ASSESMENT OF THE WEST COAST OF NEWFOUNDLAND (NAFO DIVISION 4R) HERRING STOCK IN 2019

Atlantic herring (Clupea harengus) from Nozères and al. 2010. Can. Tech. Rep. Fish. Aquat. Sci. 2866.

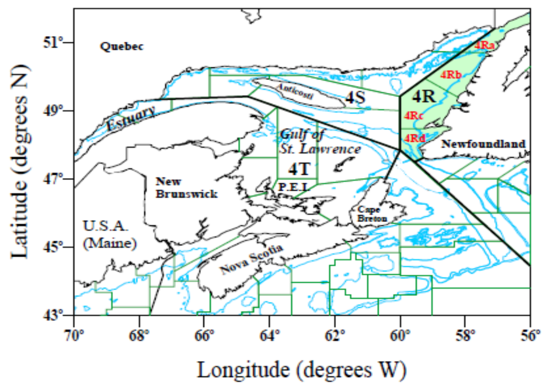

Figure 1. Map of unit areas of NAFO Division 4R (West coast of Newfoundland). Division 4R is identified by the coloured area.

Context:

Atlantic herring is a pelagic species that perform significant annual migrations associated with spawning, feeding and over-wintering. Herring is the subject of a commercial fishery. The main fishing areas in Canadian waters, are south-western Nova Scotia and the Bay of Fundy (4VWX stock complex), the southern Gulf of St. Lawrence (4TVn stocks), the northern Gulf of St. Lawrence (4S stocks), and the west (4R stocks), east and southeast coasts (3KLPs stocks) of Newfoundland. On the west coast of Newfoundland (Division 4R, Figure 1), the average annual landings of herring have been about 16,000 tonnes (t) since 1985. The main fishing gear is the purse seine, with average annual landings of nearly 13,000 t per year. Other gear used in descending order of importance are the tuck seine (modified bar seine), gillnet, and trap.

The west coast of Newfoundland herring fishery is managed by a Total Allowable Catch (TAC) associated with two spawning stocks. The current TAC of 20,000 t was established following advice from the last analytical assessments conducted in the early 2000s. The TAC is split between the various fleets as follows: 55% (11,000 t) for large seiners (>65'), 22% (4,400 t) for small seiners (<65'), and 23% (4,600 t) for fixed gear.

A first series of acoustic surveys was conducted between 1991 and 2002. A second series of surveys began in the fall of 2009 and continued until 2019. Biomass indices are calculated from these two series, and, together with commercial fishing data, constitute the main source of information used to assess the stock status.

The last assessment of the two herring spawning stocks on the west coast of Newfoundland was in 2018. The Fisheries and Aquaculture Management Branch has requested a new scientific advisory report on these stocks for the 2021 fishing season. At a meeting held from November 18 to 20, 2020, the status of these stocks was reviewed. This paper presents the results and conclusions of this meeting.

SUMMARY

- Based on preliminary data, herring catches from the West coast of Newfoundland (NAFO Division 4R) totalled 7,418 t in 2018 and 15,806 t in 2019, with an annual total allowable catch of 20,000 t. The fishery experienced difficulties due to weather, changes in herring distribution and management measures.
- The proportion of landings composed of the spring-spawning stock have increased from 2.3 % in 2014 to 30.0 % in 2019. Catches of spring-spawning herring were dominated by the 2013 cohort.
- Fall spawning herring age 11+ dominate the landings since 2014. The 2008 cohort contributed to the fishery in recent years, but was not as dominant as the 2000 year-class.
- Both of these stocks show a general downward trend in mean weight-at-age for ages 3+ herring since the beginning of the 1980s, and a downward trend in condition since early 2000s. Relative condition factors were well predicted by zooplankton indices.
- Evidence from scientific sampling and the fishery indicates the presence of young fish in recent years.
- The 2019 fall acoustic survey estimated 47,522 t and 68,796 t of spring and fall spawning herring, respectively. There is evidence of changes in catchability of the acoustic survey in recent years indicating that the survey may not consistently provide a reliable index of abundance.
- Further investigation of the assessment model used as the basis of the advice confirmed existing concerns over model sensitivity to time-varying survey catchability and other input assumptions (constant natural mortality) and model's inability to reliably estimate recruitment. As a result, the model was rejected as the basis of the advice. A review of the assessment framework for 4R herring is recommended.
- The available evidence up to 2019 (commercial catch-at-age, age and length at maturity, abundance of young fish, low exploitation rate in 2019) indicate that current harvest levels do not pose significant risk to herring stocks in 4R in the short term. This conclusion should be revisited following a review of the assessment framework.

INTRODUCTION

Species Biology

Atlantic herring (*Clupea harengus*) is a pelagic fish that frequents cold Atlantic waters. Its range in Canada extends from the coasts of Nova Scotia to the coasts of Labrador. It travels in tight schools in order to feed, spawn near the coast and overwinter in deeper waters. The same spawning, feeding and wintering sites are visited by herring year after year. At spawning, eggs attach themselves to the sea floor, forming a carpet a few centimeters thick. Egg incubation time and larval growth are linked to ambient environmental characteristics such as water temperature. Most herring reach sexual maturity at four years of age, at a total length of about 25 cm. Herring populations on the west coast of Newfoundland are characterized by two groups or spawning stocks. Spring herring generally spawn in April and May, and fall herring, in August and September.

Overview of the Fishery

The herring fishery on the west coast of Newfoundland (Division 4R, Figure 1) is managed by a Total Allowable Catch (TAC) associated with two spawning stocks. The current TAC of 20,000 t was established following science advice in the early 2000s (DFO 2002, 2003).

The main fishing gear used on the west coast of Newfoundland are the purse seine, tuck seine (modified bar seine), gillnet, and the trap. The TAC is split between the various fleets as follows: 55% (11,000 t) for large seiners (>65’), 22% (4,400 t) for small seiners (<65’), and 23% (4,600 t) for fixed gear. Herring off the west coast of Newfoundland are also the subject of a bait fishery, which is used in the snow crab, lobster and groundfish fisheries.

ANALYSIS

Commercial Fishing

In the 1980s and 1990s, Atlantic herring landings on the west coast of Newfoundland were variable and averaged 14,762 tonnes. Following the reduction in the total allowable catch (TAC) in 1999, landings gradually increased again until 2008 and stabilized around 20,000 t until 2016, limited by the TAC for those years. Landings have not reached the TAC since 2017 (Figure 2), totalling 7,419 and 15,782 tonnes in 2018 and 2019 (preliminary data, Table 1). A reduction in herring landings was also observed in NAFO division 4S in 2018 and attributed to either the management measures that were put in place in 2018 (seasonal spatial closure), adverse weather conditions for fishing activities, or the increased presence of herring at greater depths. This latter phenomenon, which would reduce the availability of fish to fishing gear, was reported by members of the fishing industry and was also observed during the acoustic survey conducted by DFO in the fall of 2018 (DFO 2019). The minimum legal size and the abundance of small fish may have contributed to limit the landings in 4R in 2019.

On the west coast of Newfoundland, most herring landings are associated with the purse seine (Figure 3). In 2019, landings by large seiners (> 65’) totalled 7,676 t compared with 3,758 t for small seiners (< 65’), 3,378 t for the tuck seine, 289 t for traps, and 681 t for gillnets (Table 2). The tuck seine, which is a modified bar seine, has been used in the herring fishery since 2005. It is considered a fixed gear. In 2018, less than half of the quotas for small and large seiners were caught. In 2019, 68% of the large seiner quota was caught, and small seiners and fixed gears landed more than 85% of their quota (Figure 4).

Fishing effort activities declined sharply at the end of the 1990s following the implementation of management measures to protect the spring spawning stock. In the fall, the herring fishery follows that of the mackerel fishery. The pattern of cumulative landings of large seiners indicates that this fishery has been starting and running later since 2014 and much later than the historical average.

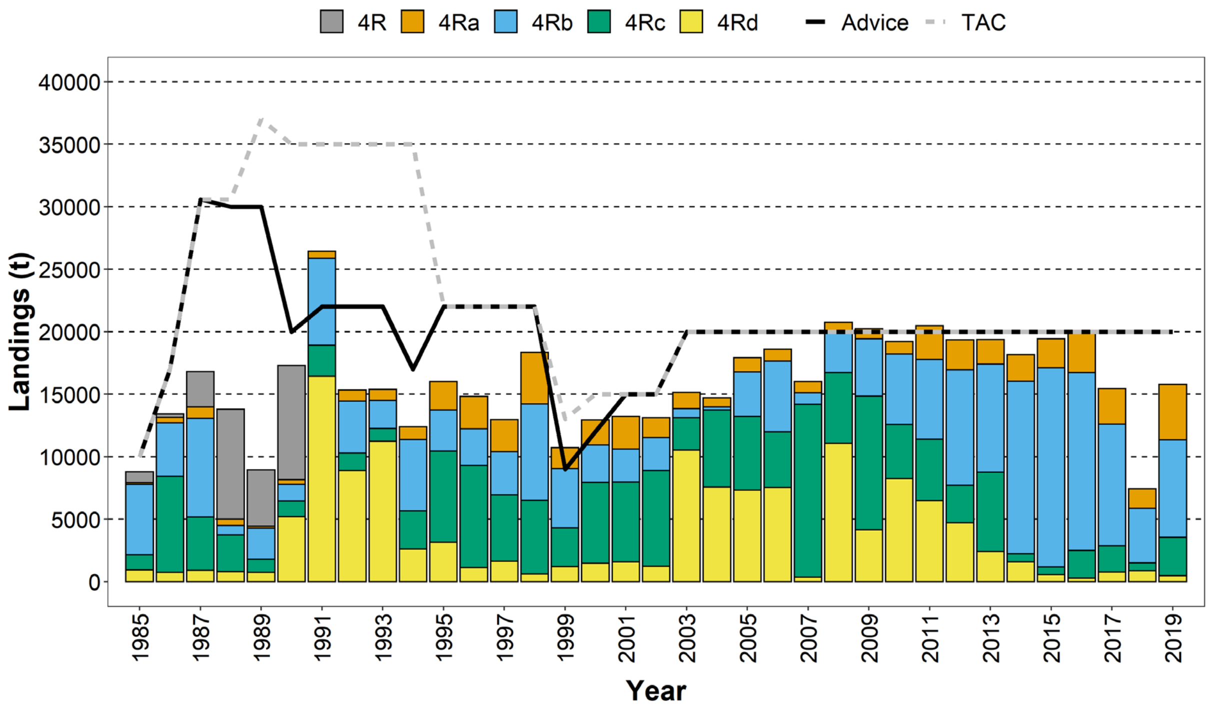

Figure 2. Herring cumulative commercial landings (t) and Total Allowable Catch (TAC) for unit areas of the West coast of Newfoundland (NAFO Division 4R), from 1985 to 2019.

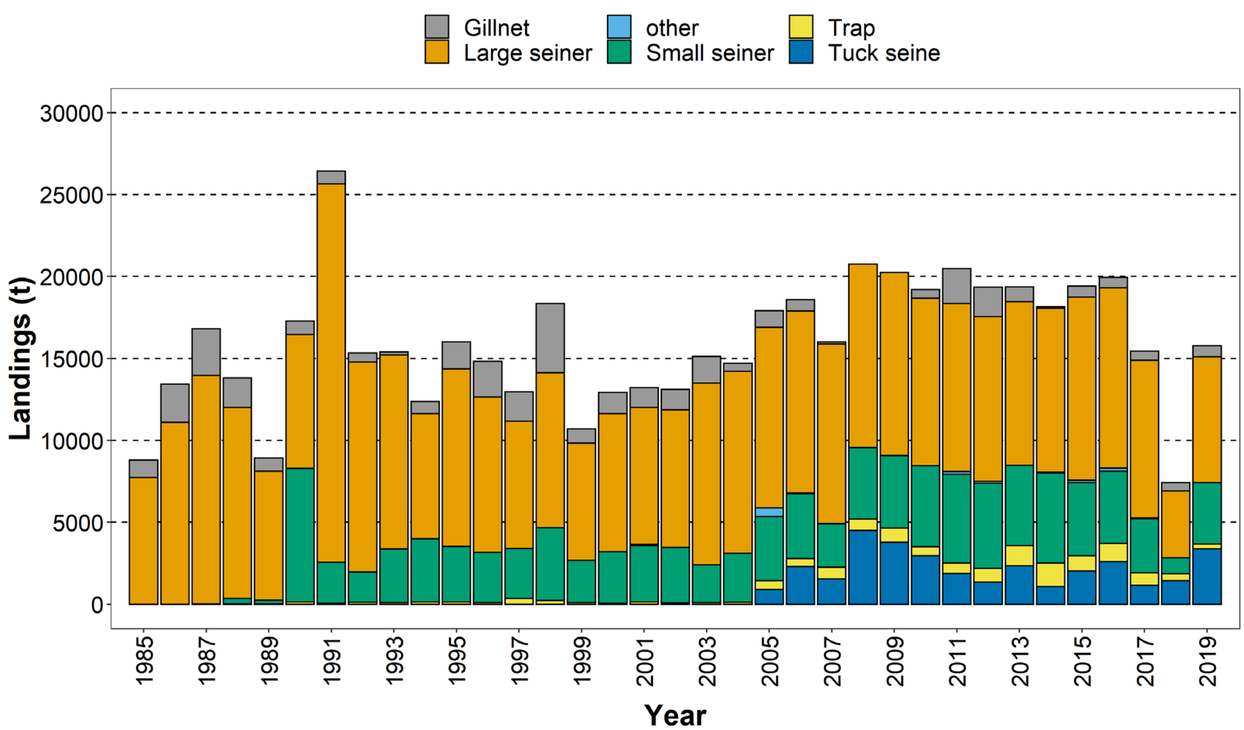

Figure 3. Herring cumulative commercial landings (t) per fishing gear for the West coast of Newfoundland (NAFO Division 4R), from 1985 to 2019.

Table 1. Herring annual landings (t) by unit area and Total Allowable Catch (TAC) on the West coast of Newfoundland (NAFO Division 4R).

UNIT AREA	AVERAGE 1985-1999	YEAR																				AVERAGE 2000-2019
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
4Ra	**1,275**	1,981	2,613	1,604	1,290	712	1,137	957	884	731	821	984	2,694	2,396	1,977	2,129	2,322	3,195	2,842	1,566	4,452	**1,864**
4Rb	**4,239**	2,995	2,643	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	14,271	9,727	4,360	7,786	**6,150**
4Rc	**3,743**	6,469	6,379	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	2,193	2,102	607	3,073	**4,882**
4Rd	**3,729**	1,470	1,589	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	**3,960**
TAC		**15,000**	**15,000**	**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**	-
TOTAL	**12,986**	**12,916**	**13,224**	**13,117**	**15,131**	**14,700**	**17,927**	**18,597**	**16,005**	**20,742**	**20,235**	**19,205**	**20,470**	**19,351**	**19,374**	**18,152**	**19,419**	**19,933**	**15,436**	**7,417**	**15,782**	**16,857**

** Preliminary data*

Table 2. Annual herring landings (t) for the main fishing gear used on the West coast of Newfoundland (NAFO Division 4R).

FISHING GEAR	AVERAGE 1985-1999	YEAR																				AVERAGE 2000-2019
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*	2019*	
Large seiner (>65')	**9,372**	8,427	8,344	8,392	11,090	11,099	11,006	11,102	10,954	11,184	11,170	10,217	10,259	10,047	9,986	9,994	11,167	10,999	9,628	4,076	7,445	9,829
Small seiner (<65')	**2,518**	3,153	3,418	3,383	2,307	2,973	3,918	3,942	2,660	4,357	4,415	4,950	5,428	5,171	4,905	5,504	4,470	4,397	3,312	966	3,989	3,881
"Tuck" seine	-	0	0	0	0	0	909	2,300	1,545	4,498	3,778	2,953	1,883	1,342	2,337	1,075	2,029	2,594	1,167	1,439	3,378	1,661
Gillnet	**1,502**	1,277	1,215	1,256	1,629	499	1,031	703	132	3	0	525	2,107	1,790	915	96	680	623	546	512	681	811
Trap	**103**	59	150	73	104	127	528	498	706	700	872	560	626	862	1,230	1,440	928	1,132	746	424	289	603
Others	**2**	0	96	13	0	2	535	53	8	0	0	0	167	138	0	43	143	188	37	0	0	71
TOTAL	**12,986**	**12,916**	**13,224**	**13,117**	**15,131**	**14,700**	**17,927**	**18,597**	**16,005**	**20,742**	**20,235**	**19,205**	**20,470**	**19,351**	**19,374**	**18,152**	**19,419**	**19,933**	**15,436**	**7,417**	**15,782**	**16,857**

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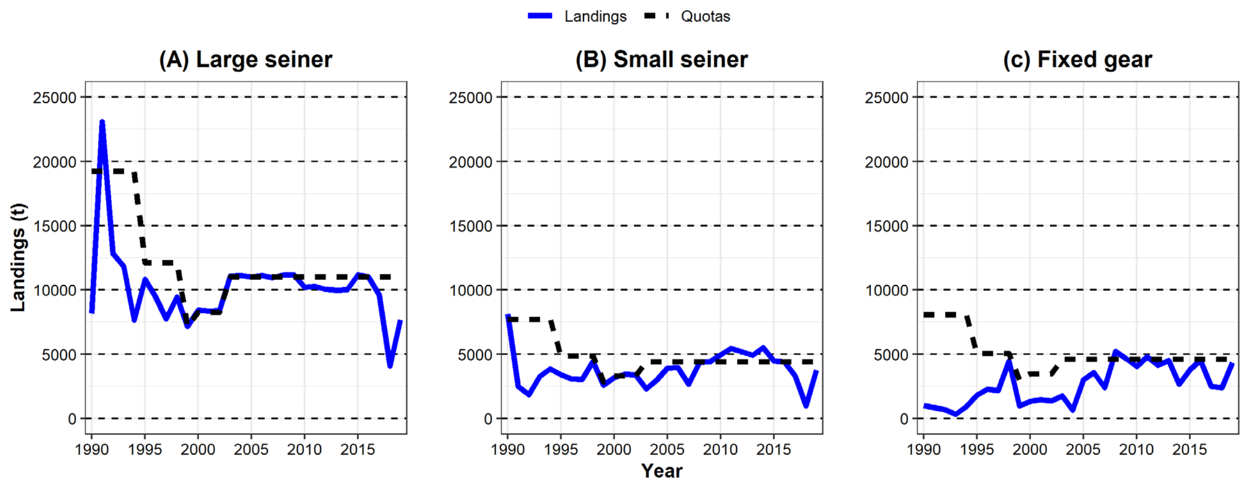

Figure 4. Herring landings (t) (blue line) and annual allocations (t) (black doted line) per fishing fleet: large seiner (A), small seiner (B) and fixed gear (C) since 1990 for NAFO Division 4R.

Biological Indicators

The proportion of spring spawning herring in total landings varied between 30% and 80% from 1965 to 2005. The proportion of spring spawning herring declined rapidly from 2005 to 2008, reaching 2.3% (the lowest value in the series) in 2014. In 2018 and 2019, the proportion of spring spawning herring in the fishery was 27.6% and 30.0%, respectively (Figure 5).

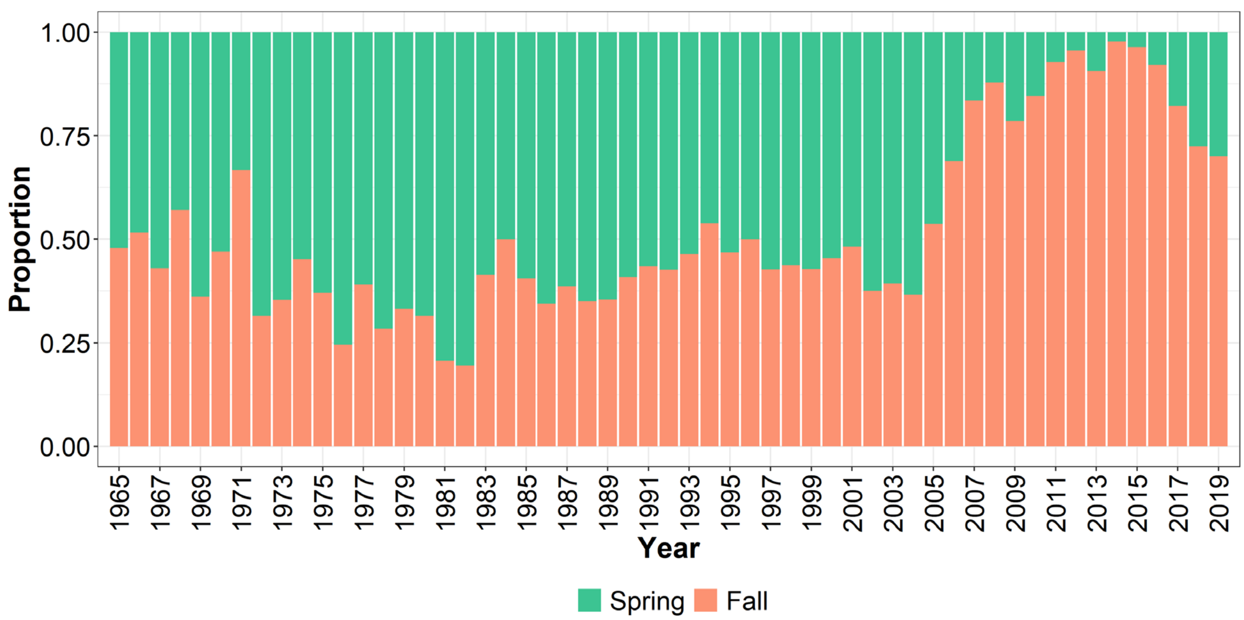

Figure 5. Proportion of spring and fall spawning herring (number of individuals) in NAFO Division 4R commercial landings from 1965 to 2019.

Overall, the age compositions of the commercial fishery for spring and fall spawners allow the dominant cohorts to be tracked from age 4 onward. Among spring spawners, catch-at-age during the 2018 and 2019 fishing seasons revealed a dominance of the 2013 cohort (Figure 6a).

This cohort made up 45.4% and 44.1% of all catches (in number) in 2018 and 2019, respectively. Regarding fall spawners, herring from the 2008 (10-year-old) cohort accounted for 26.9% of the total catch (by number) and the 11+ age group totalled 31.5% in 2018. In 2019, the 11+ age group accounted for 40.8% of the total catch (Figure 6b). In 2019, catches at age 2 (spring) and 3 (fall) were also among the highest in the series (Figure 6).

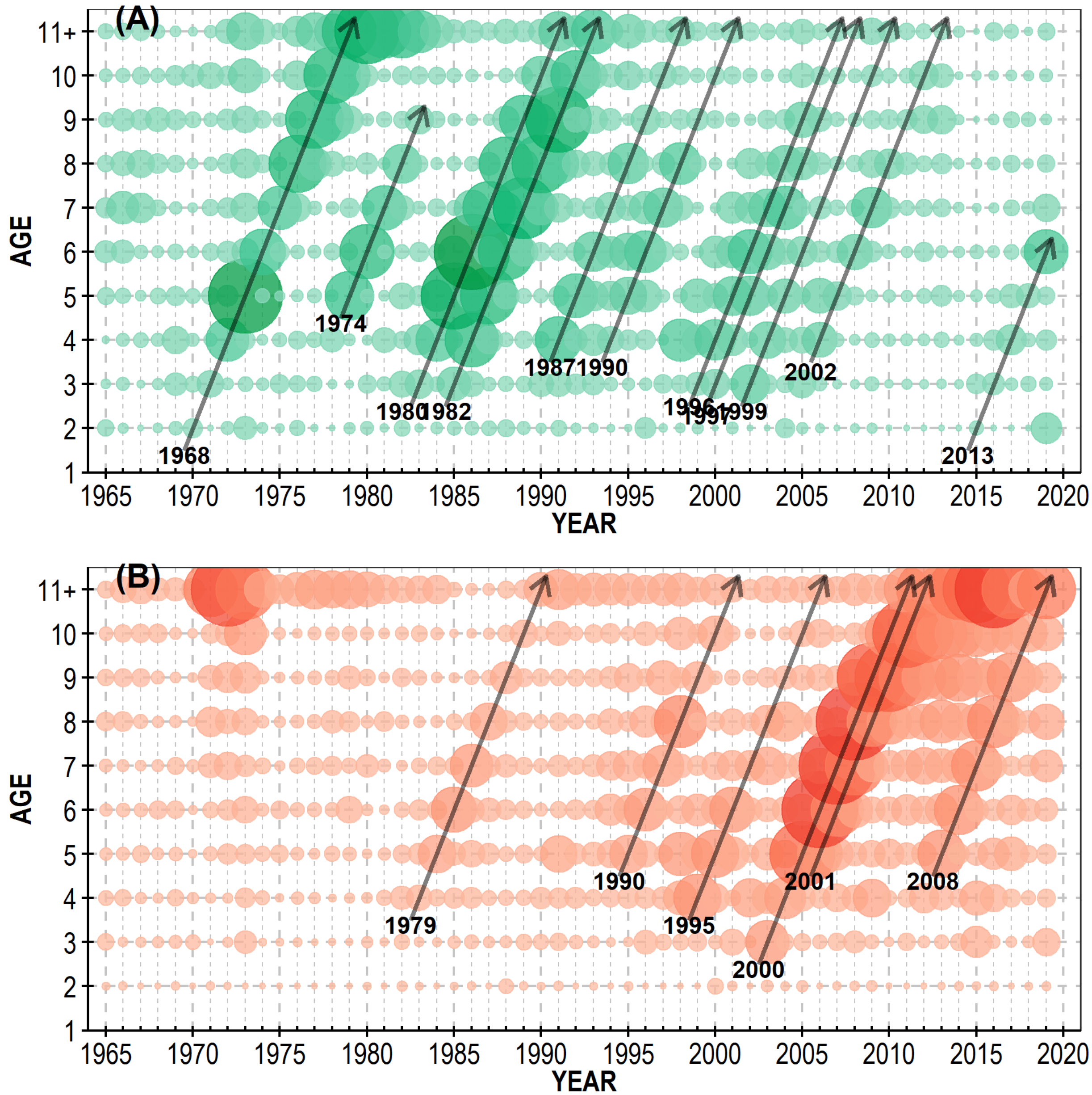

Figure 6. Spring (A) and fall (B) spawner catch-at-age from 1965 to 2019. The size of the bubbles is proportional to the number of individuals.

Among spring spawners, weights at ages 3 to 11 years and older increased from the beginning of the data series into the early 1980s and showed a variable, but generally declining trend thereafter (Figure 7a). In fall spawners, weight at ages 4 to 11 years and older increased from the beginning of the series into the early 1980s. A variable trend, yet clearly declining, is then visible until 2012 for age 7 to 11 plus, and until 2018 or 2019 for age 3 to 6 (Figure 7b). For both spawning stocks, no trend in weights at age 2 was observed. The decreasing trend in weight at age has also been observed in other stocks of small pelagic fish in the northwest Atlantic, including herring in the southern Gulf of St. Lawrence (DFO 2020), southwestern Nova Scotia, and the Bay of Fundy (Singh *et al.* 2020), and northwest Atlantic mackerel (Smith *et al.* 2020).

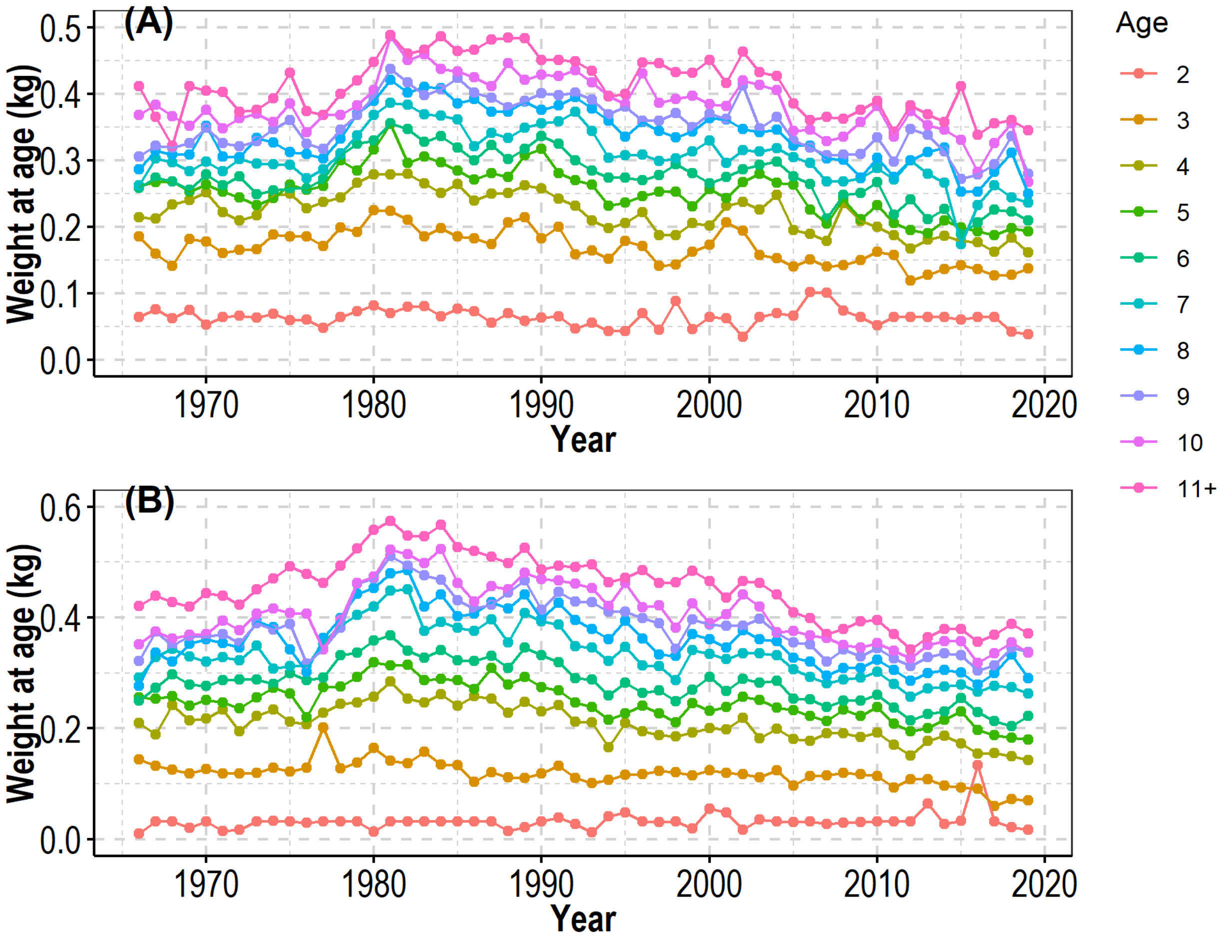

Figure 7. Standardized weight at age of spring (A) and fall (B) spawners, 1966–2019.

Relative condition indices for spring and fall spawning stock aged 4 to 9 years vary similarly across the entire (1966–2019) series and were therefore averaged annually for each of the two spawning groups. The average condition index showed a downward trend since the early 2000s for both spawning groups. The zooplankton indices explain 82.6% and 61.4% of the deviation in the spring and fall spawning condition index, respectively. The condition index of spring spawners appeared to be favoured when the phenology of *C. finmarchicus* is earlier in the spring and when the contribution in abundance of large calanoid copepods compared with small calanoid copepods is proportionally higher. The condition of fall spawning herring appeared to be favoured when *C. finmarchicus* is more abundant and when the development of the second generation of this copepod is earlier in the season.

Size frequency distributions of biological samples collected in the 2019 acoustic survey revealed a mode between 200 and 250 mm for both spring and fall spawners. The abundance index at age 2 for spring spawners and at age 3 for fall spawners were the highest observed since the beginning of the survey. These observations could be explained by a change in gear (the biological samples were collected using a pelagic trawl in 2019), and were corroborated by information provided by industry members and fisheries management. Commercial fishers report an increased presence of small-bodied fish in recent years, and this trend is also visible in the commercial catch-at-age (Figure 6).

The 2019 fall acoustic survey estimated 47,522 t and 68,796 t of spring and fall spawning herring respectively (Figure 8). These biomasses cannot be directly related to the limit reference points (LRPs) and the precautionary approach developed by McQuinn *et al.* (1999) and Grégoire and McQuinn (2010), which are based on the output of a sequential population analysis (herring stock dynamics model). The 2019 biomass estimate for spring spawners is the highest value observed since the survey was resumed in 2009. The ratios of the biomass fished in 2019 and the biomass estimated in the 2019 acoustic survey correspond to exploitation rates of 8.1% and 17.3% (F = 0.085 and 0.190) for spring and fall spawners, respectively. These exploitation rates are considered to be maximum estimates.

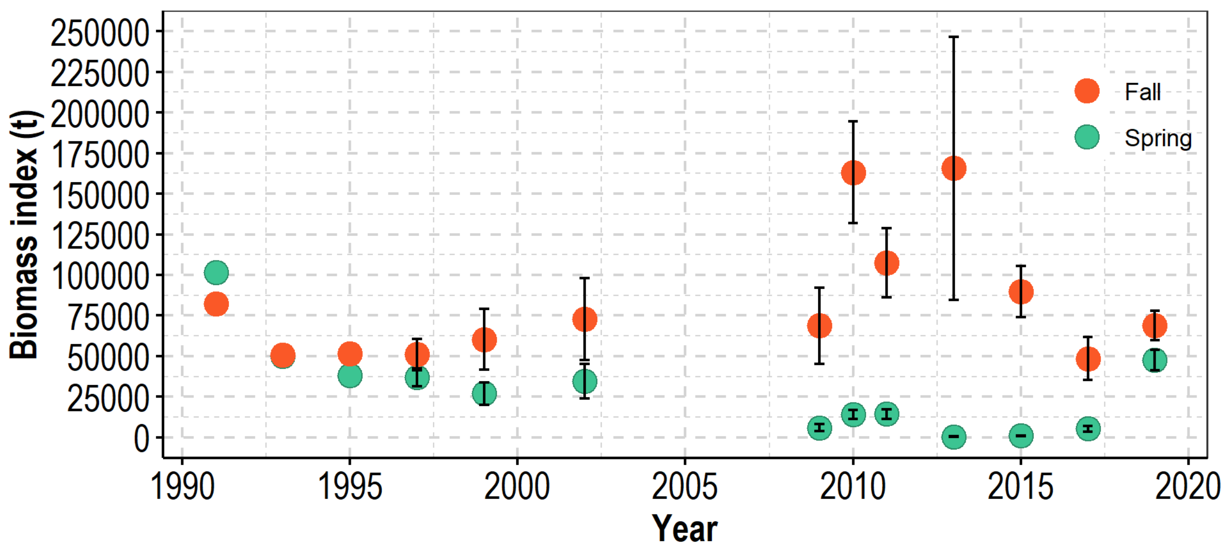

Figure 8. Biomass indices (with standard error) of spring and fall spawning herring stocks of the west coast of Newfoundland (NAFO Division 4R) estimated by the acoustic survey from 1991 to 2019.

The premise that the acoustic survey samples a constant proportion of the stock over time (constant catchability) was examined using catch curves adjusted for selectivity for estimated abundances of 3- to 10-year-old herring. Based on constant catchability, cohort abundance is expected to decline over time, reflecting depletion due to mortality, although some variability is expected due to observation errors. Catch curves for cohorts of both spring and fall spawners for the 1991 to 2009 period are generally consistent with this expectation (Figure 9). In contrast, the catch curves for 2009–2011 (spring) and 2009–2013 (fall) show increasing or asymptotic survey abundances across many cohorts, indicating increased catchability to the survey as cohorts grow older. This increase was particularly apparent between the 2017 and 2019 surveys for both spawning stocks. The temporal variability in the catchability in the acoustic survey currently limits its usefulness in providing a consistent index of the relative abundance of herring stocks.

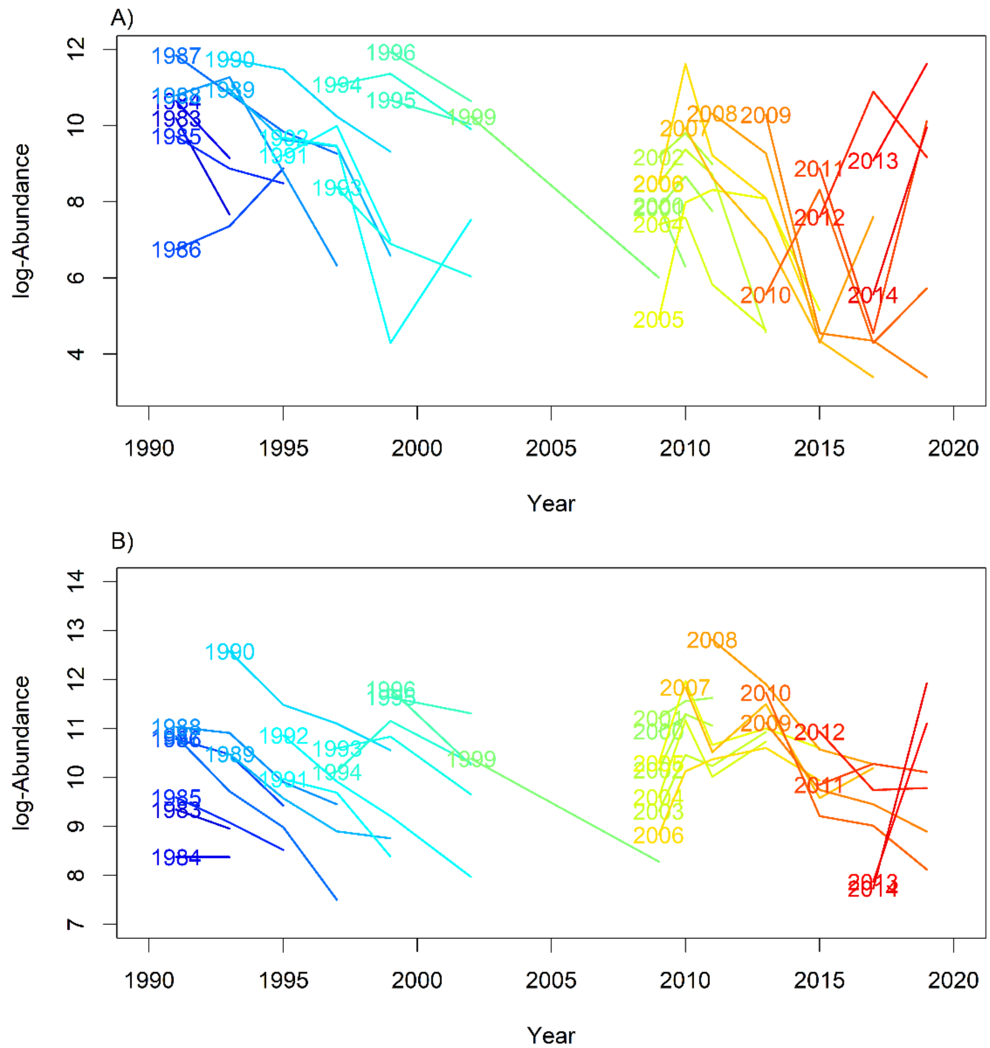

Figure 9. Selectivity adjusted catch curves for acoustic survey abundance for (a) spring and (b) fall herring aged 3–10 years. The individual lines show abundance trends for individual cohorts, identified by their year of birth.

Sequential population analyses (assessment model) using the commercial catch-at-age and the abundance-at-age index from the acoustic survey were adjusted for spring and fall spawners. For spring spawners, the adjusted model had problematic retrospective patterns for estimated fishing mortality (F), residuals were not normally distributed and presented patterns in the residuals as a function of age. In fall spawning stocks, the retrospective analysis could not be completed due to convergence problems and the residuals were normally distributed, but showed significant patterns with regards to age. Alternative versions of the sequential population analyses were also conducted, including attempts to adjust natural mortality (M) by 5-year periods, and revealed the same problems in the residuals and/or retrospective analyses, in addition to producing inconsistent M values. These outcomes confirmed existing concerns about the sensitivity of the model to time-varying catchability and other assumptions, and the inability of the model to reliably estimate recruitment. Consequently, the model was rejected as the basis for the science advice.

Sources of Uncertainty

Changes in catchability of the acoustic survey in recent years represent a major source of uncertainty for the assessment of spring and fall spawning herring spawning stocks on the west coast of Newfoundland. Several factors may explain the variations observed in the catchability in 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 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. 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 (especially in the case of spring spawning herring).

The low number of biological samples for spring spawners in the commercial fishery since 2007 represents another source of uncertainty, particularly in terms of the representativity and precision of the commercial catch-at-age and biological indices (length at maturity, age at maturity, weight at age) for this spawning stock. The increase in research samples in recent years reduces some of this uncertainty.

CONCLUSIONS AND ADVICE

The change in catchability of the acoustic survey that led to the rejection of the population model for the two spawning herring stocks on the west coast of Newfoundland makes it impossible to quantitatively determine the status of the resource. However, several biological indicators show that these herring stocks are not currently being overfished.

Catch-at-age in the commercial fishery makes it possible to monitor the progress of cohorts up to age 11+ for the two spawning stocks. Catch-at-age is also dominated by old individuals for the fall spawning stock, which accounts for the majority of landings. In an overexploited stock, cohorts would have disappeared before reaching the ‘plus’ age, and catches would have been dominated by young individuals (Berkeley *et al.* 2004).

The length at 50% maturity for both spawning stocks shows variable trends around the average for the cohorts from 1962 to 2016. Age at 50% maturity is variable around the average for spring spawners, and has increased over the last decade for fall spawners. Overfishing pressure would have decreased L50 and A50 (Kuparinen and Merilä 2007).

The abundance of young fish observed in the acoustic survey, by commercial harvesters and in the commercial catch-at-age for spring spawners is an encouraging sign for the future that will need to be monitored and validated.

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 rate estimated from these biomasses and the commercial fishery for 2019 was low.

Information available up to 2019 (commercial catch-at-age, age and length at maturity, abundance of young fish, low exploitation rate in 2019) indicates that current catch levels do not pose a significant short-term threat to the herring stocks in 4R. This conclusion will need to be reassessed following the review of the evaluation framework.

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SOURCES OF INFORMATION

This Science Advisory Report is from the November 18-20, 2020 regional advisory meeting on the Assessment of the West Coast of Newfoundland (NAFO Division 4R) herring (*Clupea harengus*) 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.

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