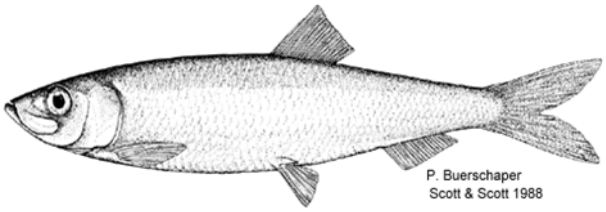
Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Maritimes Region **Science Advisory Report 2022/050**

2022 ASSESSMENT OF 4VWX HERRING



Drawing of Atlantic Herring (Clupea harengus).

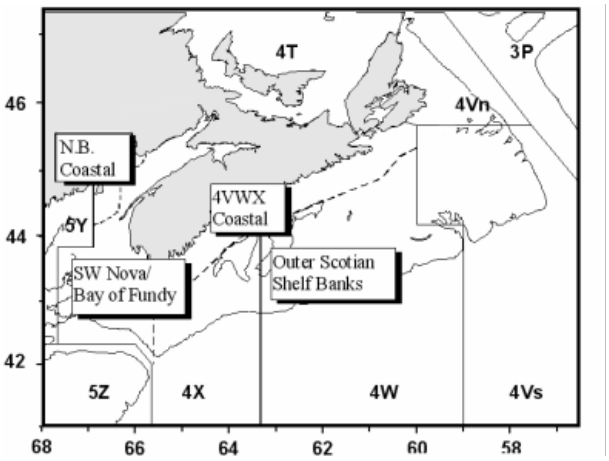


Figure 1. 4VWX Herring management area and stock component locations.

Context:

*Maritimes Fisheries and Oceans Canada (DFO) Resource Management has requested that DFO Science undertake an assessment of the North Atlantic Fisheries Organization (NAFO) Divisions 4VWX Atlantic Herring1 (*Clupea harengus*) management unit in support of the 2022 fishery. The last full assessment of the 4VWX Herring stock was conducted in March 2018 (DFO 2018), and the last update was conducted in April 2021 (DFO 2022).*

The biological and fishery information for the 4VWX Herring stock forms the basis for establishing harvest levels for the 2022 fishery, as required in the Integrated Fisheries Management Plan (IFMP). An assessment of biological and fishery information for the 4VWX Herring stock are provided in this Science Advisory Report.

A framework assessment was conducted using management strategy evaluation (MSE) from 2019 to 2022 for the Southwest Nova Scotia/Bay of Fundy (SWNS/BoF) spawning component (Singh et al. 2020, Carruthers et al. In press, Barrett In prep.[2]). The status of the SWNS/BoF component is compared to the Limit Reference Point (LRP, Clark et al. 2012). This science advice uses the 2022 framework assessment to determine whether exceptional circumstances have occurred.

DFO Resource Management requested that with this Science Advisory Report, DFO Science identify a suite of Management Procedures (MPs) that is expected to rebuild the SWNS/BoF component above the LRP with a high probability after 10–15 years. These MPs were developed by the SWNS/BoF Herring MSE Working Group and allow evaluation of tradeoffs among other management objectives.

Other spawning components for the 4VWX Herring stock are also reported based on indicators used in the 2018 stock assessment (DFO 2018).

[1] Throughout this document, 4VWX Atlantic Herring is referred to as 4VWX Herring.
[2] Barrett. T.J. In Prep. Southwest Nova Scotia/Bay of Fundy Herring: Management Strategy Evaluation Framework. DFO Can. Sci. Advis. Sec. Sci. Res. Doc. Presented at the January 16, 2022 Herring MSE Framework meeting.

This Science Advisory Report is from the March 31, 2022, regional peer review of the Stock Assessment of Herring in Northwest Atlantic Fisheries Organization (NAFO) Fishing Areas 4VWX. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule *as they become available.*

SUMMARY

Southwest Nova Scotia/Bay of Fundy Spawning Component

- Landings were 34,159 t in 2020 and 32,629 t in 2021, and the fisheries did not exceed the Total Allowable Catch (TAC) of 35,000 t for each year for the SWNS/BoF component.
- Although there is uncertainty with annual estimates of spawning stock biomass (SSB), there is a decreasing trend in the acoustic index since 1999 to present that is evident for the two remaining major spawning grounds, German Bank and Scots Bay, which are used to assess the relative stock status of the SWNS/BoF component.
- Since 2018, the three-year moving average acoustic index of SSB from Scots Bay and German Bank, that is used to determine stock status, has been below the Limit Reference Point (LRP). The SWNS/BoF stock is in the Critical zone according to DFO's Precautionary Approach (PA) policy. The PA policy requires that exploitation be kept at the lowest possible level until the stock is considered to be out of the Critical zone.
- For every surveyed spawning ground (Scots Bay, German Bank, Trinity Ledge, Spectacle Buoy and Seal Island), spawning biomass is from 16–48% less than the 1999–2021 average biomass.
- Trinity Ledge and Seal Island were historical major spawning grounds and have not recovered.
- The age structure observed in the commercial catch indicates that the conservation objective to maintain a broad range of ages is generally being met. Industry-developed management measures that limit exploitation on juvenile fish and spawning grounds are important for sustainability. Management procedures with different selectivity for small fish were evaluated in the MSE framework. Under assumptions used in the MSE operating models, there is evidence that limiting removals of small fish can increase productivity of the stock but not to the extent that was conventionally considered.
- Since the 1970s, mean weight-at-age for Ages 4–11 has been declining and mean weight-at-age for Ages 1 and 2 has been increasing. The mechanisms influencing changes in weight-at-age for the SWNS/BoF component Herring are not well understood and require further study.

Offshore Scotian Shelf Banks

- Since 1996, a fishery has occurred on aggregations on the offshore banks, primarily in May and June, with catches ranging from 20,261 t in 1997 to 37 t in 2020. Landings have been low, far less than the 12,000 t annual allocation, since 2012. Landings from the offshore are subject to market, weather, and fish availability.
- No acoustic surveys were conducted on the Offshore Scotian Shelf during the years 2015–2021.
- In the absence of recent information about stock status, there is no basis for evaluating whether the current 12,000 t catch allocation is appropriate.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

- From 2012 to 2021, landings in the Little Hope/Port Mouton area have ranged between 2,150 t and 10,747 t, and have been near or slightly above the allocation.
- From 2012 to 2021, landings in the Eastern Shore area have ranged between 771 t and 6,871 t, and have been within the allocation.
- Landings were minimal for Glace Bay, between 0 t to 9 t annually, since 2018.
- The Bras d'Or Lakes area remains closed to Herring fishing. It has been noted since 1997 that the status of Herring in the Bras d'Or Lakes is cause for concern. In the absence of current abundance information, there is no basis for provision of Science advice on appropriate catch levels for the Bras d'Or Lakes.
- Individual spawning groups within the Coastal component are considered vulnerable to fishing because of their relatively small size (biomass) and proximity to shore. For this reason, a large effort increase in new areas has a potential to markedly reduce abundance, with limited tracking of information about the status of the individual spawning groups.
- With the exception of the four main spawning areas, the biomass of various additional spawning groups and landings from these groups are poorly documented. In addition to the traditional bait and personal-use fisheries, directed roe fisheries have occurred on several spawning grounds since 1996.

Southwest New Brunswick Migrant Juvenile

- The southwest New Brunswick (NB) weir and shutoff fisheries have relied, for over a century, on the aggregation of juvenile Herring (Ages 1–3) near shore at the mouth of the Bay of Fundy.
- The landings in this fishery are usually juveniles (Age 1 or 2), as observed in 2020 and 2021; however, the catch consisted of 55% Age 3 fish in 2019.
- NB weir landings are currently at, or near, the lowest observed values since reporting began in the 1970s. Landings for this fishery are highly variable and are not indicative of abundance because catches are susceptible to market, effort, and fish availability.

Management Procedure Performance and Exceptional Circumstances

- DFO Resource Management has requested DFO Science to use the MSE framework to identify candidate Management Procedures (MPs) that are expected to rebuild the SWNS/BoF component above the LRP with a high probability.
- Of the 11 candidate MPs evaluated, 8 MPs (Nfref, fix12.5, HS_PA_F11.8, HS_PA_F13.1a, P3.5, P3.6a, P3.7_20_80, and STEP1a) had a probability of the Spawning Stock Biomass (SSB) being above the mean SSB from 2005–2010 of at least 75% in each year from years 10–15 of the projection period for each Operating Model (OM) in the reference set of OMs.
- No exceptional circumstances were triggered during the first two projection years of the MSE framework.

INTRODUCTION

Atlantic Herring (*Clupea harengus*) is a pelagic species found on both sides of the North Atlantic. Herring spawn in discrete locations to which they have a strong affinity. The majority of

Herring in the 4VWX area are fall spawners. These Herring mature in 4VWX and first spawn at three or four years of age, then begin an annual pattern of spawning, over-wintering, and summer feeding. This often involves considerable migration and mixing with members of other spawning components and stocks. Fishing takes place on dense summer feeding, over-wintering, and spawning aggregations.

The 4VWX Herring management unit contains a number of spawning areas, separated to various degrees in space and time (Figure 1). For the purposes of evaluation and management, the 4VWX Herring fishery is divided into four stock components (see the Appendix [Figure A1] for a map of place names):

- Southwest Nova Scotia/ Bay of Fundy (SWNS/BoF) spawning component (includes Scots Bay, German Bank, Trinity Ledge, Spectacle Buoy, Seal Island, and Browns Banks),
- Offshore Scotian Shelf spawning component (includes The Patch and Western Hole),
- Coastal Nova Scotia (NS) spawning component (includes South Shore, Eastern Shore, and Cape Breton), and
- Southwest New Brunswick (SWNB) migrant juveniles (NB weirs).

Each component, except SWNB migrant juveniles, has several spawning areas, and there is mixing of fish among spawning components outside of the spawning period. The Total Allowable Catch (TAC) for SWNS/BoF was 35,000 t in 2021. The Offshore Scotian Shelf has an allocation of 12,000 t, and the Coastal NS fishing areas have allocations based on the recent 5-year average of observed acoustic index of the SSB.

It should be noted that Georges Bank (NAFO area 5Z) is also considered a spawning component but is not considered in the 4VWX Herring assessment other than to document fishing activity. There is an allocation of 20,000 t for the Georges Bank component.

The Atlantic Herring Integrated Fisheries Management Plan (IFMP) set out principles, conditions, and management measures for the 4VWX Herring fisheries (DFO 2020). The main principle stated in the plan is “the conservation of the Herring resource and the preservation of all of its spawning components”. The three conservation objectives are: to maintain the reproductive capacity of Herring in each management unit, to prevent growth overfishing, and to maintain ecosystem integrity/ecological relationships (i.e., ecosystem balance). Progress against these conservation objectives was evaluated during the March 2018 assessment (DFO 2018). A review of the assessment framework was conducted in 2006/2007 (DFO 2007), followed by another framework meeting in 2011 to review assessment models. An analytical model was not chosen at that time; however, recommendations for the assessment methodology were provided (DFO 2011). In 2012, a Limit Reference Point (LRP) for the SWNS/BoF Herring spawning component (German Bank and Scots Bay) was defined as the 2005–2010 average acoustic survey biomass (371,846 t), below which the risk of serious harm is unacceptable (Clark et al. 2012). A 3-year moving average is used to determine trends in spawning biomass of the SWNS/BoF Herring (German Bank and Scots Bay) in relation to the LRP because of the variability in the annual acoustic point estimates (Clark et al. 2012). At the 2018 assessment, revisions to the method for estimating acoustic index of the SSB turnover on the Scots Bay and German Bank spawning grounds were presented and accepted. These revisions resulted in revised acoustic index of the SSB estimates over the entire time series, including the LRP of 317,846 t[3] (DFO 2018). The indicator of stock status for SWNS/BoF is the

[3] Appears as 316,316 in DFO (2018); this value was revised to 317,846 t due to a calculation error.

3-year moving average of acoustic SSB for Scots Bay and German Bank, which is compared to the LRP (DFO 2018).

Landings from the Herring fishery in 4VWX have always been dominated by purse seine (e.g., 81–99%, 1981–2021). Other gear types include weir, gillnet, shutoff, and trap net.

ASSESSMENT

Landings

The landings for the period January 1, 2021, to December 31, 2021 (the 2021 quota year) were 32,629 t against a TAC of 35,000 t for the SWNS/BoF component (Table 1). Note that the quota year previous to 2020 was from October 15th of the proceeding calendar year to October 14th of the current calendar year. The interim landings 4WX SWNS/BoF area from October 14th 2018 to December 31st, 2019 were included the 2019 quota year landings. Since 2020, the reported fishing season is now within a calendar year of January 1 to December 31st.

Table 1. Reported landings (rounded to thousands of tonnes) and total allowable catch for the 4VWX Herring management unit by component from 2010 to 2021 with decadal averages from 1970 to 2019.

Year	Avg. 1970–79	Avg. 1980–89	Avg. 1990–99	Avg. 2000–09	Avg. 2010–19	2014	2015	2016	2017	2018	* 2019	2020	2021
4WX SWNS/BoF TAC[1]	106	106	112	69	48	50	50	50	42.5	42.5	35	35	35
4WX SWNS/BoF[1]	131	131	96	66	45	50	49	50	39	40	35	34	33
4VWX Coastal NS[2]	< 1	< 1	4	7	7	5	5	8	8	10	13	18	12
Offshore Scotian Shelf[2]	38	<0.1	13	6	4	< 0.1	2	1	4	3	6	< 0.1	< 0.9
SW New Brunswick[2]	26	24	24	15	5	2	< 0.2	4	2	12	5	4	3
Total Landings	172	155	137	93	60	57	56	63	53	65	53	56	48

1 - Quota year from October 15th of the preceding year to October 14th, 2019. *An interim catch is reported from October 15th 2019 to December 31st 2019 because in 2020 Quota year was changed to match calendar year (January 1st to December 31st).
2 - Calendar year from January 1st to December 31st.

Additional landings of 15,575 t were taken in the other components (outside the SWNS/BoF area) for a total of 48,219 t for all of 4VWX. The Coastal component had total landings of 11,990 t. Landings were 921 t for the Offshore Scotian Shelf and remained well below the 12,000 t allocation for the area. Landings for SWNB weirs and shutoffs were lower in 2021 (2,662 t) compared to 2020 (3,817 t).

Southwest Nova Scotia/Bay of Fundy

Age Structure

Age structured data are presented herein using methodology developed for the 2019 to 2022 framework for SWNS/BoF spawning component (Carruthers et al. In press., Barrett In prep.[2]).

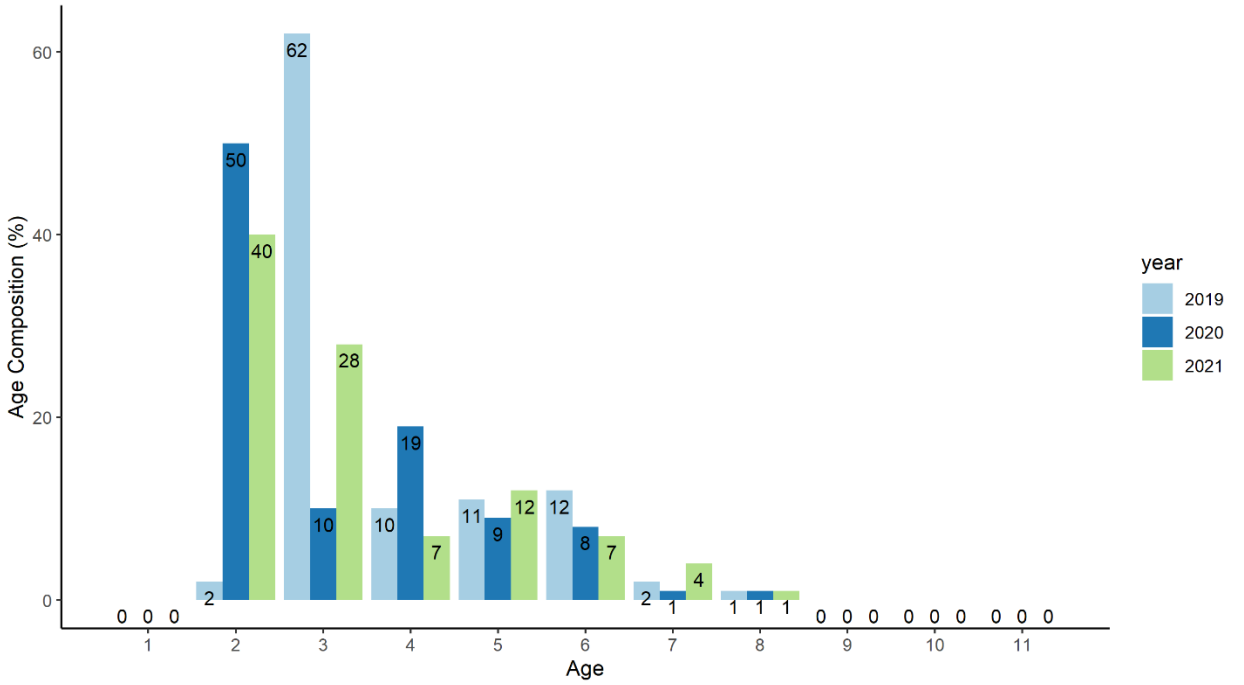


Figure 2. Commercial catch age composition (% catch by number) for Southwest Nova Scotia/Bay of Fundy spawning component for calendar years 2019, 2020 and 2021 from purse seine and gillnet gear.

The 2019 fishery landings (by number) were dominated by Age 3 fish (62%) with Age 4 (10%), Age 5 (11%), and Age 6 (12%) making up the other larger age groups (Figure 2). However, the 2020 and 2021 fishery landings were dominated by Age 2 fish. The 2020 fishery landings were dominated by Age 2 (50%) with Age 3 (10%), Age 4 (19%), Age 5 (9%), and Age 6 (8%) making up the majority of the age groups. The 2021 fishery landings were dominated by Age 2 (40%) with Age 3 (28%), Age 4 (7%), Age 5 (12%), and Age 6 (7%) making up the majority of the age groups.

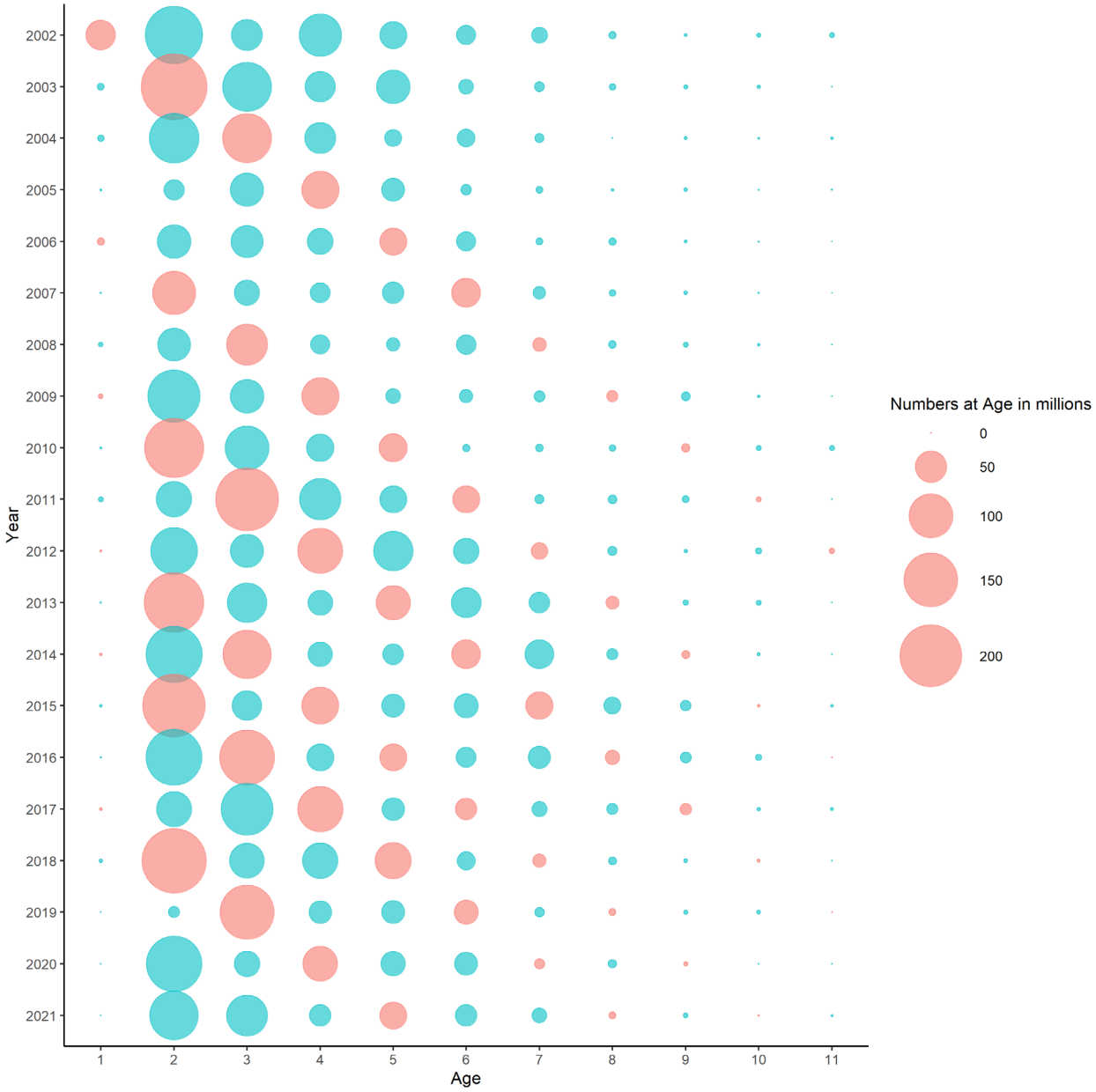


Figure 3. Numbers-at-age in the commercial landings for Southwest Nova Scotia/Bay of Fundy spawning component from 2002–2021 by quota year from purse seine and gillnet gear. The size of the bubble is proportional to the numbers by age. Selected cohort-classes from 1998, 2005, 2007, 2011, 2013, and 2016 are shown in red.

Based on the age structure, the total number of fish removed by the fishery was estimated to be 245 million in 2019, 320 million in 2020, and 305 million in 2021 (Figure 3). The 2020 and 2021 fishing seasons were estimated to harvest a higher number of fish because Age 2 fish dominated the catch in these years, whereas Age 3 fish dominated the catch in 2019.

Since the 1970s, mean weight-at-age for Ages 4 to 11 has declined and mean weight-at-age for Age 1 and 2 has increased (Figure 4). Declining trends in the older age classes in the commercial mean weight-at-age since the 1970s have reduced the productivity of the stock. The

mechanisms influencing changes in weight-at-age for SWNS/BoF component Herring are not well understood and require further study.

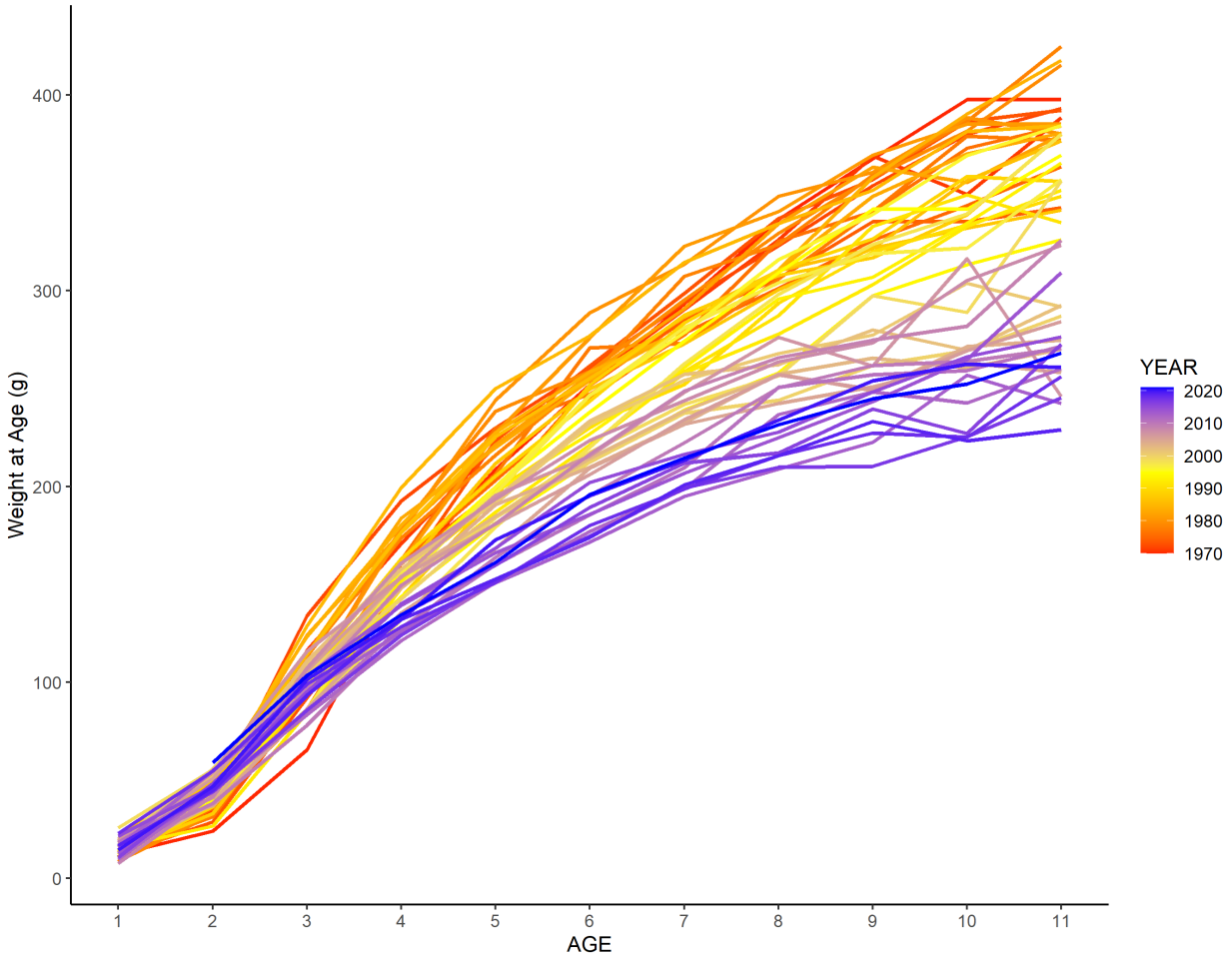


Figure 4. Fishery mean weights-at-age for the SWNS/BoF component from 1970 to 2021. Red lines indicate earlier in the time series and purple to blue lines are later in the time series.

Acoustic Surveys

Industry-led surveys with automated acoustic recording systems deployed on commercial fishing vessels were used to estimate the distribution and abundance of mainly spawning Herring aggregations. Scheduled surveys were conducted approximately every two weeks (between late-May and early-November) on the main spawning grounds, and an acoustic index of SSB for each component was estimated by summing estimates across surveys (Table 2).

At the March 2013 Assessment meeting (DFO 2013), it was noted that fish abundance could be overestimated (double-counting) or underestimated (missing fish) using the acoustic survey approach employed. Methods were presented in Melvin et al. (2014) to account for double-counting. Mark-recapture methods were used to estimate the proportion of fish remaining on the spawning grounds relative to the elapsed time between surveys. These results were used to revise the acoustic index of the SSB estimates for the entire time series, including the LRP. This resulted in a change in the absolute magnitude of the LRP from 371,067 t to 316,313 t (DFO 2018), a calculation error was identified so the LRP has since been revised to 317,846 t. Consensus was reached during the 2018 assessment to use these revised estimates as the

basis of the assessment and the advice. There was agreement to retain the current survey protocol of 10–14 days between surveys.

The results of the 2021 acoustic surveys for the SWNS/BoF component are summarized in Table 2. Inbox and outbox refer to survey tracks within and outside the designated survey boxes, respectively. There were 10 surveys in Scots Bay, 6 on German Bank, 6 on Seal Island, 5 on Trinity Ledge, and 5 in the Spectacle Buoy area. A maximum biomass estimate value is taken when surveys on Trinity Ledge, Spectacle Buoy, and Seal Island that are less than 10 days, and a single value is used in the reported biomass estimates.

The standard error and confidence interval calculations were updated using methodology applied to the data inputs for the 2019 to 2022 MSE framework. Notably, the uncertainty of the annual acoustic index of biomass estimates from acoustic energy is greater than what was considered in previous assessments.

The acoustic SSB estimates are interpreted as a relative index of biomass and not as an absolute index. The overall acoustic SSB estimate (Scots Bay, German Bank ,Trinity Ledge, Spectacle Buoy, and Seal Island) was 232,578 t (95% C.I.: +/-142,269 t) in 2021, which is lower than the 319,724 t[§] estimated in 2020 (Table 2). The overall acoustic biomass estimate in 2021 was 36% below the long-term average (1999–2021) of 361,761 t. The 2021 Scots Bay acoustic SSB estimate was 39% below the long-term average (1999–2021) at 66,977 t (95% C.I.: +/-46,729 t) in 2021. The 2021 German Bank SSB estimate is 41% below the long-term average (1999–2019) at 135,630 t (95% C.I.: +/-125,700t). For a fourth year since 2018, surveys were completed on the Seal Island spawning area with an SSB estimate of 7,334 t (95% C.I.: +/-1816t). The SSB estimate on Trinity Ledge decreased from 10,287 t in 2020 to 3,597 t (95% C.I.: +/-4,046 t) in 2021. The SSB estimate on Spectacle Buoy was 19,034 t (95% C.I.: +/-15,463 t) in 2021 an increase from 10,209 t in 2020.

[§] Acoustic estimates for 2020 were revised since DFO (2022) as sample data to inform target strength estimation were not available due to COVID-19 pandemic restrictions.

Table 2. Acoustic surveys spawning biomass index for Southwest Nova Scotia/Bay of Fundy spawning component average for 1999–2009 and biomass for 2010 to 2021 (rounded to thousands of tonnes).

Location	Avg. 1999–2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020§	2021	Avg. 2005–2010	Avg. 1999–2021
Scots Bay (inbox)	83	37	91	123	59	187	228	98	133	129	80	147	64	38	100
Scots Bay (outbox)	1	10	32	38	8	4	21	3	9	10	53	39	3	3	10
Scots Bay total	83	47	123	161	66	191	249	101	142	140	133	186	67	40	110
German Bank (inbox)	297	192	249	219	200	188	140	163	166	95	147	108	136	273	229
German Bank (outbox)	-	16	9	7	9	2	-	-	-	-	-	-	-	6	6
German Bank total	298	208	258	226	209	190	140	163	166	95	147	108	136	278	232
German + Scots	382	255	381	387	275	381	390	264	308	235	280	294	203	318	341
Trinity Ledge	8	2	7	3	1	5	1	1	14	7	20	10	4	6	7
Spec Buoy (spring)	1	2	0	-	-	-	-	-	-	-	-	-	-	1	1
Spec Buoy (fall)	44	-	-	-	-	-	-	-	9	10	23	10	19	-	23
Overall Stock Area	400	259	388	390	276	386	390	265	330	251	323	314	225	324	355
Seal Island	7	-	1	-	-	-	-	-	-	21	30	5	7	10	10
Browns Bank	26	-	-	-	-	-	-	-	-	-	-	-		8	26
Total All Areas	405	259	390	390	276	386	390	265	330	272	353	320	232	327	362

** Note: Average 2005–2010 = Limit Reference Point (German Bank and Scots Bay total only). Numbers for Scots Bay and German Bank are adjusted for turnover.*
§Acoustic estimates for 2020 were revised since DFO (2022) as sample data to inform target strength estimation were not available due to COVID restrictions.
- = no data for that year in that category.
0 = surveys conducted but the numbers recorded were either 0 or less than 500 t (rounds to 0 thousand t).

In 2021, an index of the relative exploitation rate for SWNS/BoF component estimated from total catch and acoustic index of the SSB (i.e., does not include juvenile fish) and landings was 15%, compared to a long-term (1999–2021) average of 16%.

The 2020 and 2021 acoustic catch-at-age shows fewer Age 3, Age 4, and Age 5 Herring compared to 2019, suggesting fewer young spawners on the spawning grounds for 2020 and 2021 (Figure 5, Figure 6). In 2021, older age classes Age 6, Age 7 and Age 8 dominate the age structure.

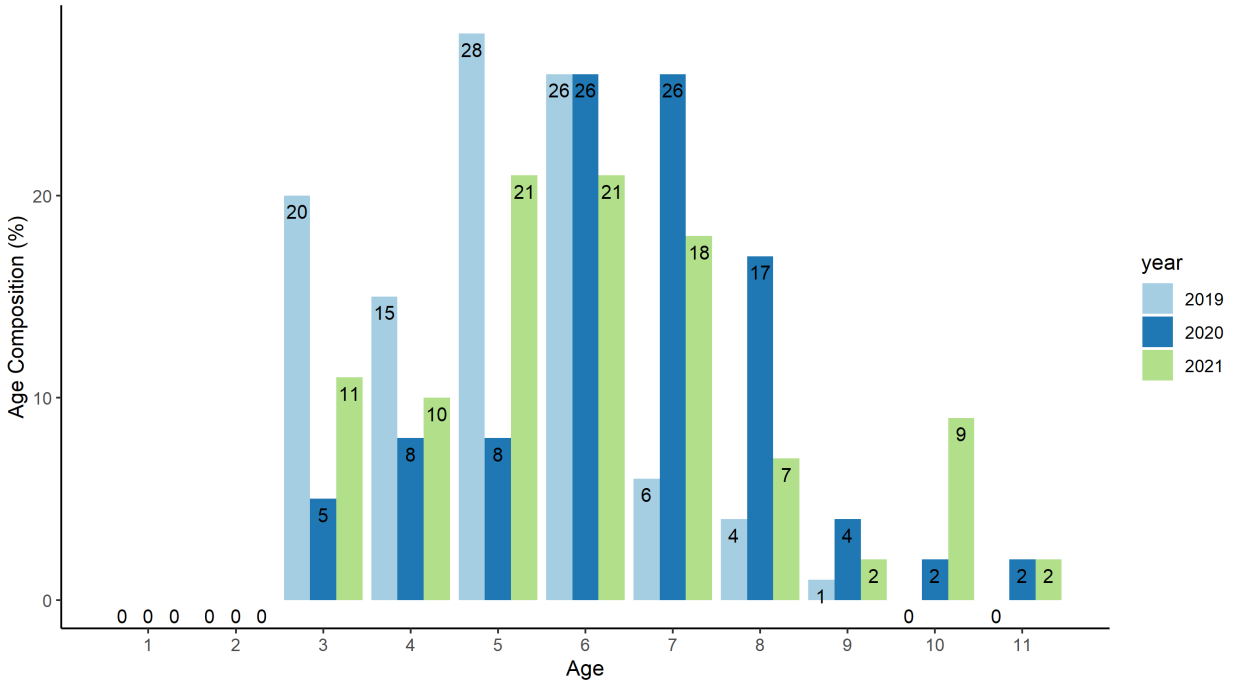


Figure 5. Acoustic survey age composition (% by number) for Southwest Nova Scotia/Bay of Fundy spawning component for Scots Bay and German Bank for calendar years (2019, 2020 and 2021) from purse seine gear.

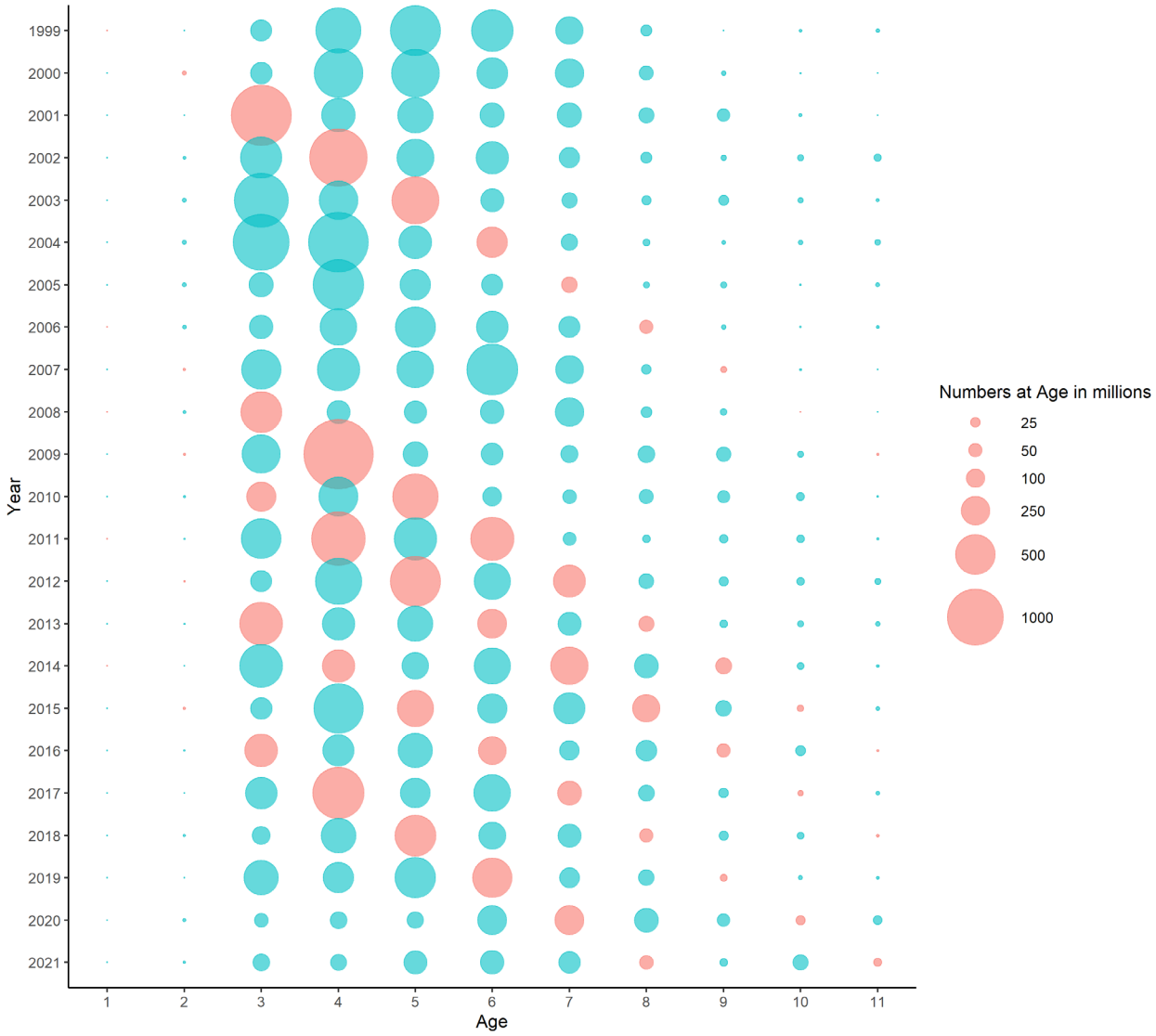


Figure 6. Acoustic survey relative numbers at age (denoted by circle size) for the Scots Bay and German Bank SWNS/BoF spawning component from purse seine gear. The size of the bubble is proportional to the numbers by age. Selected year-classes 1998, 2005, 2007, 2011, 2013 are shown in red.

Stock Status

The annual acoustic index of the SSB estimates for the past five years have been at or below the LRP (Figure 7). In 2021, the combined acoustic survey SSB estimate for Scots Bay and German Bank decreased from 293,972 t in 2020 to 202,607 t in 2021, the lowest value in the time series (Table 2). The 3-year moving average (arithmetic mean) of the summed biomass in Scots Bay and German bank is used to evaluate stock status relative to the LRP (Clark et al. 2012). The 3-year moving average of Scots Bay and German Bank decreased from 2020 (269,654 t) to 2021 (259,016 t), and remains below the LRP, and the SWNS/BoF component is considered in the Critical zone (Figure 7). The DFO PA policy (DFO 2009) states that when a stock is considered in the Critical zone, productivity is sufficiently impaired to cause serious harm.

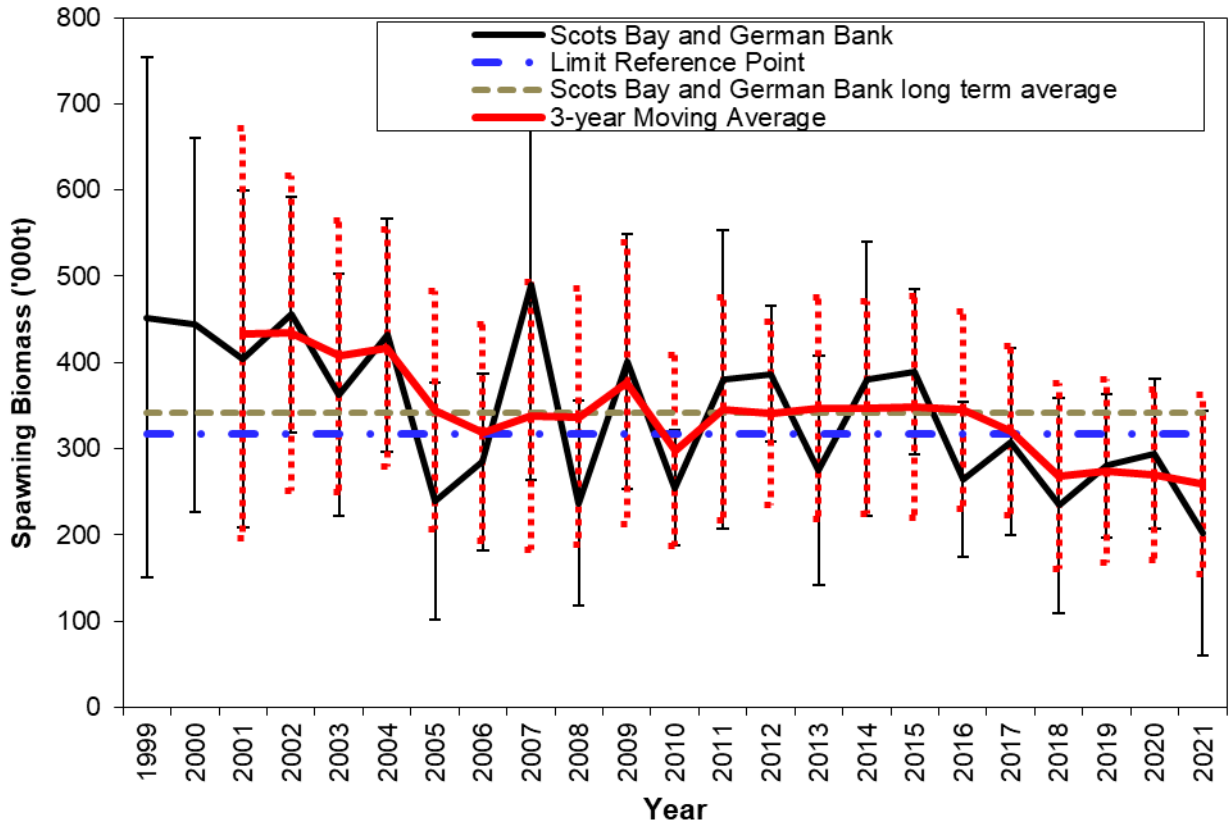


Figure 7. Acoustic index of SSB (in thousands of metric tons) (with 95% confidence intervals; black Line), the 3-year moving average (red line), the overall average since 1999 (dashed grey line), and the Limit Reference Point for the Southwest Nova Scotia/Bay of Fundy spawning component (revised 2005–2010 German Bank and Scots Bay average; dashed blue line).

Evaluation of Candidate Management Procedures

An analytical modeling framework was developed using the MSE process from 2019 to 2022 for the SWNS/BoF spawning component (Singh et al. 2020, Carruthers et al. In press., Barrett In prep.[2]). The LRP for the SWNS/BoF component is the 3-year moving average of the combined SSB for Scots Bay and German Bank (DFO 2018, Clark et al. 2012). Candidate MPs that rebuild the SWNS/BoF component above the LRP with a high probability were identified using the MSE framework. The following conservation objective was defined by DFO Resource Management to be consistent with DFO's PA policy (DFO 2009) and serves as a minimum performance standard for MP selection. The stock must be above the LRP, with at least 75% probability in each year in years 10–15 of the projection period in the closed-loop simulations to meet this objective.

Candidate MPs were defined to provide annual TAC advice as a function of the 3-year moving average, or annual values of the acoustic index of the SSB for Scots Bay and German Bank spawning grounds.

On March 16, 2022, the Scotia-Fundy Herring Advisory Committee was asked to identify preferred MPs that could be used to form the basis of management decision-making approach for the SWNS/BoF component, based on tradeoffs among management objectives. Identification of partner/stakeholder preferred MPs was not achieved during the meeting. Subsequently, DFO Resource Management requested that, with this Science Advisory Report,

DFO Science identify a suite of MPs that rebuild the SWNS/BoF component above the LRP with a high probability after 10–15 years. These MPs were developed by the Herring MSE Working Group and allow evaluation of tradeoffs among other management objectives. MPs selected for evaluation were Nfref, fix12.5, fix20, fix25, HS_PA_F11.8, HS_PA_F13.1a, P3.5, P3.6a, P3.7_20_80, STEP1a, GM_01a. The general shape of the MPs were fixed TACs, fixed harvest rates, hockey stick harvest rate MPs consistent with the provisional harvest control rule described in the PA policy (DFO 2009), and step functions (Table 3, Figure 8).

Table 3. Candidate management procedures (MPs) developed by the Herring MSE Working Group for evaluation.

MP	MP Description: All relative harvest rates (u) are defined in terms of the acoustic index of SSB (I). The MPs with variable harvesting rates are either defined as 3-year moving average of the I or the annual acoustic index	Acoustic Index Type
Nfref	No fishing reference (u=0)	n/a
fix12.5	Fixed TAC of 12.5 kt	n/a
fix20	Fixed TAC of 20 kt	n/a
fix25	Fixed TAC of 25 kt	n/a
HS_PA_F11.8	Hockey stick with (I, u) control points at (0,0%), (318, 0%), (425, 5.57%), and (∞, 5.57%)	3-yr mean I
HS_PA_F13.1a	Hockey stick with (I, u) control points at (0,0%), (318, 0%), (425, 6.14%), and (∞, 6.14%)	Annual I
P3.5	Fixed relative u of 3.5%	3-yr mean I
P3.6a	Fixed relative u of 3.6%	Annual I
P3.7_20_80	Fixed relative u of 3.7%, 20% of purse seine TAC for juvenile fish; 80% for adult fish.	3-yr mean I
STEP1a	Step function with (I, TAC in kt) line segments joining points: (0,5) to (200,5), (200,9) to (250,9), (250,11) to (300,11), (300,13) to (350,13), (350,15) to (400,15), (400,17) to (450,17), and (450,19) to (∞,19)	Annual I
GM_01a	Step function with (I, TAC in kt) line segments joining points: (0,25) to (300,30), (350,35) to (400,40), (450,45) to (500,50), (500,50) to (∞,50)	Annual I

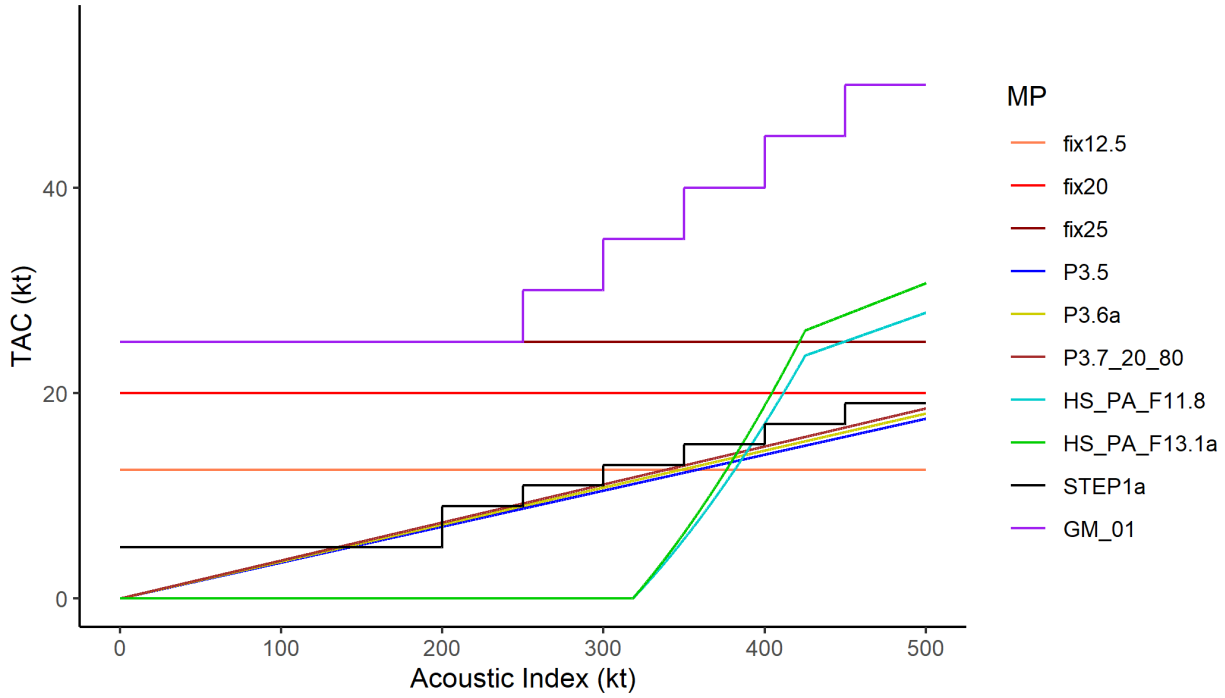


Figure 8. Plots of Total Allowable Catch vs. acoustic index of SSB (either 3-year average or 1-year annual) for fix12.5, fix20, fix25, P3.5, P3.6a, P3.7_20_80, HS_PA_F11.8, HS_PA_F13.1, STEP1a, and GM_01 Management Procedures (MPs).

Of the 11 candidate MPs evaluated, 8 MPs (Nfref, fix12.5, HS_PA_F11.8, HS_PA_F13.1a, P3.5, P3.6a, P3.7_20_80, and STEP1a) had a probability of the SSB being above the mean SSB from 2005–2010 of at least 75% in each year from years 10–15 of the projection period or each operating model (OM) in the reference set of OMs.

The 2021 annual acoustic biomass index for Scots Bay and German Bank combined is 202,607 t, and the 3-year moving average is 259,016 t. The fix12.5, P3.5, P3.6a, P3.7_20_80, and STEP1a MPs would recommend a TAC in 2022 of 12.5 kt, 9.066 kt, 7.294 kt, 9.584 kt, and 9 kt, respectively. The MPs, HS_PA_fix11.8 and HS_PA_fix13.1a, the TAC would be 0 kt for 2022 as the index is below the LRP and no fishing would be recommended with these MPs until after the 3-year average (HS_PA_F11.8) or the annual acoustic SSB index (HS_PA_F13.1a) for Scots Bay and German Bank is above the LRP. The precautionary approach requires that exploitation must be kept at the lowest possible level until the stock is out of the Critical zone. All candidate MPs that pass the conservation objective are considered to be PA compliant by having the stock above the LRP with a high probability after 1.5–2 generations (DFO 2009).

MPs that use the annual acoustic index have a higher short-term and long-term yield compared to MPs that use the 3-year moving average acoustic index. The passing MP that has the highest catch in 2022 is fix12.5. The passing MP that has the highest short yield is the HS_PA_F13.1a or P3.6a. The passing MP that has the highest long-term average yield is HS_PA_F13.1a; however, no harvesting would be allowed in the SWNS/BoF Critical component until the annual index exceeded 318 kt.

Table 4. Candidate management procedures (MPs) developed by the Herring MSE Working Group with > 75% probability of SSB above the mean SSB from 2005-2010 in each year from years 10–15, for each OM in the reference set. Projected short-term (years 1–5) and long-term (years 6–25) yield and expected Total Allowable Catch (TAC) for the 2022 fishing season if MP is used for decision making. OM(s) = Operating Model(s), SSB = Spawning Stock Biomass, n/a = not applicable.

MP	P(Model estimated SSB > Model estimated SSB 2005–2010) > 0.75 in each year in years 10–15 of the projection period for each OM in the reference set. (Pass/Fail)	Projection Year that model estimated SSB > model estimated SSB2005–2010 and probability (in brackets) across reference OMs	Projected Short Term Yield (year 1-5) median (min-max) in kt across reference OMs	Projected Long Term Yield (year 6–25) median (min-max) in kt across reference OMs	Total Allowable Catch (in kt) Recommended by each MP for the 2022 fishing season
Nfref	Pass	Year 6 (0.797)	0	0	0
fix12.5	Pass	Year 10 (0.752)	12.5	12.5	12.5
fix20	Fail	n/a	n/a	n/a	n/a
fix25	Fail	n/a	n/a	n/a	n/a
HS_PA_F11.8	Pass	Year 6 (0.767)	7.6 (5.3–9.6)	37 (26–45)	0
HS_PA_F13.1a	Pass	Year 10 (0.767)	14 (10–17)	38 (27–48)	0
P3.5	Pass	Year 10 (0.752)	12 (11–13)	27 (20–33)	9.066
P3.6a	Pass	Year 10 (0.752)	14 (12–16)	28 (21–34)	7.294
P3.7_20_80	Pass	Year 10 (0.753)	13 (12–13)	29 (21–35)	9.584
STEP1a	Pass	Year 10 (0.755)	13 (12–13)	17 (15–18)	9
GM_01a	Fail	n/a	n/a	n/a	n/a

Exceptional circumstances are commonly defined in MSE frameworks to address situations outside the range for which the MP was simulation-tested or when the data required to apply the MP are not available. The exceptional circumstance protocol were defined within the 2022 MSE framework (Barrett In prep.[2]). These provisions can be applied by decision-makers to amend the catch limits set by a candidate MP or to revise the MP itself, or in worst-case situations revise OMs, but application of these revisions should not be a frequent occurrence.

The acoustic index of SSB in the SWNS/BoF Herring MSE is estimated at the end of the calendar year after removing the annual catches. The estimated index in projection Year 1 and 2 in the MSE, therefore, correspond to the 2020 and 2021 observed acoustic index values. Therefore, the default MP to evaluate the exceptional circumstances for the observed index was a fixed TAC of 35,000 t, to reflect the catches in 2020 and 2021. The exceptional circumstances were evaluated for the 2021 fishing season and included estimates of the index for 2020 and 2021. No exceptional circumstances occurred. Results are reported below for each of the established exceptional circumstances:

1. The acoustic index of SSB Observed index is outside the 90% prediction interval (5th and 95th percentiles) for all OMs in the reference set in a single year.

   The 2020 annual acoustic index of SSB for Scots Bay and German Bank was 294 kt. This is within the 5th and 95th percentiles (minimum of 174.3 kt and maximum of 468 kt) across all OMs for year 1 projection. The 2021 annual acoustic index of SSB for Scots Bay and German Bank was 200 kt. This is within the 5th and 95th percentiles (minimum of 127.6 kt and maximum of 717.4 kt) across all OMs for year 2 projection.

2. Mean weight-at-age for Age 3, 4, 5, 6, or 7 is above/below the upper/lower 98% (2-tailed) prediction interval for the predicted weight-at-age for growth scenario Binv/B.

   Observed mean weight-at-age in 2021 for Age 3 to 7 fish were within the lower/upper 98% (2-tailed prediction interval for the growth scenario B/Binv. The mean weights-at-age were 103 g, 135 g, 161 g, 196 g, 216 g for Age 3, 4, 5, 6, and 7 Herring, respectively. Note that as the projection year advances the uncertainty in the predicted lower and upper weight-at-age decreases and increases, respectively.

Table 5. Upper and Lower 98% prediction intervals for mean weight-at-age (g) for 2021 (projection Year 1) compared to observed mean weight-at-age taken from commercial catch samples in 2021.

Age	Predicted Lower	Predicted Upper	Observed mean 2021
3	77	115	103
4	114	147	135
5	141	169	161
6	161	200	196
7	186	221	216

3. Weir landings > 50% of SWNS/BoF TAC.

   In 2021, weir landings were 10.9% of the TAC.

4. Evidence that the catch for quota fisheries for the SWNS/BoF stock area > 10% more than TAC.

   There is no evidence to suggest that these fisheries exceeded the quota in 2021.

5. DFO Science identifies new data to suggest that data inputs or model assumptions are no longer valid.

   The framework was accepted by DFO in 2022. Assumptions are considered valid.

6. The acoustic index of SSB is not available or is insufficient to apply the MP.

   There was sufficient coverage in the acoustic surveys to apply to the MP for 2021.

7. Estimates of SSB from secondary spawning grounds in the SWNS/BoF stock area become significant in magnitude. Such that an acoustic estimate of SSB on the spawning grounds outside of German Bank and Scots Bay is greater than observation error on the index for two consecutive years.

   The observation error for German Bank and Scots Bay across all years (1999–2021) was 30.4% Coefficient of Variation (CV). Therefore, the observation error for Scots Bay and German Bank was 89,367 t for 2020 and 60,939 t for 2021. The total combined biomass of spawning grounds outside of German Bank and Scots Bay (i.e., Trinity, Spectacle Buoy, and Seal Island) were 31,618 t in 2020 and 23,599 t in 2021. This observation error of 30.4% will be used to determine whether this exceptional circumstance is triggered in future years.

Offshore Scotian Shelf Component

In 2021, offshore landings were 921 t (Table 1). These landings are negligible compared to the allocation limit of 12,000 t. Since 1996, a fishery has occurred on aggregations on the offshore banks, primarily in May and June, with catches ranging from 20,261 t in 1997 to 37 t in 2020. Landings have been low, far less than the 12,000 t annual allocation, since 2012. Landings from

the offshore are subject to market, weather, and fish availability. No acoustic surveys were conducted on the Offshore Scotian Shelf during the years 2015–2021.

Coastal Nova Scotia (South Shore, Eastern Shore and Cape Breton) Spawning Component

Allocations for the Coastal NS spawning component are based on the recent 5-year average of observed acoustic index of the SSB, where available. Landings in the Little Hope/Port Mouton area were 6,355 t against the 2021 allocation of 8,622t. The 2021 landings were less than landings in 2020 at 10,747 t (Table 6). In the Eastern Shore area, landings were 5,635 t in 2021 against the 2021 allocation of 6,649 t. The 2021 landings were less than landings in 2020 at 6,871 t (Table 6). In Glace Bay, landings of 0 t were reported in 2021, and have been between 0 t to 9 t since 2018. The Bras d'Or Lakes area remained closed to Herring fishing.

A maximum biomass estimate value is taken when surveys on Little Hope/Port Mouton and Eastern Shore that are less than 10 days, and a single value is used in the reported biomass estimate.

The acoustic index of the SSB for the Little Hope/Port Mouton area increased to 71,421 t in 2021 from 31,344 t in 2020[§] and is below the 5-year average of 85,952 t (Table 7).

The acoustic index of the SSB for the Halifax/Eastern Shore area decreased to 16,425 t in 2021 from 35,835 t in 2020[§] and is below the 5-year average of 56,985 t (Table 7). As in previous years, caution is warranted in applying the acoustic index of the SSB as an absolute tonnage of Herring in the water.

Since 2013, no survey has been completed in Glace Bay.

[§] Acoustic estimates for 2020 were revised since published (DFO 2022) as sample data to inform target strength estimation were not available due to COVID-19 pandemic restrictions.

Table 6. Recorded landings and allocations (tonnes) of Herring from major gillnet fisheries on the Coastal Nova Scotia spawning component average for 1998 to 2011 and biomass for 2012–2021. Landings reported are from the MARFIS database and include Herring landed outside of the allocation season.

Landings and Allocations (t)		Avg. 98–11	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Little Hope/Port Mouton	Catch	2,587	2,150	2,499	3,596	4,160	5,943	5,557	7,353	8,707	10,747	6,355
	Allocation	2,511	2,188	2,387	3,577	3,772	6,151	6,803	7,884	9,757	10,676	8,622
Halifax/Eastern Shore	Catch	2,727	771	1,390	1,163	1,001	1,837	2,259	2,553	4,544	6,871	5,635
	Allocation	3,395	2,920	2,427	1,959	1,066	1,884	2,856	3,960	4,671	7,303	6,649
Glace Bay	Catch	1	7	2	1	0	4	0	9	1	2	0
Bras d'Or Lakes	Catch	0	0	0	0	0	0	0	0	0	0	0

Table 7. Estimated acoustic index of the Herring spawning stock biomass (tonnes) average for 1998–2011, biomass for 2012 to 2021 and recent 5-year average for the Coastal Nova Scotia spawning component areas.

Acoustic index of SSB (t)	Avg. 98–11	2012	2013	2014	2015	2016	2017	2018	2019	2020§	2021	Avg. last 5 years
Little Hope (SSB)	26,136	12,756	73,992	46,077	145,395	61,408	66,815	168,164	92,019	31,344	71,421	85,952
Allocation	2,511	2,255	2,421	3,577	3,772	6,151	6,803	7,884	9,757	10,676	8,622	-
Halifax (SSB)	31,874	3,668	6,870	9,586	68,562	54,312	58,681	42,416	141,198	26,205	16,425	56,985
Allocation	3,395	3,041	2,630	2,240	1,066	1,884	2,856	3,960	4,671	7,303	6649	-
Glace Bay	7380	51	-	50	-	-	-	-	-	-	-	-
Bras d'Or Lakes	300	-	-	-	-	-	-	-	-	-	-	-

"-" = no survey

Southwest New Brunswick Migrant Juveniles

The southwest New Brunswick weir and shutoff fisheries have relied, for over a century, on the aggregation of juvenile Herring (Ages 1–3) near shore at the mouth of the Bay of Fundy (Figure 9). These fish are considered to be a mixture of juveniles, and are conventionally considered to be dominated by fish originating from NAFO Subarea 5 spawning components and have, therefore, been excluded from the SWNS/BoF quota.

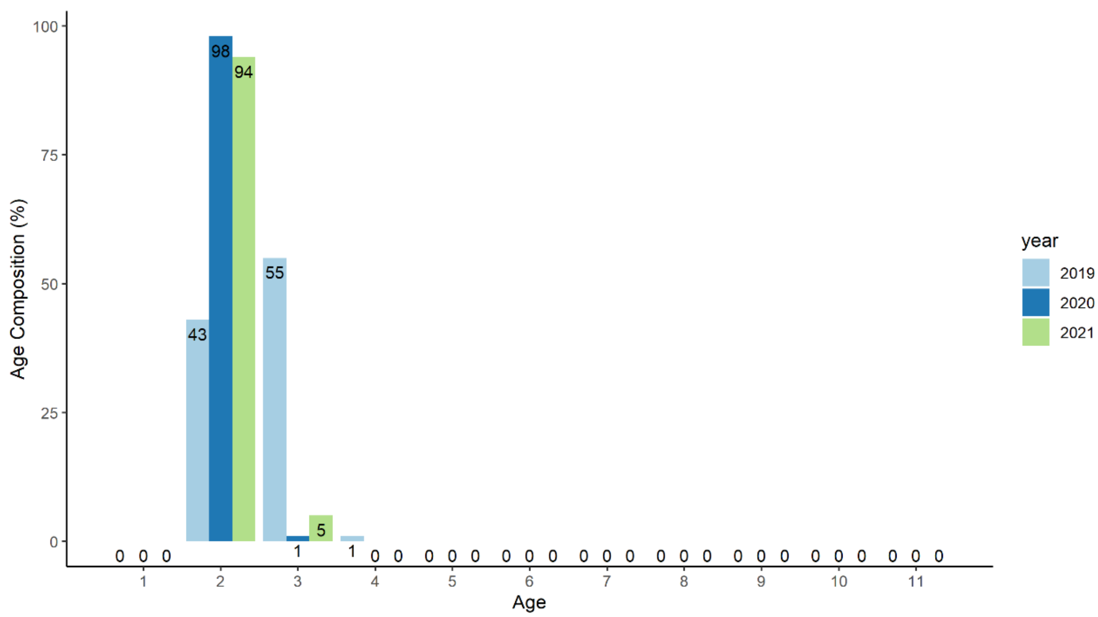


Figure 9. Age composition (% by number) for the SWNB migrant juveniles (weir and shutoff gear) for calendar years (2019, 2020 and 2021).

Landings from the New Brunswick weir and shutoff fishery were 2,625 t in 2021, which is lower than the 3,817 t landed in 2020 (Figure 10). The age distribution in 2019 was mostly juveniles Age 3 (55%), and Age 2 (43%). In 2020 and 2021, Age 2 dominated the fishery with 98% and 94% in the landings, respectively (Figure 9).

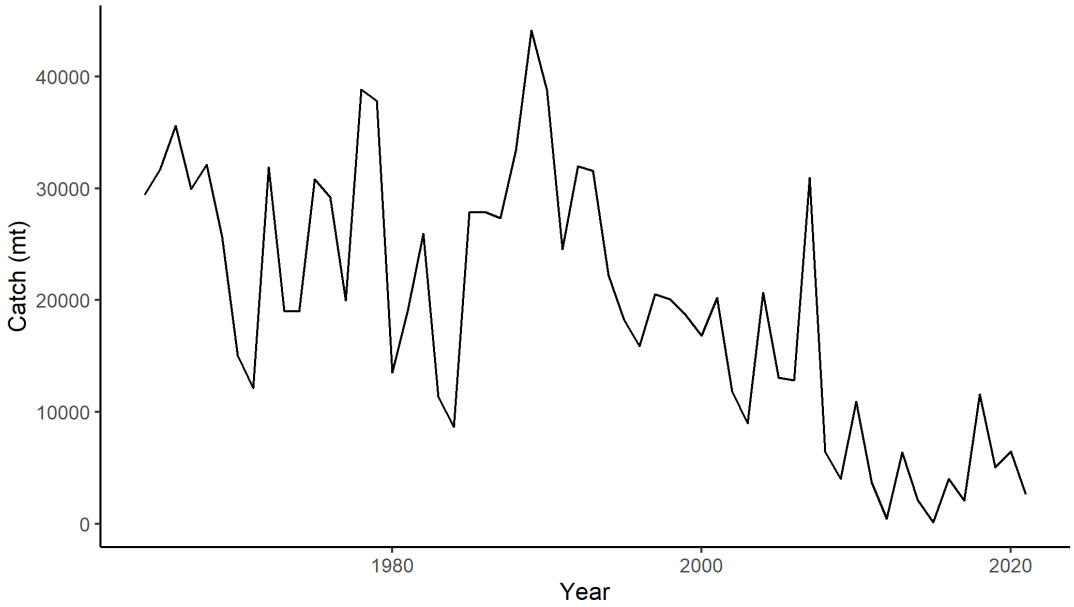


Figure 10. Herring landings in metric tonnes (t) from the New Brunswick weir and shutoff fishery for 1963–2021.

For the times series presented, current NB weir landings are at or near the lowest observed values. Landings for this fishery are highly variable and are not indicative of abundance because catches are susceptible to market, effort, and fish availability.

Sources of Uncertainty

Southwest Nova Scotia/Bay of Fundy Spawning Component

Acoustic surveys are a valuable tool for the assessment of this fishery and methods continue to be improved. Uncertainty remains for several factors including, but not limited to, estimation of biomass in the acoustic dead/blind zones at the surface and close to bottom, the assumption that the surveys are additive, and residence time on the spawning grounds. The error associated with the conversion of acoustic energy into biomass is a source of uncertainty that should be reviewed at an upcoming framework assessment. Improvements in automation programming will provide a means to review the acoustic indices and survey design to determine whether improvements could be made in the analysis of the acoustic data or in survey design and interpretation.

There are several sources of uncertainty that were captured within the various OMs within the recent MSE framework (Carruthers et al. In press., Barrett In prep.[2]), which were considered during the last assessment of the SWNS/BoF spawning component (DFO 2018). The recent MSE framework addressed these uncertainties in the evaluation of candidate MPs in closed-loop simulations. Specifically, recruitment into this fishery by year-class has been highly variable and OMs were defined with either low (0.65) or high(0.95) steepness values. Three different growth scenarios were used because the mechanisms influencing changes in fish weight-at-age are not well understood. The degree to which fish caught in the NB weirs/shut off fishery are

considered within the Canadian SWNS/BoF stock, or are considered to be migratory Herring from NAFO Subarea 5 is not well understood. OMs that considered weir catch and size composition data were included in the reference OM set. There was uncertainty in the natural mortality estimates for the stock. Therefore, a suite of robustness OMs considered alternative morality parameters. Finally, the MSE framework also considered robustness OMs with different recruitment scenarios based on mean recruitment deviations over different time periods.

An attempt to disentangle metapopulation dynamics from the various spawning grounds was not made in the MSE framework and is a source of uncertainty for local spawning ground population dynamics.

Offshore Scotian Shelf Banks

In the absence of recent information on stock status, there is no basis for evaluating the current 12,000 t catch allocation. There should be efforts undertaken to determine a means to undertake structured acoustic surveys of the offshore area. The new Canadian Coast Guard offshore science vessels (*CCGS Capt. Jacque Cartier* and *CCGS John Cabot*), have acoustic technology that could be used for direct identification of pelagic forage fishes.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

The survey method used to estimate abundance in this component differed from that used in SWNS/BoF. One difference is the way in which surveys were included, excluded, or combined, which may overestimate abundance. The error associated with the conversion of acoustic energy into biomass is also a source of uncertainty for these surveys as well, and advice provided in the review of the SWNS/BoF component should also be applied for these surveys. Advice on stock status uses relative trends in SSB because there is no accepted analytical assessment model for this component.

With the exception of the four main areas, the size of various additional spawning groups and landings from these groups are poorly documented. In addition to the traditional bait and personal-use fisheries, directed roe fisheries have occurred on several spawning grounds since 1996.

The Glace Bay area has not been surveyed since 2013.

Southwest New Brunswick Migrant Juveniles

The primary sources of information for assessing this component are the landings, which have declined markedly from the 1980s to present. The landings time series for this fishery may not be indicative of abundance because catches are extremely susceptible to many factors in addition to abundance, including effort. The relative contribution of various spawning components (e.g., Subarea 5, SWNS/BoF, etc.) to this fishery is unknown.

CONCLUSIONS AND ADVICE

Southwest Nova Scotia/Bay of Fundy Spawning Component

The overall annual acoustic index of the SSB for the SWNS/BoF spawning component decreased by 33% in 2021 compared to 2020. Although there is uncertainty with annual estimates of biomass, there is a decreasing trend in the acoustic index since 1999 to present that is evident for the two remaining major spawning grounds, German Bank and Scots Bay, which are used to assess the relative stock status of the SWNS/BoF component. The 3-year moving average (arithmetic mean) of the summed SSB in Scots Bay and German Bank is used to determine trends in the acoustic index of SSB and is compared to the LRP (Clark et al. 2012). The 3-year moving average SSB of Scots Bay and German Bank decreased from 2020

(269,654 t) to 2021 (259,016 t), and remains below the LRP, and the SWNS/BoF component is considered in the Critical zone (Figure 7). The DFO PA policy (DFO 2009) states that when a stock is considered in the Critical zone, productivity is sufficiently impaired to cause serious harm.

The acoustic index of biomass for Trinity Ledge decreased from 10,287 t in 2020 to 3,597 t in 2021. For a fourth year since 2018, surveys were completed on Seal Island. A biomass estimate of 7,334 t was recorded which is below the estimates observed in 2018 (20,734 t) and 2019 (30,000 t). These lower biomass estimates suggests that caution is warranted for these spawning component, which were historically, large-spawning grounds.

The broad range of ages observed in the commercial catch indicates that the conservation objective to maintain a broad range of ages is generally being met. Industry-developed management measures that limit exploitation on juvenile fish and spawning grounds are important for sustainability and should be continued and strengthened.

The precautionary approach requires that exploitation must be kept at the lowest possible level until the stock is out of the Critical zone. Harvest rate must be kept to an absolute minimum to promote stock growth and contribute to rebuilding the stock above the Critical zone.

A summary of the observations and conclusions for each of the corresponding objectives in the IFMP are presented in Table 8. Table 9 summarizes the conclusions on the short-term rebuilding plan objectives for SWNS/BoF spawning component in 2021.

Table 8. Observations and conclusions on conservation objective elements from the management plan for Southwest Nova Scotia/Bay of Fundy spawning component in 2021.

Objectives in Management Plan	2021: Observations and Conclusions
Persistence of all spawning components	Fish were captured in spawning condition on all surveyed spawning grounds (Scots Bay, German Bank, Trinity Ledge, Spectacle Buoy and Seal Island. In all cases, spawning biomass is less than the 1999–2021 average biomass.
Maintain biomass of each component	In all surveyed spawning grounds, spawning biomass is less than the 1999–2021 average biomass.
Maintain broad age composition	Currently, broad ranges of ages are in the commercial landings (2–9), as well as in the acoustic surveys catch-at-age (3–8). The percentage (by number) of 2-year old Herring caught in the fishery has increased in 2020 and 2021, compared to a 23-year historic low in 2019. The 2016 cohort is the strongest cohort progressing through the fishery.
Maintain long spawning period	Start of spawning in 2021 for Scots Bay and German Bank was about the same as in the past few years based on survey and sampling. Spawning was observed on Trinity Ledge early August to mid-September and early August to mid-September in the Spectacle Buoy area.
Fishing mortality at or below $F_{0.1}$	No longer an applicable objective due to the use of the MSE.
Maintain spatial and temporal diversity of spawning	The start of spawning in 2021 was the same as previous years for Scots Bay (late May to end of September), and German Bank (mid-August to beginning of November) based on survey and sampling. Fish were captured in spawning condition in Trinity Ledge and Spectacle Buoy early August to mid-September and early August to mid-September.
Maintain biomass at moderate to high levels	The overall acoustic biomass estimate increased to 36% below the long-term average (1999–2021). The total biomass for 2021 was the lowest estimate in the time series and continues the decreasing trend since 1999.
Maintain 3-year moving average above the Limit Reference Point	The 3-year moving average of Scots Bay and German Bank remains below the LRP and the SWNS/BoF component has been in the Critical zone for 4 years. The PA policy requires that exploitation must be kept at the lowest possible level until the stock is out of the Critical zone. Harvest rate must be kept to an absolute minimum to promote stock growth and contribute to rebuilding the stock above the Critical zone.

Table 9. Observations and conclusions on short-term rebuilding plan objectives for Southwest Nova Scotia/Bay of Fundy spawning component in 2021.

Short term Rebuilding Plan Objectives	2021: Observations and Conclusions
Rebuild the Herring resource to an interim target of the 2001–2004 SSB level	Not being met. Stock remains below the LRP.
Have a statistically significant positive trajectory in the reference point indicator	Not being met.
Limit small fish removals to increase productivity of the resource	Catch-at-length data in the commercial catch indicates this objective is being met. Industry-developed management measures that limit exploitation on juvenile fish and spawning grounds are important for sustainability. The MSE framework showed evidence that limiting removals of small fish can increase productivity of the stock, but not to the extent that was conventionally considered.
Maintain spatial and temporal objectives related to spawning grounds	This objective is mostly being met. Fish in spawning condition were captured in Trinity Ledge, Spectacle Buoy, Seal Island, German Bank, and Scots Bay. Where data are available, there is maintenance of temporal spawning for the major spawning ground.
Maintain biomass of each component	For every surveyed spawning ground (Scots Bay, German Bank, Trinity Ledge, Spectacle Buoy and Seal Island), spawning biomass is from 16–48% less than the 1999–2021 average biomass.

Offshore Scotian Shelf Spawning Component

There was an increase in the landings from the offshore banks from 37 t in 2020 to 921 t in 2021, well below the annual allocation limit of 12,000 t. In the absence of recent information about stock status, there is no basis for evaluating the current catch allocation of 12,000 t. Structured acoustic surveys are needed to obtain data on the stock in the offshore area.

Coastal Nova Scotia (South Shore, Eastern Shore and Cape Breton) Spawning Component

From 2018 to 2021, landings in the Little Hope/Port Mouton area have ranged between 6,355 t and 10,747 t, and have been near or above the allocation in some years (from −2,267 t to +71 t).

From 2018 to 2021, landings in the Eastern Shore area have ranged between 2,553 t and 6,871 t, and are generally within the allocation (from −1,407 t to −127 t).

Landings were minimal for Glace Bay since the last assessment (DFO 2018), with 9 t reported in 2018, 1 t in 2019, 2 t in 2020, and none in 2021.

The Bras d'Or Lakes area remained closed to Herring fishing. No Herring surveys have been conducted in the Bras d'Or Lakes since 2000. It has been noted since 1997 that the status of Herring in the Bras d'Or Lakes is cause for concern. In the absence of current abundance information, there is no information upon which to recommend a change to the management approach for the Bras d'Or Lakes.

Individual spawning groups within the Coastal component are considered vulnerable to fishing because of their relatively small size (biomass) and proximity to shore. For this reason, a large effort increase in new areas has a potential to markedly reduce abundance in the absence of information about the status of the specific spawning group.

Southwest New Brunswick Migrant Juveniles

Landings in the New Brunswick weir and shut-off fishery decreased to a historic low in 2015 of 146 t, increased to 4,060 t in 2016, and decreased to 2,102 t in 2017. It is notable that in 2007 landings were 30,944 t, the highest in nearly 20 years and higher than the long-term average of 20,680 t. From 2018 to 2021, weir landings decreased from 11,574 t to 2,663 t. Landings for this fishery are highly variable and are not indicative of abundance because catches are variable and are susceptible to market, effort, and fish availability

Abundance of Herring available to the weirs is unknown and there is very little research being conducted to investigate local Herring abundance.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Barrett, Tim	DFO Science, Maritimes Region
Cawthray, Jenness	DFO Fisheries Management, National Capital Region
Chandler, Alan	NS Department of Fisheries and Aquaculture
Cieri, Matthew (Reviewer)	State of Maine Department of Marine Resources
Collier, Lynn	DFO Science, Maritimes Region
Corey, Peter	Comeau Seafoods
Debertin, Allan (Lead)	DFO Science, Maritimes Region
d'Eon, Sherman	Cape Breeze Seafoods Ltd.
Depres, Lise	Comeau Seafoods
Deroba, Jon	National Oceanic and Atmospheric Administration - Northeast Fisheries Science
Doucette, Brandon	Turpentine Seiners Limited
Greenlaw, Michelle	DFO Science, Maritimes Region
Hatt, Terry	NB Department of Agriculture, Aquaculture and Fisheries
Hooper, Tony	Connors Brothers Clover Leaf
Kaiser, Tim	Scotia Garden Seafood Inc.
McIntyre, Tara	DFO Science, Maritimes Region
McIsaac, Ian	Seafood Producers Association of Nova Scotia
Melvin, Gary	Herring Science Council
Mitchell, Lillian	Fundy North Fishermen's Association
Mitchell, Vanessa	Maritime Indigenous Peoples Council
Moreau, Darek (Chair)	DFO Science, Maritimes Region
Munden, Jenna	Herring Science Council
Murphy, Chris	William R. Murphy Fisheries Ltd.
Murphy, Hannah	DFO Science, Newfoundland and Labrador Region
Derek Osborne	DFO Science, National Capital Region
Pardo, Sebastián	Ecology Action Centre
Quigley, Sara	DFO Fisheries Management, Maritimes Region
Reader, Jeffrey	DFO Fisheries Management, Maritimes Region
Saulnier, Billy	Comeau's Seafoods Limited
Saulnier, Brian	Seacrest Fisheries
Schleit, Katie	Oceans North
Singh, Rabindra	DFO Science, Maritimes Region
Small, Tiffany	DFO Science, Maritimes Region
Stephenson, Rob	DFO Science, Maritimes Region
Stirling, Roger	Seafood Producers Association of Nova Scotia
Townsend, Kathryn	Maritime Indigenous Aquatic Resources Secretariat
Turcotte, François	DFO Science, Gulf Region
van Beveren, Elisabeth (Reviewer)	DFO Science, Quebec Region
Walsh, Matt	Connors Brothers Clover Leaf
Wang, Yanjun	DFO Science, Maritimes Region

SOURCES OF INFORMATION

This Science Advisory Report is from the March 31, 2022, Maritimes Regional peer review of the Stock Assessment of Herring in Northwest Atlantic Fisheries Organization (NAFO) Fishing

Areas 4VWX. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Carruthers, T.R., Hordyk, A.R., Huynh, Q.C., Singh, R., and Barrett, T.J. In press. A framework for conditioning operating models for the southwest Nova Scotia/Bay of Fundy spawning component of 4VWX Herring. DFO Can. Sci. Advis. Sec. Res. Doc. Presented at the January 21 and May 26, 2021 Herring MSE Framework meetings.

Clark, D.S., Clark, K.J., Claytor, R., Leslie, S., Melvin, G.D., Porter, J.M., Power, M.J., Stone, H.H., Waters, C. 2012. Limit Reference Point for Southwest Nova Scotia / Bay of Fundy Spawning Component of Atlantic Herring, *Clupea harengus* (German Bank and Scots Bay). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/025: iii + 14 p.

DFO. 2007. Proceedings of the Maritimes Provinces Regional Advisory Process on the Assessment Framework for 4VWX Herring Stocks; 31 October–1 November 2006 and 9–11 January 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/002.

DFO. 2009. A fishery decision-making framework incorporating the precautionary approach. Fisheries and Oceans Canada.

DFO. 2011. Proceedings of the Maritimes Provinces Regional Advisory Process on the Assessment Framework for Southwest Nova Scotia/Bay of Fundy Herring; 24–28 January 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2011/031.

DFO. 2018. 2018 Assessment of 4VWX Herring. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/052.

DFO. 2020. Atlantic herring in the Maritimes Region Integrated Fisheries Management Plan. Fisheries and Oceans Canada.

DFO. 2022. Stock Status Update of 4VWX Herring for the 2020 Fishing Season. DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/040.

Melvin, G.D., Martin, R., and Power, M.J. 2014. Estimating German Bank and Scots Bay Herring Spawning Ground Turnover Rates from Tag Returns. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/068: iv + 22 p.

Singh, R., Knox, D., and MacIntyre, A. 2020. 2019 Southwest Nova Scotia/Bay of Fundy Atlantic Herring Framework: Data Inputs. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/028: v + 123 p.

APPENDIX

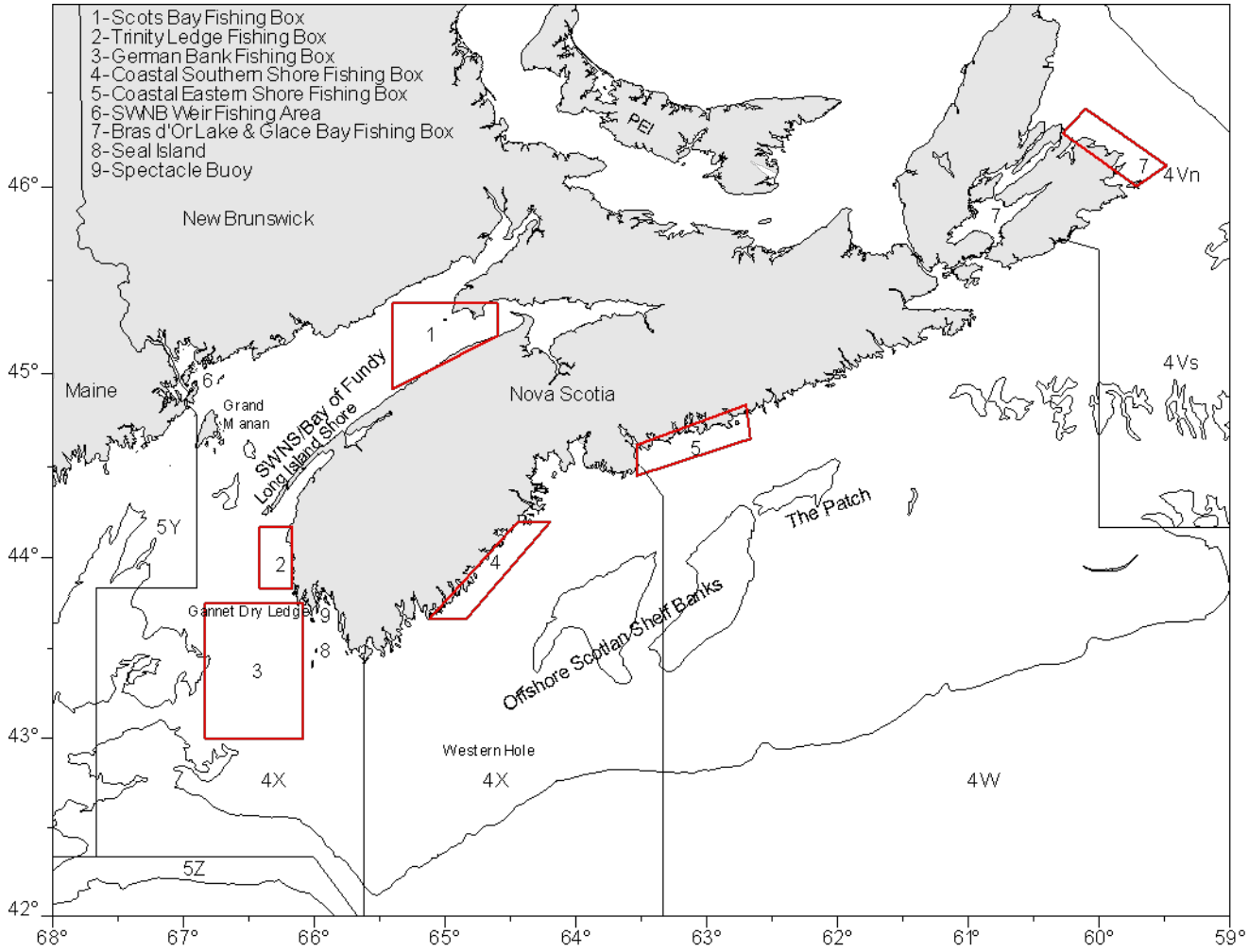


Figure A1. Place names and fishing locations for Southwest Nova Scotia/Bay of Fundy, Coastal NS (South Shore, Eastern Shore, Cape Breton), Offshore Scotian Shelf, and SWNB weirs. The vertical line between the two 4X labels indicates the outer boundary of the SWNS/BoF stock component.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
Bedford Institute of Oceanography
1 Challenger Drive, PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2

E-Mail: MaritimesRAP.XMAR@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-45790-1 Cat. No. Fs70-7/2022-050E-PDF

Correct Citation for this Publication:

DFO. 2022. 2022 Assessment of 4VWX Herring. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/050.

Aussi disponible en français :

MPO. 2022. Évaluation du hareng des divisions 4VWX de 2022. Secr. can. des avis sci. du MPO, Avis sci. 2022/050.