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Canadian Science Advisory Secretariat
Quebec Region **Science Advisory Report 2016/024**

ASSESSMENT OF THE WEST COAST OF NEWFOUNDLAND (DIVISION 4R) HERRING STOCKS IN 2015

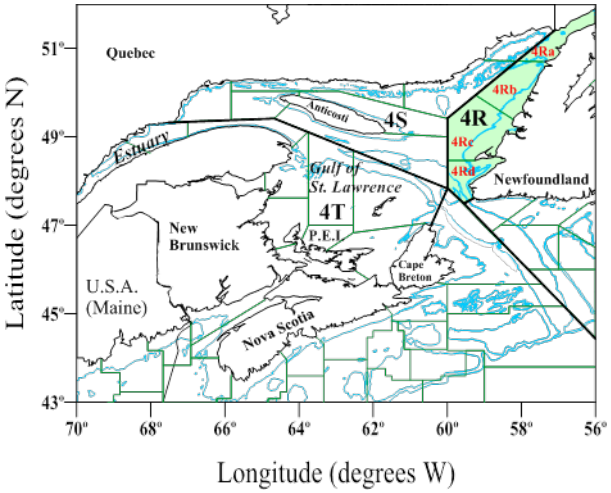

Figure 1. Map of unit areas of NAFO Division 4R (west coast of Newfoundland). Division 4R is identified by the coloured area.

Context:

Atlantic herring is a pelagic species that perform significant annual migrations associated with spawning, feeding and wintering. Atlantic herring are part of a commercial fishery and in Canadian waters, the main fishing areas are south-western Nova Scotia and the Bay of Fundy (complex of stock 4VWX), the southern Gulf of St. Lawrence (4TVn stocks), the northern Gulf of St. Lawrence (4S stock),the west coast of Newfoundland (4R stocks) and the east and south-east coasts (3KLPs stocks) of Newfoundland. On the west coast of Newfoundland (NAFO Division 4R, Figure 1), the average annual landings of herring have been about 16,000 metric tons (t) since 1975. The main fishing gear is the purse seine with average annual landings of near 13,000 t. In order of important gears, the purse seine is followed by the "tuck" seine (modified bar seine), gillnet, and traps.

The west coast of Newfoundland 4R herring fishery is managed by a Total Allowable Catch (TAC) associated with both spawning stocks. The current TAC of 20,000 t stems from advice produced during the last analytical assessments conducted in the early 2000s. The TAC is split between the various fleets as follows: 55% for large seiners (> 65 '), 22% for small seiners (<65') and 23% 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. This new series will allow for the return of an analytical assessment as well as the updating of reference points. They will help develop a strategic framework for fisheries consistent with the precautionary approach.

The last assessment of the two herring spawning stocks on the west coast of Newfoundland was done in 2014. The Fisheries and Aquaculture Management Branch has requested a new scientific advice on these stocks for the 2016 and 2017 fishing seasons. At a meeting held on March 8, 2016, the status of these stocks was reviewed. This paper presents the results and conclusions from that meeting.

SUMMARY

- Based on preliminary data for 2015, herring catches from the west coast of Newfoundland (NAFO Division 4R) totaled 19,436 tons from a TAC of 20,000 tons. The quotas allocated to the large and small seiners were reached, whereas 82% of the quota for fixed gear was taken.
- Catches of the fall-spawning stock are currently dominated by fish aged 11+ years and in lesser proportion by fish aged 7 years.
- Too few spring-spawning herring were available among the commercial samples in 2015 to reliably determine catch-at-age for this stock. The few spring-spawning herring available in the samples were mostly 2- and 3-year-old fish.
- An acoustic survey was performed in October 2015. Due to logistical constraints, it was necessary to prioritize some strata and to reduce spatial coverage intensity. Despite these constraints, the confidence interval of the biomass estimate was among the best of the time series.
- In 2015, fishing took place mostly in November and December, and thus few samples were available for the period during which the acoustic survey was conducted. Consequently, both the biomass index yielded by the survey and the age structure are sensitive to the samples used in the estimation.
- The total biomass index for spring-spawning herring from the 2015 acoustic survey was estimated at 1,200 tons. For fall spawners, the total biomass index was 97,000 tons. The biomass index for fall-spawning herring from the acoustic survey series has remained between 85,000 tons and 122,000 tons since 2009.
- A sequential population analysis (SPA) using data from the commercial fishery was tuned with the acoustic biomass indices. The 2015 acoustic index and the SPA both confirm that the spring-spawning stock has collapsed and that its current spawning biomass is below the limit reference point (LRP = 37,000 t).
- The SPA for the fall-spawning stock shows some retrospective patterns, but concurs with the acoustic indices that the spawning biomass has experienced a strong increase from 2003 to 2010 followed by a continuous decrease until 2015.
- Because of the retrospective patterns in the SPA, the absolute biomass of the fall-spawning stock remains uncertain. However, all indices agree that the current spawning biomass is above the upper reference point (URP = 61,000 t).
- If the older fish that have supported the fishery continue to decline, and in the absence of significant recruitment, there is a risk that maintaining catches at their current level will bring the fall-spawning stock below the upper reference point in the next two years.
- Given that the spring-spawning stock is still decreasing, it is recommended that the management measures implemented in the late 1990s remain in place

INTRODUCTION

Species Biology

Atlantic herring (*Clupea harengus*) is a pelagic fish that frequents cold Atlantic waters. Its distribution in Canada extends from the coasts of Nova Scotia to the coasts of Labrador. It travels in tight schools in order to feed, to spawn near the coast and to overwinter in deeper waters. Herring return to the same spawning, feeding and wintering areas year after year. This homing phenomenon is attributed to a learning behaviour with the recruitment of young year-classes in a population. At spawning, eggs attach themselves to the sea floor, forming a carpet of a few centimetres thick. The 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 length of about 27 cm. Herring populations on the west coast of Newfoundland are characterized by two spawning stocks. Spring herring generally spawn in April and May, and fall herring in August and September.

ANALYSIS

The 2015 Fishery

Herring landings on the west coast of Newfoundland increased between 1999 and 2008 and have since remained close to 20,000 t (Figure 2). In 2015, they totaled 19,436 t compared to 18,152 t in 2014, and with an annual average (2000–2013) of 17,215 t (Table 1). A total of 15,682 t were caught in unit area 4Rb, compared to 2,187 t, 805 t and 762 t for unit areas 4Ra, 4Rc and 4Rd (Table 1). Since 2007, there has been a growing concentration of the landings in area 4Rb, at the expense of areas 4Rc and 4Rd.

On the west coast of Newfoundland, most herring landings are associated with the purse seine (Figure 3). In 2015, landings by large seiners (>65') totaled 11,167 t compared to 4,509 t by small seiners (<65'), 2,173 t by the "tuck" seine, 906 t by trap and 682 t by gillnet (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 2015, the quotas allotted for the large and small seiners fleets were reached whereas the quota for the fixed gear fleet was not reached (Figure 4). Between 1990 and 2004, fixed gears took on average 30% of their quota. The arrival of the "tuck" seine in this fishing fleet increased this proportion to 82%.

Spring fishing activities were strongly reduced at the end of the 1990s following the implementation of management measures to protect the reproduction of spring-spawning herring. In the fall, the herring fishery follows the mackerel fishery. In 2014 and 2015, catches by large and small seiners' show that fall fishing activates occurred later than in 2013 and much later than the historical mean.

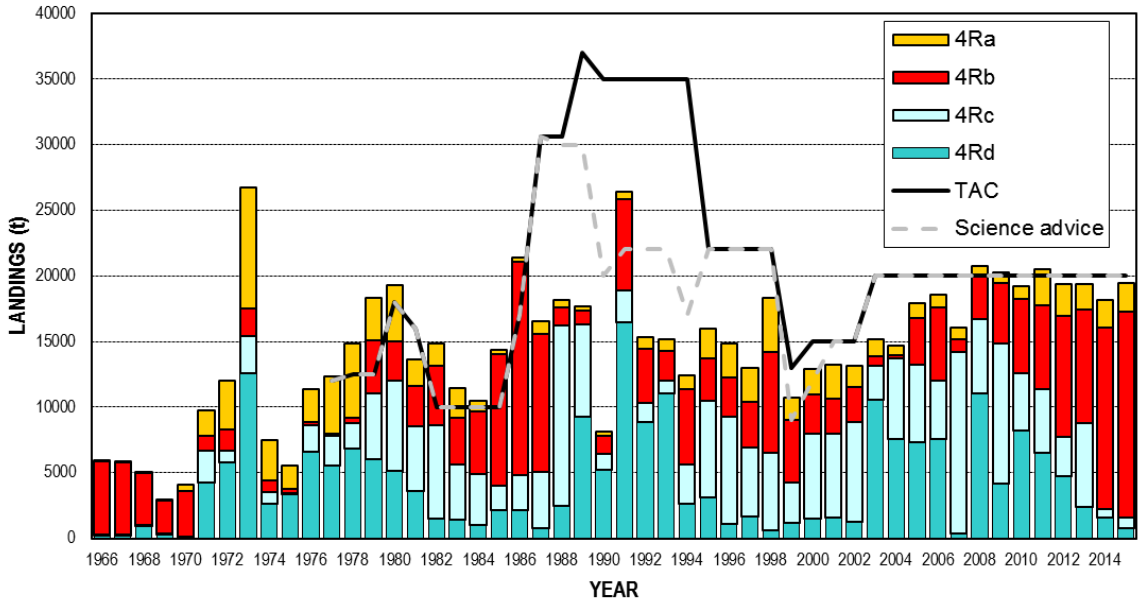

Figure 2. Herring cumulative commercial landings (t) and TACs (t) for unit areas of the west coast of Newfoundland (NAFO Division 4R), from 1966 to 2015. The science advice corresponds to a conservative estimate of the optimal exploitation rate, from the results of a virtual population analysis.

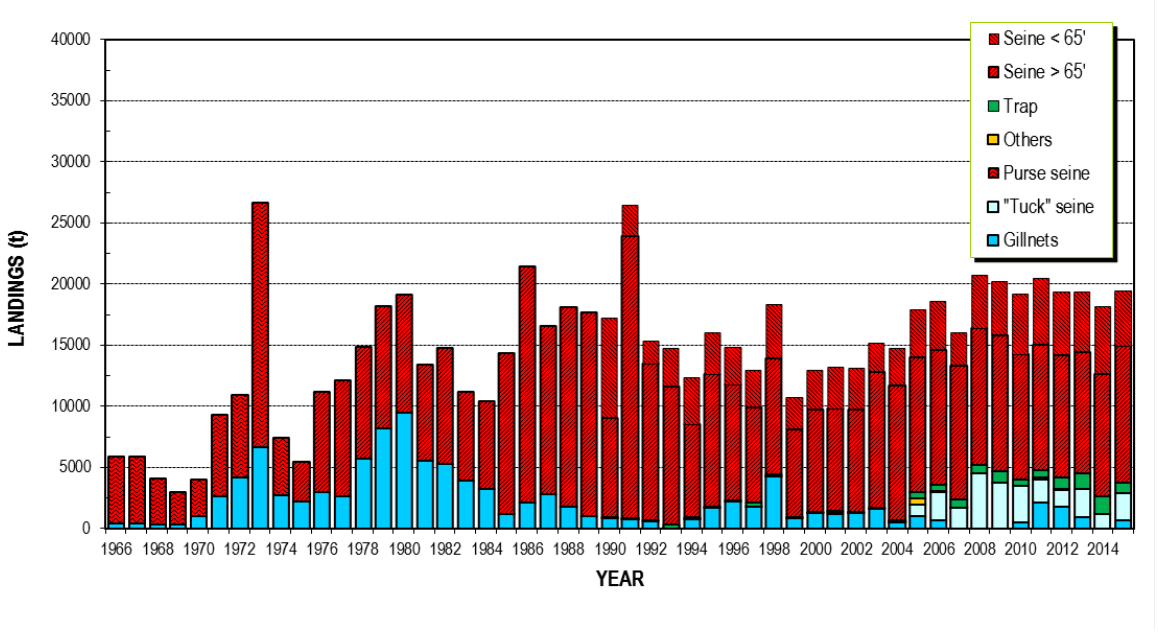

Figure 3. Herring cumulative commercial landings (t) per fishing gear for the west coast of Newfoundland (NAFO Division 4R), from 1966 to 2015.

Table 1. Annual herring catches (t) in the unit areas of the west coast of Newfoundland (NAFO Division 4R).

UNIT AREA	AVERAGE (1990-1999)	YEAR																AVERAGE (2000-2013)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014*	2015*	
4Ra	1,694	1,981	2,613	1,604	1,290	713	1,138	955	885	731	821	984	2,694	2,396	1,977	2,129	2,187	1,484
4Rb	4,253	2,995	2,643	2,621	713	252	3,573	5,647	914	3,286	4,573	5,651	6,389	9,249	8,651	13,798	15,682	4,083
4Rc	3,900	6,469	6,379	7,660	2,594	6,162	5,890	4,457	13,861	5,668	10,707	4,342	4,899	2,994	6,322	640	805	5,977
4Rd	5,183	1,471	1,589	1,232	10,534	7,575	7,327	7,524	375	11,058	4,134	8,228	6,489	4,712	2,424	1,585	762	5,334
Unknown	912	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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*	
TOTAL	15,943	12,916	13,224	13,117	15,131	14,702	17,928	18,583	16,035	20,742	20,235	19,205	20,470	19,351	19,374	18,152	19,436	17,215

** Preliminary data*

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

FISHING GEAR	**AVERAGE (1990-1999)**	**YEAR**																**AVERAGE (2000-2013)**
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014***	**2015***	
Gillnet	**1,378**	1,277	1,216	1,257	1,629	499	1,031	702	132	3	0	525	2,107	1,790	915	96	682	**935**
"Tuck' seine'	**0**	0	0	0	0	0	909	2,286	1,545	4,498	3,778	2,953	1,883	1,342	2,337	1 075	2,173	**1,538**
Other seine	**2**	0	96	13	0	2	530	53	8	0	0	0	167	138	0	43	0	**72**
Trap	**150**	59	150	73	104	127	534	498	706	700	872	560	626	862	1,230	1,440	906	**507**
Small seiner (<65')	**3,612**	3,153	3,418	3,382	2,307	2,974	3,918	3,941	2,688	4,357	4,415	4,950	5,428	5,171	4,905	5,504	4,509	**3,929**
Large seiner (>65')	**10,801**	8,427	8,344	8,392	11,091	11,100	11,007	11,102	10,955	11,184	11,170	10,217	10,259	10,047	9,994	9,994	11,167	**10,234**
TOTAL	**15,943**	**12,916**	**13,224**	**13,117**	**15,131**	**14,702**	**17,928**	**18,583**	**16,035**	**20,742**	**20,235**	**19,205**	**20,470**	**19,351**	**19,374**	**18,152**	**19,436**	**17,215**

** Preliminary data*

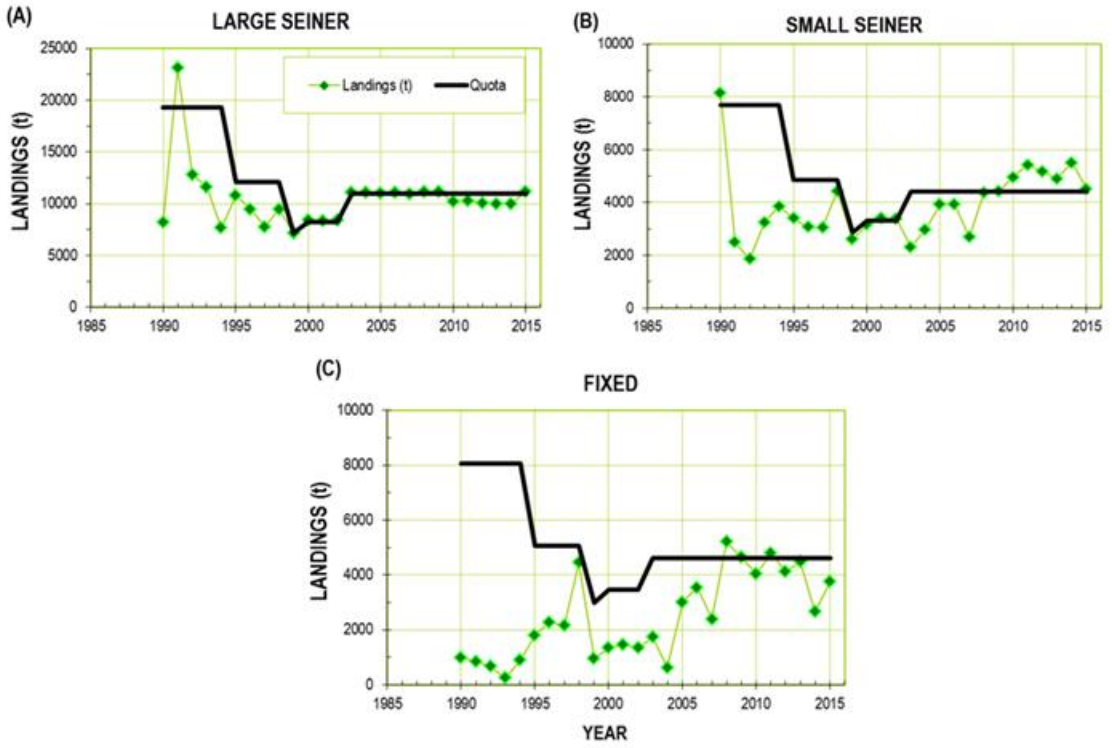

Figure 4. Herring landings (t) and quotas (t) per fishing fleet in 2015 for the west coast of Newfoundland (NAFO Division 4R).

Biological Data

Length frequency analysis indicates that herring stocks on the west coast of Newfoundland are characterized by the periodic occurrence of dominant year-classes. For spring spawners, the most recent of these year-classes was 2002, and to a lesser extent that of 2001 (Figure 5A) However, tracking new year-classes (3 to 6 year-old) in 2014 and 2015 is made difficult by the low number of individual spring spawners in the samples.

For fall spawners, the dominant year-class since 2005 is the 2000 year-class, followed by the 2001 year-class (Figure 5B). Between 2005 and 2009, the 2000 year-class alone accounted for 43 % to 53% of total landings (in numbers). The 2008 year-class has now entered the fishery. However, its contribution to the fishery at age 7 (in 2015) is not as large as that of the 2000 year-class (which still dominates the stock).

The proportion of mature fish at length in both stocks has varied slightly over the years. For spring spawners, length at 50% of maturity (L_{50}) changed from 273 mm in the 1980s to 258 mm in the 2010s (Figure 6A). For fall spawners, L_{50} changed from 288 mm in the 1980s to 272 mm in the 2010s (Figure 6B). These variations could reflect the effect of fishing pressure (and fluctuations in stock size), but could also be driven by environmental factors.

Both herring spawning stocks showed similar annual variations in their condition indices although the average condition (1970-2015) was higher for spring spawners (Figures 7A and 7B). These indices increased at a high rate from the mid-1970s to the early 1980s. They were relatively stable until 1992; however, significant annual variations were observed thereafter. Both indices showed a significant decrease from 2009 to 2011, followed by an increase that brought them back near the long-term average.

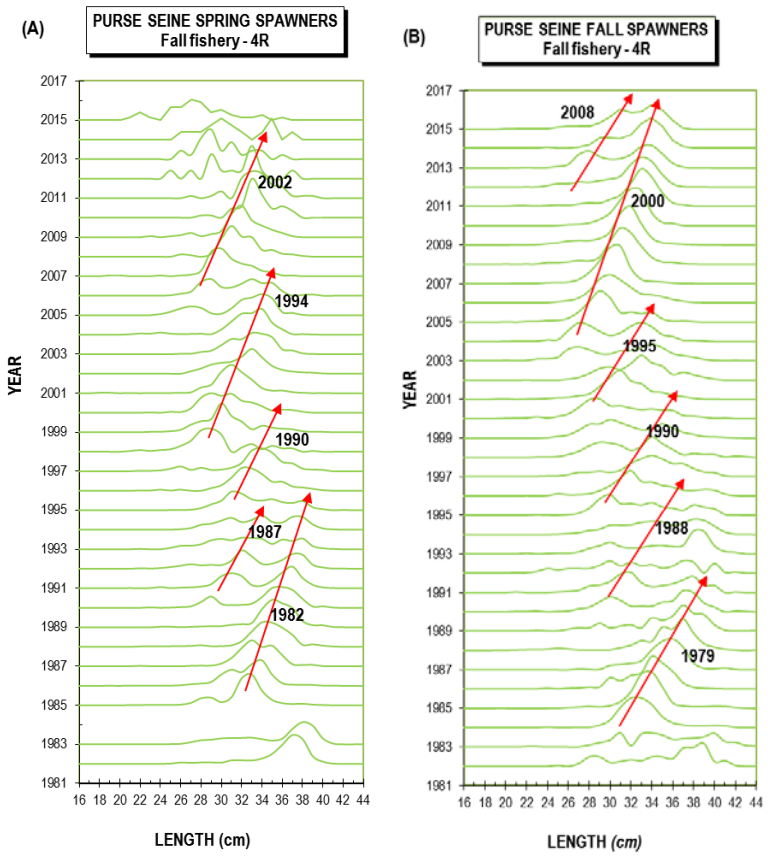

Figure 5. Annual length (cm) frequencies (%) of spring (A) and fall (B) spawning herring caught in the fall with the purse seine in Division 4R (some dominant year-classes are indicated).

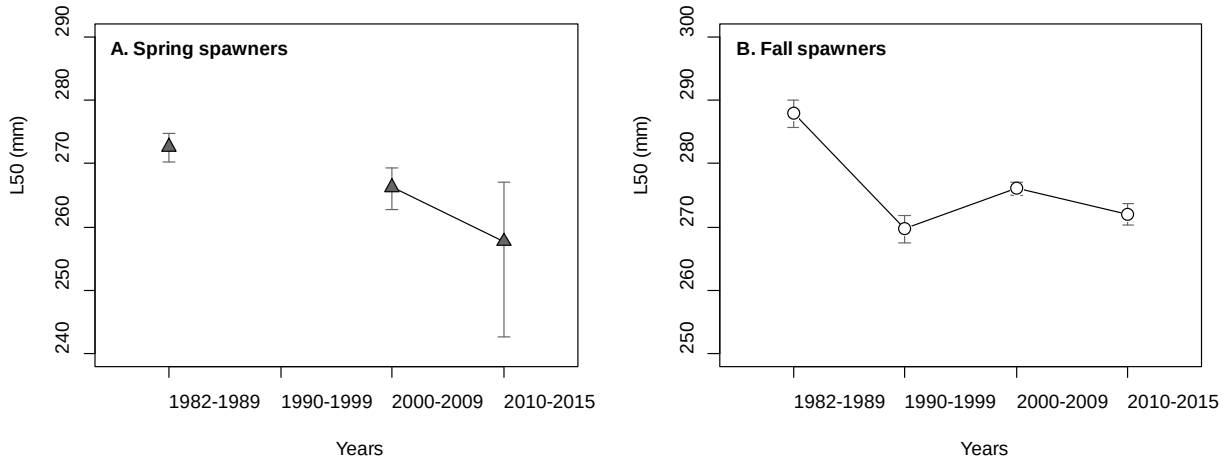

Figure 6. Length at which 50% of herring have reached maturity (L_{50}) by year period for spring (A) and fall (B) spawning herring stocks of the west coast of Newfoundland (NAFO Division 4R).

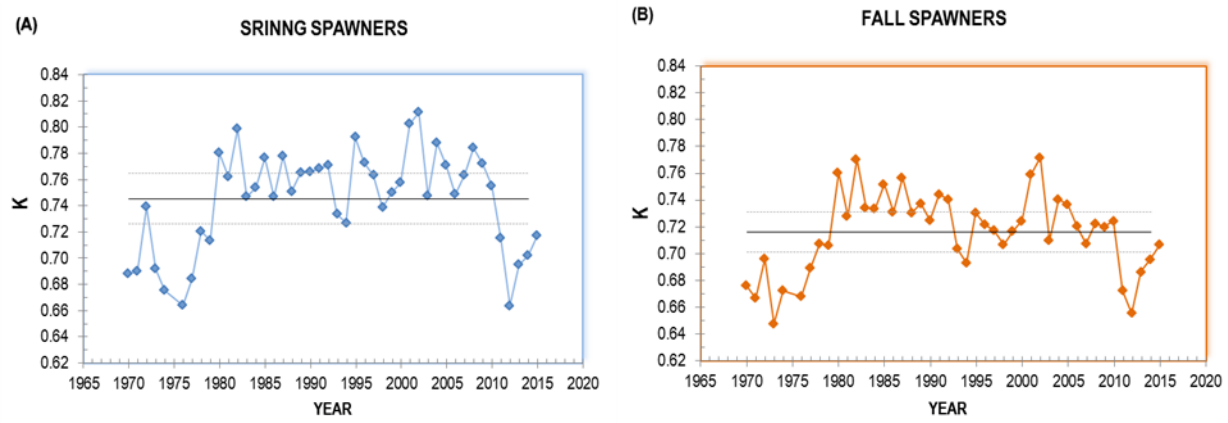

Figure 7. The average annual condition for spring (A) and fall (B) herring spawners on the west coast of Newfoundland (NAFO Division 4R). The horizontal lines show the 1970-2013 averages ± 0.5 standard deviation.

Resource Status

Acoustic Survey

A first series of acoustic surveys was conducted between 1991 and 2002. A second series of surveys began in the fall of 2009. The 2015 acoustic survey took place between October 14 and 25, and was characterized by difficult weather conditions and shorter ship availability than in previous years. It was thus necessary to prioritize some strata (only strata 1, 2, 5, 6 and 10 were covered) and to reduce coverage intensity in strata 6 and 10 (surveying every other line).

In 2015, the most significant acoustic signals were measured in strata 5 and 6 (Figure 8C), which is similar to the patterns observed during the 2013 survey (Figure 8B), whereas in 2011 the most significant signals were measured in stratum 10 (Figure 8A). With the assistance of industry, several biological samples were obtained to associate biological parameters with the acoustic signals. However, commercial fishing activities occurred late in 2015 (due in part to unfavorable weather conditions in October), creating a temporal mismatch between collection of samples and survey dates. This adds uncertainty to the representativeness of the samples for characterization of the acoustic signals in the various survey strata.

The total biomass index of spring-spawning herring fell considerably between 1991 and 1993 (Figure 9). After some stability, this index fell again, decreasing from 34,500 t in 2002 to less than 1,500 t in 2015. In 2002, spring herring accounted for 29.6% of the abundance (in number) of the two spawning stocks compared to only 1.2% in 2015.

The total biomass index of fall-spawning herring also fell between 1991 and 1993, then increased until 2010 (Figure 9). From 2010 to 2013, the index decreased from 122,000 t to 97,000 t. Note the presence of large standard deviations in 2009 and 2013, whereas the standard deviation of the 2015 estimate is among the smallest in the series.

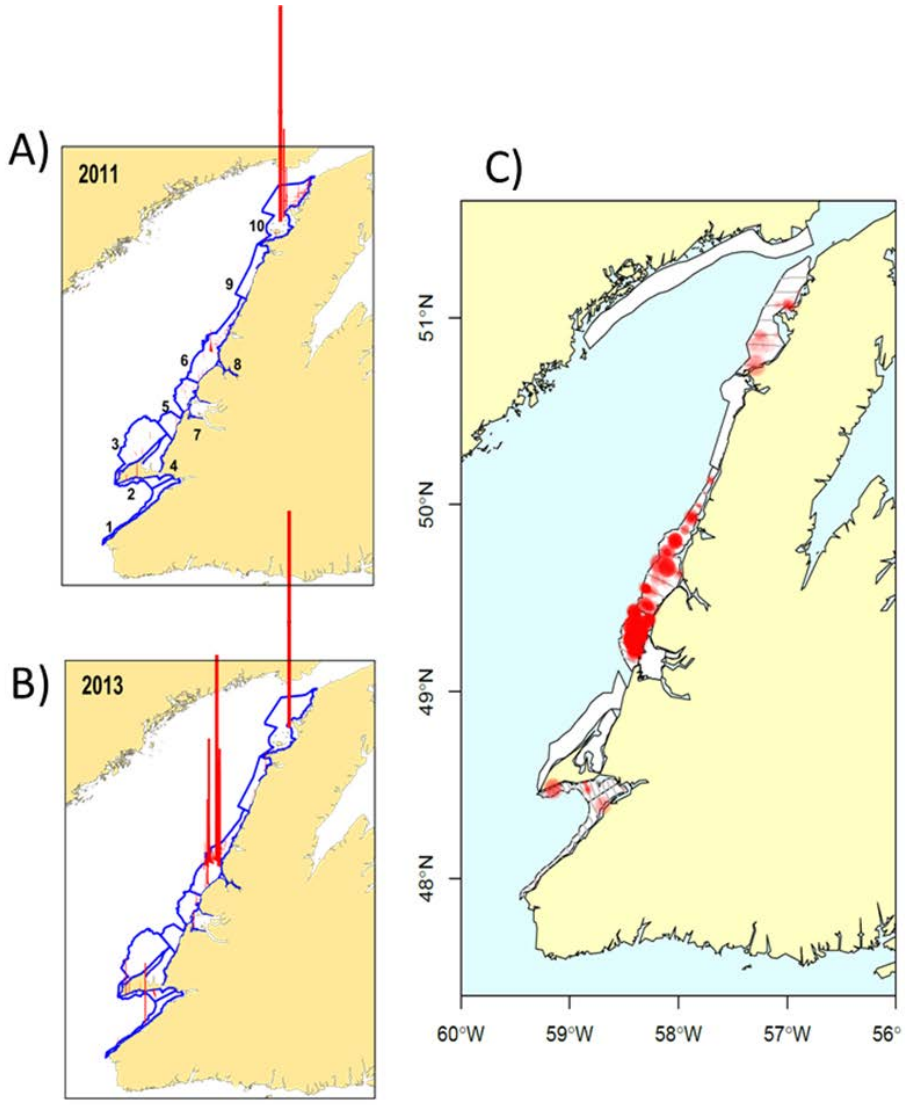

Figure 8. Herring density distribution (acoustic signal) along the west coast of Newfoundland in the fall of 2011 (A), 2013 (B) and 2015 (C). Completed transects are indicated (grey lines).

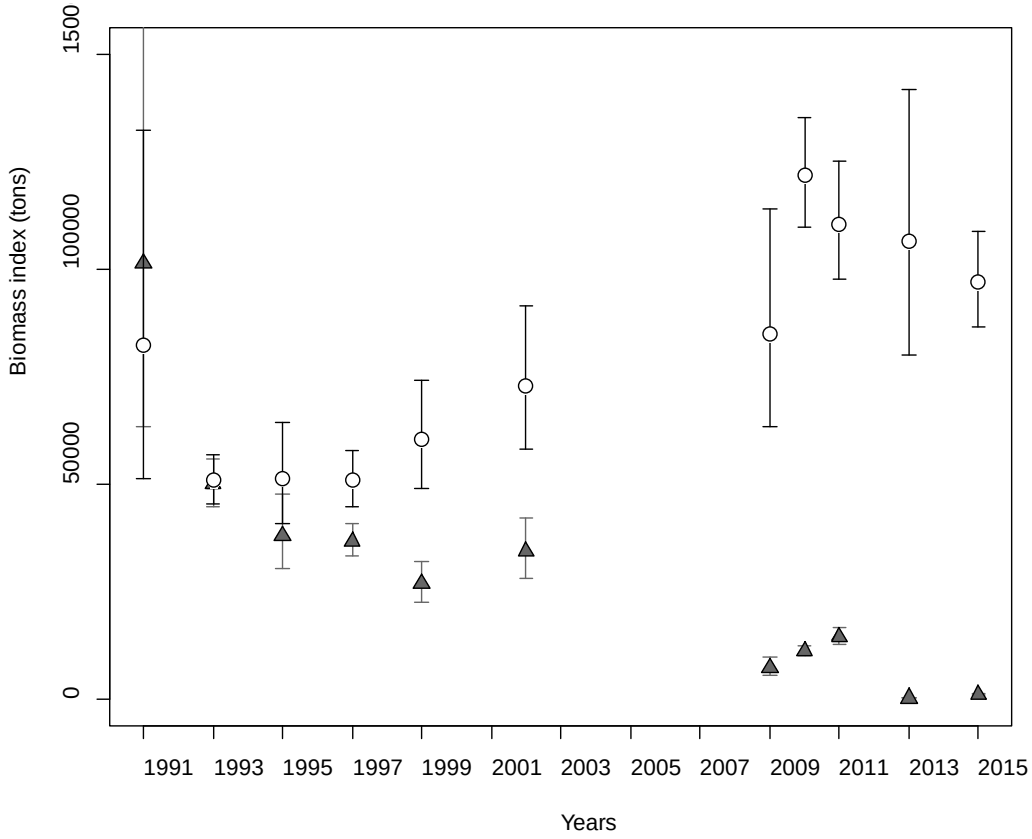

Figure 9. Total biomass index (with 25% – 75% quantiles) for the 11 surveys of spring (triangles) and fall (circles) spawning herring stocks on the west coast of Newfoundland (NAFO Division 4R) estimated by the acoustic survey.

Analytical Assessment

A sequential population analysis (SPA) using data from the commercial fishery was tuned with the abundance indices from the 11 acoustic surveys from 1991 to 2015. For spring spawners, the SPA confirms the spring-spawning stock's strong decline (Figure 10A) and indicates that its current spawning biomass is below the limit reference point (LRP = 37,000 t, URP = 57,000 t), despite long-standing conservation measures.

The SPA for the fall-spawning stock shows significant retrospective patterns (Figure 10B), but concurs with the acoustic indices that the spawning biomass has experienced a strong increase from 2003 to 2010 followed by a continuous decrease until 2015. Sensitivity analyses show that the absolute value of the current biomass, as well as the timing and value of the recent biomass peak, strongly depend on which data are used. In particular, inclusion of the 2015 survey forces the model to postulate a higher biomass. Because of these retrospective patterns, the absolute biomass of the fall-spawning stock remains uncertain and use of this model was not recommended for the calculation of new reference points. However, both the SPA and the 2015 acoustic index agree that the current spawning biomass is above the upper reference point (LRP = 48,000 t, URP = 61,000 t).

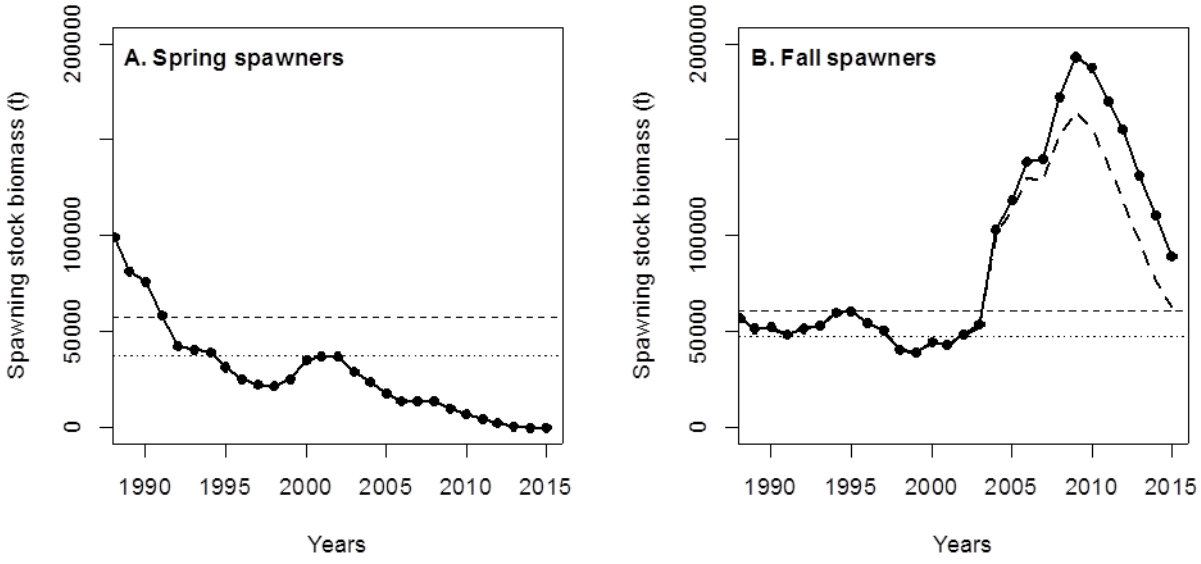

Figure 10. Spawning stock biomass estimated by the sequential population analysis for spring (A) and fall (B) spawners. The model uses all fishery data and acoustic surveys for the period 1989 – 2015. The dashed line shows the retrospective pattern observed when excluding the 2015 acoustic survey. Horizontal dashed lines: upper reference points. Horizontal dotted lines: limit reference points.

Sources of Uncertainty

Industry participants have been arguing that the acoustic surveys were being conducted too early in the season. The last five surveys were conducted between mid-October and early November. According to fishery statistics, the largest landings usually occurred during this period. In 2015, however, most of the fishing activities took place in November and December, in part because of unfavourable weather conditions in October, but this also reflects a tendency for the industry to fish later in the fall in recent years. The surveys are conducted not only in fishing areas, but also offshore in order to measure those concentrations that are migrating to the coast and could be fished afterwards. This being said, the temporal mismatch between the survey and the fishery in 2015 made it difficult to obtain biological samples for the interpretation of acoustic signals, which compromises the independence between fishery and survey data, and thus creates uncertainty around survey estimates. It would be advisable to adjust the timing of future surveys to better match the timing of the fishery if the trend of later fishing continues in the future.

It is possible that errors in the aging of herring based on otolith readings for older fish may create errors in the tracking of year-classes. This could lower the capacity of analytical models to fit the commercial catch-at-age data and be partly responsible for the observed retrospective patterns.

At the 2014 assessment, environmental models showed that interannual variations in condition index and weight-at-age of 4R herring stocks could be explained for the most part by variations in physical environmental conditions and zooplankton dynamics. Models also suggested that recruitment for the 1990–2003 period was mainly driven by environmental conditions rather than by stock size. However, predictions of these models are not in agreement with the recent population trajectory suggested by the acoustic index and the SPA for fall spawners. An analytical assessment model that could take into account different productivity regimes would improve our understanding of the effect of environmental factors.

CONCLUSION AND ADVICE

Acoustic survey results from the fall of 2015 continue to suggest the almost complete disappearance of spring-spawning herring in 4R, despited sustained conservation efforts over the last 20 years. It is likely that the population trajectory of the spring-spawning stock mostly reflects the effect of environmental changes. Nevertheless, in the absence of signs of recovery, it is recommended that the management measures implemented to protect the reproduction of this stock remain in place.

Survey results from 2015 also indicate a downward trend in the abundance of fall-spawning herring. This stock consists mainly of fish aged 10 years and more (accounting for 65% of all catches in numbers), as well as some fish from the 2008 year-class (16% of catches).

In recent years, catches of about 20,000 t have been supported for the most part by the dominant 2000 year-class of fall spawners, which has ensured stability in the herring fishery on the west coast of Newfoundland. Because of natural mortality, the old fish that have supported the fishery will continue to decline. Without strong recruitment, there is a risk that maintaining catches at their current level will bring the fall-spawning stock below the upper reference point (61,000 t) in the next few years. The 2008 year-class seems significant, but its contribution to the fishery at age 7 (in 2015) is less than that of dominant classes that have been previously observed in this stock. Catch-at-age should therefore be monitored closely until the next acoustic survey, which is scheduled for fall of 2017.

In the future, it would be advisable to improve biological sampling during the survey. More flexible statistical models could better take into account errors made in the aging of biological samples as well as the effect of environmental changes on population dynamics. It will also be important to re-examine the reference points of both spawning stocks.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 8, 2016 Assessment of the 4R herring stocks in 2015. 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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