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Gulf Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/029

SOUTHERN GULF OF ST. LAWRENCE (NAFO DIVISION 4TVN) SPRING SPAWNING ATLANTIC HERRING (*CLUPEA HARENGUS*) STOCK ASSESSMENT TO 2023

CONTEXT

The Fisheries and Harbour Management sector of Fisheries and Oceans (DFO) has requested a stock status for the southern Gulf of St. Lawrence (sGSL) (Northwest Atlantic Fisheries Organization (NAFO) 4TVn) Atlantic Herring (*Clupea harengus*) spring spawning component. This stock is prescribed under section 6 of the *Fisheries Act*. The last scientific assessment for this stock was completed in March 2022 to provide advice for the 2022 and 2023 fisheries (DFO 2022). This stock follows a two-year assessment and management cycle. This Science Advisory Report is from the regional peer review of March 19-20, 2024 on the Southern Gulf of St. Lawrence, NAFO Division 4TVn, Atlantic Herring (*Clupea harengus*) Stock Assessment to 2023. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

SCIENCE ADVICE

Status

- The Spawning Stock Biomass (SSB) of southern Gulf of St. Lawrence (NAFO division 4TVn) spring spawning Atlantic Herring has been in the Critical Zone of the Precautionary Approach (PA) Framework since the early 2000s.
- As of 2022 and 2023, SSB of spring spawning Atlantic Herring has likely (> 95% probability) remained in the Critical Zone.

Trends

- Since 2022, the estimated SSB of spring spawning Atlantic Herring has remained consistently low, with little to no sign of increasing biomass.
- Recruitment of spring spawning Atlantic Herring has remained relatively stable at low levels since 1993.
- Starting in 2010, natural mortality estimates for older ages of spring spawning Atlantic Herring sharply increased up to 2018, then slightly decreased and remained at high levels.

Ecosystem and Climate Change Considerations

- Low recruitment of spring spawning Atlantic Herring associated with long-term environmental trends including water temperature increases and changes in prey dynamics is not expected to improve.
- Higher water temperature, poor food availability and high predator abundance likely have negative implications for Atlantic Herring size-at-age, fecundity and overall abundance.

Stock Advice

- Under current conditions of high natural mortality, declines in weight-at-age, and low recruitment, the probabilities that SSB of spring spawning Atlantic Herring will have a 5% increase by 2026 ranges from 58.6% at a catch of 0 tonnes (t) to 57.3% at a catch 500 t.
- Even in the absence of fishery removals, it is likely (> 84.7% probability) that the stock of spring spawning Atlantic Herring will remain in the Critical Zone by 2029. The probability of a 5% increase in SSB by 2029 is around 49% depending on the catch option.

Other Management Questions

- Since 1998, fishing mortality of spring spawning Atlantic Herring exceeded the provisional harvest decision rule of the Precautionary Approach Framework. Since the closure of the commercial and bait fisheries in 2022, low levels of bycatch in fall fisheries and scientific surveys are the main sources of reported catch.
- Total bait removals and discards-at-sea of spring spawning Atlantic Herring are not included in this assessment.

BASIS FOR ASSESSMENT

Assessment Details

Year Assessment Approach was Approved

2021 (Turcotte et al. 2021)

Assessment Type

Full Assessment

Most Recent Assessment Date

1. Last Full Assessment: 2021 (DFO 2022; Rolland et al. 2022)
2. Last Interim Year Update: n/a

Assessment Approach

1. Broad category: Single stock assessment model
2. Specific category: Statistical catch-at-age

Stock Structure Assumption

The southern Gulf of St. Lawrence (sGSL) spring spawning component of Atlantic Herring (hereafter; spring Herring) is genetically distinct from the fall spawning component (Lamichhaney et al. 2017). Spawning of spring Herring occurs primarily in April-May but extends to June 30 at depths < 10 m. The current spatial distribution of data collected and a lack of sufficient scientific evidence preclude the use of regionally disaggregated models for sGSL spring Herring. Therefore, the model and all advice of catch options are presented at the scale of the entire sGSL.

Reference Points

- Limit Reference Point (LRP): The LRP has been reviewed as part of the rebuilding plan and the use of 40%$BMSY_{proxy}$, i.e. 40% of the average biomass over a productive period (1988-1994), was approved. This LRP estimate is evaluated at 51,938 t.
- Upper Stock Reference (USR): The USR has been reviewed as part of the rebuilding plan and the use of 80%$BMSY_{proxy}$, i.e. 80% of the average biomass over a productive period (1988-1994), was approved. This USR estimate is evaluated at 103,877 t.
- Removal Reference (RR): The RR has been reviewed as part of the rebuilding plan. $F_{0.1}$ in the Healthy Zone of the Precautionary Approach Framework, is now set at 0.21.
- Target (TRP): The TRP has been reviewed as part of the rebuilding plan and the use $BMSY_{proxy}$, i.e. the average biomass over a productive period (1988-1994), was approved. This TRP estimate is evaluated at 129,846 t.

Data

- Commercial landings extracted from dockside monitoring reports, purchase slips and ZIFF (Zonal Interchange File Format) files (1978 – 2023)
- Telephone Survey to inform fishing effort calculation of CPUE (1986 – 2021)
- Dockside Monitoring Program to inform fishing effort calculation of CPUE (1978 – 2021)
- Experimental Net Program (2022 – 2023)
- Scientific Commercial Net Program (2022 – 2023)
- DFO Port Sampling to inform catch-at-age (1978 – 2023)
- Fishery-Independent Acoustic Survey (1994 – 2023)
- Ecosystem Information (2001 – 2021)

Commercial landings are provided by the Statistics Branch of DFO and the Dockside Monitoring Program. DFO staff also conduct port sampling to collect a sample of landed fish in order to understand the biological composition. The yearly telephone survey is also conducted when the fishery is opened to understand changes in biomass from a fisher's perspective and to inform the Catch Per Unit Effort (CPUE) index.

The acoustic survey in the Chaleur Bay region is a fisheries independent survey conducted each year. This survey estimates biomass of Herring aged 4-8. A proportion of fish is sampled for analyses in the lab at the Gulf Fisheries Centre and is used for spawning stock assignment to understand the proportion of spring spawners observed in each data source (see Rolland et al. 2022).

Data changes: Since the closure of the 4T spring Herring fishery in 2022, there were no commercial landings during the spring season and therefore no data is available to calculate the CPUE for 2022 and 2023. A small-scale scientific commercial net program was set up in spring 2022 and is being explored as an alternative to address this lack of data. The catches from this program and the experimental nets were sampled by DFO port samplers to continue to inform the catch-at-age index.

ASSESSMENT

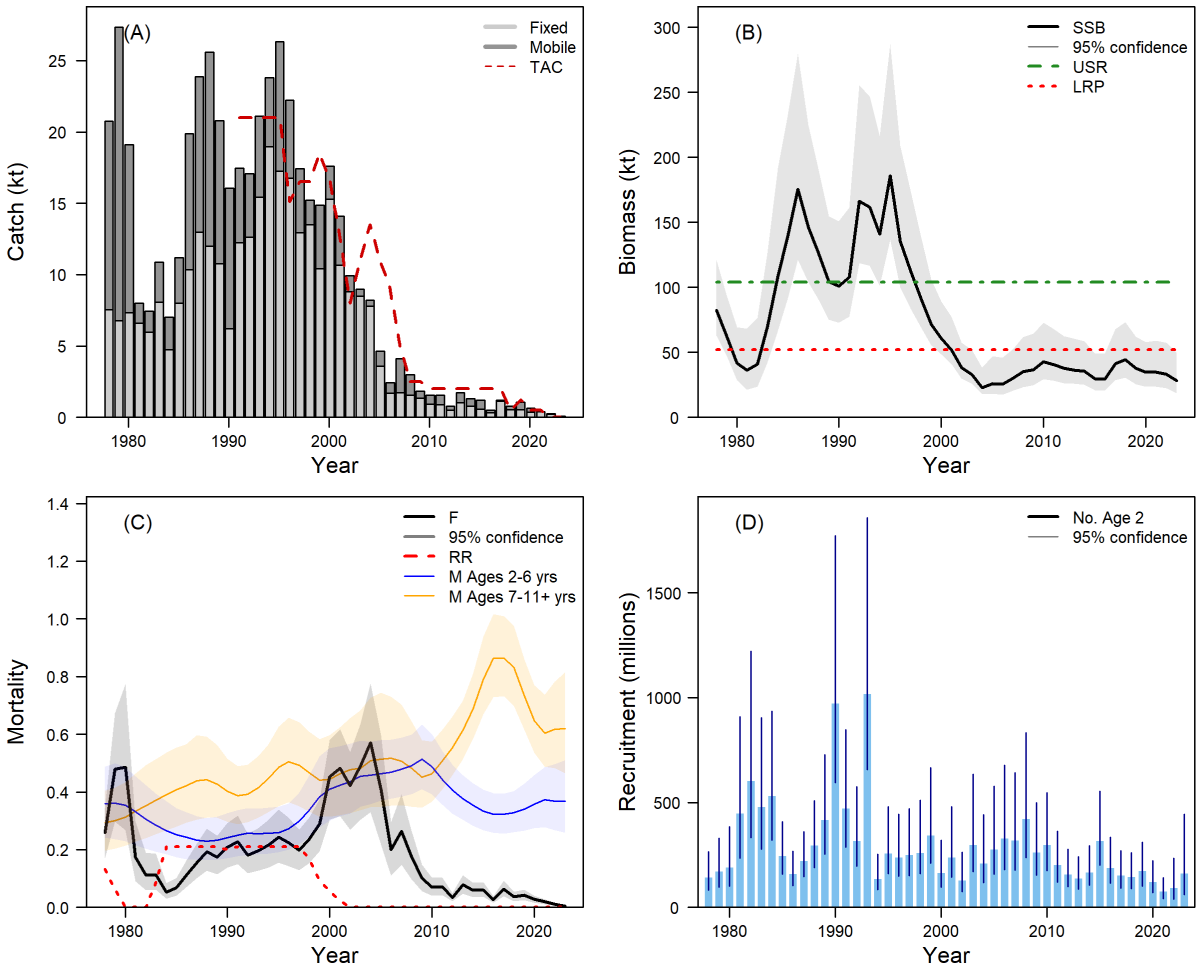

Figure 1. (A) Catch in kilotonnes by gear (kt; fixed and mobile) vs Total Allowable Catch (kt; TAC; red), (B) Spawning Stock Biomass (SSB; kt) in relation to the Limit Reference Point (LRP; red) and Upper Stock Reference (USR; green), (C) Fishing Mortality (F; black) in relation to the Removal Reference (RR, red) and Natural Mortality (M) for ages 2-6 years (blue) and ages 7-11+ years old (yellow), (D) Recruitment (number-at-age 2).

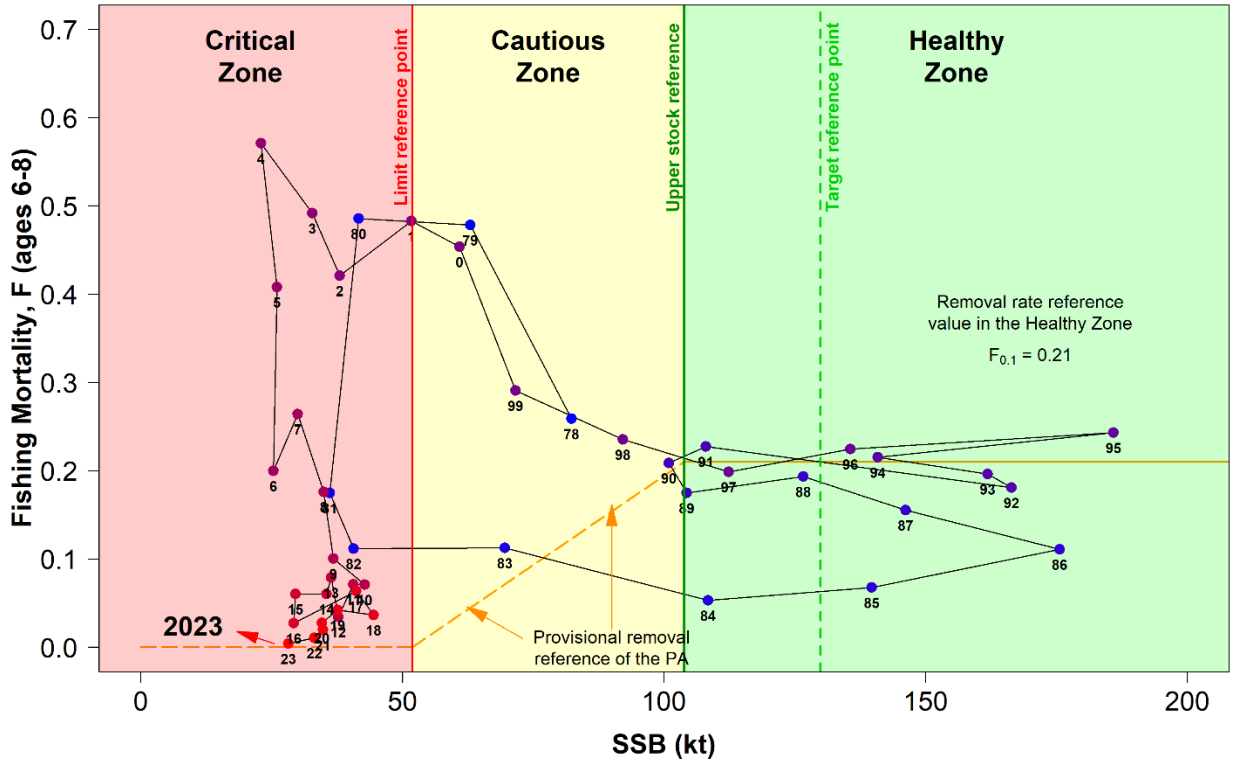

Figure 2. The southern Gulf of St. Lawrence Atlantic Herring spring spawner component trajectory in relation to Spawning Stock Biomass (SSB; kt = kilotonnes) and abundance weighted fishing mortality rates for ages 6 to 8 years. The red vertical line is the Limit reference point, the green vertical line is the Upper Stock Reference and the green dashed vertical line is the Target Reference Point. The orange solid horizontal line is the removal rate reference value ($F_{0.1}$ = 0.21) in the Healthy Zone and orange dashed line is the provisional harvest decision rule of the Precautionary Approach Framework in the Cautious and Critical Zones. Point labels are years (83 = 1983, 0 = 2000).

Historical and Recent Stock Trajectory and Trends

Abundance and biomass indices

The fishery-independent acoustic survey in the Baie-des-Chaleurs provides a biomass index and the abundance-at-age of spring Herring for ages 4 to 8 for 1994 to 2023. For 2022 and 2023, the biomass index was slightly lower than those observed in 2020 and 2021 and at an all-time low of 4,142 t in 2022, with little improvements in 2023 (4,667 t). The biomass index was highest in the mid-1990s and subsequently declined and has remained at relatively stable low levels since the early 2000s, with the exception of 2010.

The CPUE index for spring Herring shows internal consistency as the abundance of cohorts is correlated between years. Decreases in the CPUE of younger fish and increases in the CPUE of older fish have been noted since 2011 (ages 6-8). For 2021 the CPUE has increased compared to the low values of 2018-2020 and the dominant ages were 7 and 8. CPUE for 2022 and 2023 could not be estimated given the fishery closure, but the scientific commercial net program will be explored as an alternative in the future.

Biomass

Estimates of SSB (age 4+) are presented at the start of the fishing season (April 1st) to account for three months of natural mortality-at-age 7 to 11+ (Figure 1B). Estimated SSB in 2022 and 2023 were 33,214 t (95% confidence interval: 22,412 – 57,440 t) and 28,245 t (95% CI: 18,477 – 49,755 t), respectively. The stock remains in the Critical Zone of the Precautionary Approach (Figure 1B and Figure 2). The probabilities that April 1st SSB was in the Critical Zone were 96% in 2022 and 99% in 2023.

Removal Rate

Estimated exploitation rates were high from 1979 to 1980 and from 1999 to 2006 (Figure 1C and Figure 2). After 2006, exploitation rates rapidly declined and since 2010, they remained at relatively low levels. Fishing mortality in the spring season was negligeable in 2022 and 2023 as a result of the fishery closure.

Natural Mortality

Natural mortality estimates for the younger age group (ages 2-6) have fluctuated between 0.23 and 0.51 (between 21% and 40% of annual mortality) from 1978-2023 and was at an average of 0.37 in 2022 and 2023 (95% CI 0.26 - 0.50). For the older age group (ages 7-11+), natural mortality gradually increased from 0.30 to 0.52 (between 25% and 41% of annual mortality) between 1978 and 2006, before decreasing to 0.4 (37% annual mortality) in 2009. Starting in 2010, estimates sharply increased to reach a maximum of 0.86 (57% annual mortality) in 2018 (Rolland et al. 2022) before decreasing to a mean value of 0.62 (46% annual mortality) in 2022 and 2023 (Figure 1C).

Recruitment

The estimated recruitment (number of age 2 fish) of spring Herring in the southern Gulf of St. Lawrence has displayed considerable variation from 1978 to 2019 with a high of 993,399,000 individuals in 1991 and a low of 42,072,000 in 2018. Estimated recruitment was generally highest in the early 1980s, in 1990, and 1993. Recruitment has been relatively stable at lower values since 1993, with slightly higher values between 2006 and 2008. Recruitment then declined to its lowest values of the time-series after 2008 up to 2023, except a small peak in 2015 (Figure 1D).

History of Commercial Landings and TAC

A Total Allowable Catch (TAC) for the combined harvest of both components (spring and fall spawners) in 4T and 4Vn has been in place since 1972. Since 1991, TAC has been allocated by spawning component. The total landings have generally been less than the TAC since 1988 (Figure 1A). The TAC values for spring Herring were 0 t in 2022 and 2023 due to the fishery closure (Figure 1A).

In the sGSL, Atlantic Herring are harvested by a gillnet fleet (referred to as “fixed” gear fleet) and a purse seine fleet (“mobile” gear fleet). The fixed gear fishery is focused in NAFO Division 4T whereas the mobile gear fishery occurs in Division 4T and occasionally in Division 4Vn. Most of the spring Herring were estimated to have been landed in the fixed-gear fleet over the 1981 to 2021 period, prior to the fishery closure. Local stocks are generally targeted by the fixed gear fishery which takes place on the spawning grounds.

There were approximately 243 and 88 t of total landings (Table 1) of spring Herring during 2022 and 2023, from the scientific commercial nets program (6 t) and the bycatch from the fall fishery.

Table 1. Landings and Total Allowable Catch (TAC) in tonnes (t) of southern Gulf of St. Lawrence Atlantic Herring spring spawner component by recent year (2019-2023), fishing season (spring and fall) and gear (fixed and mobile). The percentage (%) of catch in the fixed gear fishery is also provided.

Year	TAC (t)	Spring fishery landings (t)			Fall fishery landings (t)			Total landings	Fixed gear (%)
		Fixed	*Mobile*	*Total*	*Fixed*	*Mobile*	*Total*		
2019	1,250	484	0	484	44	518	562	1,046	50.5%
2020	500	343	0	343	18	286	304	647	55.6%
2021	500	379	0	379	17	0	17	396	100%
2022	0	0	0	0	236	7	243	243	96.4%
2023	0	6	0	6	82	0	82	88	100%

Projections

The population model was projected forward to April 1st, of 2025 and 2026 and 6 years forward to 2029. Projections were conducted at several levels of annual catch (0, 100, 250 and 500 t) using random recruitment values from the last five years (2019-2023) and average natural mortality by age group from the last five years.

SSB was projected to remain stable from 2023 to 2024, and to increase slightly from 2024 to 2026 at all annual catch levels from 0 to 500 t. The probability of a 5% increase in SSB between April 1 2025 and April 1 2026 was between 57% and 59% at all catch levels (Table 2).

At all catch levels (including no catch) it was unlikely (0-15%) that SSB would exceed the LRP at the start of the 2026 spring fishing season (Table 2). In the short term, there is no chance that the population would reach the USR by 2026.

Six years projections in SSB show an increase from 2023 to 2029. By 2029, the probability of exceeding the LRP was between 30 and 32% at all catch levels (Table 2), with SSB values ranging between 38,624 and 39,765 t.

Table 2. Risk analysis table of annual catch options (between 0 and 500 tonnes (t) for 2025 to 2029, with predicted resulting SSB in kilotonnes (kt) in 2025, 2026 and 2029, resulting probabilities (%) of SSB being greater than the LRP, resulting probabilities of increases in SSB by 5%, and resulting abundance weighted fishing mortality rate (F6-8) for the spring spawner component of Atlantic Herring from the southern Gulf of St. Lawrence.

	Year	0 t	100 t	250 t	500 t
SSB(kt)	2025	29.7	29.6	29.5	29.3
	2026	33.1	32.9	32.7	32.4
	2029	39.8	39.5	39.2	38.6
SSB>LRP (%)	2025	3.3	3.3	3.2	3.2
	2026	5.6	5.5	5.5	5.2
	2029	15.3	15.1	14.6	14.0
Increase in SSB (%)	2025	72.3	72.0	71.4	70.7
	2026	58.6	58.3	57.9	57.3
	2029	49.1	49.0	49.0	48.7
Median F6-8	2024	0.0	0.0	0.0	0.0
	2025	0.0	0.0	0.0	0.0

Ecosystem and Climate Change Considerations

Recruitment in Atlantic Herring is influenced by a combination of abiotic (e.g., temperature, wind patterns, ocean currents, etc.) and biotic factors (e.g., zooplankton abundance and phenology, parental size, egg size, etc.; Burbank et al. 2022). A combination of zooplankton abundance, zooplankton phenology (timing) and temperature, including sea surface temperature and spring warming rate, can be used to predict recruitment, explicitly linking ecosystem conditions and change to Atlantic Herring recruitment dynamics (Turcotte 2022; Burbank et al. 2023b). Spring Herring has been in a persistent low recruitment regime since the mid-1990s. In the 1990s, the sGSL sea surface temperature shifted from a cold water to a warmer water regime, likely resulting in shifts in relative abundance of important zooplankton prey, which coincided with a shift from a high to a low Atlantic Herring recruitment regime. Given the ongoing trend towards warmer conditions and shifts in the relative abundance and phenology of the zooplankton community in the sGSL (Blais et al. 2021; Galbraith et al. 2023), spring Herring recruitment is not expected to increase in future years. Suitable ecosystem conditions combined with sufficient reproductive output would be required to facilitate substantial recruitment events. However, as the sGSL ecosystem is changing, the synchronicity of the required zooplankton relative abundance and quality with the timing of the release of Atlantic Herring larvae is unpredictable.

Atlantic Herring is an important forage fish species, and an essential prey for numerous predators (Benoît and Rail 2016). Given the role of Atlantic Herring as forage fish, it is expected they experience substantial natural mortality from predation. Consequently, increases in the abundance of Atlantic Herring predators in the sGSL have coincided with increases in the natural mortality of older Atlantic Herring (ages 7-11+) in recent years. High natural mortality in

older ages limits the number of older individuals available to spawn which produce disproportionately more eggs of higher quality. With high mortality in older age groups from natural causes, we expect negative implications for total reproductive output. Additionally, warmer water temperatures increase energetic demands at the expense of growth, resulting in smaller size-at-age Atlantic Herring with lower egg production (Burbank et al. 2023a) and may have negative implications for total reproductive output and the capacity of the stock to rebuild.

BYCATCH

While the fishery is closed during the spring season, spring Herring may still be caught during the fall fishery and with the mobile fishery (generally winter). In 2022 and 2023, while the spring Herring fishery was closed, 243 and 82 t of spring Herring were fished during the fall fishery (96% and 100% of catches with fixed gear in 2022 and 2023, respectively; Table 1). In 2022, the mobile fleet caught less than 7 t of spring Herring, which represented only 3% of all spring Herring fished in 2022. In 2023, there was no fishing activities with mobile gear and thus all spring Herring bycatch was caught with fixed gear. Spring Herring can also be caught during the bait fishery when targeting fall spawning Atlantic Herring. Lastly, with the upcoming reopening of the Redfish fishery, potential bycatch of Atlantic Herring should be monitored and quantified where possible, especially during the winter months when Atlantic Herring are overwintering along the Laurentian Channel.

SOURCES OF UNCERTAINTY

Catches of spring Herring in bait fisheries are presently accounted for in the assessments through natural mortality estimates, but the proportion of unreported catch, disease, or predation mortality cannot be disentangled. In 2020, it became mandatory to hail-in bait catches. Compliance with the requirement to complete and return logbooks to DFO is higher than historically, however there is no official oversight on reporting of baitfish catches. Recent estimates of catches of Atlantic Herring in the bait fishery were 30% higher than previously thought (Calder et al. 2022) since the inception of mandatory reporting. Given the lack of oversight and dockside monitoring for the bait fishery, reported numbers may still be an underestimate. Overall, these catches are important to document and attempts should be made in future assessments to directly account for this source of uncertainty.

Furthermore, the current spring fishing closure has invoked another source of uncertainty. Given the fishing closure, a CPUE index cannot be derived as is typically done. To address this, we have undertaken a small-scale scientific commercial netting program. In this program, fishers set a small number of commercial nets to facilitate computation of the CPUE index. This new CPUE index will require more years of data and calibration to explore its potential use as an alternative to the previous CPUE index.

There have been numerous observations on the water by harvesters of an increase in the abundance of Atlantic Herring, particularly young individuals, which have not been apparent within the population assessment. We will continue to monitor the stock for signs of increases in fish abundance.

Lastly, to better understand abundance on spawning grounds, an industry acoustic survey had been tested over the past few years. Unfortunately, given the shallow depths at which spring Herring spawn, the acoustic data collected in the survey were subject to high degrees of noise and could not be effectively used to estimate biomass, and thus do not contribute to the stock assessment. Future studies will be conducted to better understand and classify contemporary

spawning grounds, but at present acoustic surveys during spring Herring do not appear effective for this purpose.

Research Recommendations

Various research directions that would help advance understanding of Atlantic Herring population dynamics and improve the science available for species management are either currently ongoing or being considered. Research on the incorporation of ecosystem based predictions of recruitment could be used to drive projections, better informing population dynamics given the ecosystem conditions.

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ISSN 1919-5087
ISBN 978-0-660-71610-7 Cat. No. Fs70-6/2024-029E-PDF

Correct Citation for this Publication:

DFO. 2024. Southern Gulf of St. Lawrence (NAFO Division 4TVn) Spring Spawning Atlantic Herring (*Clupea harengus*) Stock Assessment to 2023. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/029.

Aussi disponible en français :

*MPO. 2024. Évaluation de la composante reproductrice de printemps du Hareng de l'Atlantique (*Clupea harengus*) de printemps dans le sud du Golfe du Saint-Laurent (Division OPANO 4TVn) jusqu'en 2023. Secr. can. des avis sci. du MPO. Avis sci. 2024/029.*