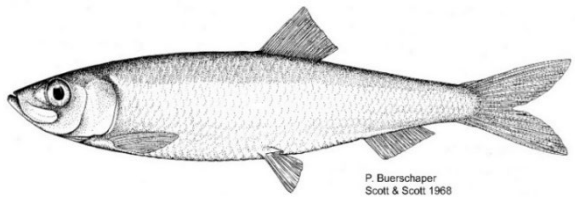
Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Quebec Region

Canadian Science Advisory Secretariat
Science Advisory Report 2022/020

ASSESSMENT OF THE WEST COAST OF NEWFOUNDLAND (NAFO DIVISION 4R) HERRING (*CLUPEA HARENGUS*) STOCKS IN 2021



Atlantic herring (Clupea harengus).

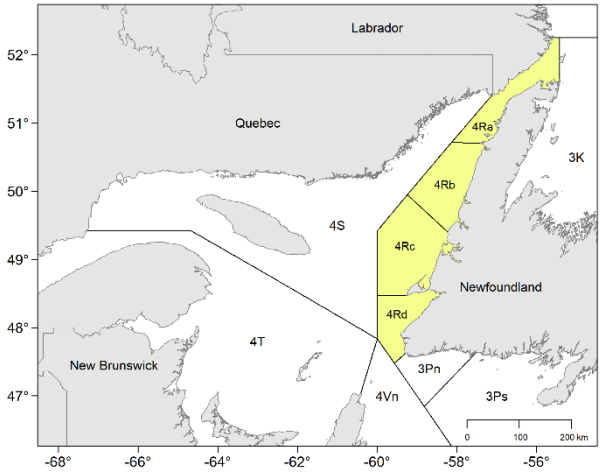


Figure 1. Map of unit areas of NAFO Division 4R.

Context:

The herring populations on the west coast of Newfoundland (NAFO Division 4R) are characterized by the presence of two spawning components or stocks. Spring spawners generally spawn in April and May, and fall spawners in August and September. Spring- and fall-spawning herring are considered separate stocks and, as such, are assessed separately.

The herring fishery on the west coast of Newfoundland is managed by a total allowable catch (TAC) applied to all catches without differentiating between the two spawning stocks. The current TAC of 20,000 t was established following scientific advice in the early 2000s and has remained unchanged since that time. Average annual herring landings have been around 15,000 t since 1975.

A first series of acoustic surveys was carried out in the fall between 1991 and 2002. A second series of surveys was initiated in the fall of 2009 and continued until 2021. These surveys target pre-wintering aggregations of both spring and fall spawners. A summer acoustic survey was also initiated in 2019 to target fall spawner aggregations during their spawning season. The data collected from these surveys are used to calculate biomass indices for the two spawning stocks. These biomass indices are, along with commercial fishery data, the main source of information used to assess stock status of herring on the west coast of Newfoundland.

The last assessment of the two herring spawning stocks in Division 4R was in 2020. During this meeting, the assessment model was rejected as the basis for the science advice, resulting in the rejection of the reference points and the precautionary approach. The Fisheries and Aquaculture Management Branch has requested a new scientific advisory report on these stocks for the 2022 and 2023 fishing seasons. This Science Advisory Report is from the March 1-2, 2022 Assessment of the west coast of Newfoundland (NAFO Division 4R) herring (Clupea harengus) stocks in 2022. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Based on preliminary data, landings of herring from the west coast of Newfoundland (NAFO Division 4R) totaled 4,862 t in 2020 and 3,074 t in 2021, with an annual total allowable catch (TAC) of 20,000 t. The fishery experienced difficulties due to a high incidence of herring below the legal size.
- The proportion of spring-spawners in the landings increased from a time-series low of 1.6% in 2014 to 89.6% in 2021. The proportion of spring spawners in the summer and fall acoustic surveys also increased from an average of 7.3% for the 2009-2017 period to an average of 44.6% in 2020 (summer: 44.8%, fall: 40.6%) and 51.5% in 2021 (summer: 229 %, fall: 75.4%).
- Landings of spring-spawning herring in 2020 and 2021 were mainly composed of fish of the 2013 year-class (age 7-8), and to a lesser extent of fish of the 2017 year-class (age 3-4).
- The acoustic survey biomass estimates of spring-spawning herring in 2020 and 2021 were mainly composed of fish of the 2017 year-class (age 3-4).
- Landings of fall-spawning herring in 2020 and 2021 were mainly composed of fish aged 9 years and over.
- The acoustic survey biomass estimates of fall-spawning herring were dominated by the 2016 year-class in 2020 (age 4) and 2021 (age 5). The 2021 summer acoustic survey was dominated by fish aged 8 years and over.
- The mean fork length at which 50% of individuals were mature (L_{50}) was respectively 24.5 cm and 25.4 cm for spring and fall spawners. These values are higher or near the current minimum size limit of 24.76 cm in the commercial fishery. The L_{50} of both spring- and fall-spawning stocks has varied around the long-term average since the 2000 year-class.
- Both spring- and fall-spawning herring stocks show a downward trend in mean length-at-age and weight-at-age since the beginning of the 1990s. Since 2014, the relative condition index of the two spawning stocks is below the series' average. The condition of both herring spawning stocks is positively related to the abundance of large-bodied copepod species.
- The acoustic surveys estimated the highest biomass indices since the beginning of the survey in 2021 for spring spawners (122,145 t, 95% CI: ± 20,803 t) and in 2020 for fall spawners (226,005 t, 95% CI: ± 35,507 t). These values represent minimum estimates of the amount of fish available at the time of the survey.
- The ratio of the biomass fished over the highest biomass index estimated in the acoustic surveys was considered to be a proxy for the maximum exploitation rate. In 2020 and 2021, the maximum exploitation rate was respectively 1.1% (1.0-1.2%) and 2.4% (2.0-2.9%) for spring spawners, and 1.7% (1.4-2.0%) and 0.2% (0.1-0.2%) for fall spawners. If the 20,000 t TAC had been taken in 2020-2021, the maximum exploitation rates would have resulted in 4.5-15.6% (4.2-19.1%) for spring spawners and 1.2-6.8% (1.0-8.0%) for fall spawners.
- Available evidence up to 2021 (low exploitation rates, commercial and acoustic survey catch-at-age, age- and length-at-maturity) indicates that maintaining the TAC at status quo should not pose a significant short-term risk to herring stocks in 4R.

INTRODUCTION

Species biology

Herring (*Clupea harengus*) is a schooling 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 long-distance 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 during the spawning season. The same herring return to the same spawning sites year after year (Wheeler and Winters 1984). 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 into 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). Adults can reach a maximum size of 39 cm and weight of 680 g, and can reach 18 years of age. Herring populations in the northwest Atlantic are characterized by the presence of two spawning groups or stocks (Melvin et al. 2009). Spring spawners generally spawn in April and May, and fall spawners in August and September. Spring-spawned larvae typically reach the size of metamorphosis (40-50 mm) before their first winter, while autumn-spawned individuals overwinter as larvae and metamorphose during the following spring (Sinclair and Tremblay 1984). Spring- and fall-spawning herring on the west coast of Newfoundland (NAFO Division 4R; Figure 1) are considered separate stocks and are assessed separately. Recent studies have confirmed genetic differentiation between these two spawning components (Lamichhaney et al. 2017, Chen et al. 2021).

Overview of the commercial fishery

In NAFO Division 4R, the herring fishery is managed by a total allowable catch (TAC) without distinction between the two spawning stocks. The current TAC of 20,000 t was established following scientific advice in the early 2000s (DFO 2003). The TAC is sub-divided into three allocation categories: mobile gear (purse seine) greater than 65 ft (55% of the TAC: 11,000 t), mobile gear less than 65 ft (22% of the TAC: 4,400 t), and fixed gear including modified bar seine known as “tuck seine” (23% of the TAC: 4,600 t). The greater than 65 ft mobile gear fishery operates under an individual transferable quota (ITQ) regime, whereas the less than 65 ft mobile gear fishery operates under an individual quota (IQ) regime. The fixed gear fishery is fully competitive with separate quotas for herring fishing areas 13 and 14. The 4R herring stock is also a bait fishery in which harvesters are permitted to use gillnets to catch herring for use in commercial fisheries requiring bait such as lobster and snow crab. Since 2018, an annual allocation of 50 t for the bait fishery has been taken in the fixed gear allocation. Up until 2017, the minimum size limit for herring was established at a fork length of 26.5 cm and a maximum of 10% undersized herring (by count) per fishing trip was allowed. In 2017 and 2018, the minimum size limit for herring was decreased to 24.76 cm following an update of the mean length at 50% maturity, and the tolerance for undersized fish was increased to 20% (DFO 2018).

ASSESSMENT

Commercial landings

During the 1980s and 1990s, herring landings on the west coast of Newfoundland were variable and averaged approximately 15,405 t per year with a high of 26,437 t in 1991 and a low of 8,164 t in 1990 (Figure 2). Landings increased slowly but regularly between 2000-2008 and stabilized at around 20,000 t until 2016, limited by the TAC for those years. Landings have not reached the TAC since 2017 and totaled 4,863 t in 2020 and 3,075 t in 2021 (preliminary data; Table 1). In 2020, harvesters in 4R reported that a significant amount of herring below the legal size of 24.76 cm has impeded their ability to harvest the available quota, and this continued to be an issue for the 2021 fishing season. Since 2012, most landings were reported from NAFO unit area 4Rb, except in 2020 and 2021 where most landings were reported from unit areas 4Ra and 4Rc, respectively (Figure 2).

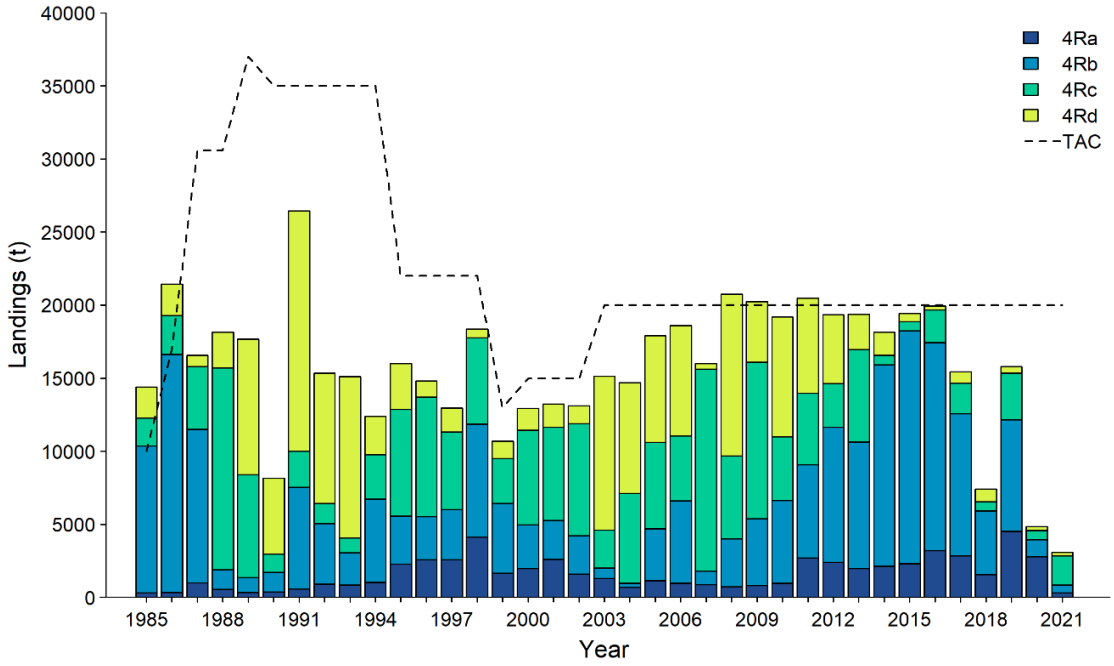


Figure 2. Herring cumulative commercial landings (t) and total allowable catch (TAC) for unit areas of the west coast of Newfoundland (NAFO Division 4R), from 1985 to 2021. Landings for 2019, 2020 and 2021 are preliminary.

On the west coast of Newfoundland, the majority of the herring is landed by the large seiner fleet (Figure 3). In 2020 and 2021, the large seiners landed only 1,198 t and 2,044 t respectively, much lower than the 2002-2019 average of 10,033 t (Table 2). The small seiner fleet landed less biomass in 2021 (110 t) than in 2020 (1,148 t), while the 2002-2019 average was 3,934 t (Table 2, Figure 3). The biomass landed with the tuck seine totaled 2,215 t in 2020 and 749 t in 2021, while the other fixed gears (gillnet and trap) landed 302 t and 172 t in 2020 and 2021, respectively (Table 2). In 2020, less than a quarter of the small and large seiners quotas were caught (Figure 4). In 2021, less than 20% of the large seiner quota was caught, and the small seiners and fixed gears landed less than 5% of their quota (Figure 4).

Fishing activities in the spring by the large and small purse seiner fleets declined at the end of the 1990s following the implementation of management measures to protect the main spawning

grounds of the spring-spawning stock. Since then, these fisheries, as well as the tuck seine fishery, are mostly practiced in the fall. Cumulative landings of large and small seiners indicate that these fisheries have been starting and running later since the 2010s. Landings by the fixed gear fleet generally occur throughout the season. However, the 2020 season had the slowest start since 2010 with landings occurring mostly in November and December.

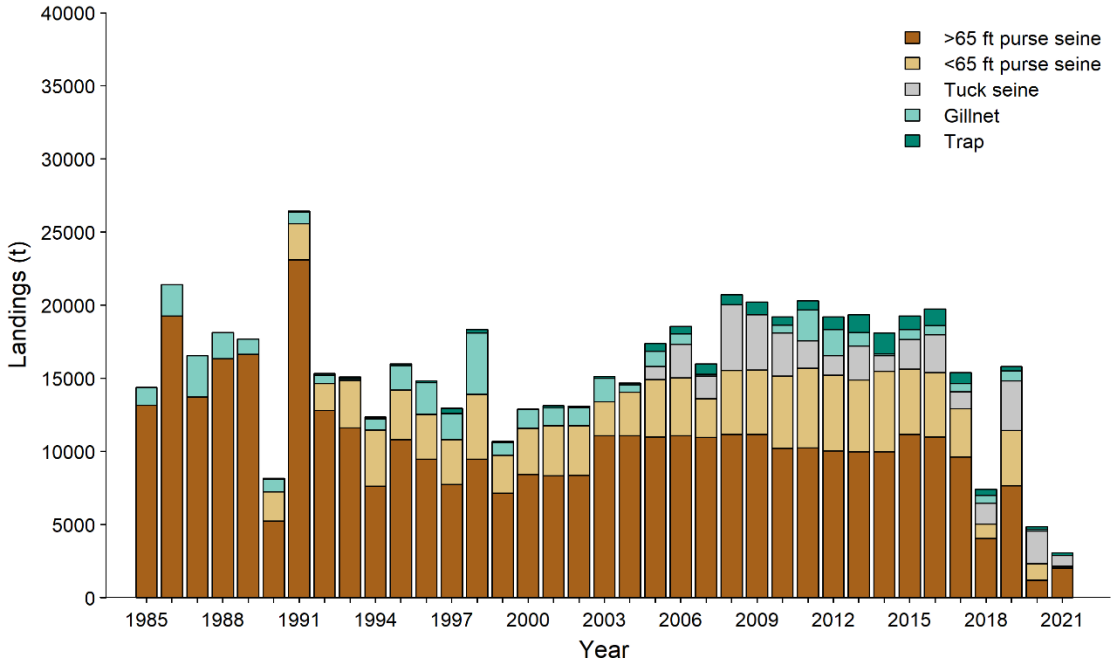


Figure 3. Herring cumulative commercial landings (t) per fishing gear of the west coast of Newfoundland (NAFO Division 4R), from 1985 to 2021. Landings for 2019, 2020 and 2021 are preliminary.

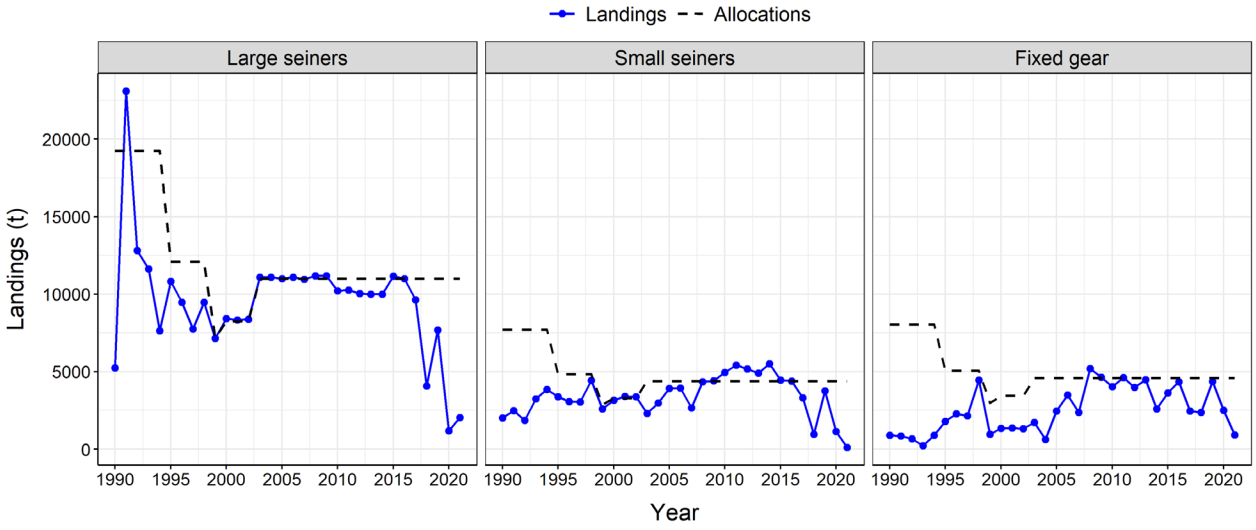


Figure 4. Herring commercial landings (t; solid blue line) and allocations (t; dashed black line) per fishing fleet (large seiner ≥ 65', small seiner < 65', and fixed gear) in NAFO Division 4R.

Table 1. Herring annual commercial landings (t) by unit area and total allowable catch (TAC) on the west coast of Newfoundland (NAFO Division 4R). Landings for 2019, 2020 and 2021 are preliminary.

UNIT AREA	AVERAGE 1985-2001	YEAR																				AVERAGE 2002-2019
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*	2020*	2021*	
4Ra	**1,416**	1,604	1,290	712	1,138	957	884	731	821	984	2,694	2,396	1,977	2,129	2,322	3,195	2,842	1,566	4,512	2,803	316	**1,820**
4Rb	**5,140**	2,621	714	252	3,574	5,645	915	3,286	4,573	5,651	6,389	9,249	8,651	13,798	15,915	14,253	9,727	4,360	7,642	1,154	530	**6,512**
4Rc	**4,796**	7,660	2,593	6,162	5,889	4,457	13,831	5,668	10,707	4,342	4,899	2,994	6,322	640	637	2,211	2,102	607	3,182	618	2,018	**4,717**
4Rd	**4,215**	1,232	10,533	7,574	7,326	7,538	375	11,058	4,134	8,228	6,489	4,712	2,424	1,585	546	273	767	885	470	288	211	**4,231**
TAC	**-**	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	-
TOTAL	**15,567**	**13,117**	**15,130**	**14,700**	**17,927**	**18,597**	**16,005**	**20,743**	**20,235**	**19,205**	**20,471**	**19,351**	**19,374**	**18,152**	**19,420**	**19,932**	**15,438**	**7,418**	**15,806**	**4,863**	**3,075**	**17,279**

** Preliminary data*

Table 2. Herring annual commercial landings (t) for the main fishing gears used on the west coast of Newfoundland (NAFO Division 4R). Landings for 2019, 2020 and 2021 are preliminary.

FISHING GEAR	AVERAGE 1985-2001	YEAR																				AVERAGE 2002-2019
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*	2020*	2021*	
Large seiner (> 65')	**11,826**	8,392	11,090	11,099	11,005	11,101	10,954	11,185	11,171	10,218	10,260	10,047	9,985	9,994	11,168	10,999	9,628	4,076	7,677	1,198	2,044	**10,003**
Small seiner (< 65')	**2,151**	3,383	2,307	2,974	3,918	3,941	2,659	4,357	4,416	4,950	5,429	5,172	4,905	5,504	4,471	4,397	3,312	966	3,758	1,148	110	**3,934**
Tuck seine	-	0	0	0	908	2,300	1,546	4,498	3,778	2,953	1,883	1,342	2,337	1,075	2,030	2,594	1,167	1,439	3,401	2,215	749	**1,847**
Gillnet	**1,486**	1,256	1,630	499	1,031	702	132	3	0	525	2,108	1,790	915	96	680	623	546	512	680	117	2	**763**
Trap	**96**	73	104	127	529	499	706	700	872	560	625	862	1,231	1440	928	1,132	746	424	289	185	170	**658**
Other	**8**	13	0	2	535	53	8	0	0	0	166	137	0	43	144	188	37	0	0	0	0	**74**
TOTAL	**15,567**	**13,117**	**15,130**	**14,700**	**17,927**	**18,597**	**16,005**	**20,743**	**20,235**	**19,205**	**20,471**	**19,351**	**19,374**	**18,152**	**19,420**	**19,932**	**15,438**	**7,418**	**15,806**	**4,863**	**3,075**	**17,279**

** Preliminary data*

Commercial catch-at-age composition

The annual proportion of spring-spawning herring in the landings varied between 25.8% and 81.7% over the 1965-2005 period (Figure 5). The proportion of spring spawners decreased rapidly from around 2005 onwards and reached the lowest value of the time series (1.6%) in 2014. Since then, the proportion of spring spawners in the fishery has been increasing and accounted for 89.6% in 2021, the highest value of the time series (Figure 5).

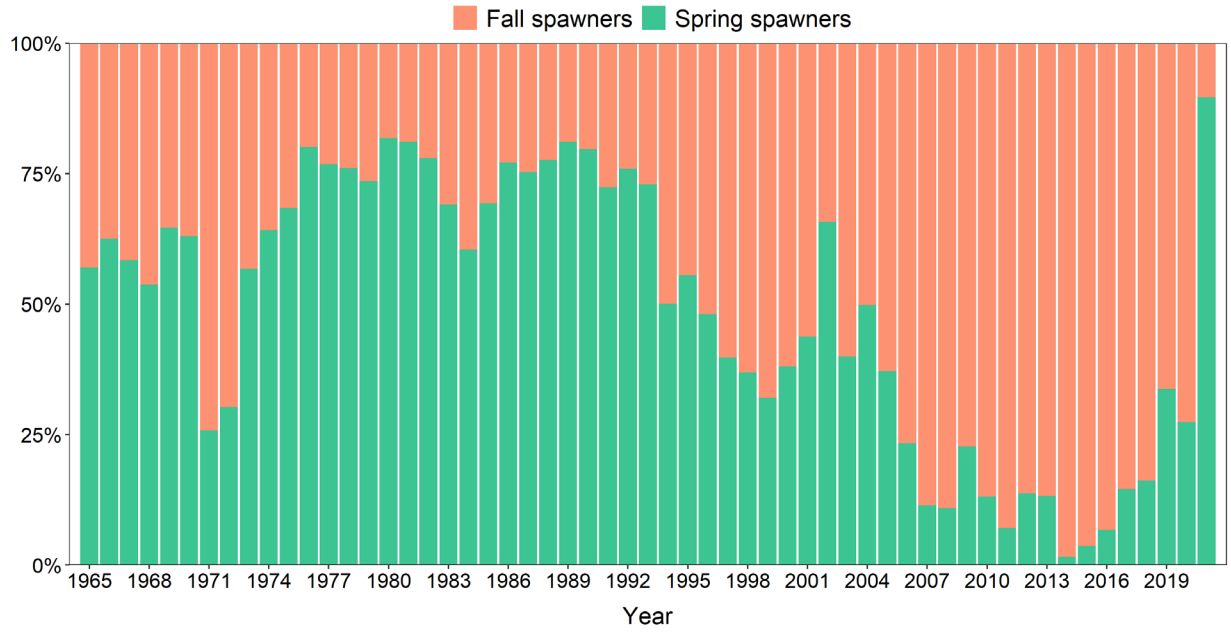


Figure 5. Annual proportion of spring- and fall-spawning herring (number of individuals) in NAFO Division 4R commercial landings from 1965 to 2021.

The age composition of the commercial catches indicates that the two herring spawning stocks of the west coast of Newfoundland are characterized by the occasional occurrence of dominant year-classes (Figure 6). In the spring spawners, the most recent year-classes are those of 2013 (age 7 in 2020 and age 8 in 2021) and 2017 (age 3 in 2020 and age 4 in 2021). In the fall spawners, the last relatively abundant year-class in the fishery was observed in 2008 (age 12 in 2020 and age 13 in 2021).

Catches of spring-spawning herring in 2020 and 2021 were mainly composed of fish of the 2013 year-class (39.9% in 2020 and 42.7% in 2021), and to a lesser extent of fish of the 2017 year-class (25.8% in 2020 and 15.6% in 2021). For fall-spawning herring, landings in 2020 and 2021 were mainly composed of fish aged 9 years and over. These age groups made up 60.0% and 85.3% of all fall spawner catches in 2020 and 2021, respectively. A new year-class (2016) seemed to have emerged in the fishery for fall spawners in 2019 (DFO 2021a). Although relatively abundant in 2019 and 2020 (catches at age 3 in 2019 and 4 in 2020 were among the highest in the series), this year-class was absent from the catches in 2021(Figure 6).

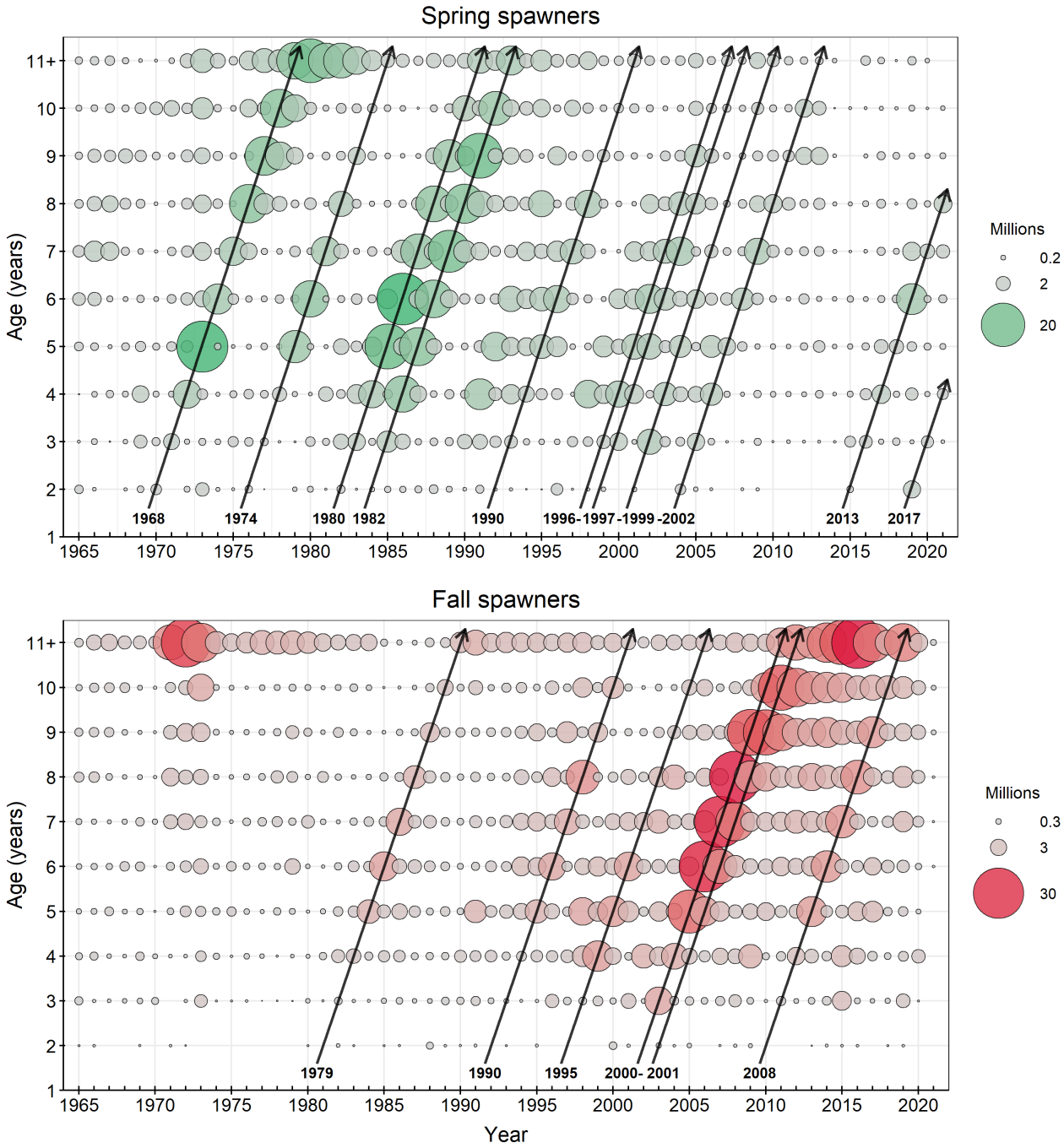


Figure 6. Annual catch-at-age composition (number of individuals) of spring spawners (upper panel) and fall spawners (lower panel) in NAFO Division 4R from 1965 to 2021. Dominant year-classes are indicated with arrows.

Biological indicators

Length and age at 50% maturity

Due to issues with the high incidence of undersized herring in recent years, a request was made for Science to re-examine the length at which 50% of individuals are mature (L_{50}). The L_{50} values were also compared to the commercial size limit. The L_{50} of the most recent estimable year-class (2017) was estimated at 24.5 cm and 25.4 cm (fork length) for spring and fall spawners, respectively. These values are higher or near the current minimum size limit of 24.76 cm in the commercial fishery. Following a decline for the 1970-1980 year-classes, the L_{50} of both spring and fall spawners increased slightly for the 1990 year-classes and varied around the long-term average since the 2000 year-class (Figure 7A and 7B).

Following an extended period of relative stability over the 1975-2010 year-classes, the age at 50% maturity (A_{50}) of spring spawners increased and reached the highest values of the series for the 2016-2017 year-classes (Figure 7C). The A_{50} of fall spawners declined over the 1960-1970 year-classes and increased since then, reaching the highest values of the series for the 2015-2017 year-classes (Figure 7D).

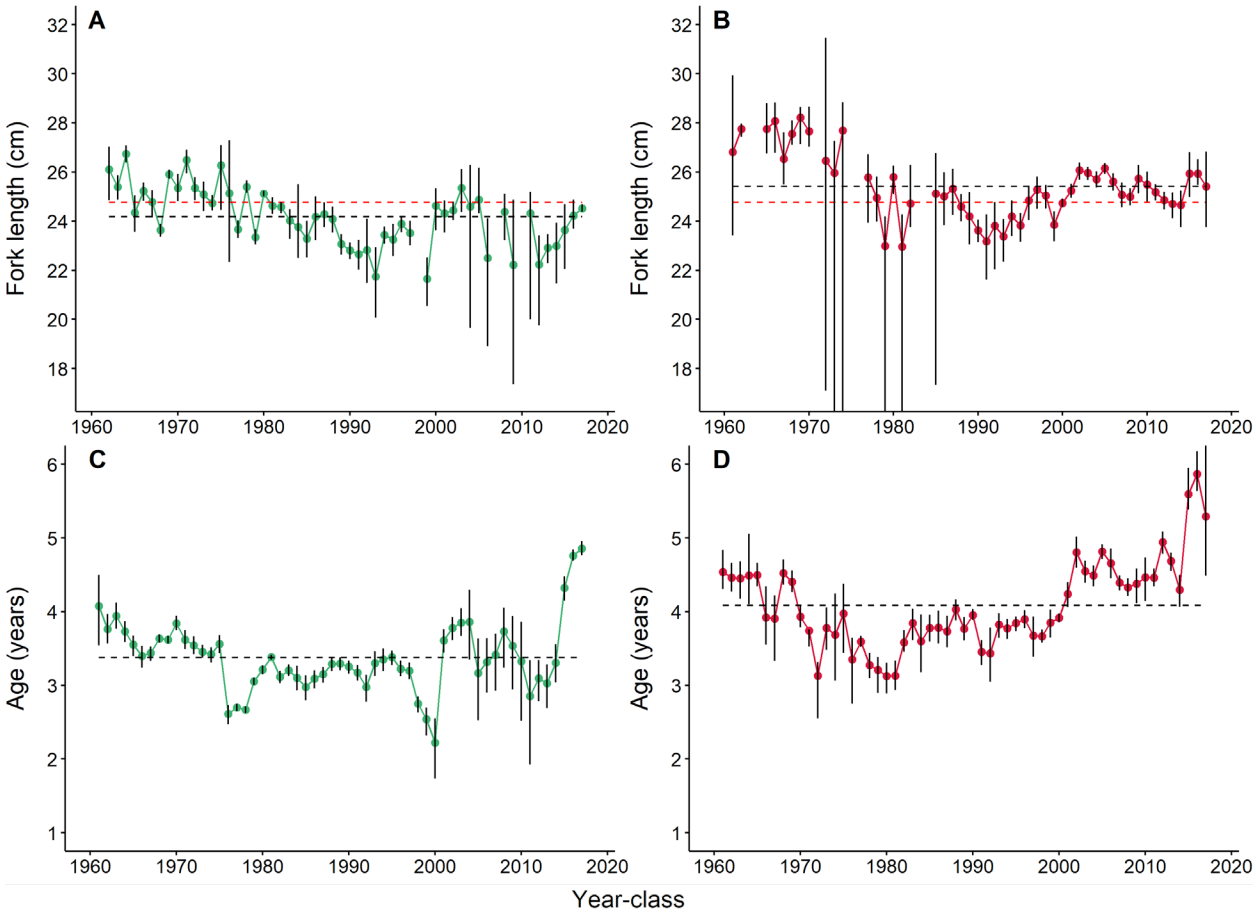


Figure 7. Fork length (A, B) and age (C, D) at 50% maturity by year-class for spring (in green) and fall (in red) spawners in NAFO Division 4R. Error bars represent bootstrapped 95 % confidence intervals. The horizontal dashed black line is the series average and the red dashed line in plots A and B is the legal catch size (24.76 cm).

Length- and weight-at-age

The average lengths- and weights-at-age of spring- and fall-spawning herring on the west coast of Newfoundland declined throughout the 1990s and 2000s in all age-classes (2 to 11+), and then remained relatively stable and below long-term averages since the early 2010s (Figure 8). Except for age 2 (which were not well represented in samples), the decline was more severe for weight-at-age than for length-at-age for both spawning components. On average, length-at-age declined by 10.3% and 9.9% between 1990 and 2021 for spring and fall spawners, respectively, whereas mean weight-at-age declined by 29.5% for spring spawners and 27.5% for fall spawners over the 1990-2021 period. A decrease in the average weight-at-age was also observed in the other Northwest Atlantic herring stocks, including those on Quebec's North Shore (DFO 2021b), southern Gulf of St. Lawrence (Turcotte et al. 2021), and southwest Nova Scotia and the Bay of Fundy (Singh et al. 2020).

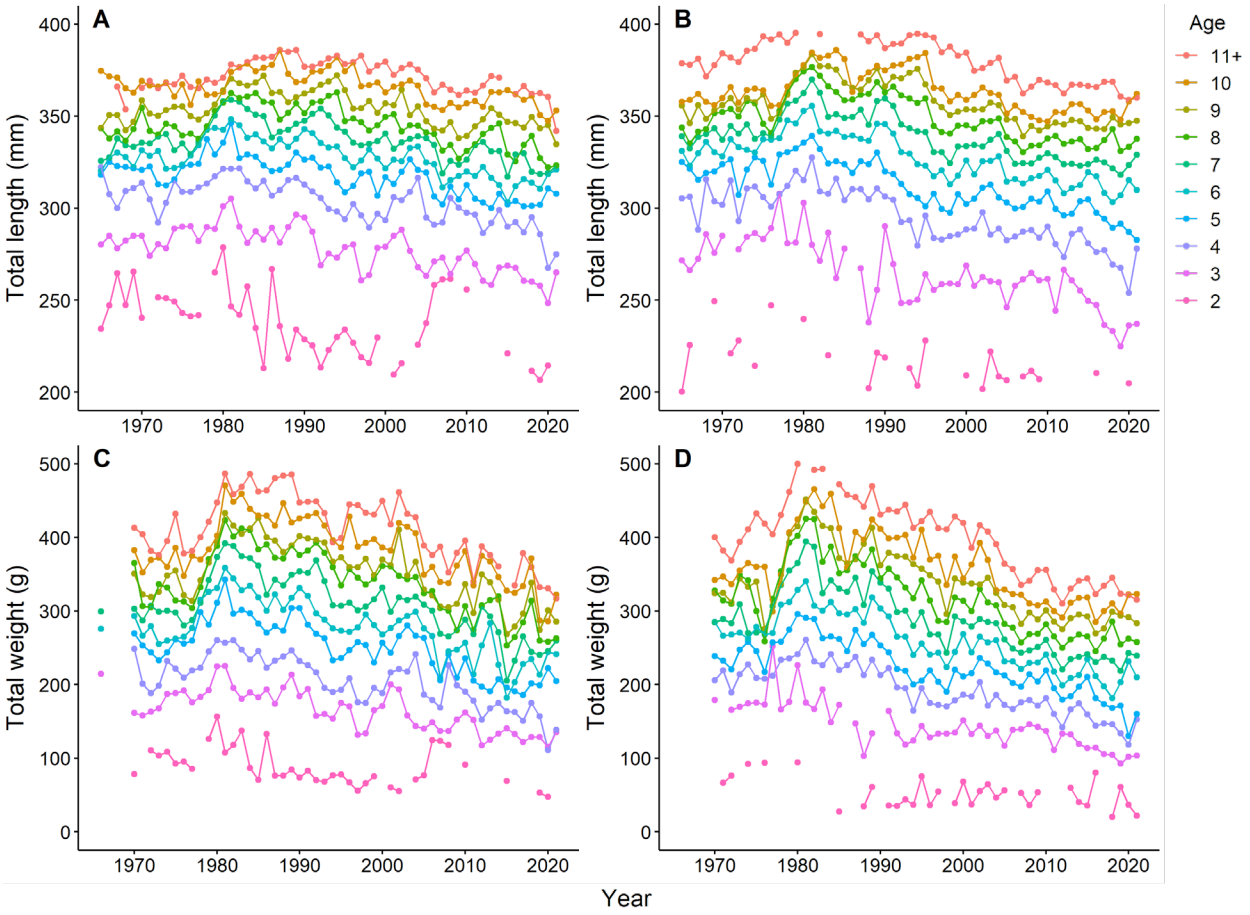


Figure 8. Total length (mm) and total weight (g) at age of spring (A and C) and fall (B and D) spawners in NAFO Division 4R from 1965 to 2021. The series have been standardized to take into account the NAFO unit area, fishing gear and month of capture.

Relative condition index

The relative condition indices of both spawning stocks (average of the 4-9 age-classes) has been decreasing since the early 2000s and is below the series averages since 2014 (Figure 9). Interannual variations in the condition index were related to physical environmental conditions

and biological conditions (zooplankton), which explained 83% and 66% of the variability in the condition indices of spring and fall spawners, respectively. Better spring spawner condition was associated with longer spring phytoplankton bloom duration, earlier phenology (more advanced development) of the large calanoid copepod *Calanus hyperboreus*, a primary prey item of Atlantic herring (Darbyson et al. 2003), and a low abundance of *Pseudocalanus* ssp. *Pseudocalanus* are small calanoids that provide less energy per unit than large calanoids, which could favor a lower net energy gain by herring during years of greater abundance of these small calanoids. The condition of fall spawners was favoured when surface water temperature in August and September was colder, *C. finmarchicus* was more abundant, and when *C. finmarchicus* phenology occurred earlier. Thus, the condition of both herring spawning stocks was favoured by the high abundance of large energy-rich calanoid copepods, which is consistent with the results obtained for Division 4S herring stocks (DFO 2021b).

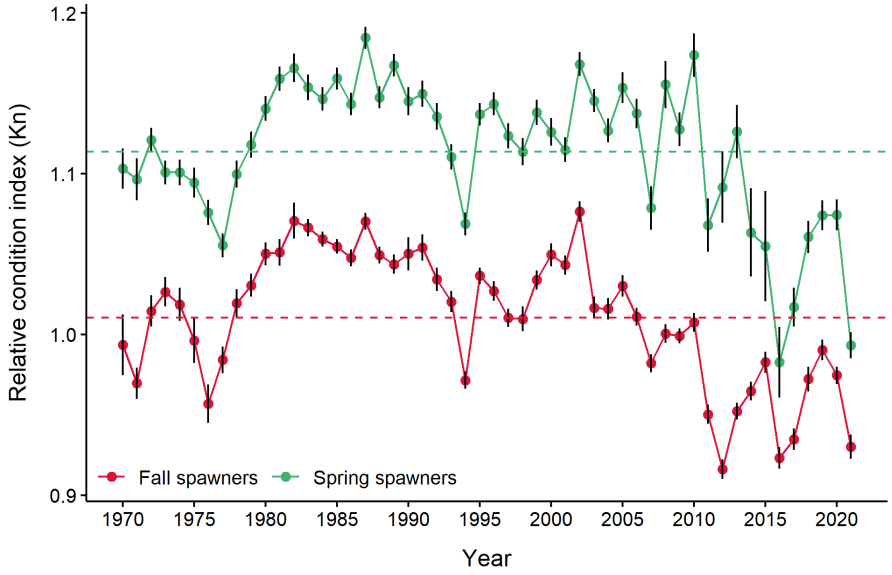


Figure 9. Relative condition index (with 95% confidence intervals) for spring (in green) and fall (in red) spawners in NAFO Division 4R from 1970 to 2021. The series have been standardized to take into account the NAFO unit area, fishing gear and month of capture.The dashed horizontal lines indicate the series average.

Acoustic survey

Acoustic surveys of fall (October-November) concentrations of herring have been carried out in NAFO Division 4R since 1991. In 2019, 2020 and 2021, acoustic surveys were also conducted in the summer (August) in addition to the fall survey. The survey covers the entire west coast of Newfoundland, from Cape Anguille to the southern portion of the Strait of Belle Isle. In 2019, two new strata were added on the eastern and western sides of the Strait of Belle Isle, which is considered an important summer-fall feeding area for herring (Moores and Winters 1984).

In 2020, the summer and fall surveys estimated respectively 103,564 t (95% CI: ± 9316 t) and 7,877 t (95% CI: ± 921 t) of spring spawners, and 226,005 t (95% CI: ± 35,507 t) and 16,283 t (95% CI: ± 2,053 t) of fall spawners (Figure 10). In 2021, the summer and fall surveys estimated respectively 45,580 t (95% CI: ± 4,659 t) and 112,145 t (95% CI: ± 20,803 t) of spring-spawning herring, and 210,121 t (95% CI: ± 36,845 t) and 43,170 t (95% CI: ± 6,154 t) of fall-spawning herring. The acoustic surveys estimated the highest biomass indices since the beginning of the survey in 2021 for spring spawners and in 2020 for fall spawners (Figure 10). These values

were considered to represent minimum estimates of the amount of fish available at the time of the survey. However, changes in survey catchability and coverage hinder inter-annual comparisons and the typical assessment of long-term trends in biomass (Chamberland et al. 2022).

The proportion of spring spawners in the summer and fall acoustic surveys increased substantially in recent years, jumping from an average of 7.3% for the 2009-2017 period to an average of 42.4% in 2019 (summer: 23.7%, fall: 53.8%), 44.6% in 2020 (summer: 44.8%, fall: 40.6%), and 51.5% in 2021 (summer: 22.9%, fall: 75.4%). The acoustic survey biomass estimates of spring-spawning herring were mainly composed of fish of the 2017 year-class in 2020 (summer: 88.4%, fall: 68.1%) and 2021 (summer: 23.9%, fall: 91.1%; Figure 11). The acoustic survey biomass estimates of fall-spawning herring in 2020 were dominated by the 2016 year-class (summer: 60.5%, fall: 52.6%). The 2016 year-class also dominated the 2021 fall acoustic survey (40.6%), but not the 2021 summer acoustic survey (10.4%), which was dominated by fish aged 8 years and over (70.1%).

The ratio of the biomass fished over the highest biomass index estimated in the acoustic surveys was considered to be a proxy for the maximum exploitation rate. In 2020 and 2021, the maximum exploitation rates were respectively 1.1% and 2.4% for spring spawners, and 1.7% and 0.2% for fall spawners (Table 3). If the 20,000 t TAC had been taken, the maximum exploitation rates would have resulted in 4.5% in 2020 and 15.6% in 2021 for spring spawners, and 6.8% in 2020 and 1.2% in 2021 for fall spawners (Table 3). These exploitation rates are lower than commonly used biological reference points for species with similar life history characteristics (e.g. Turcotte et al. 2021).

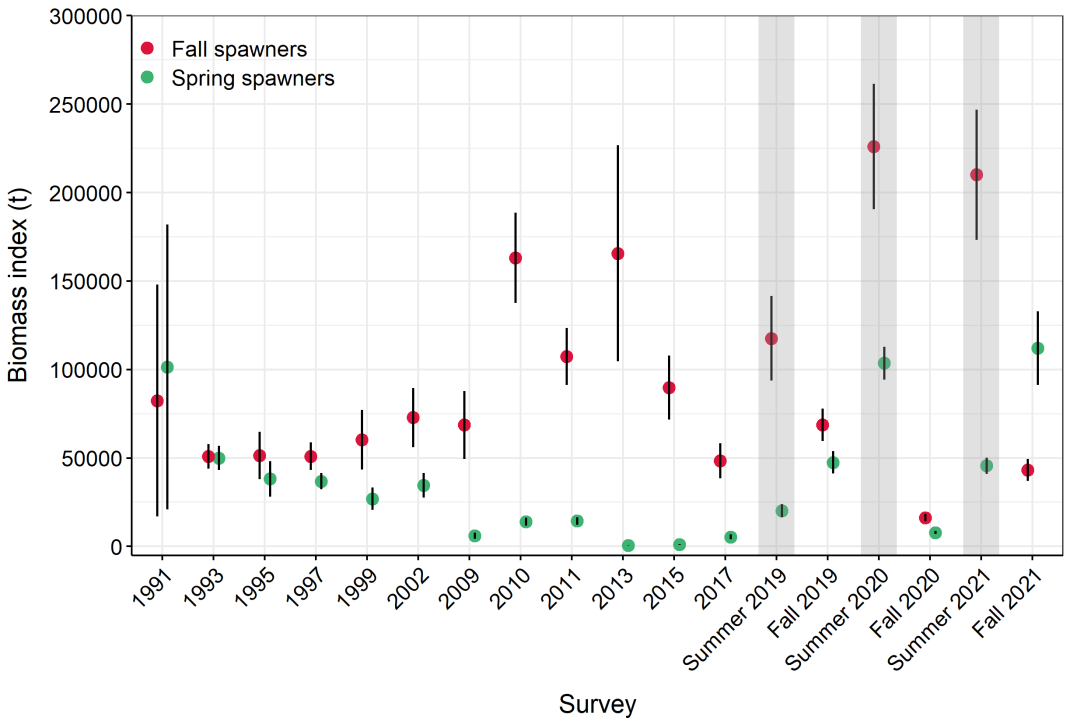


Figure 10. Fall and summer acoustic survey biomass indices for spring- (in green) fall-spawning herring (in red) stocks of the west coast of Newfoundland (NAFO Division 4R) from 1991 to 2021. Error bars represent 95% confidence intervals. Summer surveys are shaded in gray.

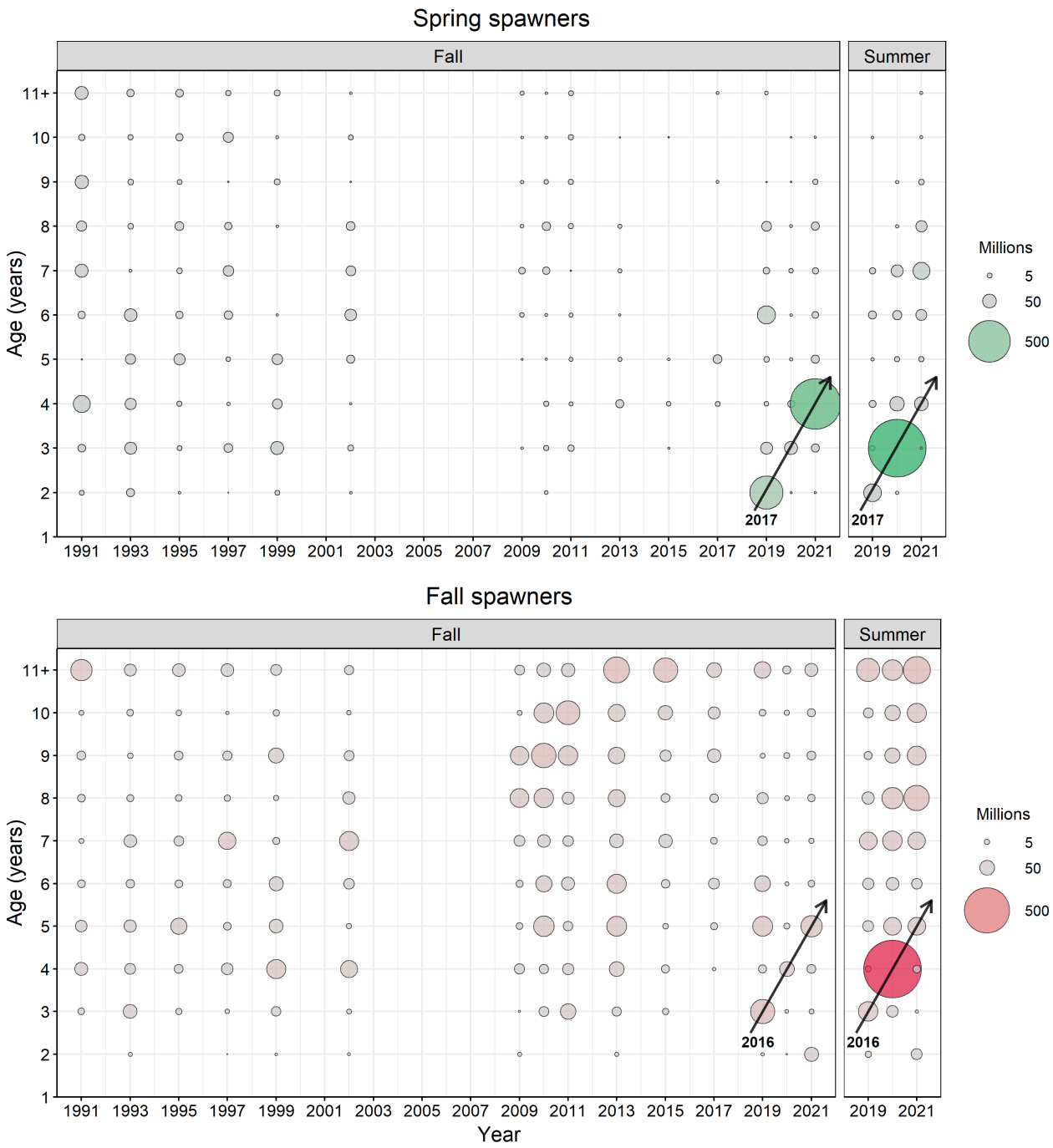


Figure 11. Annual numbers-at-age composition of spring spawners (upper panel) and fall spawners (lower panel) from the summer (right) and fall (left) acoustic surveys conducted in NAFO Division 4R between 1991 and 2021. The dominant 2017 spring-spawner and 2016 fall-spawner year-classes are indicated with arrows.

Table 3. Exploitation rates (%) for the spring- and fall-spawning herring stocks in NAFO Division 4R in 2020-2021. The exploitation rates are estimated as the ratio of the landings (t) over the highest biomass index (t) estimated in the acoustic surveys. Presumed landings of each spawning component if the TAC had been taken are based on the proportions of the two spawning stocks in the 2020-2021 commercial catch-at-age composition.

Year	Spawning stock	Landings (t)	Acoustic biomass index (t)	Exploitation rate (%)
Based on 2020-2021 preliminary landings:				
2020	Spring	1,143	103,565 (± 9316)	1.10 (1.01-1.21)
	Fall	3,719	226,005 (± 35,507)	1.65 (1.42-1.95)
2021	Spring	2,682	112,145 (± 20,803)	2.39 (2.02-2.94)
	Fall	342	210,121 (± 36,845)	0.16 (0.14-0.20)
If the 20,000 t had been taken:				
2020	Spring	4,702	103,565 (± 9316)	4.54 (4.17-4.99)
	Fall	17,448	226,005 (± 35,507)	6.77 (5.85-8.03)
2021	Spring	15,298	112,145 (± 20,803)	15.56 (13.12-19.10)
	Fall	2,552	210,121 (± 36,845)	1.21 (1.03-1.47)

Sources of Uncertainty

Changes in catchability of the fall acoustic survey represent a major source of uncertainty for the assessment of spring- and fall-spawning herring stocks on the west coast of Newfoundland. Several factors may explain the variations observed in the catchability of the survey. Survey dates (late October to early November) have remained relatively constant, while the commercial fishery has shifted in time (late September to early-late December), which may indicate a change in fish behaviour and availability of herring for the survey. Inter-annual variations in acoustic sampling effort and spatial coverage of the survey may also influence catchability and add important uncertainty to the time series. Lastly, the biological sampling used to divide the acoustic biomass between spring- and fall-spawning herring and convert it into numbers-at-age was carried out with gear that varied from year to year, generally using small sample sizes from the commercial fishery.

The lack of information on herring population structure in the northern Gulf of St. Lawrence is also a major source of uncertainty. Tagging studies have shown that exchanges occur between the herring stocks in Divisions 4R and 4S (Moores and Winters 1984). 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.

CONCLUSIONS AND ADVICE

The data and knowledge available are insufficient to quantitatively assess the status of the resource. However, evidence available as recently as 2021 indicates that maintaining the TAC at *status quo* should not pose any significant risk to the two herring spawning stocks in Division 4R in the short term. Although the acoustic survey has uncertainties, which adversely affect the interpretation of temporal trends and absolute values of abundance, the calculated biomass represents a minimum estimate of the amount of fish available at the time of the

survey. The maximum exploitation rates estimated from these biomasses and the commercial fishery for 2020-2021 were low (< 15%).

There are signs of recent increase for the spring-spawning stock. The proportion of spring spawners has increased significantly in recent years in the commercial catches and the acoustic survey. The 2020 and 2021 acoustic surveys also estimated the highest spring spawner biomass since the beginning of the survey.

The acoustic survey biomass estimates in 2020 and 2021 were mainly composed of spring spawners of the 2017 year-class (age 3-4) and of fall spawners of the 2016 year-class (age 4-5). The abundance of 3- and 4-year-olds for spring spawners was the highest observed since the beginning of the survey. The abundance of young fish observed in the 2020-2021 acoustic surveys for both spring and fall spawners is an encouraging sign for the future of these stocks. Landings have been trending downward since 2017, and the recent decrease of 81% since 2019 can be explained by the high incidence of fish under the legal size that prevented harvesters from landing their quotas.

Catch-at-age in the commercial fishery makes it possible to monitor the progress of year-classes up to age 11+ for the two spawning stocks. Catch-at-age was dominated by older individuals (9 years and over) for the fall-spawning stock, which accounted for the majority of landings. The dominance of older year-classes in catches suggests that the stock is not overfished (Berkeley et al. 2004). Furthermore, excessive fishing pressure would have been expected to reduce the L_{50} and A_{50} over time.

During the last peer-review meeting in 2020, concerns related to some aspects of the acoustic survey led to the rejection of the assessment model as the basis for the science advice, resulting in the rejection of the reference points and the precautionary approach (DFO 2021a). A review of the assessment framework will be carried out in 2022-2023.

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SOURCES OF INFORMATION

This Science Advisory Report is from the regional peer review of March 1-2, 2022 Assessment of the west coast of Newfoundland (NAFO Division 4R) herring (*Clupea harengus*) stocks in 2022. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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