t was maintained in Subdivision 4Sw to encourage the dispersion of fishing effort. The TAC is applied to all catches, without differentiating between spawning stocks. Despite a high number of herring licence holders in Division 4S (251 in 2019 and 249 in 2020), active licences only numbered 12 and 15 in 2019 and 2020, respectively. Purse seine (vessel < 65 ft), traps, and gillnets are the main fishing gear used. There is no TAC distribution among the different types of fishing gear, and the fishing is competitive. The minimum legal size was set at 26.5 cm (fork length). However, this minimum size does not apply to individuals caught using gillnets. Following the recommendations in the 2017 Science Advisory Report (DFO 2017), management measures had been put in place for the 2017 and 2018 fishing seasons to limit fishing effort in the eastern end of Division 4S and protect the spawning season of spring and fall spawners. These measures included a change to the authorized fishing period for purse seine licence holders (DFO 2021a). However, these measures were removed following the conclusions of the 2019 assessment (DFO 2019).

ASSESSMENT

Commercial landings

Herring catches on Quebec's North Shore have increased significantly since 2011 (Figure 2). Average annual landings went from 456 t for the 1985–2010 period, to 3,187 t for the 2011–2020 period. However, landings have decreased by 63% since 2016, reaching 1,482 t in 2020, or 33% of the TAC (Figure 2). This decrease may be partly due to a reduction in purse seine fishing effort. The number of days fished with purse seines in Division 4S has declined, going from 139 fishing days in 2016 to 43 days in 2020—a drop of 69%.

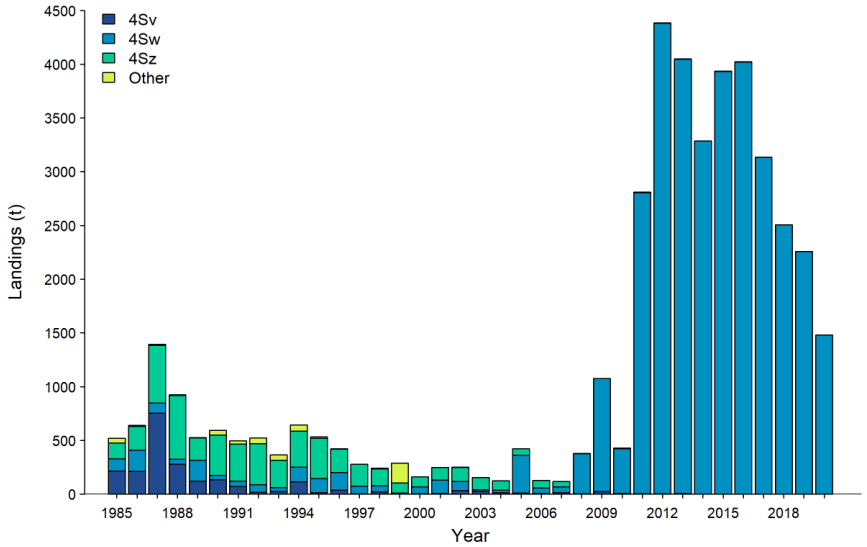


Figure 2. Herring cumulative commercial landings (tons) in the unit areas on the Quebec North Shore (NAFO Division 4S) from 1985 to 2020.

Since 2008, most herring catches on Quebec's North Shore have come almost exclusively from subarea 4Sw of 4S east (Figure 2). Herring landings from the 4S west area (4Sz), which accounted for 55% of catches on average between 1985 and 2007, declined sharply during the 2000s (Figure 2). This decrease in catches in Division 4S West seems to be due to economic factors. In 2019 and 2020, almost all landings of herring occurred in the eastern end of 4Sw, between Vieux-Fort and Blanc-Sablon (Figure 3).

From 1985 to 2007, most herring landings on the North Shore of Quebec were associated with the gillnet (Figure 4). From 2008 to 2010, when fishing effort shifted to Division 4S East, traps were replaced by gillnets. Since 2011, purse seine catches exclusively in sub area 4Sw have increased dramatically, with an annual average of 86% of herring catches; compared to 13% for traps and less than 1% for gillnets (Figure 4). In 2019 and 2020, the purse seine fishery accounted for the majority of landings, i.e. 92%, while the trap fishery represented 8% of landings.

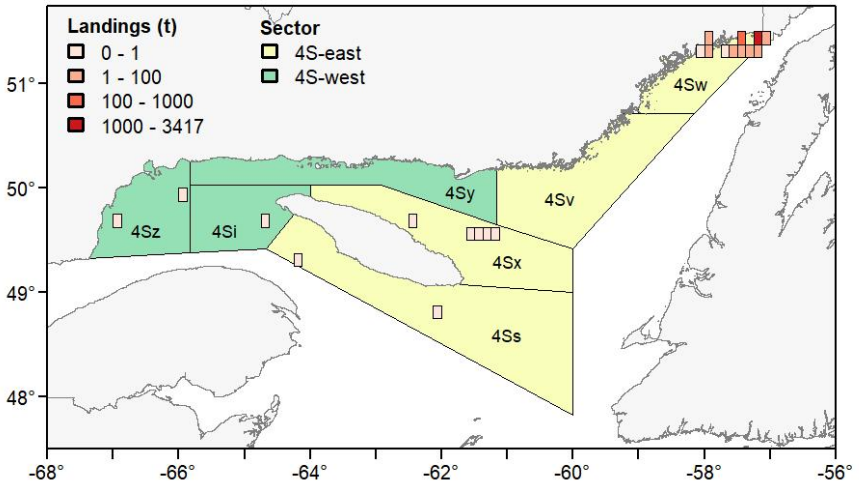


Figure 3. Spatial distribution of herring commercial catches on Quebec's North Shore (NAFO Division 4S) for 2019 and 2020 combined.

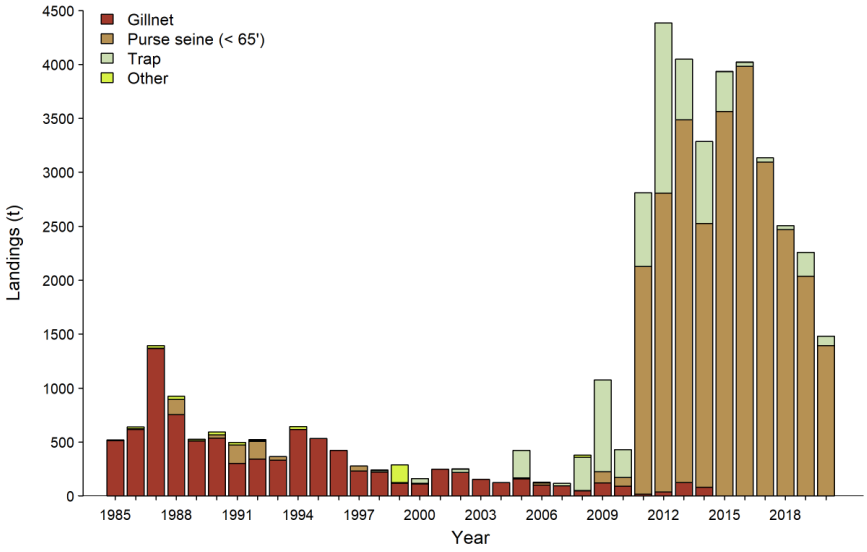


Figure 4. Herring cumulative commercial landings (tons) by fishing gear on the Quebec North Shore (NAFO Division 4S) from 1985 to 2020.

The annual proportion of spring spawners observed in catches has seen a substantial decline since 2008 (Figure 5). Between 1985 and 2007, spring spawners accounted for an average of 65% of commercial herring landings. Since 2008, they have accounted for only 8% of landings on average. This change coincides with the shift of fishing effort from the western area (where fishing activities are mostly carried out in spring) towards the eastern end of Division 4S (where activities take place mainly during summer and fall). However, the proportion of spring spawners observed in catches rose to 28% in 2020 (Figure 5).

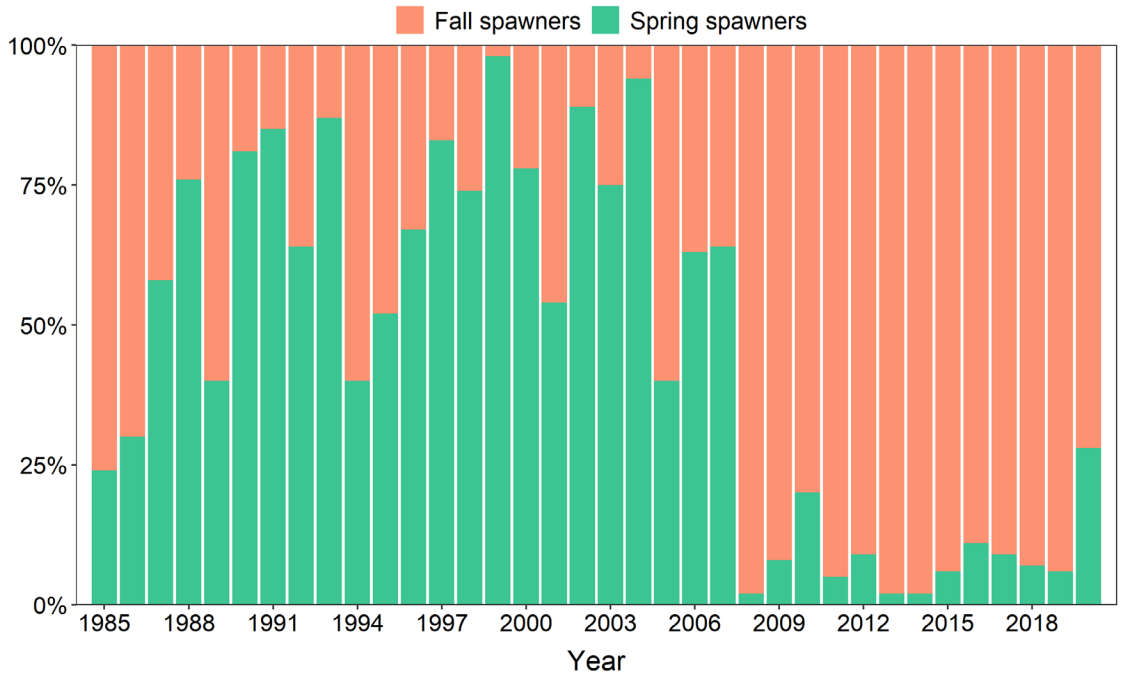


Figure 5. Annual proportion of spring and fall spawners in Quebec North Shore herring commercial catches (NAFO Division 4S) from 1985 to 2020.

Commercial catch-at-age composition

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. In the spring spawners, the most recent year-classes are that of 2013 and 2017 (Figures 6A and 7A). In the fall spawners, the last relatively abundant year-class was observed in 2008 (Figures 6B and 7B). A new year-class (2016) was also observed in 2020 in the fall spawners (Figure 6B).

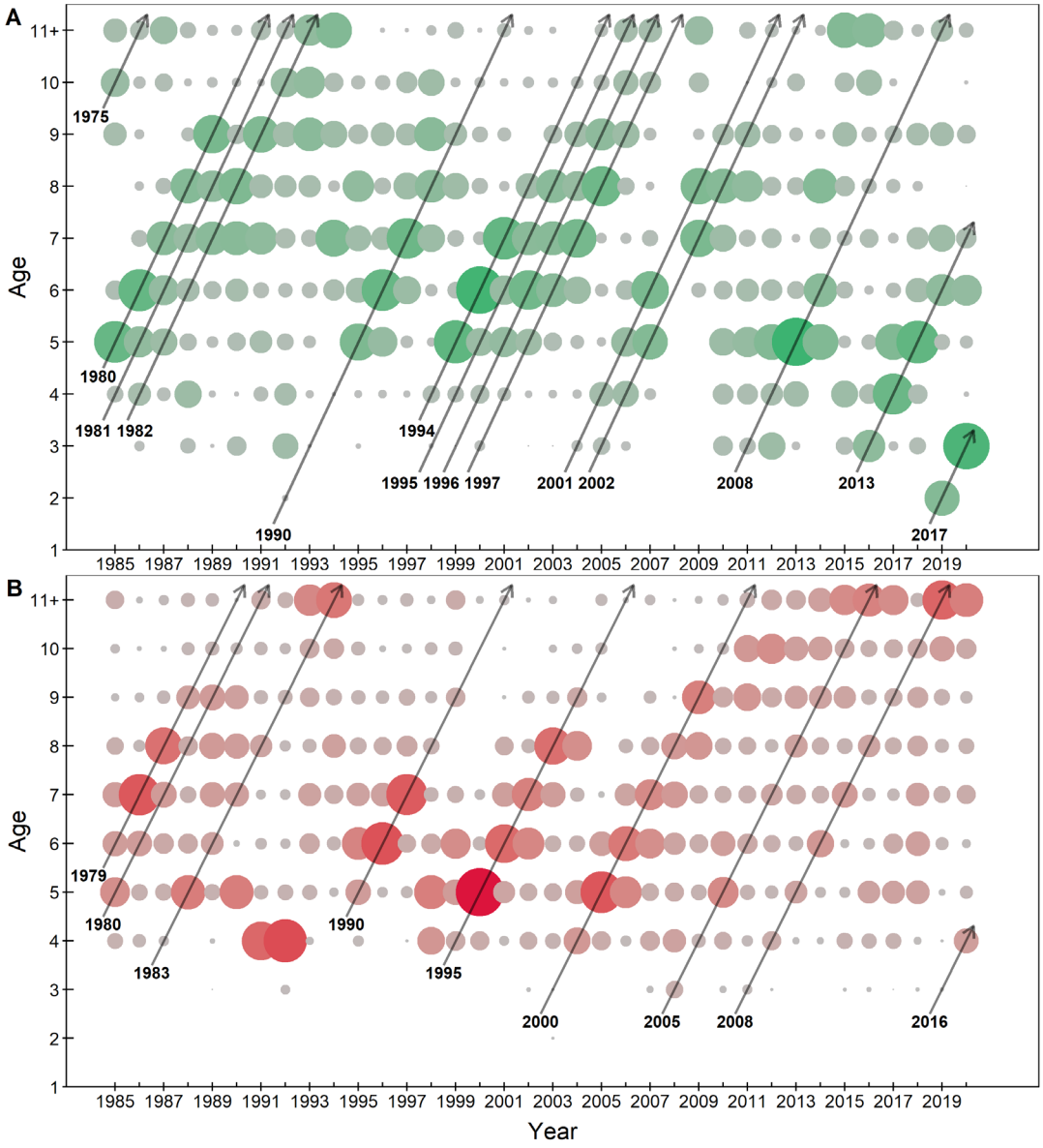


Figure 6. Annual catch-at-age composition (%) of herring, spring (A) and fall (B) spawners, on the North Shore of Quebec (NAFO Division 4S) from 1985 to 2020. Dominant year-classes are indicated with arrows.

Catches of spring spawning herring in 2019 and 2020 consisted primarily of small fish from the 2017 year-class (47%), and to a lesser degree, from the 2013 year-class (33%). Catches at ages 2 and 3 (corresponding to the 2017 year-class) of spring spawners in 2019 and 2020 are among the highest values in the series (Figures 6A and 7A). Catches of fall spawning herring in 2019 and 2020 consisted mainly of fish aged 11 years and over (46%). A strong fall spawning year-class has not been seen in commercial catches since 2005 (Figure 7B).

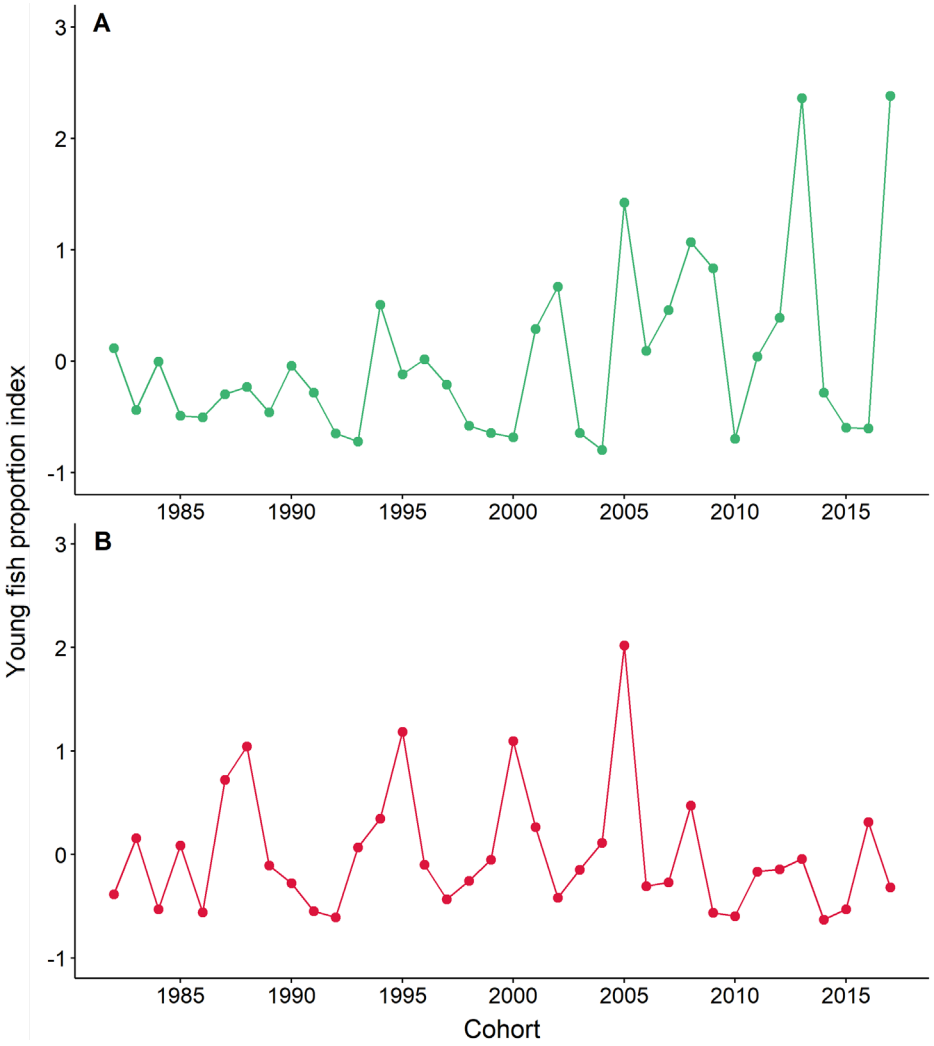


Figure 7. Index of the proportion of young spring (A) and fall (B) spawning herring in commercial catches on Quebec's North Shore (NAFO Division 4S) for the 1981 to 2017 cohorts. The index was obtained by averaging the standardized proportions of ages 3, 4 and 5 for years y, y+1 and y+2, excluding the 2016 and 2017 cohorts for which ages 3 and 4 were used for years y and y+1 and age 3 was used for year y, respectively.

Biological Indicators

The average length- and weight-at-age of 4- to 10-year-old spring and fall spawning herring on Quebec's North Shore declined throughout the 1990s (Figure 8). Average length- and weight-at-age values for the spring spawning stock remained relatively stable throughout the 2000s, staying close to the long-term averages (Figures 8A and 8C). With respect to fall spawners, length- and weight-at-age have remained stable and below long-term averages since the early 2000s (Figures 8B and 8D). A decrease in the average weight-at-age was also observed in the other Northwest Atlantic herring stocks, including those on the west coast of Newfoundland (DFO 2021b), the southern Gulf of St. Lawrence (Turcotte et al. 2021), and southwest Nova Scotia and the Bay of Fundy (Singh et al. 2020).

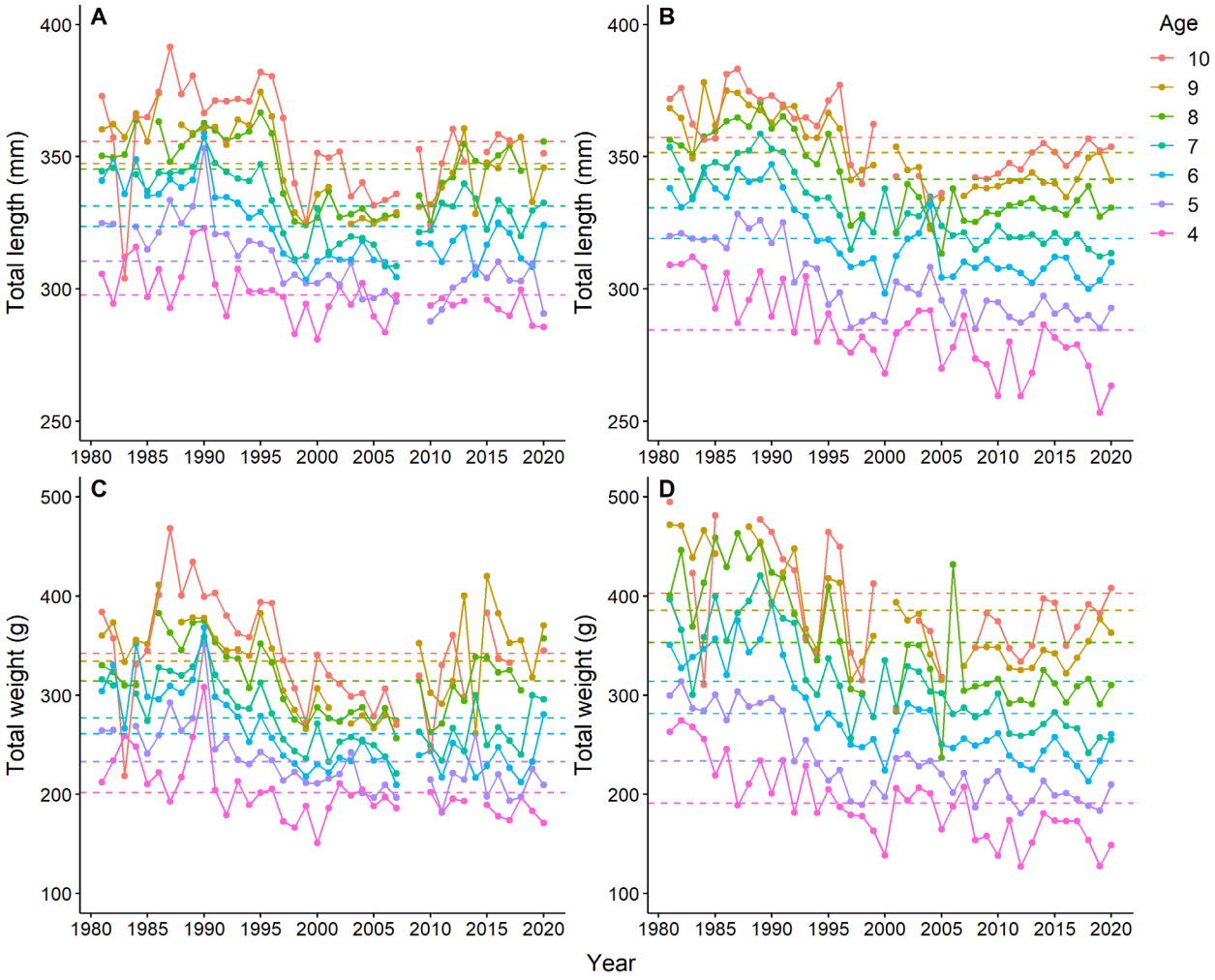


Figure 8. Total length (mm) and total weight (g) at age of spring (A and C) and fall (B and D) herring spawners on Quebec's North Shore (NAFO Division 4S) from 1981 to 2020. The series has been standardized to take into account the fishing sector (4S-east/4S-west), fishing gear and month of capture.The dashed horizontal line indicates the series average.

The standardized condition index of both spawning stocks (average of the 4–9 year age-classes) has varied around the long-term average since the early 1990s with no clear trend (Figure 9). Interannual variations in the condition index are related to physical environmental conditions and biological conditions (zooplankton), which explain 81% and 62% of the variability in the condition indices of spring and fall spawners, respectively. Better spring spawner condition is associated with early ice retreat, earlier spring warming and a high abundance of *Calanus finmarchicus* copepods, a primary prey item of Atlantic herring (Darbyson et al. 2003). The condition of fall spawners is favoured when *C. finmarchicus* phenology occurs earlier in spring and *C. hyperboreus* phenology occurs later. Thus, the condition of both herring spawning stocks is favoured by early spring conditions and the high abundance of large energy-rich calanoid copepods, which is consistent with the results obtained for Division 4R herring stocks (DFO 2021b).

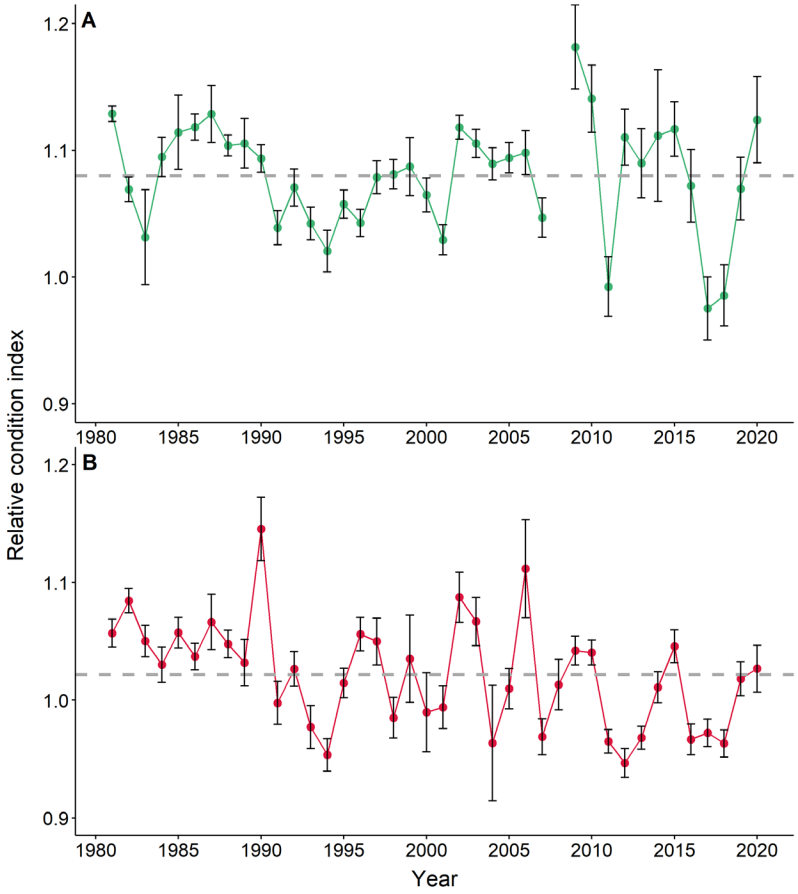


Figure 9. Standardized relative condition index (with a 95% confidence interval) for spring (A) and fall (B) herring spawners on Quebec's North Shore (NAFO Division 4S) from 1981 to 2020. The series has been standardized to take into account the fishing sector (4S-east/4S-west), fishing gear and month of capture.The dashed horizontal line indicates the series average.

Acoustic Survey

Eight fall acoustic surveys were carried out across the coastal area of Subdivision 4Sw between 2009 and 2020. The objective of these surveys was to estimate the abundance of spring and fall spawning herring as they gather near the coast to feed before beginning their migration to overwintering areas. The total biomass index of spring spawners in Subdivision 4Sw dropped from 2,448 t in 2009, to 24 t in 2016, and then rose to 9,649 t in 2020, the highest value ever observed in the series (Figure 10). Following a substantial decrease from 26,734 t in 2010 to 1,200 t in 2016, the biomass index for fall spawners remained fairly stable in 2018–2020 and was comparable to the values observed at the beginning of the series in 2009–2011 (Figure 10). The total biomass of fall spawners in 2020 was estimated at 12,190 t. The proportion of spring spawners in the biomass index of Subdivision 4Sw increased dramatically, jumping from an average of 7% for the 2009–2018 period to over 50% in 2019 and 2020.

The abundance indices at ages 2 and 3 (2017 year-class) for spring spawners and at ages 3 and 4 (2016 year-class) for fall spawners in 2019 and 2020 were at historically high values. These observations are related to a change in the fishing gear used for biological sampling (in 2019 and 2020, the biological samples used to convert the acoustic index to biomass were collected using a mid-water trawl instead of a purse seine, which was what had been used in

previous years). However, these observations are corroborated by commercial fishers, who have reported an increased presence of small fish in recent years. This trend is also visible in commercial catches-at-age (Figure 6).

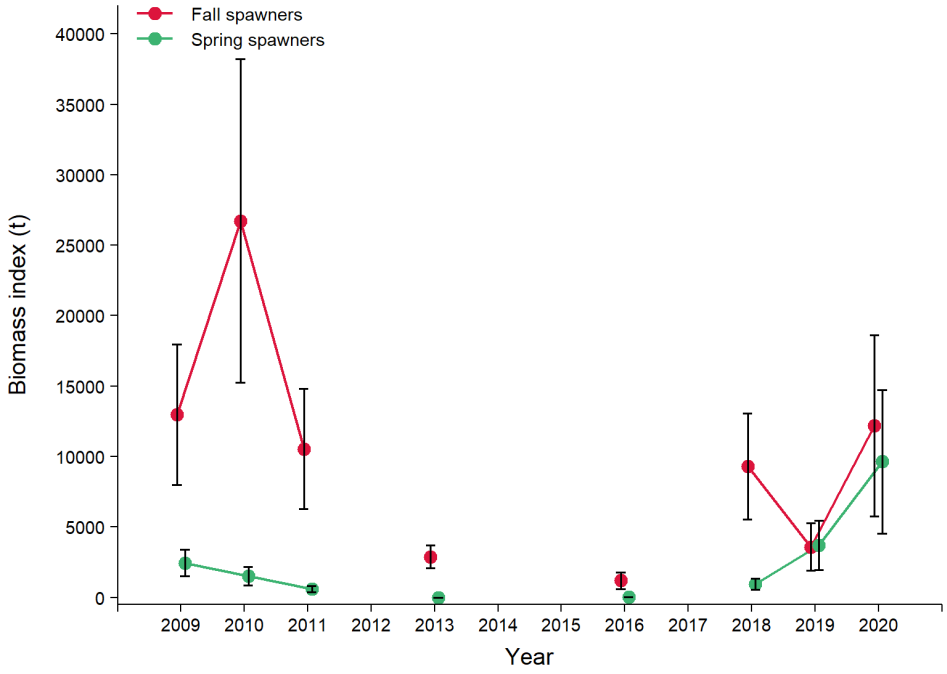


Figure 10. Total biomass index (tons, with standard error) of the spring (A) and fall (B) herring spawners in unit area 4Sw located in the eastern part of the Lower North Shore of Quebec from 2009 to 2020.

Cumulative stock productivity index

A cumulative index combining three stock productivity parameters has been developed to integrate available information and to describe temporal patterns in the productivity of the two herring spawning stocks on Quebec's North Shore.

The sum of the annual (positive and negative) anomalies, relative to the 1985–2020 average, in the proportion of young fish in catches (Figure 7), the average total length at age 6 (Figures 8A and 8B) and the relative condition index (Figure 9), were calculated for both spawning groups. These standardized anomalies represent the difference between the annual average of the indicator and the series average divided by the standard deviation of the series.

In the 1980s, anomalies in the cumulative stock productivity index were predominantly positive (Figure 11). Following a period of negative anomalies in the 1990s and 2000s, the productivity of the spring spawning stock fluctuated between positive and negative anomalies throughout the 2010s. For fall spawners, the stock productivity varied between positive and negative anomalies in the 1990s and 2000s, and has remained largely negative since 2009 (Figure 11). In 2020, the cumulative stock productivity index was positive for spring spawners but primarily negative for fall spawners.

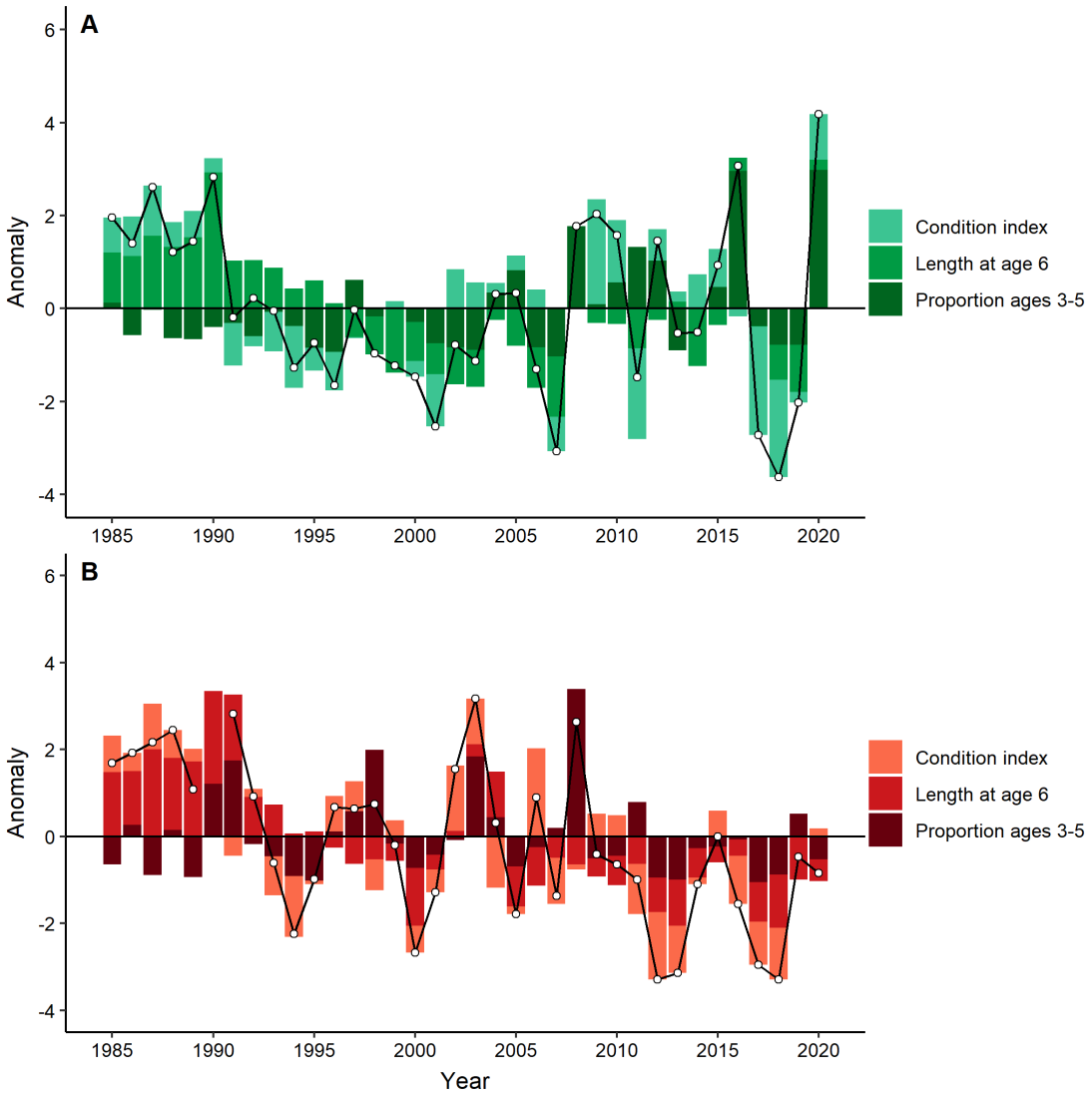


Figure 11. Cumulative stock productivity index based on the sum of annual standardized anomalies of key stock productivity indicators (relative condition index, average total length at age 6 and proportion of young fish in commercial catches) of spring (A) and fall (B) herring spawning stocks on Quebec's North Shore (NAFO Division 4S) from 1985 to 2020.

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 (catchability) is unknown, which limits the accuracy and precision of abundance indices and the interpretation of temporal trends. Interannual variations in the sampling effort (number of transects, spatial coverage) can also affect the catchability of the acoustic survey.

Biological samples used to estimate the acoustic biomass and convert it into numbers-at-age are generally limited and are collected using fishing gear that varies from year to year. Sometimes, they come from the commercial fishery (particularly in the case of spring spawning herring). 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 takes place almost exclusively in the eastern part of 4S since 2007, the sampling is not representative 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

The data and knowledge available are insufficient to quantitatively assess the status of the resource. However, evidence available as recently as 2020 indicates that current catch levels should not pose any significant risk to the two herring spawning stocks in Division 4S in the short term.

Two strong year-classes of spring spawners appeared in 2013 and 2017 and accounted for the majority of this stock's commercial catches in 2019 and 2020. For fall spawners, catches-at-age in 2019 and 2020 were dominated by fish aged 11 years and over. The dominance of an older cohort in catches suggests that the stock is not overfished. A new year-class (2016) was also observed in 2020 for fall spawners.

Although a high degree of uncertainty is associated with biomass estimates, the results of the acoustic survey suggest that the abundance index for spring spawning herring (and/or their availability to the survey) in 4Sw has been increasing since 2018, reaching a record high value in 2020. The abundance index for fall spawners has remained relatively stable since 2018.

The abundance of young fish observed in commercial catches-at-age, in the acoustic survey and by commercial fishers is an encouraging sign for spring spawners. The appearance of a new year-class (2016) in 2020 for fall spawners is another encouraging sign for this stock. However, it will need to be validated in the next assessment.

Landings have been trending downward since 2016, and the recent decrease of 41% can partly be explained by a decline in the purse seine fishing effort which is related to economic factors.

The trends observed in Division 4S herring stocks (increased proportion of spring spawners in commercial catches, the abundance of young fish, an increase in the acoustic biomass of spring spawners) are consistent with those observed in Division 4R herring stocks.

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 May 4-5, 2021 assessment, it was agreed that during the intervening year, DFO Science would not update any of the indicators.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Beaudoin, Tony	Fisher
Boudreau, Mathieu	DFO Science
Boudreau, Mélanie	DFO Science
Bourdages, Hugo	DFO Science
Brassard, Claude	DFO Science
Castonguay, Martin	DFO Science
Chamberland, Jean-Martin	DFO Science
Cyr, Charley	DFO Science
Dionne, Hélène	DFO Science
Dubé, Sonia	DFO Science
Émond, Kim	DFO Science
Fequet, Ross	Fisher
Girard, Linda	DFO Science
Lehoux, Caroline	DFO Science
Munden, Jenna	Herring Science Council
Nadeau, Paul	LNSFA
Nilo, Pedro	DFO Science
Paquet, Frédéric	DFO Science
Pellerin, Mathieu	DFO Fisheries Management
Plourde, Stéphane	DFO Science
Robert, Dominique	UQAR - ISMER
Roux, Marie-Julie	DFO Science
Roy, Virginie	DFO Science
Saint-Onge, Benoît	Pêcherie Uapan
Scarratt, Michael	DFO Science
Senay, Caroline	DFO Science
Smith, Andrew	DFO Science
Van Beveren, Elisabeth	DFO Science

SOURCES OF INFORMATION

This Science Advisory Report is from the May 4-5, 2021 regional advisory meeting on the Assessment of the Quebec North Shore (4S) herring stocks in 2020. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Darbyson, E., Swain, D. P., Chabot, D. and Castonguay, M. 2003. Diel variation in feeding rate and prey composition of herring and mackerel in the southern Gulf of St Lawrence. J. Fish Biol., 63 : 1235-1257.

DFO. 2017. Assessment of the Quebec North Shore (Division 4S) herring stocks in 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/027.

DFO. 2019. Assessment of the Quebec North Shore (Division 4S) herring stocks in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/037.

DFO. 2021a. Integrated fisheries management plan of Atlantic herring Division 4S (Herring Fishing Area 15).

DFO. 2021. Assessment of the West Coast of Newfoundland (NAFO Division 4R) Herring Stock Assessment in 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/005.

Lamichhaney, S., Fuentes-Pardo, A. P., Rafati, N., Ryman, N., McCracken, G. R., Bourne, C., Singh, R., Ruzzante, D. E. and Andersson, L. 2017. Parallel adaptive evolution of geographically distant herring populations on both sides of the North Atlantic Ocean. Proceedings Nat. Acad. Sci., 11 : E3452-E3461.

McQuinn, I. H. 1997. Metapopulations and the Atlantic herring. Rev. Fish Biol. Fish., 7 : 297-329.

Melvin, G. D., Stephenson, R. L., and Power, M. J. 2009. Oscillating reproductive strategies of herring in the western Atlantic in response to changing environmental conditions. ICES J. Mar. Sci., 66 : 1784-1792.

Singh, R., Knox, D., MacIntyre, A., and Melvin, G.D. 2020. 2018 Evaluation of Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX Herring. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/062. v + 157 p.

Stephenson, R. L., Melvin, G. D. and Power, M. J. 2009. Population integrity and connectivity in Northwest Atlantic herring: a review of assumptions and evidence. ICES J. Mar. Sci., 66 : 1733-1739.

Turcotte, F., Swain, D.P., McDermid, J.L., and DeJong, R.A. 2021. Assessment of the NAFO Division 4TVn southern Gulf of St. Lawrence Atlantic Herring (*Clupea harengus*) in 2018-2019. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/030. xiv + 158 p.

Wheeler, J. P., Purchase, C. F., Macdonald, P. D. M., Fill, R., Jacks, L., Wang, H. and Ye, C. 2009. Temporal changes in maturation, mean length-at-age, and condition of spring-spawning Atlantic herring (*Clupea harengus*) in Newfoundland waters. ICES J. Mar. Sci., 66 : 1800-1807.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Quebec Region
Fisheries and Oceans Canada
Maurice Lamontagne Institute
850 Route de la Mer
Mont-Joli, Quebec
G5H 3Z4

Telephone: 418-775-0825
Email: bras@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-40355-7 Cat. No. Fs70-6/2021-037E-PDF

Correct Citation for this Publication:

DFO. 2021. Assessment of the Quebec North Shore (Division 4S) herring stocks in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/037.

Aussi disponible en français :

MPO. 2021. Évaluation des stocks de hareng de la Côte-Nord du Québec (division 4S) en 2020. Secr. can. de consult. sci. du MPO. Avis sci. 2021/037.