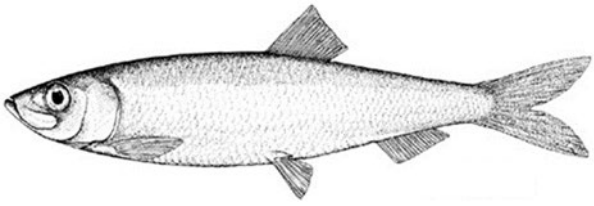
Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Gulf Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/022

SCIENCE ADVICE TO SUPPORT THE REBUILDING PLAN OF SOUTHERN GULF OF ST. LAWRENCE (NAFO DIVISION 4T-4VN) SPRING SPAWNING ATLANTIC HERRING (*CLUPEA HARENGUS*)



*Atlantic Herring (*Clupea harengus*)*
Credit: Scott and Scott 1998

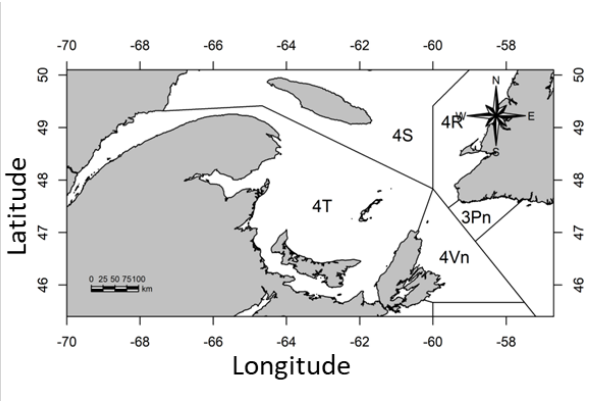


Figure 1. NAFO Divisions in the Gulf of St. Lawrence and Cabot Strait

Context:

*The spring spawning component of Atlantic Herring (*Clupea harengus*) stock in the southern Gulf of St. Lawrence (NAFO Division 4T-4Vn) has been below its limit reference point and in the Critical Zone of the Fisheries and Oceans Canada (DFO) Precautionary Approach framework since 2001. The new Fish Stocks Provisions and the amended Fisheries Act legally require DFO to develop a rebuilding plan for this stock. A rebuilding plan comprises several elements that require DFO Science sector advice including: (i) stock status, (ii) causes of stock decline, (iii) rebuilding target and timeline, (iv) additional measurable objectives, (v) likelihood of management measures meeting rebuilding objectives, (vi) how to track rebuilding progress, and (vii) frequency of the periodic review of the rebuilding plan.*

*This Science Advisory Report is from regional peer review of March 21-22, 2024 on Science Advice to Support the Rebuilding Plan for the Spring Spawning Atlantic Herring (*Clupea harengus*) Stock in the Southern Gulf of St. Lawrence, NAFO Division 4TVn. Participants at the meeting included DFO Science (Gulf, Québec, National), DFO Fisheries Management (Gulf, Newfoundland and Labrador, Québec, National), academia, provincial and state governments, Indigenous organizations, ENGOs, and the fishing industry. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.*

SUMMARY

- The main source of serious harm to the southern Gulf of St. Lawrence (NAFO Division 4T-4Vn) Atlantic Herring spring spawning stock productivity and the probable cause of stock decline was environmentally-driven recruitment failure since 1992 associated with a regime shift from cold water/high recruitment to warmer water/low recruitment.
- Other sources of serious harm include reduced growth, increased predation-driven natural mortality, high fishing mortality during and after the stock decline in the late 1990s and early 2000s, reduced fecundity, and a state of low production and low biomass.
- A review of candidate spawning stock biomass (SSB) reference points identified the Limit Reference Point (LRP) of $0.4BMSY_{proxy.}$ A proposed Upper Stock Reference was $0.8BMSY_{proxy}$, a target reference point of $BMSY_{proxy}$, and a removal reference of $FMSY_{proxy}$.
- The stock has been below the LRP and in the Critical Zone of Fisheries and Oceans Canada (DFO) Precautionary Approach framework since 2001 (previously 2002).
- The current definition of the rebuilding target from the rebuilding plan is that the stock must have a 75% probability of being at or above the LRP. It should be amended to include that: (1) the stock must be at or above this level for 2 consecutive years (rebuilt state), and (2) population projections must also show that the stock is likely to continue its positive trajectory under a directed fishery for 2 years after this rebuilt state has been achieved.
- Even in the absence of fishing mortality, the SSB is unlikely to increase to the rebuilding target under prevailing stock productivity and ecosystem conditions or under various scenarios of natural mortality. In order for the stock to rebuild, recruitment must increase to the intermediate to high levels observed prior to the mid-1990s.
- With annual fishery removals (directed, bycatch, bait, science) of 150 to 500 tonnes (t), it is expected that SSB will decrease by a small amount (1 to 4%) over a decade compared to no fishery removals. These differences may be negligible because of the associated uncertainty.
- The main source of spring spawning Atlantic Herring bycatch is the fall season Atlantic Herring fisheries. Historically, the fall mobile gear fishery has landed more spring spawning Herring, however in half of the years from 2017 to 2022, the fixed gear fishery landed the majority. Bycatch in the fall fixed gear fishery is greatest in the South and North regions with minimal contribution from the Middle region.
- The removals from the spring season bait fishery are highly uncertain, but recent analysis indicates that they were higher than previously assumed and reported. In the event that this bait fishery reopens, removals should be monitored and reported to accurately estimate the associated fishing mortality.
- An additional measurable objective of the rebuilding plan is increasing the proportion of older fish to levels observed historically (1978-2004).
- Rebuilding progress will be tracked using the stock assessment model. The periodic review of the rebuilding plan should be set to every 4 years (every other stock assessment cycle) unless the stock productivity or external factors influencing stock dynamics change.

INTRODUCTION

Under the Fish Stocks Provisions (FSP) section 6.2 in the amended Fisheries Act (2019) and section 70 of the Fishery General Regulations, it is a legislated requirement to develop and

implement a rebuilding plan for a prescribed major fish stock, within 24 months of the day on which the Minister first has knowledge the stock has declined to or below its limit reference point (LRP). If a stock is already at or below its LRP when it is prescribed under the FSP, the 24-month timeline to develop a rebuilding plan for the stock starts the day the stock is prescribed in regulation, which occurred April 4, 2022 for spring spawning Atlantic Herring (*Clupea harengus*) in the southern Gulf of St. Lawrence (hereafter; spring Herring).

The management unit for the southern Gulf of St. Lawrence (sGSL) spring Herring stock consists of the Northwest Atlantic Fisheries Organization (NAFO) Division 4T as well as overwintering off the north and east coast of Cape Breton in NAFO 4T and 4Vn (Figure 1). The spring Herring commercial and bait fisheries were closed in 2022. A total allowable catch (TAC) of 50 tonnes (t) remains to allow for bycatch in other fisheries, and catch for scientific purposes. The main sources of spring Herring bycatch are the fixed and mobile gear fisheries targeting fall spawning Atlantic Herring during the fall season and likely the fall season bait fishery.

The recent stock assessments for spring Herring confirmed that the stock has remained below the LRP and in the Critical Zone of the Fisheries and Ocean Canada (DFO) Precautionary Approach (PA) framework for two decades and a rebuilding plan is require. The specific objectives of this document are to: (1) review and update the LRP and establish the stock status and trajectory, (2) provide advice on the rebuilding target, (3) calculate and evaluate the likelihood of achieving the rebuilding target in a specified timeline under various environmental and fishery management scenarios, (4) propose additional measurable objectives, (5) identify indicators for tracking rebuilding progress, and (6) provide guidance on the frequency of the periodic review of the rebuilding plan.

ANALYSIS

Serious harm and cause of decline

Spring Herring spawning stock biomass (SSB; Figure 2) increased from low levels in the early 1980s to the highest levels in the mid-1980s to mid-1990s due to high recruitment. SSB then declined in the mid-1990s following recruitment failure associated with a shift from a cold water/high recruitment regime (1978-1991) to a warmer water/low recruitment regime (1992-2017). The stock continued to decline from 1993 to reach the Critical Zone in 2001, where it has remained. During the decline, fishing mortality was high in most years. In addition, natural mortality of older spring Herring began to increase sharply in 2010 from approximately 0.5 to reach a maximum of 1.05 in 2018 before decreasing slightly to a mean value of 0.9 in 2020 and 2021. Herring is an important pelagic prey species for numerous predators in the sGSL, and the trends in Grey Seal, Atlantic Bluefin Tuna, and Northern Gannet abundance were strongly correlated with the increase in natural mortality of older (age group 7-11+) spring Herring. Throughout the time series, a gradual decline of almost 40% in mean weight-at-age was observed. Furthermore, the decrease in size at age also lead to a 32% reduction in reproductive output. A low production-low biomass state has occurred since the beginning of the 2000s when both biomass and production reached low levels that persist afterwards.

The sources of serious harm to sGSL spring Herring are multiple consisting of environmentally-driven recruitment failure since 1992, a lasting state of low production-low biomass, high predation-driven natural mortality, high fishing mortality during and after the stock decline in the late 1990s and early 2000s, and declines in growth and fecundity. The main source of serious harm to stock productivity and the stock cause of decline was environmentally-driven recruitment failure since 1992 associated with a regime shift from cold water/high recruitment to warmer water/low recruitment. The source of serious harm to the stock productivity that can be

used to inform the selection of a limit reference point (LRP) is the lasting state of low production-low biomass since 2004.

Biomass reference points and stock status

An evaluation of 11 different candidate LRPs identified $0.4BMSY_{proxy}$ as the best candidate LRP for spring Herring. The proxy for B_{MSY} was estimated using the PA recommendations and is defined as the average SSB in productive years (1988 to 1994), estimated from the statistical catch-at-age population model. Its value was estimated at 55,000 t of SSB. Using the default rules suggested by the PA, a upper stock reference (USR) and target reference point (TRP) can be calculated from the proxy for B_{MSY}. The USR ($0.8BMSY_{proxy}$) was estimated at 108,000 t of SSB and the TRP ($BMSY_{proxy}$) was estimated at 135,000 t of SSB. Using the newly defined LRP and proposed USR from this study, the 2021 stock status remains in the Critical Zone (no change from previous assessment; Rolland et al. 2022). There was a change in the estimated year when stock decreased below the LRP to the Critical Zone which was 2001 with $40\%BMSY_{proxy}$ versus 2002 with the former LRP, $B_{recover}$ (Figure 2). A removal reference was also determined according to the PA recommendations as the average fishing mortality that did not lead to stock decline over a productive period. The removal reference was defined as the average fishing mortality of fishes age 6 to 8 in the years 1988 to 1992 ($FMSY_{proxy}$ = 0.21). A harvest control rule was developed based on these reference points and the default rules of the PA (Figure 3).

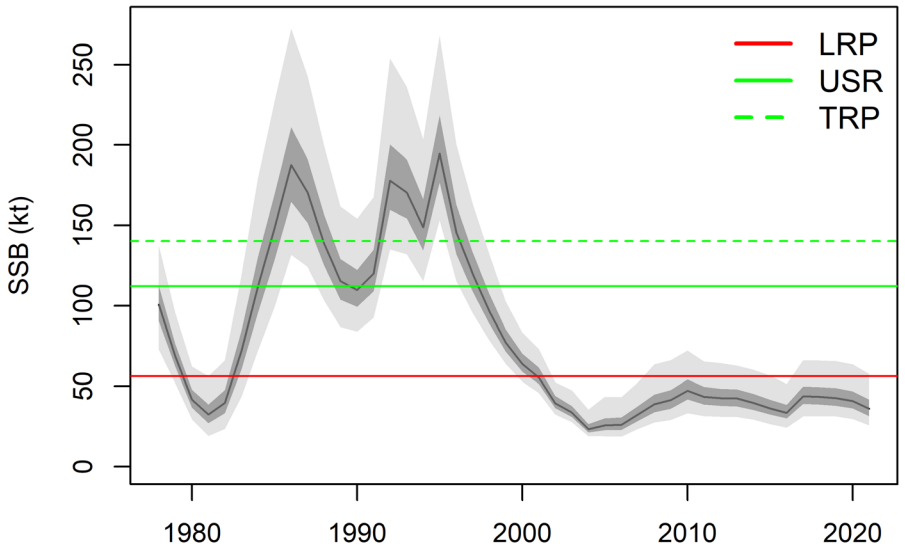


Figure 2. Southern Gulf of St. Lawrence (NAFO Division 4TVn) spring spawning Atlantic Herring Precautionary Approach reference points (Limit Reference Point; LRP, red line, Upper stock Reference; USR, green line and Target Reference Point, TRP, green dashed line) based on the $BMSY_{proxy}$. Black line is the median spawning stock biomass (SSB) estimate (kilotonnes; kt) and dark and light grey shading are the 50% and 95% confidence interval, respectively.

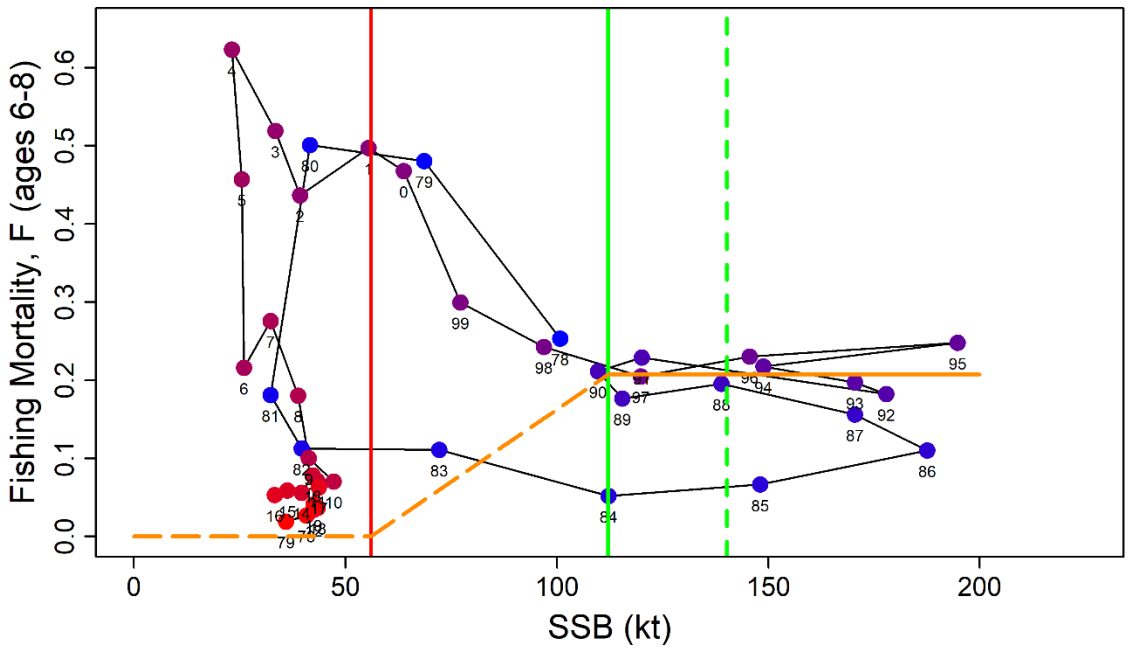


Figure 3. Proposed southern Gulf of St. Lawrence spring spawning Atlantic Herring harvest control rule. X axis is spawning stock biomass (SSB; kilotonnes (kt)) and y axis is abundance weighted fishing mortality rates (F) for ages 6 to 8 years. The red vertical line is the LRP, the green vertical line is the proposed Upper Stock Reference (USR), and the green vertical dashed line is the Target Reference Point (TRP). The orange solid horizontal line is the removal rate reference value ($FMSY_{proxy}$ = 0.21) in the Healthy Zone (above the USR) and the orange dashed line is the provisional harvest decision rule of the Precautionary Approach Framework in the Cautious (<USR and >LRP) and Critical Zones (<LRP). Point labels are years (83 = 1983, 0 = 2000).

Rebuilding target and timeline

The DFO science guidelines to support the development of rebuilding plans states that the rebuilding target should be set far enough above the LRP such that there is a low probability of falling below the LRP in the short to medium term (DFO 2021). The current rebuilding target proposed for this stock is being at or above the LRP with 75% probability. The uncertainty in SSB estimates for spring Herring is relatively small, therefore the rebuilding target is very near the LRP. As such, this target theoretically offers a higher probability of the stock falling below the LRP than a target set closer to the USR or the TRP for example. This rebuilding target should be amended to include that the stock must be at or above this level for 2 consecutive years (rebuilt state), and population projections must show the stock is likely to continue its positive trajectory under a directed fishery for 2 years after the rebuilt state has been achieved. Two years was selected since a rebuilding timeline could not be calculated or used to inform the choice of the number of years of growth that would minimize the probability of the stock falling below the LRP in the short to medium term. The number of years has consequently been set to the multi-year assessment cycle and projection timeline for advice for this stock.

A rebuilding plan also requires that the timeline to rebuild be identified in order to track rebuilding progress with respect to the objectives and management measures. The international standard and the approach recommended by DFO (2021) is to estimate the time to reach the rebuilding target in the absence of all fishing (T_{min}). In the absence of fishing mortality and under current low recruitment and high natural mortality conditions, the stock is not expected to

recover. Scenarios of future recruitment and natural mortality were performed to identify the conditions needed for the stock to rebuild. Irrespective of the level of natural mortality, the stock was unable to exceed the LRP with a probability of 75% within a 30 year time period in the current recruitment conditions. In order for the stock to rebuild, high recruitment (as observed prior to 1993) needs to occur at an intermediate to high frequency. It is highly unlikely that these levels of recruitment would be observed, particularly as climate change trends towards warming as opposed to cooling waters. If, however, these recruitment events were to occur consecutively the stock could rebuild within 5 to 6 years.

Since the stock is unlikely to rebuild to the rebuilding target under prevailing stock productivity and ecosystem conditions, even in the absence of fishing mortality T_{min} cannot be calculated. Therefore, an estimate of an alternative such as generation time provided by DFO Science can be used by Fisheries and Harbour Management to define a rebuilding timeline. The generation time for spring Herring is 6 years (Burbank et al. 2023).

Bycatch mitigation

As outlined in the PA framework (DFO 2009), the primary objective of a rebuilding plan is to promote stock growth above the LRP by ensuring removals from all fishing sources are kept to the lowest possible level until the stock has cleared the Critical Zone. Assuming that the directed commercial fishery and the fixed gear bait fishery in the spring season remain closed, the main catch of spring Herring is bycatch from the commercial fall season mobile and fixed gear Herring fisheries as well as the presumed minor fall bait fishery.

Since 2002 when the stock was in the Critical Zone, bycatch of spring Herring in the fall fisheries have averaged 100 t in the fixed gear fishery and 575 t in the mobile fishery. The proportion of spring Herring bycatch in the fall mobile fishery has averaged 24.8% since 2002, whereas the proportion of bycatch in the fall fixed gear fishery has been much smaller at 2.5%. The fall mobile fishery tends to capture younger spring Herring dominated by ages 3 to 6, while the fall fixed gear fishery captures predominately ages 6 to 8. Historically, the fall mobile gear fishery has landed more spring spawning Herring, however in half of the years from 2017 to 2022, the fixed gear fishery landed the majority. In recent years, fishing activities have decreased in the mobile gear fishery including not fishing in some years, while participation in the fixed gear fishery has remained consistent. Bycatch in the fall fixed gear fishery is greatest in the South and North regions with minimal contribution from the Middle region. Spring Herring bycatch in the fixed gear has predominantly occurred in the South region in recent years.

Reducing bycatch of spring Herring is unlikely to rebuild the stock, since population projections in the absence of fishing removals showed that the stock would remain in the Critical Zone in the long term. At 50 t of annual fishery removals from directed, bycatch, bait, and science, the population SSB in 10 years would be reduced by 0.3%. At 100 t of bycatch, SSB in 10 years would be reduced by 0.75%. At annual removals of 150 t, SSB is reduced by 1% in 10 years compared to zero fishing removals. At 300 and 500 t SSB is reduced by 2% and 4% in 10 years compared to zero fishing, respectively.

Bait removals

In NAFO Division 4T, bait fishery licences are issued to all commercial fish harvesters who hold a licence for a species and fishing gear requiring bait. This includes the fisheries for: American Lobster, Snow Crab, Atlantic Bluefin Tuna, and Atlantic Halibut. The 2020 changes to licence conditions that required mandatory reporting of bait catch estimates by hail-ins highlights potentially important issues of underreporting through logbooks. In 2020-2021, Herring bait

catches averaged 215 t which was were over 4 fold higher than the 49 t average reported from the previous 5 years. Assuming the proportion of spring Herring landed in the bait fishery in 2020 and 2021 is representative of the actual bait removals prior to 2020, earlier years fishery removals could be underestimated by 21 to 30%.

Using the sGSL Lobster harvesters telephone survey data (Boudreau and Giard 2022), it was estimated that respondents used an average of 30% Herring and 30% Mackerel as bait. Scaling these results to the entire Lobster fleet gives an estimate of 229 t of spring Herring fished for bait in 2016, a quantity that is much higher than reported. The bait removals for the other fisheries using Herring as bait (Snow Crab, Atlantic Bluefin Tuna, and Atlantic Halibut) are unknown.

Additional measurables objectives

The proportion of older spring Herring (aged 9+) declined to very low levels in the mid-2000s and has since remained low. Older and larger herring have been found to make greater contributions to recruitment (Burbank et al. in revision[1]). An additional measurable rebuilding plan objective is to increase the proportion of spring Herring age 9+ to averages observed historically (1978 to 1994).

How to track rebuilding progress

Rebuilding progress will be tracked using the spring Herring stock assessment model and the associated uncertainty of the model results. The stock assessment will be used to monitor productivity parameters including natural mortality, recruitment, and growth. Projections and decision tables will be provided to monitor the progress towards attaining objectives of the rebuilding plan. Rebuilding plan progress should be tracked as part of the multi-year stock assessment cycle. Objectives should be revised and models should be updated as estimates of stock productivity changes.

Frequency of periodic review of the plan

The periodic review of the rebuilding plan should be set to every 4 years, which corresponds to every other stock assessment for spring Herring. Objectives should be revised and models will be updated if stock productivity or external factors influencing stock dynamics change.

Sources of Uncertainty

The rebuilding target considerations regarding the number of years to be at or above the target and number of years to display positive stock trajectory in population projections under a directed fishery, cannot be quantified. As the current stock production and trajectory are not increasing, estimating the number of years that would minimize the likelihood of the stock returning to the Critical Zone after rebuilding is not feasible. If the stock was to approach the rebuilding target, the number of years and conditions of stock trajectory to be considered rebuilt

[1]Burbank, J., McDermid, J.L., Turcotte, F., Sylvain, F.É., and Rolland, N. Temporal declines in fecundity: A study of southern Gulf of St. Lawrence Atlantic herring (*Clupea harengus*) and implications for potential reproductive output. J. Fish Biol. *In revision*.

should be re-evaluated. The number of years has consequently been set to the multi-year assessment cycle and projection timeline for advice for this stock.

CONCLUSIONS AND ADVICE

The Science Advisory Report provides advice for elements of the rebuilding plan for spring Herring.

Stock status and causes of stock decline

- The LRP for the stock has been revised as 40%$BMSY_{proxy}$. The stock has been below the LRP and in the Critical Zone since 2001.
- The main source of serious harm to stock productivity and the cause of stock decline was likely environmentally-driven recruitment failure since 1992 associated with a regime shift from cold water/high recruitment to warmer water/low recruitment.
- Other sources of serious harm include reduced growth, increased predation-driven natural mortality, high fishing mortality during and after the stock decline, reduced fecundity, and a state of low production and low biomass.

Rebuilding target and timeline

- The rebuilding target, where the stock has a 75% probability of being at or above the LRP, should be amended to include that the stock must be at or above this level for 2 consecutive years (rebuilt state) and population projections must show the stock is likely to continue its positive trajectory under a directed fishery for 2 years after the rebuilt state has been achieved.
- A timeline to rebuild could not be calculated since even in the absence of fishing mortality, the stock is unlikely to rebuild under prevailing stock productivity and ecosystem conditions. The timeline should be set to the 6 year generation time of spring Herring.
- For the stock to rebuild, recruitment must increase to the intermediate to high levels observed prior to 1992, irrespective of the level of natural mortality.

Likelihood of management measures meeting rebuilding objectives

- At annual removals of 150 to 500 t, it is expected that SSB will decrease by 1 to 4% in 10 years compared to zero fishing.
- In the event that this bait fishery reopens, removals should be monitored and reported to accurately estimate the associated fishing mortality.

Additional measurable objectives

- A rebuilding plan objective to increase the proportion of Herring age 9+ to averages observed historically should be included.

Rebuilding progress

- Rebuilding progress will be tracked using the stock assessment models and associated uncertainty.
- The frequency of review should be set to every 4 years, every other stock assessment cycle.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Augustine, Ethan	North Shore Mi'kmaq Tribal Council
Barlow, Trevor	Prince Edward Island Fishermen's Association
Boudreau, Mathieu	DFO Science – Quebec Region
Boudreau, Stephanie	DFO Science – Gulf Region
Burbank, Jacob	DFO Science – Gulf Region
Carroll, Lindsay	The Confederacy of Mainland Mi'kmaq
Chlebak, Ryan	DFO Science – National
Cieri, Matthew	Maine Department of Marine Resources
Duguay, Gilles	Regroupement des pêcheurs professionnels du sud de la Gaspésie
Ferguson, Louis	Maritimes Fishermen's Union
Giard, David	DFO Fisheries and Harbour Management – Gulf Region
Gregoire, Benjamin	DFO Science – Quebec Region
Kadivar, Leila	DFO Fisheries and Harbour Management – National
Lagacé, Nicolas	Government of New Brunswick
Leger, Sylvie	DFO Fisheries and Harbour Management – Gulf Region
MacDonald, Reagan	Government of Prince Edward Island
Maynard, Laurie	DFO Science – Gulf Region
McDermid, Jenni	DFO Science – Gulf Region
Patterson, Maryline	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation
Paul, Tyson	Unama'ki Institute of Natural Resources
Pellerin, Mathieu	DFO Fisheries and Harbour Management – Quebec Region
Ramsay, Laura	Prince Edward Island Fishermen's Association
Rolland, Nicolas	DFO Science – National
Roy, Mélanie	DFO Science – Gulf Region
Schleit, Katie	Oceans North
Sylvain, François-Étienne	DFO Science – Gulf Region
Turcotte, François	DFO Science – Gulf Region
Vautier, Jeffrey	Transformateur sud de la Gaspésie

SOURCES OF INFORMATION

This Science Advisory Report is from the regional peer review of March 21-22, 2024 on Science Advice to Support the Rebuilding Plan for the Spring Spawning Atlantic Herring (*Clupea harengus*) Stock in the Southern Gulf of St. Lawrence, NAFO Division 4TVn. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Boudreau, S.A., Giard, D. 2022. Description of the Gulf Region lobster fishery in 1993, 2005, 2011, and 2016 from standardized phone surveys of Southern Gulf of St. Lawrence lobster fishers. Can. Manuscr. Rep. Fish. Aquat. Sci. 3247: iv + 99 p.

Burbank, J., McDermid, J.L., Turcotte, F. and Rolland, N., 2023. Temporal variation in Von Bertalanffy growth curves and generation time of southern Gulf of St. Lawrence spring and fall spawning Atlantic Herring (*Clupea harengus*). *Fishes*, *8*(4), p.205.

DFO. 2009. A fishery decision-making framework incorporating the precautionary approach. Last updated 2009-03-23.

DFO. 2021. Science Guidelines to Support Development of Rebuilding Plans for Canadian Fish Stocks. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/006.

Rolland, N., Turcotte, F., McDermid, J.L., DeJong, R.A., and Landry, L. 2022. Assessment of the NAFO Division 4TVn southern Gulf of St. Lawrence Atlantic Herring (*Clupea harengus*) in 2020-2021. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/068. xii + 142 p.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Gulf Region
Fisheries and Oceans Canada
P.O. Box 5030, Moncton, NB, E1C 9B6

E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-71346-5 Cat. No. Fs70-6/2024-022E-PDF

Correct Citation for this Publication:

DFO. 2024. Science Advice to Support the Rebuilding Plan of Southern Gulf of St. Lawrence (NAFO Division 4T-4Vn) Spring Spawning Atlantic Herring (*Clupea Harengus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/022.

Aussi disponible en français

*MPO. 2024. Avis scientifique à l'appui du plan de rétablissement de la composante de reproducteurs de printemps du hareng de l'Atlantique (*Clupea harengus*) dans le sud du golfe du Saint-Laurent (divisions 4T-4Vn de l'OPANO). Secr. can. des avis sci. du MPO. Avis sci. 2024/022.*