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Quebec Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/056

ASSESSMENT OF THE WEST COAST OF NEWFOUNDLAND (DIVISION 4R) HERRING STOCKS IN 2013

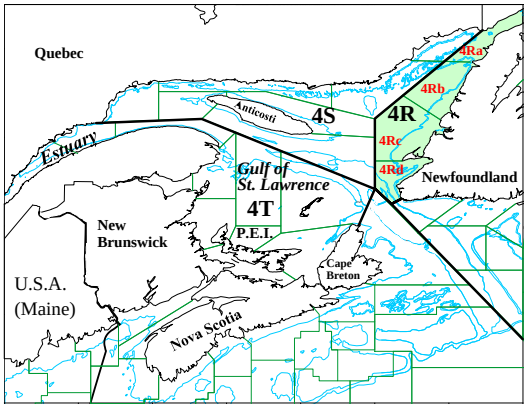

Figure 1. Map of unit areas of NAFO Division 4R (west coast of Newfoundland). Division 4R is identified by the coloured area.

Context:

Herring is a pelagic species that perform significant annual migrations associated with spawning, feeding and wintering. 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 stocks), and the west (4R stocks), 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 t since 1975. The main fishing gear is the purse seine with average annual landings of near 11,000 t. In order of important gears, the purse seine is followed by the "tuck" seine (modified bar seine), the gillnet, and the trap.

The west coast of Newfoundland herring fishery is managed by a Total Allowable Catch (TAC) associated with both spawning stocks. The current TAC of 20,000 t was set 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 following the recommendations of the Fisheries Resource Conservation Council (FRCC). This 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. This framework aims to reduce the risk of serious or irreversible damage to commercially exploited stocks.

The last assessment of the two herring spawning stocks on the west coast of Newfoundland was done in 2012. The Fisheries and Aquaculture Management Branch has requested a scientific advice on these stocks for the 2014 and 2015 fishing seasons. At a meeting held on June 11, 2014, the status of these stocks was reviewed. This paper presents the results and conclusions from that meeting.

SUMMARY

- Based on preliminary data for 2013, herring catches from the west coast of Newfoundland (NAFO Division 4R) totalled 19,364 t for a TAC of 20,000 t. The quotas allocated to the large seiner and fixed gear fleets were nearly reached whereas the quota for small seiners was slightly surpassed.
- Herring catches on the west coast of Newfoundland currently consist of older fish. In 2013, the catch at age was dominated by fish aged 8+ years. For fall spawners, age 5 herring seem relatively more abundant than in recent years.
- A significant decrease in the condition index of both spawning stocks has been observed over the past three years. These two stocks have also been characterized by a clear downward trend in mean weight at age since the early 1980s.
- For spring spawners, the proportion of mature fish at length has varied little over the years. For fall spawners, the lowest proportions of mature fish at length were observed in the 1980s and 2000s, and the highest in the 1990s and 2010s.
- Based on the acoustic survey, the total biomass index for spring-spawning herring varied between 7,448 t and 14,624 t between 2009 and 2011, then plummeted to only 335 t in 2013. In 2002, spring-spawning herring represented 29.6% of the total herring abundance compared to 0.4% in 2013.
- The acoustic survey shows that the total biomass index for fall-spawning herring has remained between 85,014 t and 121,888 t since 2009.
- An environmental model suggests that the variations in the condition index, weight at age (1990-2012) and recruitment (1990-2002) of spring and fall stocks are primarily associated with fluctuations in zooplankton dynamics and physical conditions. The analysis does not reveal that spawning biomass has a significant impact on recruitment.
- Recruitment predictions based on the environmental model for the 2003 to 2012 period suggest that recruitment of both stocks dropped in the mid-2000s. This decline was more evident in spring spawners.
- According to the environmental model, the spring-spawning stock biomass varies depending on fishing mortality, recruitment (environmental effect) and the predation mortality index, whereas the fall stock fluctuates according to recruitment and the predation mortality index. The model shows that the biomass of both stocks has declined in the last ten years.
- The vast majority of herring catches now consist of fall spawners. In recent years, catches of about 20,000 t have been supported by older fish. Given the age structure of the stocks, the current catch level should not be increased for 2014 or 2015. Moreover, with the decline in older fish and no significant recruitment, it is unlikely that the current catch level can be sustained in the medium term.
- Given the ever-decreasing spring-spawning stock, it is recommended that the management measures implemented in the late 1990s remain in place.

INTRODUCTION

Species Biology

Atlantic herring (*Clupea harengus 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. The same herring return to the same spawning, feeding and wintering sites 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 25 cm. Compared with other herring populations, the west coast of Newfoundland herring are characterized by two spawning stocks. Spring herring generally spawn in April and May, and fall herring in August and September.

ANALYSIS

The 2013 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 2013, they totalled 19,364 t compared to 19,351 t in 2012, and with an annual average (2000–2011) of 16,857 t (Table 1). A total of 7,816 t were caught in unit area 4Rb, compared to 6,548 t, 3,036 t and 1,964 t for unit areas 4Rc, 4Rd and 4Ra (Table 1).

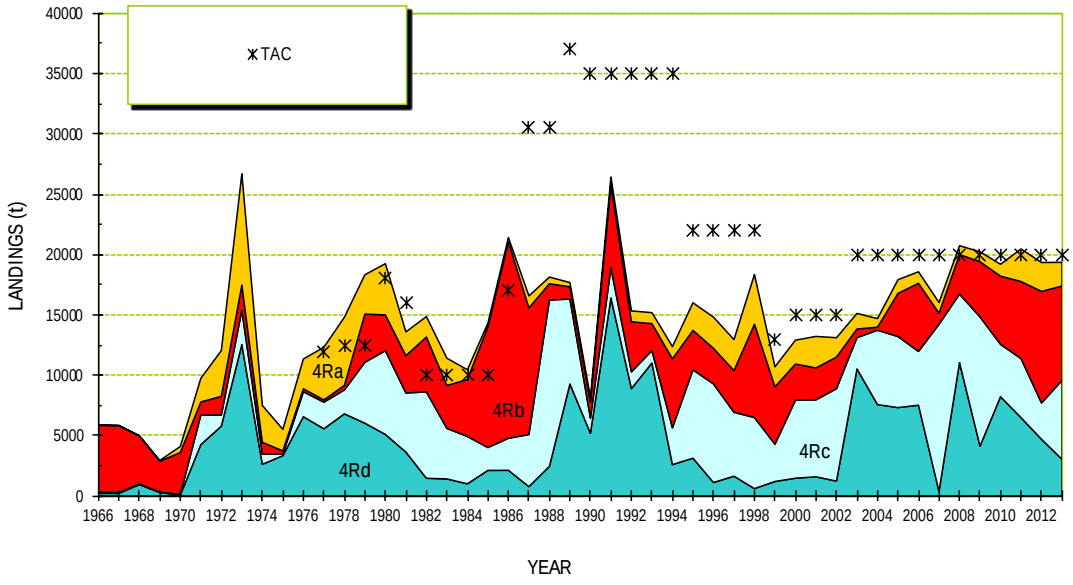

Figure 2. Herring cumulative commercial landings (t) and TACs (t) for unit areas of the west coast of Newfoundland (NAFO Division 4R), from 1966 to 2013.

On the west coast of Newfoundland, most herring landings are associated with the purse seine (Figure 3). In 2013, landings by large seiners (>65') totalled 9,996 t compared to 4,888 t by small seiners (<65'), 2,306 t by the "tuck" seine, 1,228 t by trap and 946 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 2013, the quotas allotted for the large seiners' and fixed gear fleets were almost reached whereas the quota for the small seiners' fleet was exceeded (Figure 4A). Between 1990 and 2004, fixed gear took on average only 30% of their quota. The arrival of the "tuck" seine in this fishing fleet increased the average for the 2005–2011 period to 86%.

In 2012 and 2013, catches by large and small seiners were mostly made in unit area 4Rb (Figure 4B). The "tuck" seine was used mainly in 4Rd in 2012 and in 4Rc in 2013 compared to the gillnet and the trap in 4Ra. The herring purse seine fishery is practised mainly in the fall. 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.

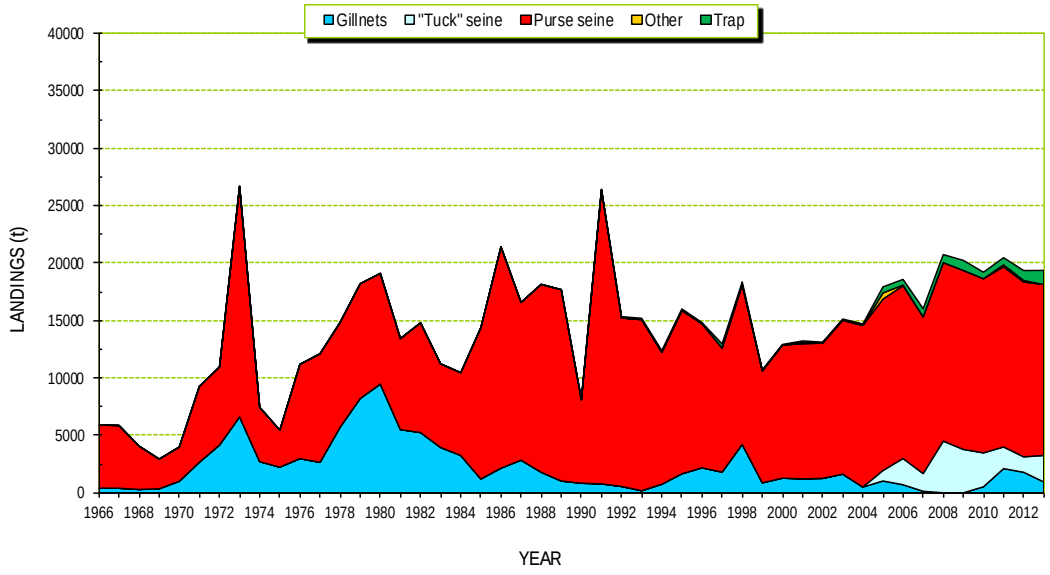

Figure 3. Herring cumulative commercial landings (t) per fishing gear for the west coast of Newfoundland (NAFO Division 4R), from 1966 to 2013.

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 (2000-2011)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*	2013*	
4Ra	1 694	1 981	2 613	1 604	1 290	713	1 138	955	885	731	821	984	2 694	2 396	1 964	1 367
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	7 816	3 271
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	3 009	6 548	6 591
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	4 696	3 036	5 628
Unknown	912	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*	
TOTAL		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	19 364	16 857

** 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 (2000-2011)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*	2013*	
Gillnet	1 378	1 277	1 216	1 257	1 629	499	1 031	702	132	3	0	525	2 107	1 790	946	865
"Tuck" seine	0	0	0	0	0	0	909	2 286	1 545	4 498	3 778	2 953	1 883	1 342	2 306	1 488
Other seine	2	0	96	13	0	2	530	53	8	0	0	0	167	138	0	72
Trap	150	59	150	73	104	127	534	498	706	700	872	560	626	862	1 228	417
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	4 888	3 744
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	9 996	10 271
TOTAL		12 915	13 224	13 117	15 131	14 701	17 928	18 582	16 034	20 742	20 236	19 205	20 470	19 351	19 364	16 857

** Preliminary data*

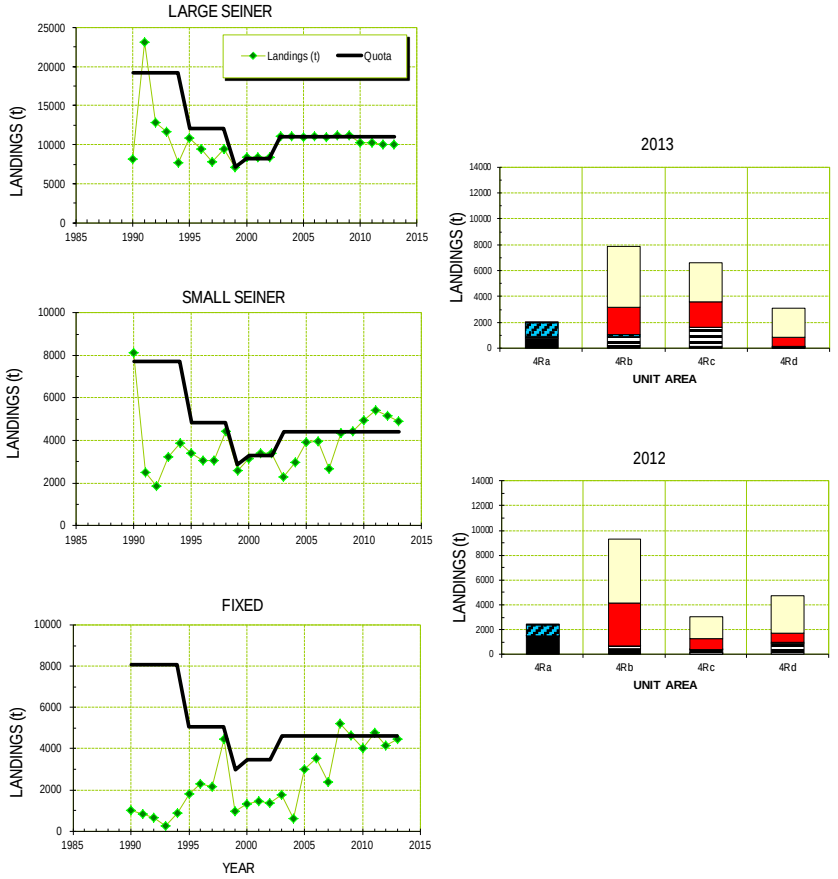

Figure 4. Herring landings (t) and quotas (t) per fishing fleet (A) and landings per fishing gear for unit areas of the west coast of Newfoundland (NAFO Division 4R) (B) in 2012 and 2013.

Biological Data

As for the age structure, length frequency analysis indicates that herring stocks on the west coast of Newfoundland are characterized by the periodic occurrence of dominant year-classes. These dominant year-classes are identified by the occurrence of a main mode that shifts toward longer lengths over the years. For spring spawners, the most recent of these year-classes was 2002 (Figure 5A) compared to the 2000 year-class of fall spawners (Figure 5B). From 2005 to 2009, this year-class alone accounted for 43% to 53% of catches (in number). However, this

proportion decreased to 18% in 2010. In 2011, herring in the 11^{+} age group, which are included in this year-class, accounted for 15% of catches. In 2013, the 2004 year-classes (age 9) and 2003 year classes (age 10) dominated the spring and fall spawners catches respectively.

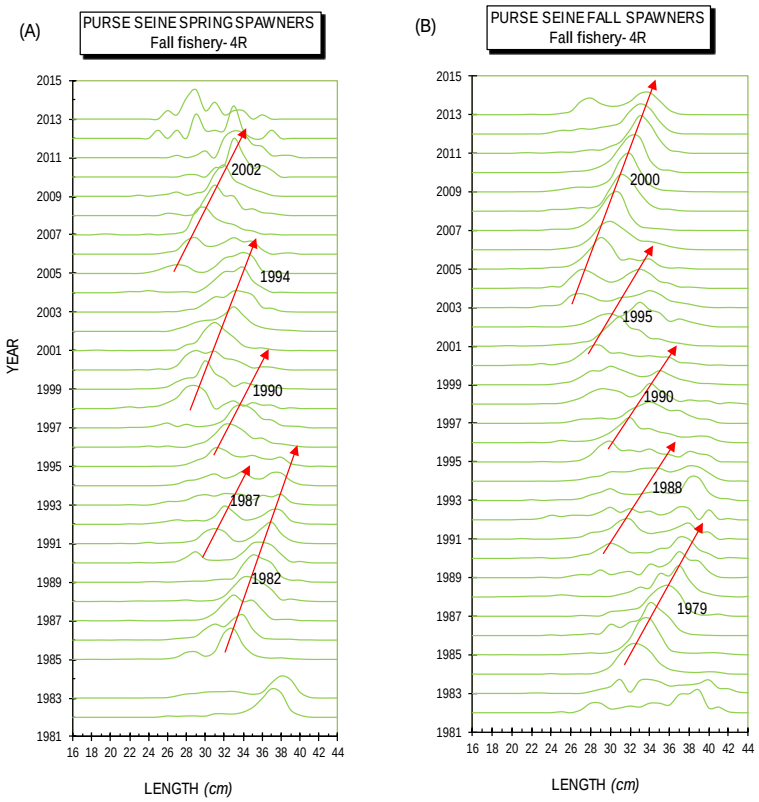

Figure 5. Annual length (cm) frequencies (%) of spring (A) and fall (B) spawning herring caught in the fall with the purse seine in Division 4R (some dominant year-classes are indicated).

For spring spawners, the proportion of mature fish at length has varied little over the years (Figure 6A). Lengths at 50% of maturity (L_{50}) were 273 mm in the 1980s compared to 266 mm and 261 mm in the 2000s and 2010s. For fall spawners, the lower proportions of mature fish at length were observed in the 1980s and 2000s and the highest in the 1990s and 2010s (Figure 6B). The length at 50% maturity was 288 mm and 276 mm in the 1980s and 2000s. This length was 270 mm and 268 mm in the 1990s and in the 2010s. For both spawning stocks, the age at 50% of maturity (A_{50}) was higher in 2010 and 2011 compared to the 2000s.

Both herring spawning stocks showed similar annual variations in their condition indices although the average condition (1970-2012) 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 such that the value measured in 2012 is among the lowest of the series. A slight increase was measured in 2013.

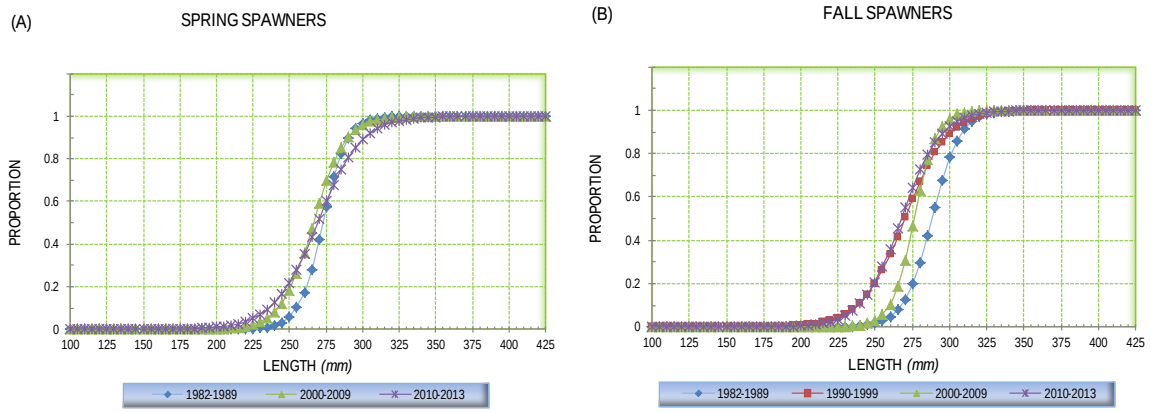

Figure 6. Proportion of maturity at length by year period for spring (A) and fall (B) spawning herring stocks of the west coast of Newfoundland (NAFO Division 4R).

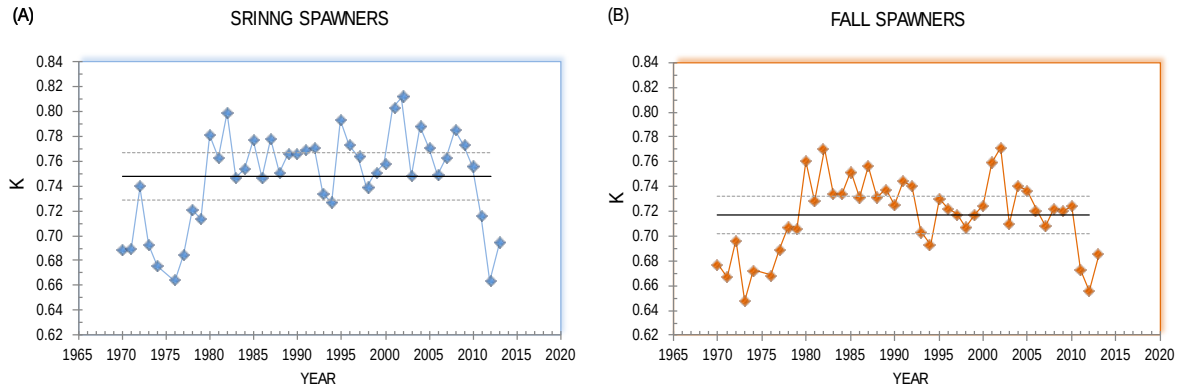

Figure 7. The average annual condition for spring (A) and fall (B) herring spawners on the west coast of Newfoundland (NAFO Division 4R). The horizontal lines show the 1970-2012 averages ± 0.5 x standard deviation.

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 following the FRCC recommendations. It was suggested at the outset that the first surveys from this new series be conducted on an annual basis to enable the fastest possible return of an analytical assessment as well as the updating of reference points. It was also decided to begin this new series of surveys on Quebec's Lower North Shore and in the northern portion of the west coast of Newfoundland so as to cover more territory than during the first series, whose surveys began further south and did not always cover the entire northern portion owing to poor weather conditions.

The 2013 acoustic survey took place between October 11 and 23. Quebec's Lower North Shore was covered first, followed by unit areas 4Ra and 4Rb (strata 10 and 9) (Figure 8). The survey then continued southward (strata 8 through 3), ending in St. George's Bay (strata 2 and 1).

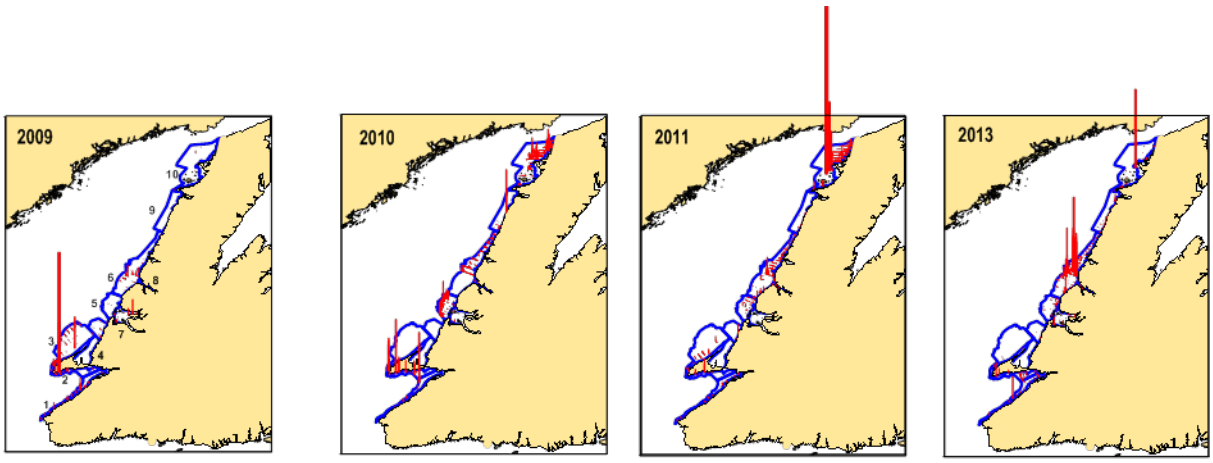

Figure 8. Herring density distribution (acoustic signal) along the west coast of Newfoundland in the fall of 2009, 2010, 2011 and 2013 (no survey was conducted in 2012). Completed strata and transect numbers are indicated; scale densities expressed by the height of the bars differ from one survey to the other.

In 2013, the most significant acoustic signals were measured in stratum 6 - a first since 2009. In 2011, the most significant signals were measured in stratum 10, compared to strata 10, 5 and 2 in 2010 and stratum 2 in 2009. With the assistance of industry, several biological samples were obtained for those strata associated with the most significant acoustic signals. For example, for strata 3 through 6, nearly 300 herring were used to convert the acoustic signals into biomass. The age structure of fall-spawning herring across all these samples (n=691) was similar to that of the commercial fishery (n=1,559) (Figure 9).

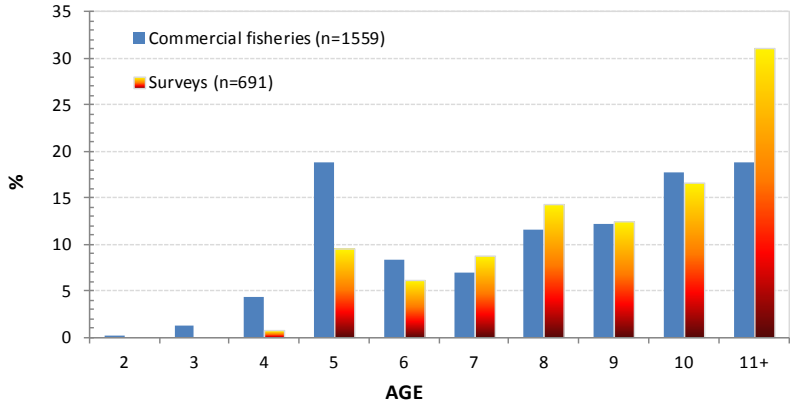

Figure 9. Age distributions of fall-spawning herring from the samples obtained from the commercial fishery and collected during the acoustic survey.

The total biomass index of spring-spawning herring fell considerably between 1991 and 1993 (Figure 10A). After some stability, this index fell again, decreasing from 34,550 t in 2002 to 7,448 t in 2009, 11,363 t in 2010, 14,624 in 2011 and finally 335 t in 2013. In 2002, spring herring accounted for 29.6% of the abundance (in number) of the two spawning stocks compared to 6.9% in 2009, 8.0% in 2010, 7,7% in 2011 and only 0.4% in 2013 (Figure 11). The mean size of herring used to calculate the biomass index was 335 mm in 2002 compared to 313 mm in 2013 (Figure 12A).

The total biomass index of fall-spawning herring also fell between 1991 and 1993 (Figure 10B). In 2009, this index was estimated at 85,014 t compared to 72,916 t in 2002. From 2010 to 2013, the index decreased from 121,888 t to 106,521 t. Note the presence of large standard deviations in 2009 and 2013.The mean size of herring used to calculate the biomass index was 329 mm in 2002 compared to 337 mm in 2013 (Figure 12B).

A) B)

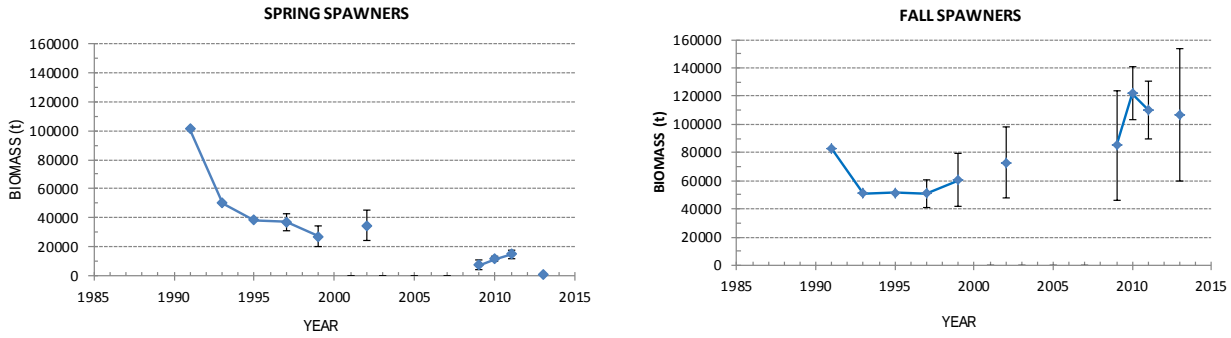

Figure 10. Total biomass index (t) (with 95% confidence intervals for the last six surveys) of spring (A) and fall (B) spawning herring stocks on the west coast of Newfoundland (NAFO Division 4R) estimated by the acoustic survey. The horizontal lines represent the 1991-2002 average ± 0.5 x standard deviation.

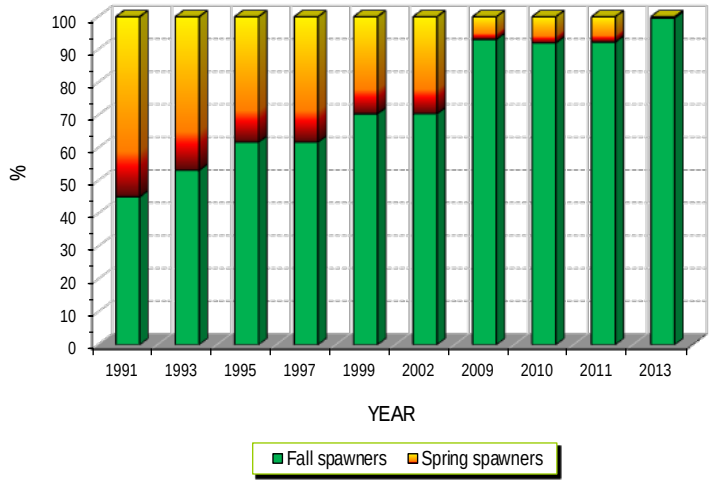

Figure 11. Percentage of the spring- and fall-spawning herring abundance (in number) estimated from the acoustic surveys.

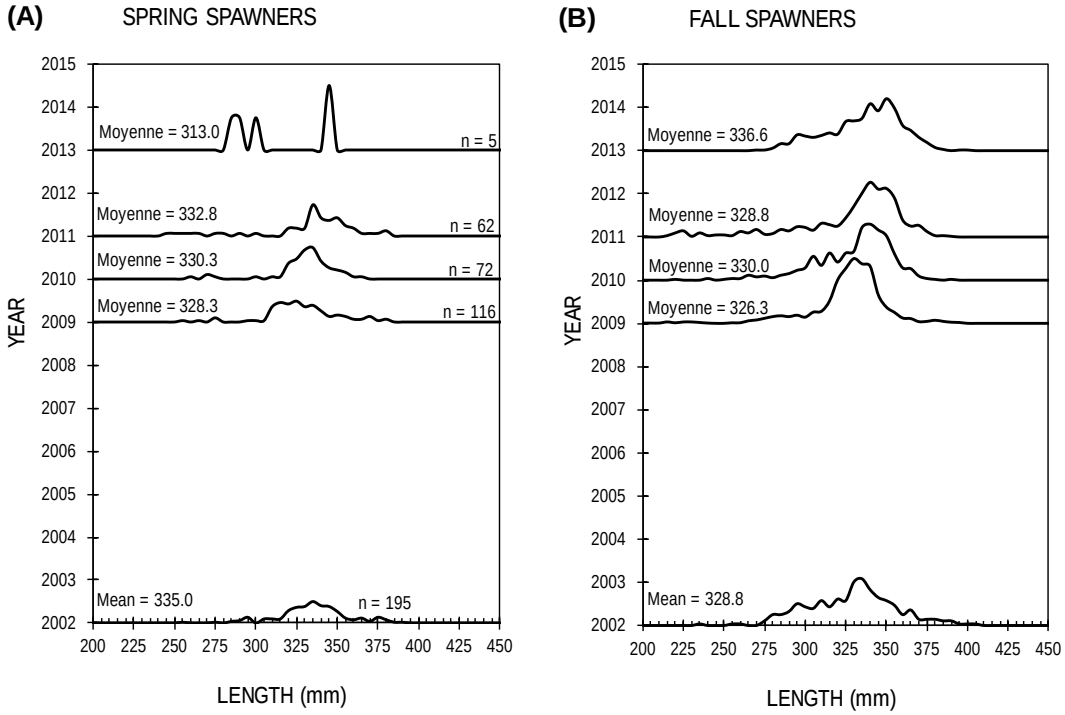

Figure 12. Length frequencies (mm) of spring- (A) and fall- (B) spawning herring used to calculate biomass indices from the acoustic survey results.

Ecosystemic considerations

Physical environmental conditions and zooplankton dynamics have shown important variations in the Gulf of St. Lawrence at various temporal scales, with evidences for a strong link between physical processes and zooplankton productivity. Environmental models were built with the aim of describing potential effects of these environmental variations and reproductive biomass on the condition and weight-at-age of 4R herring from 1990 to 2012. Results show that changes in physical environmental conditions and zooplankton dynamics explain most of the variability in body condition and weight-at-age of the spring and fall stocks (see Fig. 13 for weight-at-age). These models accurately predict the very low weight-at-age observed over the last few years resulting from a gradual decrease initiated in 2004 for both stocks (Fig. 13).

The analyses also suggest that recruitment of the spring and fall stocks from 1990 to 2003 was mainly affected by the environmental conditions, variations in the productivity of these stocks being not associated to the variations in spawning stock biomass (Fig. 14). Predictions made with these models from 2004 to 2012 suggest that recruitment of these two stocks would have suddenly decreased during the mid-2000s, this event being followed by a sharp decrease in recruitment of the spring stock until 2012 (Fig. 14). These results suggest that changes in environmental conditions could have had affected the productivity of these two 4R herring stocks, even more so in the case of the spring stock.

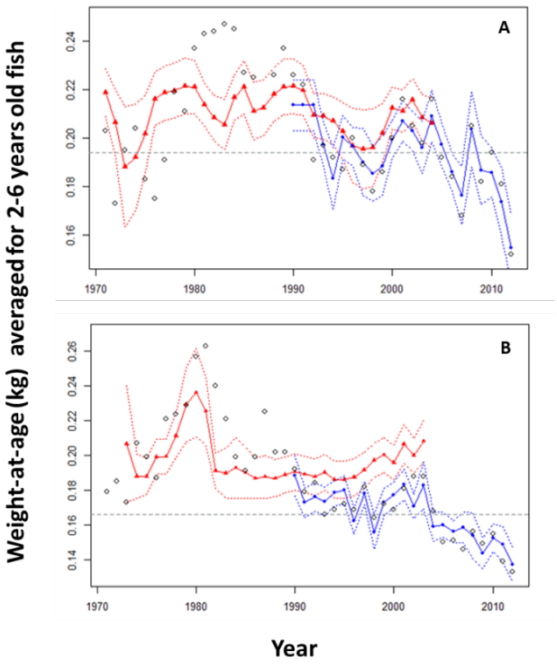

Figure 13. Environmental models performance of the weight-at-age averaged for 2-6 years old spring (A) and Fall (B) 4R herring. White circles: observations based on independent biological samples. Red: predictions based on the effect of spawning stock biomass alone. Blue: predictions based on the effect of environmental variations from 1990 to 2012. Dotted lines: uncertainty (2 s.d.) around predicted values.

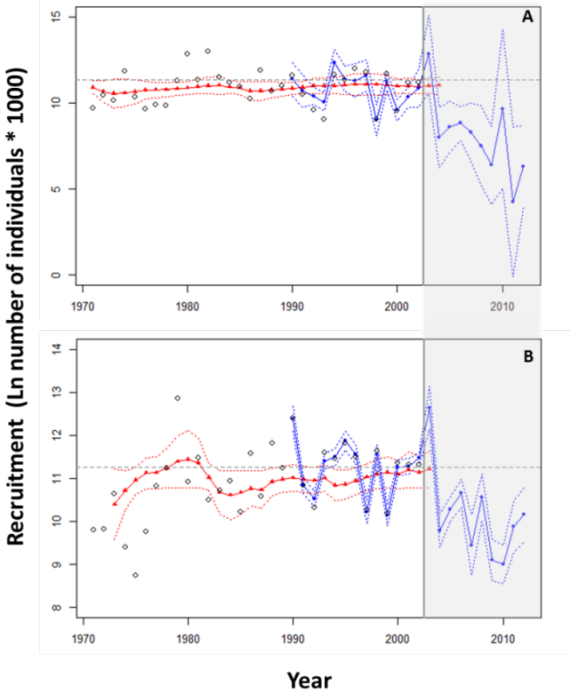

Figure 14. Environmental models performance of the Spring (A) and Fall (B) 4R herring recruitment. White circles: observations based on a Virtual Population Analysis (VPA). Red: predictions based on the effect of spawning stock biomass alone. Blue: predictions based on the effect of environmental variations from 1990 to 2003. Dotted lines: uncertainty (2 s.d.) around predicted values. Grey area: period without a VPA.

The potential effect of variations in recruitment, weight-at-age, fishing mortality and in a predation index on the reproductive stock biomass was also explored with environmental models. Results suggest that variations in recruitment (mainly environmentally-driven) and in the predation index would largely explain spawning stock biomass fluctuations of the Spring and Fall stocks, the former being also affected by fishing mortality (Fig. 15). The combined effect of these factors largely explained the decreasing tendency estimated for these two stocks with the VPA ran from 1971 to 2003 (Fig. 15).

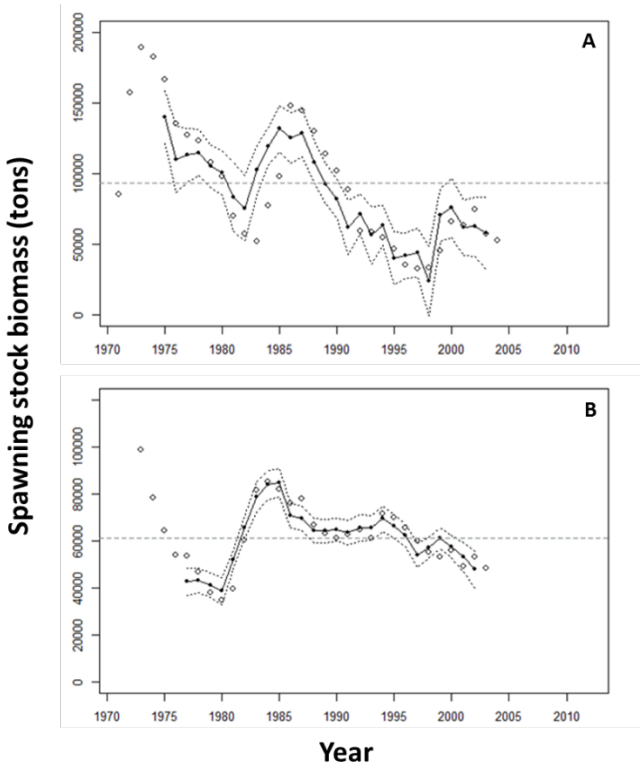

Figure 15. Environmental models performance of the Spring (A) and Fall (B) 4R herring spawning stock biomass from 1971 to 2003. White circles: observations based on a Virtual Population Analysis (VPA). Black circles: predictions based on the effect of environmental variations. Dotted lines: uncertainty (2 s.d.) around predicted values.

Analytical Assessment

Exploratory sequential population analyses were conducted using abundance data from the last four acoustic surveys. Adjustment problems occurred for the models particularly in recent year-classes owing to the low number of surveys.

Sources of Uncertainty

The main source of uncertainty concerning the 4R herring fishery is the lack of statistics for the gillnet bait fishery. There are currently more than 300 licenses for bait in St. George's Bay, Port au Port Bay and Bay of Islands. This bait fishery is practised during the lobster fishery season and therefore targets spring-spawning herring, whose abundance is always at very low levels. However, the industry has recently proposed an interesting approach to calculating these bait catches. After some adjustments, this approach could be an appropriate solution to this problem.

Industry members mentioned that the acoustic surveys were being conducted too early in the season. The last four surveys were conducted between mid-October and early November. According to fishery statistics, the largest landings occur during this period. 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 that could be fished afterwards. December is apparently not the best month for such a survey, because few catches are made that month. For example, in 2011 and 2013, 8% of annual landings were made in December, compared to 39% in 2010 and only 3% in 2009.

CONCLUSION AND ADVICE

Acoustic survey results from the fall of 2013 suggest the almost complete disappearance of spring-spawning herring. Predictions made using the environmental model indicate that recruitment and weight-at-age for this stock have declined dramatically since the mid-2000s owing to changing environmental conditions. Therefore, in the absence of signs of rebuilding, it is recommended that the management measures implemented several years ago to protect the reproduction of this stock remain in place. However, despite these measures, stock status levels remain very low.

Survey results from 2013 also indicate a slight decrease in the abundance of fall-spawning herring. This stock consists mainly of older fish. In 2013, fish aged 8 years and over accounted for 65% of all catches (by number). The other year-classes were dominated by the 2008 year-class with 16% of catches. Predictions made using the environmental model indicate that recruitment and weight-at-age for this stock have fallen below their long-term average since the mid-2000s, which seems consistent with the lack of strong year-classes over the last decade. These characteristics therefore indicate that this stock's productivity was below the long-term average over the last 10 years.

In recent years, catches of about 20,000 t have been supported by the dominant 2000 year-class of fall spawners. This year-class alone has ensured stability in the herring fishery on the west coast of Newfoundland over the past few years. With the decline of this year-class, and without strong recruitment, it is unlikely that catches of about 20,000 t can be sustained in coming years. The 2008 year-class seems significant, but its contribution to the fishery at age 5 (in 2013) is less than those of the dominant classes that have already been observed in this stock.

The dispersal of fishing effort along the coast and throughout the year is recommended where possible to support the conservation of the two spawning stocks.

Without abundant recruitment, the current catch level (20,000 t) should not be increased for 2014 and 2015. Catch-at-age should therefore be monitored closely until the next acoustic survey, which is scheduled for fall 2015.

SOURCES OF INFORMATION

This Science Advisory Report is from the June 11, 2014 Assessment of the 4R herring stocks in 2013. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2012. Assessment of the West Coast of Newfoundland (Division 4R) Herring Stocks in 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/024.

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