5 Herring (*Clupea harengus*) in divisions 6.aS and 7.b–c

This is the first time since 2015 that the working group presents a separate assessment of herring in Division 6.aS, 7.b-c. This follows from the benchmark workshop, ICES WKNSCS (2022).

The WG noted that the use of “age”, “winter rings”, “rings” and “ringers” still causes confusion outside the group (and sometimes even among WG members). The WG tries to avoid this by consequently using “rings”, “ringers”, “winter ringers” or “wr” instead of “age” throughout this section. However, if the word “age” is used, it is qualified in brackets with one of the ring designations. It should be observed that, for autumn and winter spawning stocks, there is a difference of one year between “age” and “rings”, which is not the case for the spring spawners. Further elaboration on the rationale behind this can be found in the Stock Annex. It is the responsibility of any user of age-based data for any of these herring stocks to consult the stock annex and if in doubt, consult a relevant member of the Working Group.

5.1 The Fishery

5.1.1 Advice applicable to 2021–2022

ICES gave separate advice for the stocks in 6aS, 7b,c and 6aN up to 2015 and advice for the combined stocks since 2016. After the benchmarking process in early 2022 (WKNSCS, 2022), the stocks were assessed separately again.

In February 2016, the European Commission asked ICES to provide advice on a TAC of sufficiently small size to enable ongoing collection of fisheries-dependent data and continue the long-term catch-at-age dataset. This monitoring TAC was 4840 t, split of 3480 t in 6.aN and 1360 t in 6.aS and 7.b-c for 2021 (EU 2021/92). Since 2016 the fishery has been restricted to a monitoring fishery with a TAC of 1,630 t between 2016 – 2019, and 1,360 t in 2020 and 2021.

The advice in 2022 is provided for herring in 6aS, 7b,c and is a category 3 assessment, which is a biomass or abundance trends based assessment. The method applied is a constant harvest rate (method 2.2, ICES 2021g) that uses length, survey and catch data from 2014-2021.

5.1.2 Changes in the fishery

Since 2016 the fishery has been restricted to a monitoring fishery with a TAC of 1630 t between 2016 – 2019, and 1360 t in 2020 and 2021. The monitoring TAC, introduced in 2016 and continued up to 2021, has led to a change in the pattern of the fishery. In previous years, larger vessels dominated in the fishery and took their quotas often in one haul, in a somewhat opportunistic basis. The monitoring TAC was allocated to vessels in six different categories from over 24 m down to under 12 m. In 6.aS, two main areas have been fished in recent years, particularly in Lough Swilly and in inshore areas of Donegal Bay. There has been little effort in 7.b in recent years. In 6.aS a wide size range of pair and single trawlers predominate, and there are also small-scale artisanal fisheries using drift and ringnets in coastal waters.

The Herring fishery in 2021 opened on 1st November and was concentrated in 6.aS, primarily in two statistical rectangles (Figure 5.1.2). This was similar to the 2019 and 2020 fishery. As in 2020, there was also a fishery in January and February to allow for additional data collection.

5.1.3 Regulations and their affects

The north–south boundary between 6.aN and 6.aS (56° parallel) is not appropriate as a boundary, because it traverses the spawning and feeding grounds of 6.aS herring. Transboundary catches have occurred along this line in the past, although this has been less of an issue recently.

5.1.4 Catches in 2021

The Working Group's best estimate of removals from the stock is shown in Table 5.1.4 for herring in 6.aS and 7.b–c. The time series from 1957-2021 is presented in Figure 5.1.4 and the Irish catch map is shown in Figure 5.1.2. In 2021 the majority of the catch was taken in the fourth quarter mainly in 6aS and close inshore.

5.2 Biological Composition of the Catch

5.2.1 Catches in numbers-at-age

Catch-at-age data for this fishery are shown in Table 5.2.1.1 and Figure 5.2.1 and in percentage terms since 1994 in Table 5.2.1.2. In 2021, the fishery was dominated by 2- 5-ringers, accounting for 95% of the catch (Table 5.2.1.2). Smaller proportions of 6-9 ringers are evident in the catch data and account for 5% of the total. 3 ringers are the dominant age class (58%) followed by 4 ringers (15%), 2 (13%), 5 (9%). 2019 was the first year since 2012 that 1 ringers are well represented in the catch-at-age data. These have followed through as 2 ringers in 2020 and 3 ringers in 2021.

The proportion-at-age in the catches from the fishery are similar to the catches from the split Malin shelf acoustic survey for most years. In 2020 the proportions of 1 ringers was higher in the acoustic survey than the catch while in 2019 a higher proportion of 1 ringers were found in the catch (Figure 5.3.1.3). In 2021 the catch picks up a high proportion of 3 ringers (2018 year class) while the survey peaks at 2 ring (2019 year class).

5.2.2 Quality of the catch and biological data

The 6.aS, 7.b–c stock is well sampled and there have been sufficient samples to achieve the precision level sought by the ICES advice on the monitoring fishery since 2016. The number of samples and the associated biological data collected by Ireland are shown in Table 5.2.2.

5.3 Fishery-independent Information

5.3.1 Acoustic surveys (A9526)

The Malin Shelf Acoustic Survey (MSHAS) is carried out annually in June/July. The Malin Shelf index includes all herring in the stock complex located in ICES areas 6.a and 7.b, c. The survey area is bounded in the west and north by the 200m depth contour, in the south by the 53.5°N latitude, and in the east by the 4°W longitude. The survey targets herring of 6.aN and 6.aS spawning origin in mixed feeding aggregations on the Malin Shelf in the summer. Full details about the survey and the genetic sampling and splitting procedure are presented in O'Malley *et al.* 2021 and summarised below.

Genetic samples have been collected since 2014 and averaged about 6 samples per year, but varied between 3 samples in 2019 and 10 samples in 2020. The target for an individual sample was 120 fish per haul, with most sampling events reaching that target. In the early years of the project, sampling effort was targeted only at fish > 23cm, this was to align with a corresponding effort that was underway looking into stock splitting using morphometric methods; a continuation of the SGHERWAY project methods (ICES SGHERWAY, 2010). Prior to 2018, hauls comprising mostly < 23 cm fish were not sampled. The stock had also been at a low level during these years, some of the lowest in the time-series, meaning that obtaining samples on the MSHAS survey was generally very difficult during this time.

Application of the Genetic Assignments

Genetic Analyses: Baseline spawning samples and putatively mixed MSHAS samples were analysed with a panel of 45 informative genetic markers (45 SNPs) derived from whole genome sequencing analyses undertaken as part of a Norwegian/Swedish/Danish funded project entitled '*GENetic adaptations underlying population Structure IN herring*' (GENSINC) (Han et al., 2020). The baseline genetic analyses indicated that herring in ICES Division 6.a comprise at least three distinct populations; 6.aS herring, 6.aN autumn spawning herring and 6.aN spring spawning herring. The 6.aS herring are a primarily a winter spawning population though there is a later spawning component present in the area also. These components are currently inseparable and for the purposes of stock assessment should be combined as 6.aS herring. The Celtic Sea herring and Irish Sea herring are distinct from each other and from the populations in ICES Divisions 6.a however the current genetic marker panel is not optimised for their inclusion in the baseline assignment dataset. This is not considered to be a significant issue as there is no robust evidence that Irish Sea herring are found in large abundance west of the Hebrides during summer. Subsequent to the completion of the EASME project further analyses were undertaken and additional baseline samples added to the 6.aS herring and 6.aN autumn spawning herring baselines. The revised baseline was used for the final assignment of the MSHAS 2014-2020 samples.

Genetic Assignment method: A Support Vector Machine learning (SVM) algorithm was used for classification of fish from mixed MSHAS samples to baselines, based on (Approach 1) prior knowledge of baseline sample origin and (Approach 2) genetic clustering of baseline samples. Approach 2 is more precautionary but neither approach would artificially inflate either stock in the resulting split as each approach allows for 'mixed' and 'unknown' categories that would not be included in either 6aN or 6aS indices. Both approaches resulted in self-assignment rates of >90% indicating a high level of assignment accuracy and both were endorsed in an independent review by the ICES Stock Identification Methods Working Group (ICES SIMWG 2021). The more objective classification method of approach 2, genetic clustering, was therefore chosen by the sub-group. All further reference to genetic assignment refers to approach 2.

Successful Assignment Threshold (0.67): A probability of classification of 0.67 was used as the threshold for successful stock assignment of an individual herring. This threshold indicated that an individual was twice as likely to be from one baseline group than the alternate group. The effects of different assignment thresholds were investigated by the sub-group. The results of this work are presented in the working document. Most resulting probabilities for approach 2 were in the region of 0.95 and the sub-group decided that a threshold probability of 0.67 struck an appropriate balance between certainty of stock assignment and retaining as many fish as possible in the analysis.

Genotyping fails vs. threshold fails: It was decided by the sub-group that genotyping fails were to be disregarded from the analysis (e.g. samples that could not be genetically analysed due to DNA degradation or did not pass genotyping quality control etc. See section 4.8 page 81 of the EASME report for details Farrell *et al* 2021). Such samples were NOT included as 'unknown' her-27.6a7bc when proportioning biomass. Threshold failures however WERE included in the analysis and were therefore counted towards 'unknown' her-27.6a7bc.

StoX survey analysis software: The group decided that using StoX (Johnsen *et al.* 2019) would be the preferred method to split the MSHAS index. StoX is the accepted survey analysis software tool used by MSHAS and the wider WGIPS group dealing with acoustic surveys for herring in the Northeast Atlantic. StoX programmers (IMR, Norway) designed the StoX project and functions to suit the MSHAS split work. This helps ensure that the project is easily implemented in the Transparent Assessment Framework (ICES TAF) and that the survey projects can be re-run by any StoX user by downloading files from the ICES DB. The StoX project is designed to include bootstrapping of results to generate associated CVs.

MSHAS Splitting Results

The SSB time series for each index from 2014-2021 is presented in Figure 5.3.1.1. Herring in 6aS, 7bc (her-irlw) shows a significant increase in biomass since the low SSB seen in all components in 2016. The catch numbers at age from the split are presented in Table 5.3.1.1. The CVs on the split survey estimates are within expected values for acoustic surveys for herring in this area (Table 5.3.1.1). The mean weights from the split survey are presented in Table 5.3.2.2. The maturity at age from the survey shows the most variability at 2 winter ring, with between 25% and 100% of fish mature at that age (Table 5.3.1.3). Cohort tracking of the catch numbers at age of the split MSHAS for 6aS,7.b,c is shown in figure 5.3.1.2. Some cohorts can be tracked and this is expected to improve when more data is added.

A comparison of the proportions at age in the catch versus the split MSHAS 6aS,7b,c index is shown in figure 5.3.1.3. Smaller and younger fish, particularly 1-wr fish are caught sporadically on this survey, and in some years don't appear in the samples on the survey. Younger immature fish may be outside of the survey area during the survey, and can be difficult to sample in some years.

The internal consistency for the split Malin shelf survey is presented in Figure 5.3.1.4. and is variable across ages. The time series is relatively short and the internal consistency is expected to improve when more data becomes available.

5.3.2 Industry–Science Acoustic survey

An industry science acoustic survey has been carried out in 6aS, 7b,c since 2016. The survey design has been evolving since its inception in 2016. The survey area covered in the first 3 years (2016-18) included significant offshore coverage in areas 6aS and 7b. The survey in 2019 was much reduced and mostly confined to inshore bays because of poor weather. The survey design changed in 2020 compared with previous years in that only 6 core areas with prior knowledge of herring distribution from the monitoring fishery were targeted for surveying. This was largely based on the results from ICES WKHASS (ICES 2020) and from lessons learned in the previous surveys in this area from 2016-2019. This design resulted in a much reduced survey area compared to previous years, but with better coverage of most of the important inshore bays where the monitoring fishery takes place. The survey design objective remained the same; to capture the distribution of winter spawning herring in the 6aS,7b area. The timing of surveys in the core areas was flexible from the outset by design. It was decided that greater flexibility would allow for a targeted spatial and temporal approach, which avoided the inevitable poor weather that can happen in this area during this time of the year and which lead to reduced survey effort in 2019, but also to some extent in 2017 and 2018. Using smaller vessels allowed surveys to be conducted in shallow inshore areas where herring are known to inhabit during this time of the year.

The 2021 survey again focused on 6 core areas and was carried out in December 2021 and January 2022. The 2021 survey was conducted using five vessels; MFVs Crystal Dawn WD201, Ros Ard SO745, Girl Kate SO427, K-Mar-K SO695 and Rachel D SO976. This survey is the sixth consecutive annual acoustic survey for pre-spawning herring in this area at this time of the year. A polemounted system with a combi 38 kHz (split) 200 kHz (single) transducer was used successfully for the survey on small vessels (<18m) in 2021. Herring were again distributed inshore in shallow areas, and the improved survey design and use of small vessels for the survey resulted in a good measure of uncertainty (CV =0.23). The stock was not overall contained in 2021, particularly in the Donegal Bay area (Malin Beg, etc.) and more effort is required to target surveys earlier and later than December and January when herring tend to show up in these areas in difficult to predict patterns. Very strong herring marks were evident in Lough Foyle and Lough Swilly in the channel in marks that extended for many miles in some cases. This was in areas where smaller boats in the fishery were concentrating effort. Herring had left the Swilly by mid-December and the Foyle by mid-January. There was also a series of strong herring marks in Bruckless Bay, Fintra Bay (SE of Inishduff) and Inver Bay in discreet areas. The monitoring fishery was being conducted on smaller boats in the same areas and close to the same time as the survey and biological samples from some of these vessels were used. There was a fairly tight distribution of length classes in all hauls, with most hauls dominated by larger (> 22 cm) mature fish. The 2- and 3-wr age class of herring accounted for 74% of the overall numbers in 2021. The total stock biomass (TSB) estimate of 35,944 tonnes is considered to be a minimum estimate of herring in the 6aS,7b survey area at the time of the survey. The flexible survey design and focusing on discreet areas was generally successful and is providing a good template for future survey designs. The NASC values from the 2020 and 2021 surveys is presented in Figure 5.3.2.1.

The full time series of herring acoustic surveys carried out in this area since 1994 is presented in Table 5.3.2.1. Surveys were not conducted every year and there are gaps in the time series. These surveys had different timing and design changes and are not comparable. The biomass estimates from the industry survey (2016-2021) are included in this table.

5.3.3 Bottom-trawl surveys

As part of the benchmark (WKNSCS, 2022), a herring index was developed from three groundfish surveys (IBTS), namely

- IE-IGFS – Irish Groundfish Survey (2003-2020) (G7212)
- SWC-IBTS – Scottish West Coast Groundfish Survey (1985-2009) (G1179, G4299)
- SCOWCGFS – Scottish West Coast Groundfish Survey (2011-2020) (G4748, G4815)

Using the same methodology as that used for the index calculations for many herring stocks, the model combines GAMs and continuation ratio logits (CRL) to model the probability of age given fish length and location. A geographic split was used, i.e. hauls were only included in the index calculation if they occurred within ICES divisions 6aS or 7b,c (Figure 5.3.3.1). The optimum model includes the effect of haul location, depth and time of day. The internal consistency of this time series is presented in Figure 5.3.3.2. The internal consistency of the index is poor outside of the range 2-7 and ages 1, 8 and 9 were excluded from exploratory assessment runs.

5.4 Mean Weights-at-age, Maturity-at-age and natural mortality

5.4.1 Mean weight-at-age

Weights-at-age in the catches for 6.aS, 7.b-c are presented in Table 5.4.1.1 and Figure 5.4.1.1. Catch weights are calculated from Irish sampling data from all quarters of the fishery. Over much of the time series the mean weight there is little trend with weights stable from the late 80s up to the late 00s. The mean weights have been declining since about 2012 for many age classes. Increases can be seen for many age classes in 2021.

Weights-at-age in the stock are presented in Table 5.4.1.2 and Figure 5.4.1.2. Variable mean weights are available from 1985. In the previous separate assessment, the stock weights were calculated from Irish samples collected during the main spawning period that extends from October to February. These weights are used from 1985-2007. Mean weights from the Malin shelf acoustic survey are used from 2008-2013 and from the split acoustic survey from 2014. There is a downward trend in the stock weights over time but it is not as pronounced as for the catch weights. Greater variability is seen at the older ages. The weights-at-age in the stock have also increased for many age classes in 2021. In some years there were no 1 wr fish found on the survey. In these years a three year running average is used.

5.4.2 Maturity ogive

The proportions at age of herring in 6.aS, 7b-c that are considered mature are presented in Figure 5.4.2. Prior to 2007 a constant maturity ogive was used which assumes 0%, 57% and 96% maturity at 1, 2 and 3 wr respectively and from 2008 to the present the ogive is derived from the summer acoustic survey in quarter 3. The full survey is used from 2008-2013 and the split survey used from 2014 – 2021. The majority of herring in this area are mature at 4 wr with the greatest annual variability seen for 2 and 3 wr herring. The proportion mature at 2 wr is highly variable without any apparent trend and varies between 25% and 100%. For 3 wr herring the proportion mature varies between 64% and 100%. A high proportion of immature fish were encountered in the 2020 survey. Overall, it is not clear what drives this annual variability and it is also seen for other herring stocks such as North Sea and Irish Sea herring. It is likely a combination of limited sampling of that age group, varying proportions of herring from each population within the survey area and natural variability (ICES, 2015).

5.4.3 Natural mortality

Following the procedure agreed at WKWEST 2015 and applied to other herring stock around Ireland, the natural mortality values for the assessment were updated. The average M at age over the time series 1974-2019 from the 2020 SMS key run was calculated and is presented in figure 5.4.3 with the previous values used in the combined assessment for comparison. The updated values show a lower natural mortality across all ages and are presented in the text table below.

1	2	3	4	5	6	7	8	9
0.528	0.303	0.255	0.225	0.207	0.193	0.186	0.180	0.180

A Detailed explanation regarding the natural mortality estimates can be found in the Stock Annex.

5.5 Recruitment

There is little information on terminal year recruitment in the catch-at-age data and there are as yet no recruitment indices from the surveys. Numbers of 1-ringers in the catches vary widely but, with the exception of 2012 (2010 cohort), have been consistently low. In 2019, however 1-ringers represented a significant proportion (15%) of the catch-at-age. In 2020 the number of 1-ringers in the catch was lower than 2019 but higher than 2013-2018. In 2021 the numbers of 1-ringers is lower than 2019 and 2020 and similar to the levels from 2013. Since the mid-1990s recruitment has been low, based on exploratory assessments.

5.6 Assessment of 6.aS and 7.b–c herring

The assessment presented here follows the procedure agreed by the recent benchmark (WKNSCS 2022)

5.6.1 Data Exploration

A comparison of the age structure in the catch data, acoustic survey and IBTS survey, is presented in Figure 5.6.1. In some years the surveys picks up a larger proportion of 1 winter ring fish but this is variable between years. Some years the 1 winter ring fish are not found in the catch or the survey but may be found in considerable quantities the following year as 2 winter ring fish.

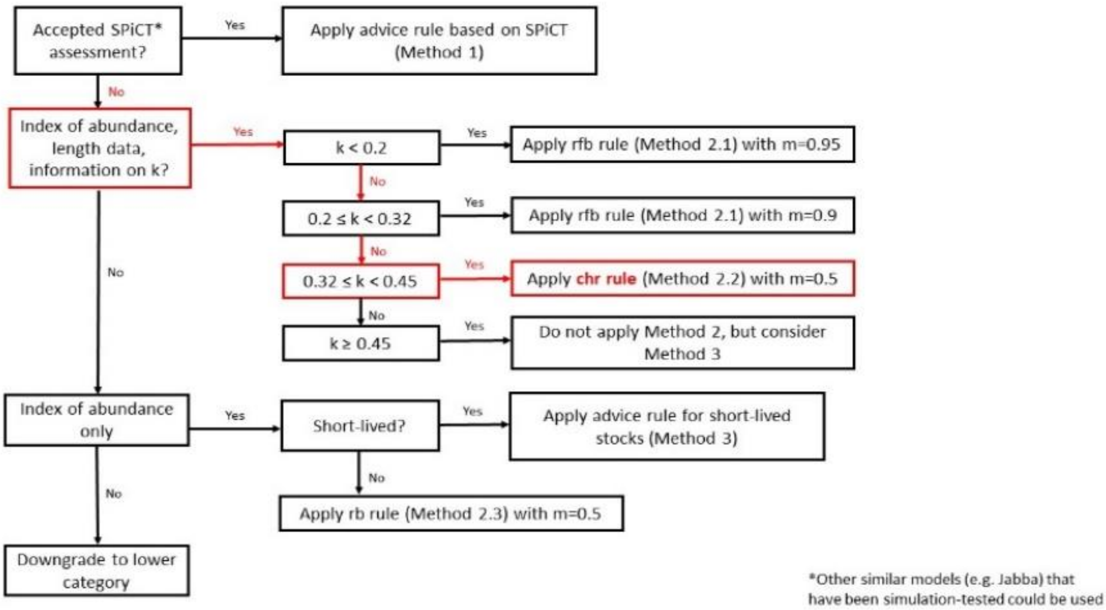
1 ringers in 2019 were not found in a high proportion in the acoustic survey but were found in the catch and contributed to a high proportion of the IBTS data. This 2018 year-class was found by the catch and the survey as 2 ringers in 2020 and 3 ringers in 2021.

The 2017 year-class was found in high quantities by the IBTS survey and was strong in the acoustic survey but not in the catch in 2018. In 2019 this 2017 year-class was strong in the catch data and this has followed through to 4 ringers in 2021. The 2019 year-class was strongest in the acoustic survey in 2020 and is seen in significant proportions in 2021 in both surveys but is not as strong in the catch data. The ability of each of the data sources to track cohorts is variable.

The Malin shelf acoustic survey is used as the index in the assessment because this index is split genetically and known to contain fish from this stock only. The IBTS survey was not used in the final assessment as further investigations are needed to evaluate its utility in the assessment. The fact that the series begins in 2003 means it could be an important element to include in future analytical assessments at the next benchmark. The time-series of the Industry/Science acoustic survey is relatively short and the methodology has been evolving so the index was ultimately not included. While the genetically split MSHAS was the best biomass index available for the chr calculation, the reasons behind the variable internal consistency across age pairs need to be further investigated, particularly if this stock is to move to a category 1 or age-based assessment in the future.

5.6.2 Final Assessment for 6.aS and 7.b–c herring

The final assessment method applied to herring in 6aS, 7b,c and agreed at the 2022 benchmark (WKNSCS) was the category three method 2.2 – constant harvest rate (the chr rule).



5.6.2.1 Calculation of k

The growth parameter k was calculated using length data from commercial catch sampling. Herring samples from 6aS and 7b from 2000-2021 were included in the analysis. This totaled over 594 thousand individual herring caught in a variety of gear types. The R packages 'FSA' and 'nlstools' were used to estimate the growth parameters and to plot the fit of the growth curve (Figure 5.2.6.1). The resulting growth parameters were:

- k = 0.339
- L_{inf} = 30.50cm
- t0 = -2.61

Catches of 6aS7bc herring have been taken close to the north-west coast of Ireland since the introduction of the monitoring TAC in 2015. To ensure the growth fit was not influenced by mixed catches before 2015, an estimate using length data from 2015-2021 was also run. The resulting k was almost identical. This value is further supported by the literature, with a k of 0.37 for herring north-west of Ireland reported by Brunel and Dickey-Collas (2010); albeit calculated on the weight rather than the length.

As a further test, k was also calculated using length data from the genetically split MSHAS (6aS only). Due to sampling protocols, herring less than 23cm were not routinely sampled for genetics prior to 2018 so only split data from 2018 onwards were included. The resulting k from this further analysis was 0.5, which is quite different to the other values presented and would place herring 6aS7bc in the short lived species bracket. It is thought that this unusual growth estimate is due to the difference in timing of the survey versus the catch, which can be separated by up to 6 months. 1-ringed fish encountered during the summer survey would have recently turned 1 whereas 1 ringed fish in the catch would be approaching 2. Further work is required to understand the different survey k but nevertheless the most appropriate k to use for the category 3 flowchart and the chr calculation is that from the catch sampling (0.339) as far more data points exist over a much wider timeframe.

5.6.2.2 Calculation of Constant Harvest Rate (chr)

Method 2.2 of WKLIFEX is the constant harvest rate (chr), also called the F_{proxy} rule or the "Icelandic" rule. It applies a constant harvest rate ($F_{MSY\ proxy}$) that is considered a proxy for an MSY harvest rate, and applies this to the biomass index (split MSHAS). As per the WKLIFEX (2021) report, advised catch (C_{y+1}) is calculated as follows:

$$C_{y+1} = I_{y-1} \times F_{proxy,MSY} \times b \times m$$

Definitions of the components used to calculate chr are presented in Table 5.6.2.2. This information is explained in further detail in the WKLIFEX report (see table 3.4.2.1 of that report for a full description of how $F_{MSY\ proxy}$ is calculated).

Table 5.6.2.3. shows the estimate of natural mortality (M) used in the exploratory assessments for herring in 6aS, 7bc and various M/k ratio calculations. Most appropriate M/k ratio highlighted in bold.

Target Harvest Rate

The derivation of the target harvest rate, $F_{MSY\ proxy}$, from length frequency data requires calculating the target reference length, $L_{F=M}$. Target reference length is calculated using the following equation:

$$L_{F=M} = (0.75 \times Lc_{(y)}) + (0.25 \times L_{inf})$$

where L_c refers to the length at first catch. This calculation assumes that the M/k ratio is equal to 1.5 (ICES 2018). The actual M/k ratio for 6aS7bc herring is 0.649, which is considerably different to the assumed value. ICES Technical Guidelines (2018) state that stock specific M/k values can be applied by using the following alternative $L_{F=M}$ equation from Jardim *et al*. (2015):

$$L_{F=\gamma M, K=\theta M} = \frac{\theta L_\infty + L_c(\gamma + 1)}{\theta + \gamma + 1}.$$

Using the assumed M/k of 1.5 and the best estimate of k, 0.339, implies a natural mortality of 0.51, which differs substantially from that used in the exploratory SAM and ASAP runs: Average for ages 3-6 of 0.22. It was therefore deemed appropriate to use the stock specific M/k and the Jardim *et al*. (2015) equation to calculate $F_{MSY\ proxy}$, for herring in 6aS,7bc.

All other calculations followed the WKLIFEX protocols.

5.6.2.3 Constant Harvest Rate Results

The split survey index is increasing since 2016 and the latest biomass estimate is above the trigger, which is 1.4 times the lowest observed survey biomass (Figure 5.6.2.3.1).

$F_{MSY\ proxy}$ is estimated at 0.034 and the target reference length for the latest year is 27.11 cm. Length frequency distribution are presented in Figure 5.6.2.3.2 These values will update for each year of data added to the time series.

The multiplier, m, was set at 0.5 as per ICES WKLIFEX guidelines for this method.

See table 5.6.2.3.1 for full details of the constants and calculations used.

Stability Clause

A stability clause constraining the change in advised catch to -30% or +20% is also included. ICES guidelines state the mean of the previous 3 years' catch should be used when calculating the stability clause for the first time, which in this case is appropriate given the uptake of the monitoring quota in those years. It was agreed at WKNSCS that the most appropriate starting value would be the average catch in the past three years (ICES, 2021h). Subsequent years will use the previously advised catch as the basis of the stability clause.

Summary

Category 3 method 2.2 chr rule using a stock specific M/k value was recommended by the benchmark group. Table 5.6.2.3.2 presents a summary table and resultant advice based on a chr using length, survey and catch data from 2014 – 2021 (inclusive). Note that $F_{MSY\ proxy}$, can change with each year of additional data. In conjunction with herring in 6aN, implementation of these calculations in R is being developed and will be uploaded to TAF.

5.7 State of the Stock

The genetically split Malin shelf acoustic survey abundance and biomass estimates for 2014-2021 (incl.) provide the most reliable index for this stock. The biomass has been increasing since 2016 (36,706 t) with the 2021 estimate of 189,856 the second highest since the time series began in 2014 (Table 5.3.1.1. and Figure 5.3.1.1). Recent catches are among the lowest in the time series. A monitoring TAC has been in place for this stock since 2016 and this has restricted fishing mortality. There is little information on terminal year recruitment in the catch-at-age data and there are as yet no recruitment indices from the surveys. Recruitment of the 2018 year-class was good and this year class is now 3 winter ring and accounted for 58% of the catch numbers at age in 2021.

5.8 Short-term Projections

5.8.1 Short-term projections

No short term forecast was conducted at HAWG 2022.

5.8.2 Yield-per-recruit

No yield-per-recruit analysis was conducted at HAWG 2022.

5.9 Precautionary and Yield Based Reference Points

$F_{MSY\ proxy}$ is estimated at 0.034 for the years 2014-2021 (inclusive) and the target reference length for the latest year is 27.11 cm. These values will update for each year of data added to the time series.

5.10 Quality of the Assessment

Herring in 6.a South, 7.b-c have been part of a combined assessment with 6.a North since 2015 (ICES, 2015a). Following a benchmark meeting in 2022 (ICES, 2022a), these two stocks are now assessed separately. This was made possible by the development of a genetically split acoustic survey index (MSHAS; ICES, 2022b). This assessment represents one stock 6.aS,7.b–c herring.

A proportion of the acoustic survey biomass remains unassigned to either 6aS, 7bc or 6aN (Figure 5.10.1). There is a spring spawning category that could be 6aN fish or late spawning 6aS, 7b,c fish. There is also an unknown category that contains a mix of herring from 6a, 7bc and are unknown or below threshold. Continued genetic work will reduce the portion of this unassigned biomass in future years.

The calculation of the length-based indicator (LBI) portion of the constant harvest rate (chr) requires adequate length frequency data from the commercial catch. Catch sampling in 6.aS,7.b-c has been comprehensive in all years included in the current assessment (2014-2021).This sampling will continue in future years.

The length at first capture (Lc) and the target reference length were calculated independently for every year of data in order to be more responsive to changes in the stock and/or fishery selectivity as the stock rebuilds. As such, the $F_{MSY\ proxy}$ reference point may change in subsequent years.

5.11 Management Considerations

From 2015 to 2021 this stock was jointly assessed with herring in 6.a North because it was not possible to segregate the two stocks in commercial catches or surveys. The development of a genetic method to split the summer acoustic survey (MSHAS) into the component stocks means that separate advice is now possible. The survey index has been genetically split from 2014-present but catches are still apportioned geographically (south of 56°N and west of 7°W). This is not an issue in recent years as the agreed 6.aS,7.b-c monitoring TAC has been taken close to the Irish coast at a time when the stocks are geographically isolated. Genetic sampling to split the commercial catches is required, particularly as the stocks recover and fishing expands. The Malin shelf acoustic survey index is an important part of this assessment and the continuation of the genetic sampling and analysis of this survey is also required. New baseline samples should be collected annually if possible and analysed at least with the established 45 SNP panel detailed in Farrell et al. (2021). Particular attention should be paid to building up the baseline samples of late spawning 6.a.S and the spring spawning 6aN fish to improve the assignment of these fish.

5.12 Ecosystem Considerations

The Atlantic herring, *Clupea haregus*, is numerically one of the most important pelagic species in North Atlantic ecosystems. As well as being a commercially important species, herring represent an important prey species in the ecosystem west of the British Isles (ICES, 2021). Herring link zooplankton production with higher trophic levels (fish, sea mammals and birds) but also can act as predators on other fish species by their predation on fish eggs (ICES, 2015).

In this area the main oceanographic features are the Islay and Irish Shelf fronts. The waters to the west of Ireland are separated by the Irish shelf front. These fronts create turbulence and this may bring nutrients from deep waters to the surface, promoting the growth of phytoplankton and dinoflagellates in areas of increased stratification. Aggregations of fish are associated with these areas of increased productivity. The Islay front persists throughout the winter due to the stratification of water masses at different salinities (ICES, 2006). The ability to quantify any variability in frontal location and strength is an important element in understanding fisheries recruitment (Nolan and Lyons, 2006). These fronts play an important role in the transport of larvae and juveniles.

5.13 Changes in the Environment

Grainger (1978; 1980) found significant negative correlations between sea surface temperature and catches from the west of Ireland component of this stock at a time-lag of 3–4 years later. This indicates that recruitment responds favourably to cooler temperatures. The influence of the environment on herring productivity means that the biomass will always fluctuate (Dickey-Collas *et al.*, 2010).

Changes in environmental conditions can have significant impacts for a variety of marine fish species. Oceanographic variation associated with temperature and salinity fluctuations appears to impact herring in the first year of life, possibly during the winter larval drift (Grainger, 1980). In addition, temperature increases and a positive AMO (Atlantic multi-decadal oscillation) index are thought to be related to drops in weight-at-age in Celtic Sea herring (Lyashevska, 2020). This study by Lyashevska, 2020 also found more stable size at age for herring in 6aS, 7b,c and this may reflect the stocks more northerly distribution, where there is less exposure to sub optimal temperatures. Reductions in size of after 1990 are noted which indicates a vulnerability to future temperature rises.

Table 5.1.4 Herring in divisions 6.aS, 7.b–c. Estimated Herring catches in tonnes, 1992–2021. These data do not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	France	Germany	Ireland	Netherlands	UK (England & Wales)	UK Scotland	Total landings	Unallocated / area misre-ported	Discards *	ICES estimated catch
1992	0	250	26000	900	0	0	27150	4600	100	31850
1993	0	0	27600	2500	0	200	30300	6250	250	36800
1994	0	0	24400	2500	50	0	26950	6250	700	33900
1995	0	11	25450	1207	24	0	26692	1100	0	27792
1996	0	0	23800	1800	0	0	25600	6900	0	32500
1997	0	0	24400	3400	0	0	27800	700	50	28550
1998	0	0	25200	2500	0	0	27700	11200	0	38900
1999	0	0	16325	1868	0	0	18193	7916	0	26109
2000	0	0	10164	1234	0	0	11398	8448	0	19846
2001	0	0	12820	2088	0	0	14908	1390	0	16298
2002	515	0	13072	366	0	0	13953	3873	0	17826
2003	0	0	12921	0	0	0	12921	3581	0	16502
2004	0	0	12290	64	0	0	12354	2813	0	15167
2005	0	0	13351	0	0	0	13351	2880	0	16231
2006	0	0	14840	353	0	6	15199	4000	0	19199
2007	0	0	12662	13	0	0	12675	5116	0	17791
2008	0	0	10237	0	0	0	10237	3103	0	13340
2009	0	0	8533	0	0	0	8533	1935	0	10468
2010	0	0	7513	0	0	0	7513	2728	0	10241
2011	0	0	4247	0	0	0	4247	2672	0	6919
2012	0	0	3727	0	0	0	3791	2780	0	6571
2013	0	0	1460	40	0	0	1500	2468	0	3968

Year	France	Germany	Ireland	Netherlands	UK (England & Wales)	UK Scotland	Total landings	Unallocated / area misre-ported	Discards *	ICES estimated catch
2014	0	0	2933	0	0	0	2933	2163	0	5096
2015	0	0	73	0	0	5	78	1000	0	1078
2016	0	0	1171	72	0	0	1243	971	0	2214
2017	0	0	1707	0	0	0	1707	520	0	2227
2018	0	0	970	0	0	0	970	525	0	1495
2019	0	0	1625	65	0	0	1690	0	0	1690
2020	0	0	1138	3	0	0	1141	79	0	1220
2021	0	0	1715	0	0	0	1715	106	0	1821

***Unraised discards**

Table 5.2.1.1. Herring in divisions 6.aS, 7.b–c. Catch in numbers-at-age (winter rings) from 1970–2021.

	1	2	3	4	5	6	7	8	9
1970	135	35114	26007	13243	3895	40181	2982	1667	1911
1971	883	6177	7038	10856	8826	3938	40553	2286	2160
1972	1001	28786	20534	6191	11145	10057	4243	47182	4305
1973	6423	40390	47389	16863	7432	12383	9191	1969	50980
1974	3374	29406	41116	44579	17857	8882	10901	10272	30549
1975	7360	41308	25117	29192	23718	10703	5909	9378	32029
1976	16613	29011	37512	26544	25317	15000	5208	3596	15703
1977	4485	44512	13396	17176	12209	9924	5534	1360	4150
1978	10170	40320	27079	13308	10685	5356	4270	3638	3324
1979	5919	50071	19161	19969	9349	8422	5443	4423	4090
1980	2856	40058	64946	25140	22126	7748	6946	4344	5334
1981	1620	22265	41794	31460	12812	12746	3461	2735	5220
1982	748	18136	17004	28220	18280	8121	4089	3249	2875
1983	1517	43688	49534	25316	31782	18320	6695	3329	4251
1984	2794	81481	28660	17854	7190	12836	5974	2008	4020
1985	9606	15143	67355	12756	11241	7638	9185	7587	2168
1986	918	27110	27818	66383	14644	7988	5696	5422	2127
1987	12149	44160	80213	41504	99222	15226	12639	6082	10187
1988	0	29135	46300	41008	23381	45692	6946	2482	1964
1989	2241	6919	78842	26149	21481	15008	24917	4213	3036
1990	878	24977	19500	151978	24362	20164	16314	8184	1130
1991	675	34437	27810	12420	100444	17921	14865	11311	7660
1992	2592	15519	42532	26839	12565	73307	8535	8203	6286
1993	191	20562	22666	41967	23379	13547	67265	7671	6013
1994	11709	56156	31225	16877	21772	13644	8597	31729	10093
1995	284	34471	35414	18617	19133	16081	5749	8585	14215
1996	4776	24424	69307	31128	9842	15314	8158	12463	6472
1997	7458	56329	25946	38742	14583	5977	8351	3418	4264

	1	2	3	4	5	6	7	8	9
1998	7437	72777	80612	38326	30165	9138	5282	3434	2942
1999	2392	51254	61329	34901	10092	5887	1880	1086	949
2000	4101	34564	38925	30706	13345	2735	1464	690	1602
2001	2316	21717	21780	17533	18450	9953	1741	1027	508
2002	4058	32640	37749	18882	11623	10215	2747	1605	644
2003	1731	32819	28714	24189	9432	5176	2525	923	303
2004	1401	15122	32992	19720	9006	4924	1547	975	323
2005	209	28123	30896	26887	10774	5452	1348	858	243
2006	598	22036	36700	30581	21956	9080	2418	832	369
2007	76	24577	43958	23399	13738	5474	1825	231	131
2008	483	12265	19661	28483	11110	5989	2738	745	267
2009	202	12574	12077	12096	12574	5239	2040	853	17
2010	1271	13507	20127	6541	7588	6780	2563	661	189
2011	121	14207	9315	9114	3386	3780	2871	980	95
2012	5142	12844	16387	4042	1776	553	541	103	21
2013	61	3118	4532	12238	1665	1792	425	382	202
2014	34	465	8825	6735	12146	2406	1045	437	204
2015	27	1842	598	2553	1699	685	96	9	0
2016	69	1983	4252	1369	3025	2085	824	43	9
2017	30	1051	5241	4078	1025	2250	1061	480	76
2018	6	1567	1838	3280	2288	613	700	260	29
2019	1995	2627	3259	1509	1895	1166	381	464	171
2020	140	5164	2683	1703	597	684	265	98	48
2021	25	1975	8818	2297	1302	315	410	116	21

Table 5.2.1.2. Herring in divisions 6.aS, 7.b–c. Percentage age composition (winter rings).

Year	1	2	3	4	5	6	7	8	9+
1994	6%	28%	15%	8%	11%	7%	4%	16%	5%
1995	0%	23%	23%	12%	13%	11%	4%	6%	9%
1996	3%	13%	38%	17%	5%	8%	4%	7%	4%
1997	5%	34%	16%	23%	9%	4%	5%	2%	3%
1998	3%	29%	32%	15%	12%	4%	2%	1%	1%
1999	1%	30%	36%	21%	6%	3%	1%	1%	1%
2000	3%	27%	30%	24%	10%	2%	1%	1%	1%
2001	2%	23%	23%	18%	19%	10%	2%	1%	1%
2002	3%	27%	31%	16%	10%	9%	2%	1%	1%
2003	2%	31%	27%	23%	9%	5%	2%	1%	0%
2004	2%	18%	38%	23%	10%	6%	2%	1%	0%
2005	0%	27%	29%	26%	10%	5%	1%	1%	0%
2006	0%	18%	29%	25%	18%	7%	2%	1%	0%
2007	0%	22%	39%	21%	12%	5%	2%	0%	0%
2008	1%	15%	24%	35%	14%	7%	3%	1%	0%
2009	0%	22%	21%	21%	22%	9%	4%	1%	0%
2010	2%	23%	34%	11%	13%	11%	4%	1%	0%
2011	0%	32%	21%	21%	8%	9%	7%	2%	0%
2012	12%	31%	40%	10%	4%	1%	1%	0%	0%
2013	0%	13%	19%	50%	7%	7%	2%	2%	1%
2014	0%	1%	27%	21%	38%	7%	3%	1%	1%
2015	0%	25%	8%	34%	23%	9%	1%	0%	0%
2016	0%	15%	31%	10%	22%	15%	6%	0%	0%
2017	0%	7%	34%	27%	7%	15%	7%	3%	0%
2018	0%	15%	17%	31%	22%	6%	7%	2%	0%
2019	15%	20%	24%	11%	14%	9%	3%	3%	1%
2020	1%	45%	24%	15%	5%	6%	2%	1%	0%
2021	0%	13%	58%	15%	9%	2%	3%	1%	0%

Table 5.2.2. Herring in divisions 6.aS, 7.b–c. Sampling intensity of catches in 2021.

Year	Quarter	Landings (t)	No. Samples	No. aged	No. Measured	Aged/1000 t
6.aS	1	426	6	382	1841	896
6.aS	4	1395	34	1655	8162	1187
Total	2021	1821	40	2037	10003	1119

Table 5.4.1.1. Herring in divisions 6.aS, 7.b–c. Mean weights-at-age in the catches 1970–2021.

	1	2	3	4	5	6	7	8	9+
1970	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1971	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1972	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1973	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1974	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1975	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1976	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1977	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1978	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1979	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1980	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1981	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1982	0.110	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1983	0.090	0.129	0.165	0.191	0.209	0.222	0.231	0.237	0.241
1984	0.106	0.141	0.181	0.210	0.226	0.237	0.243	0.247	0.248
1985	0.077	0.122	0.161	0.184	0.196	0.206	0.212	0.225	0.230
1986	0.095	0.138	0.164	0.194	0.212	0.225	0.239	0.208	0.288
1987	0.085	0.102	0.150	0.169	0.177	0.193	0.205	0.215	0.220
1988	0.082	0.098	0.133	0.153	0.166	0.171	0.183	0.191	0.201
1989	0.080	0.130	0.141	0.164	0.174	0.183	0.192	0.193	0.203
1990	0.094	0.138	0.148	0.160	0.176	0.189	0.194	0.208	0.216
1991	0.089	0.134	0.145	0.157	0.167	0.185	0.199	0.207	0.230
1992	0.095	0.141	0.147	0.157	0.165	0.171	0.180	0.194	0.219

	1	2	3	4	5	6	7	8	9+
1993	0.112	0.138	0.153	0.170	0.181	0.184	0.196	0.229	0.236
1994	0.081	0.141	0.164	0.177	0.189	0.187	0.191	0.204	0.220
1995	0.080	0.140	0.161	0.173	0.182	0.198	0.194	0.206	0.217
1996	0.085	0.135	0.172	0.182	0.199	0.209	0.220	0.233	0.237
1997	0.093	0.135	0.155	0.181	0.201	0.217	0.217	0.231	0.239
1998	0.095	0.136	0.145	0.173	0.191	0.196	0.202	0.222	0.217
1999	0.106	0.144	0.145	0.163	0.186	0.195	0.200	0.216	0.222
2000	0.102	0.129	0.154	0.172	0.180	0.184	0.204	0.203	0.204
2001	0.086	0.122	0.139	0.167	0.183	0.188	0.222	0.222	0.213
2002	0.097	0.127	0.140	0.155	0.175	0.196	0.204	0.218	0.226
2003	0.102	0.134	0.150	0.167	0.183	0.196	0.216	0.210	0.228
2004	0.085	0.140	0.150	0.167	0.182	0.193	0.222	0.221	0.285
2005	0.105	0.135	0.150	0.162	0.174	0.188	0.200	0.237	0.296
2006	0.106	0.137	0.141	0.158	0.169	0.178	0.199	0.221	0.243
2007	0.118	0.144	0.145	0.168	0.179	0.189	0.197	0.233	0.237
2008	0.1108	0.1478	0.1503	0.1663	0.1745	0.1845	0.1938	0.1990	0.2407
2009	0.077	0.146	0.171	0.194	0.200	0.207	0.211	0.218	0.275
2010	0.104	0.131	0.168	0.189	0.201	0.212	0.218	0.226	0.229
2011	0.094	0.122	0.141	0.174	0.193	0.202	0.217	0.218	0.246
2012	0.09	0.134	0.179	0.196	0.214	0.237	0.228	0.243	0.236
2013	0.083	0.121	0.141	0.170	0.181	0.196	0.202	0.226	0.226
2014	0.105	0.139	0.136	0.155	0.168	0.175	0.184	0.183	0.187
2015	0.090	0.113	0.145	0.152	0.161	0.168	0.176	0.185	0.188
2016	0.09	0.125	0.149	0.163	0.182	0.188	0.19	0.21	0.201
2017	0.072	0.106	0.132	0.145	0.159	0.168	0.172	0.179	0.183
2018	0.085	0.101	0.127	0.144	0.155	0.166	0.172	0.170	0.174
2019	0.063	0.099	0.127	0.147	0.159	0.164	0.180	0.174	0.172
2020	0.059	0.091	0.109	0.121	0.134	0.146	0.152	0.158	0.168
2021	0.080	0.108	0.116	0.124	0.134	0.141	0.147	0.151	0.173

Table 5.4.1.2. Herring in divisions 6.aS, 7.b–c. Mean weights-at-age in the stock at spawning time 1970–2021.

	1	2	3	4	5	6	7	8	9+
1970	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1971	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1972	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1973	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1974	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1975	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1976	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1977	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1978	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1979	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1980	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1981	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1982	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1983	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1984	0.120	0.169	0.210	0.236	0.260	0.273	0.283	0.290	0.296
1985	0.100	0.150	0.196	0.227	0.238	0.251	0.252	0.269	0.284
1986	0.098	0.169	0.209	0.238	0.256	0.276	0.280	0.287	0.312
1987	0.097	0.164	0.206	0.233	0.252	0.271	0.280	0.296	0.317
1988	0.097	0.164	0.206	0.233	0.252	0.271	0.280	0.296	0.317
1989	0.138	0.157	0.168	0.182	0.200	0.217	0.227	0.238	0.245
1990	0.113	0.152	0.170	0.180	0.200	0.217	0.225	0.233	0.255
1991	0.102	0.149	0.174	0.190	0.195	0.206	0.226	0.236	0.248
1992	0.102	0.144	0.167	0.182	0.194	0.197	0.214	0.218	0.242
1993	0.118	0.166	0.196	0.205	0.214	0.220	0.223	0.242	0.258
1994	0.098	0.156	0.192	0.209	0.216	0.223	0.226	0.230	0.247
1995	0.090	0.144	0.181	0.203	0.217	0.226	0.227	0.239	0.246
1996	0.086	0.137	0.186	0.206	0.219	0.234	0.233	0.249	0.253
1997	0.094	0.135	0.169	0.194	0.210	0.224	0.231	0.230	0.239
1998	0.095	0.136	0.145	0.173	0.191	0.196	0.202	0.222	0.217

	1	2	3	4	5	6	7	8	9+
1999	0.104	0.145	0.154	0.174	0.200	0.222	0.230	0.240	0.246
2000	0.100	0.134	0.157	0.177	0.197	0.207	0.217	0.230	0.245
2001	0.091	0.125	0.150	0.172	0.191	0.200	0.203	0.203	0.216
2002	0.092	0.127	0.146	0.170	0.190	0.201	0.210	0.227	0.229
2003	0.094	0.131	0.155	0.175	0.192	0.203	0.232	0.222	0.243
2004	0.081	0.133	0.151	0.175	0.194	0.207	0.238	0.233	0.276
2005	0.095	0.127	0.15	0.172	0.185	0.196	0.223	0.234	0.274
2006	0.092	0.130	0.133	0.162	0.177	0.186	0.209	0.238	0.247
2007	0.114	0.133	0.133	0.171	0.186	0.196	0.208	0.228	0.229
2008	0.098	0.136	0.140	0.174	0.185	0.196	0.192	0.205	0.234
2009	0.072	0.141	0.162	0.197	0.215	0.223	0.225	0.221	0.286
2010	0.092	0.128	0.157	0.189	0.208	0.227	0.234	0.239	0.247
2011	0.082	0.118	0.136	0.177	0.199	0.207	0.225	0.239	0.240
2012	0.084	0.135	0.182	0.203	0.214	0.226	0.225	0.21	0.226
2013	0.074	0.114	0.140	0.170	0.188	0.198	0.204	0.223	0.222
2014	0.093	0.128	0.135	0.154	0.169	0.170	0.188	0.169	0.206
2015	0.077	0.112	0.146	0.155	0.165	0.173	0.179	0.183	0.217
2016	0.078	0.119	0.147	0.164	0.185	0.191	0.197	0.21	0.175
2017	0.064	0.099	0.130	0.145	0.163	0.173	0.176	0.185	0.180
2018	0.072	0.097	0.126	0.146	0.156	0.168	0.172	0.169	0.170
2019	0.062	0.098	0.124	0.149	0.164	0.166	0.180	0.180	0.175
2020	0.056	0.088	0.110	0.125	0.144	0.154	0.157	0.164	0.168
2021	0.070	0.109	0.151	0.171	0.182	0.196	0.203	0.205	0.211

Table 5.3.1.1. Herring in divisions 6.aS, 7.b–c Total numbers (millions) and biomass (tonnes) of herring June–July 2014-2021. From the Split Malin Shelf acoustic survey

Year	Age(-wr)	1	2	3	4	5	6	7	8	9+	CV	SSB (t)
2014	her-irlw		30.02	118.63	271.01	252.21	99.34	31.38	10.39	4.90	0.26	149270
2015	her-irlw		122.52	255.67	395.26	254.82	225.28	58.96	9.38		0.24	226293
2016	her-irlw		8.09	45.22	42.18	38.06	42.34	26.05	1.71	0.91	0.23	36707
2017	her-irlw		6.55	112.57	87.69	39.22	58.66	39.21	21.65	0.33	0.33	66342
2018	her-irlw	572.95	303.59	68.30	199.14	92.34	36.80	47.08	14.63	6.14	0.57	96138
2019	her-irlw	3.80	170.70	213.96	103.46	91.97	47.16	5.93	17.27	8.92	0.26	92364
2020	her-irlw	895.11	776.20	401.75	188.20	71.45	120.21	24.77	6.64	8.51	0.24	135335
2021	her-irlw	173.49	1389.15	532.79	105.14	66.21	27.17	46.06	12.62	12.82	0.31	189856

Table 5.3.1.2. Herring in divisions 6.aS, 7.b–c. Mean Weights at age of herring June–July 2014-2021. From the Split Malin Shelf acoustic survey

Year	Age(-wr)	1	2	3	4	5	6	7	8	9+
2014	her-irlw		134.74	159.19	177.5	201.06	211.04	213.03	224.16	231.2
2015	her-irlw		134.47	173.81	188	194.66	201.2	205.55	206.98	
2016	her-irlw		130.72	133.84	168.5	204.33	204.86	206.58	210.52	274.3
2017	her-irlw		133.46	161.43	172.3	185.24	196.36	194.56	202.98	177
2018	her-irlw	48.67	107.92	149.17	172.5	183.84	206.14	208.64	210.24	218.7
2019	her-irlw	86.42	116.56	153.2	167.5	190.95	182.68	189.54	220.5	218.9
2020	her-irlw	54.98	110.01	136.84	157.8	171.39	190.92	203.78	201.1	233.3
2021	her-irlw	70.22	108.67	151.23	171.12	182.24	195.80	203.31	205.02	210.58

Table 5.3.1.3. Herring in divisions 6.aS, 7.b–c. Maturity at age of herring June–July 2014-2021. From the Split Malin Shelf acoustic survey

Year	Age(-wr)	1	2	3	4	5	6	7	8	9+
2014	her-irlw	0	0.85	0.81	0.99	1	1	1	1	1
2015	her-irlw	0	0.41	0.84	0.98	0.94	0.99	0.98	1	
2016	her-irlw	0	1	1	1	1	1	1	1	1
2017	her-irlw	0	1	0.99	0.99	1	1	1	1	1
2018	her-irlw	0.01	0.42	0.82	0.97	0.98	1	1	1	1
2019	her-irlw	0	0.51	0.94	1	1	1	1	1	1
2020	her-irlw	0	0.25	0.64	1	1	1	1	1	1
2021	her-irlw	0.01	0.38	0.92	1	1	1	1	1	1

Table 5.3.2.1. Herring in divisions 6.aS, 7.b–c. Details of acoustic surveys dedicated to the 6a.S/7.b–c stock.

Year	Type	Biomass	SSB
1994	Feeding phase	-	353772
1995	Feeding phase	137670	125800
1996	Feeding phase	34290	12550
1997	-	-	-
1998	-	-	-
1999	Autumn	23762	22788
2000	Autumn	21000	20500
2001	Autumn	11100	9800
2002	Winter	8900	7200
2003	Winter	10300	9500
2004	Winter	41700	41399
2005	Winter	71253	66138
2006	Winter	27770	27200
2007	Winter	14222	13974
2016	Winter	35475	35475
2017	Winter	40646	40646
2018	Winter	50145	49523
2019*	Winter	25289	22386
2020**	Winter	45046	44107
2021**	Winter	35944	35859
*reduced survey area			
** Survey design changed significantly compared to other years, only 6 core areas covered			

Table 5.6.2.2. Herring in divisions 6.aS, 7.b–c. Definitions of the components used to calculate chr (from WKLIFEX, see table 3.4.2.1 of that report for a full description of how $F_{MSY\ proxy}$ is calculated).

Component	Definition	Description and use
I_{y-1}		The index in year *y*–1.
$F_{proxy,MSY}$	$\frac{1}{u}\sum_{y\in U} C_y/I_y$	Is the mean of the ratio C_y/I_y for the set of historical years U for which the quantity *f* > 1, and u is the number of years in the set U. The quantity *f* is the ratio of the mean length in the observed catch that is above the length of first capture relative to the target reference length (mean length/target reference length). The target reference length is $L_{F=M} = 0.75L_c + 0.25L_\infty$, where L_c is defined as length at 50% of modal abundance (ICES, 2018b).
b	$\min\left\{1, \frac{I_{y-1}}{I_{\text{trigger}}}\right\}$	Biomass safeguard. Adjustment to reduce catch when the most recent index data I_{y-1} is less than $I_{trigger} = 1.4I_{loss}$ such that b is set equal to $I_{y-1}/I_{\text{trigger}}$. When the most recent index data I_{y-1} is greater than I_{trigger}, b is set equal to 1. I_{loss} is generally defined as the lowest observed index value for that stock.
m	[0,1]	Multiplier applied to the harvest control rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. May range from 0 to 1.0.
Stability clause	$min\{max(0.7C_y, C_{y+1}), 1.2C_y\}$	Limits the amount the advised catch can change upwards or downwards between years. The recommended values are +20% and −30%; i.e. the catch would be limited to a 20% increase or a 30% decrease relative to the previous year's advised catch. The stability clause does not apply when *b* < 1.

Table 5.6.2.3. Herring in divisions 6.aS, 7.b–c. Estimate of natural mortality (M) used in the exploratory assessments for herring in 6aS, 7bc and various M/k ratio calculations. Most appropriate M/k ratio highlighted in bold.

Age	1	2	3	4	5	6	7	8	9	1 to 9	2 to 9	3 to 6
M	0.528	0.303	0.255	0.225	0.207	0.193	0.186	0.180	0.180	0.251	0.216	0.220
k										0.339	0.339	0.339
M/k										0.740	0.637	0.649

Table 5.6.2.3.1. Herring in divisions 6.aS, 7.b–c. Constants, lengths, survey index and catch data used in the calculation of $F_{MSY\ proxy}$ and target reference lengths.

Year	2014	2015	2016	2017	2018	2019	2020	2021
Catch (t)	5,096	1,078	2,213	2,227	1,495	1,690	1,220	1,821
Biomass estimates (I)	149,270	226,293	36,707	66,342	96,138	92,364	135,335	189,856
modal length in catch L	28.00	27.00	28.00	26.00	27.00	25.50	24.00	25.5
L_c (Length of first capture)	26.00	26.50	25.00	25.00	25.50	23.00	22.50	24.5
Mean length > L_c in catch	27.996	27.68	27.298	27.006	27.184	26.17	25.03	25.99
Target reference length ($L_{F=\gamma M,\ k=\theta M}$)	27.958	28.241	27.393	27.393	27.676	26.264	25.981	27.11
f	1.001	0.98	0.996	0.986	0.982	0.996	0.963	0.959
C_y / I_y where f > 1	0.034							
$F_{MSY\ proxy}$	0.034							
L_∞	30.50							
M	0.220							
k	0.339							
γ	1.000							
θ (=k/M)	1.541							

Notes

Catch (t)	Catch from 6aS7bc only
Biomass estimates (I)	MSHAS split 6aS7bc SSB
modal length in catch L	L = modal abundance (ICES, 2018).
L_c	Length of first capture = length at 50% of modal abundance (ICES,2018)
Mean length > L_c in catch	mean length (L_{y-1}) in the observed catch that is above the length of first capture relative to the target reference length (mean length/target reference length).
Target reference length	$L_{F=\gamma M,\ k=\theta M}$ using Jardim *et al.* (2015) equation (see text)
f	The quantity f is the ratio of the mean length in the observed catch that is above the length of first capture relative to the target reference length (mean length/target reference length).
C_y / I_y where f > 1	Is the ratio Cy/Iy for the set of historical years U for which the quantity f > 1, and u is the number of years in the set.
$F_{,MSY\ proxy}$	Is the mean of the ratio C_y/I_y for the set of historical years U for which the quantity f > 1, and u is the number of years in the set.
L_∞	L infinity estimated from catch sampled length data
M	Mean natural mortality ages 3-6
k	von Bertalannfy growth parameter estimated from catch sampled length data
γ	Gamma set to 1
θ	Theta =k/M

Table 5.6.2.3.2. Herring in divisions 6.aS, 7.b–c. chr summary table and advice using length, survey and catch data from 2014 – 2021 (inclusive).

$Catch_{y-1}$ (mean of last 3 years catch)	1,577 t
$Index_{y-1}$ (survey SSB)	189,856 t
$F_{MSY\ proxy}$	0.034
b (biomass safeguard)	1
m (multiplier)	0.5
chr ($C_{y+1} = I_{y-1} \times F_{proxy,MSY} \times b \times m$)	3,241 t
% Change (from previous 3yr catch)	+106%
Stability Clause Applied (-30% or +20%)	1,892 t
Advised Catch $_{y+1}$	1,892 t

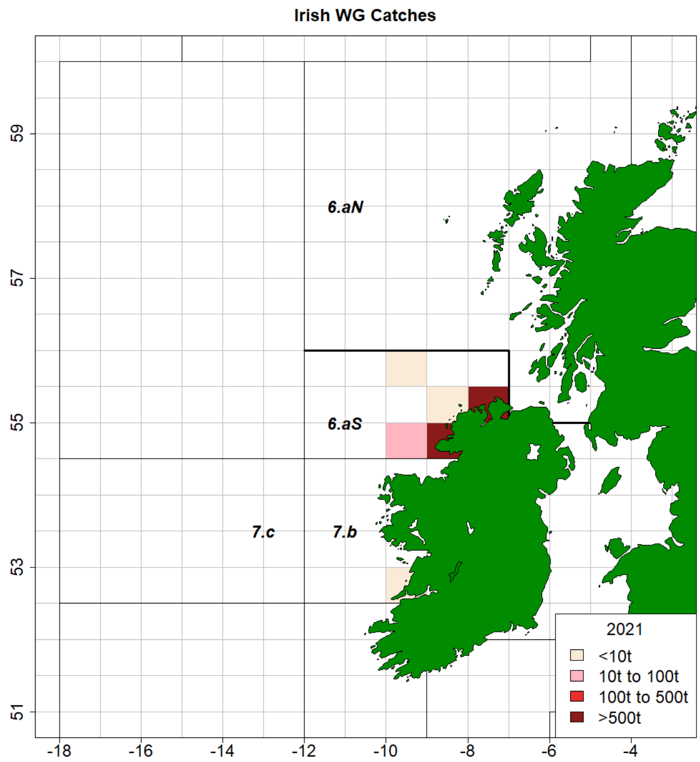


Figure 5.1.2 Herring in divisions 6.aS, 7.b–c. Irish catches in 2021.

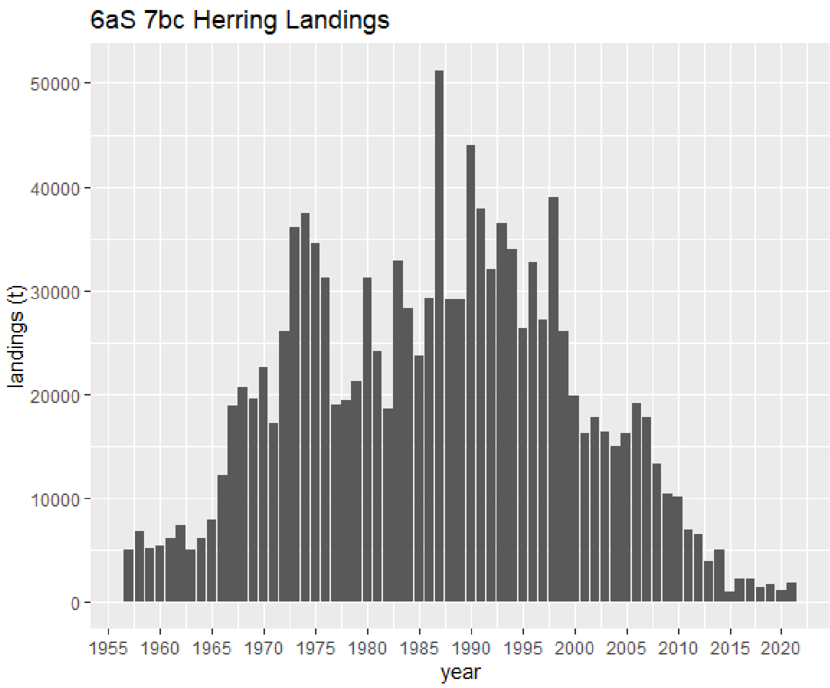


Figure 5.1.4 Herring in divisions 6.aS, 7.b–c. Working group estimate of catches from 1957–2021.

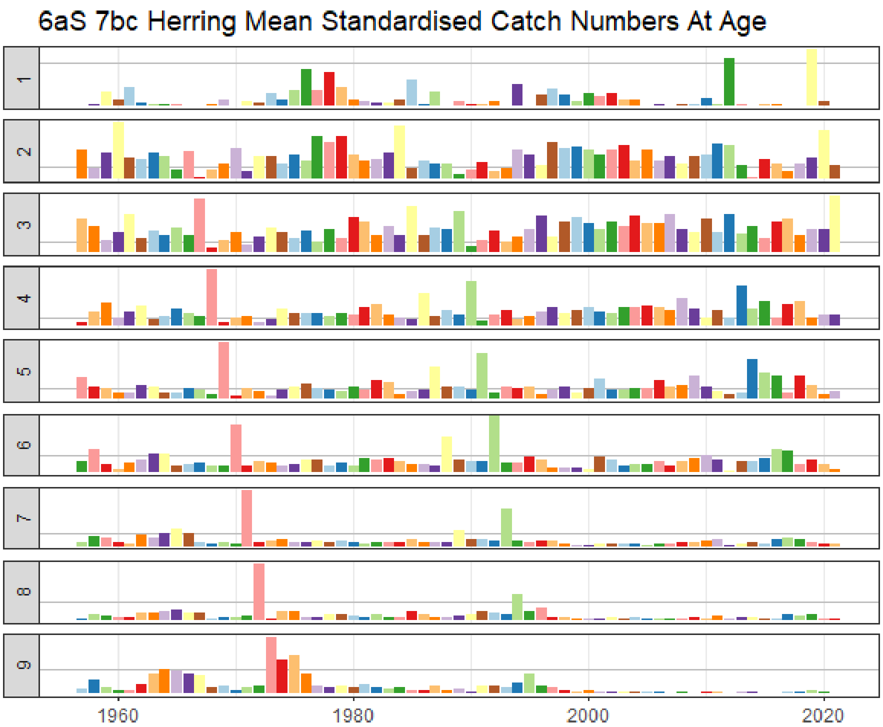


Figure 5.2.1. Herring in divisions 6.aS, 7.b–c. catch numbers-at-age standardized by year for the fishery 1957–2021.

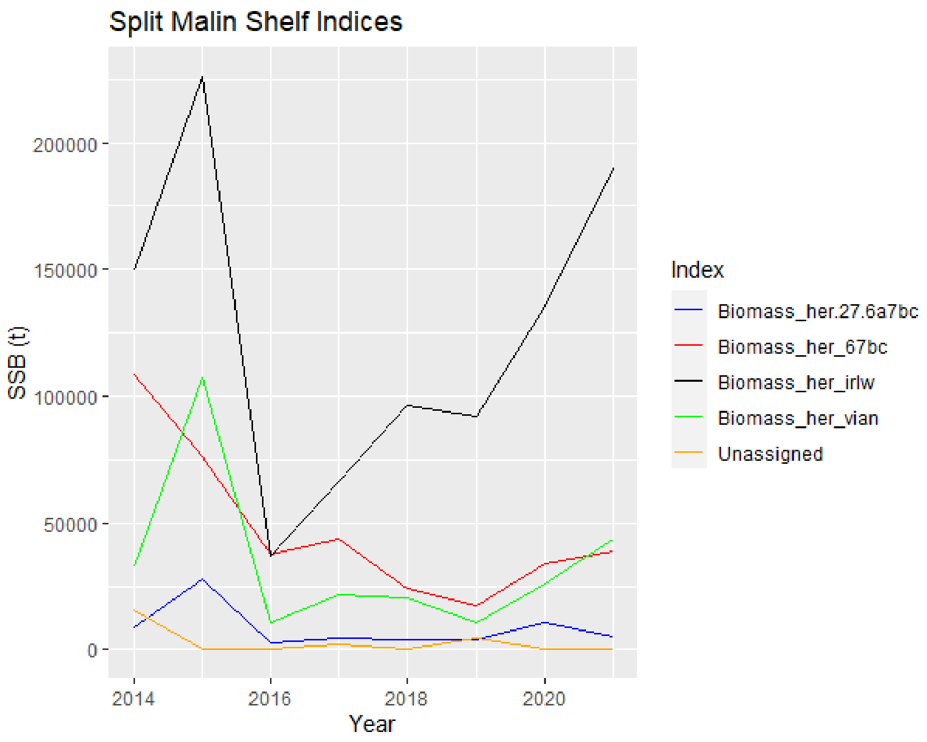


Figure 5.3.1.1. Herring in divisions 6.aS, 7.b–c . SSB (t) time-series for the individual MSHAS split indices (2014 – 2020). her-irlw refers to her.27.6aS,7b,c

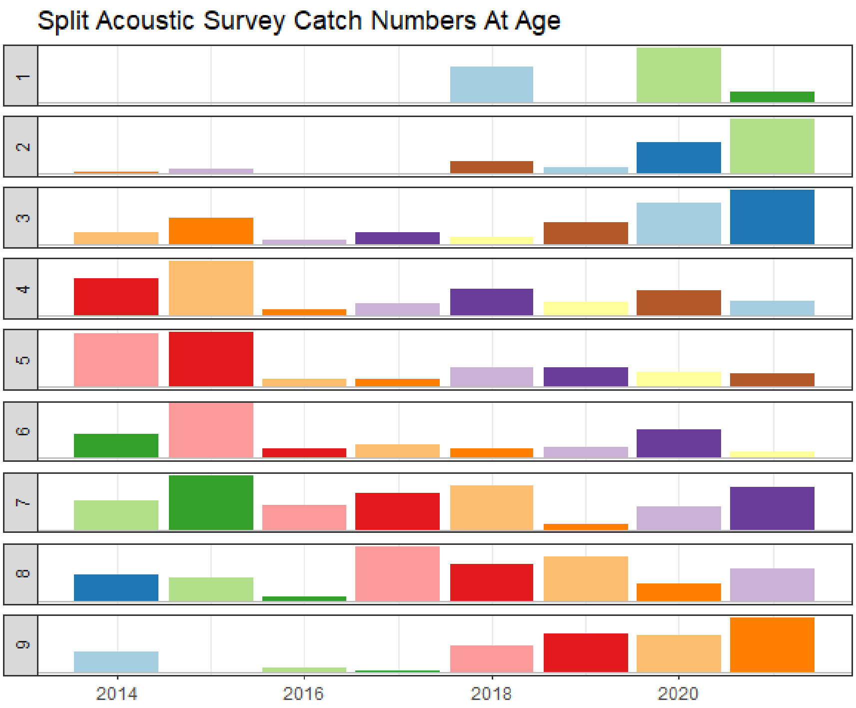


Figure 5.3.1.2. Herring in divisions 6.aS, 7.b–c. Malin Shelf Acoustic Survey - split catch numbers at age.

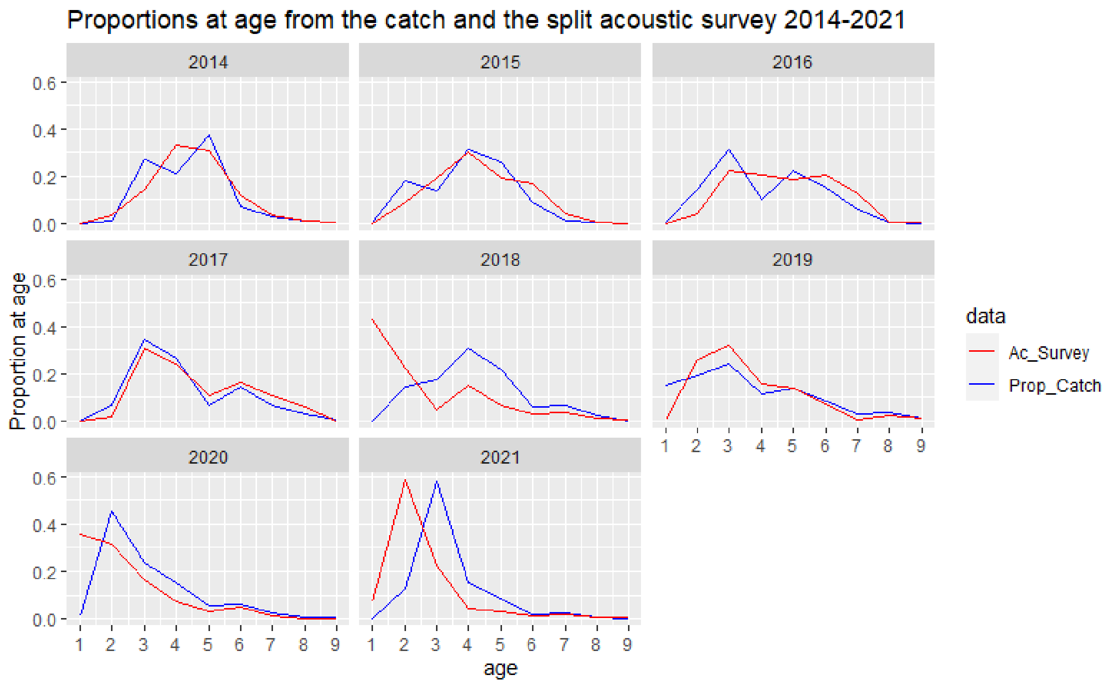


Figure 5.3.1.3. Herring in divisions 6.aS, 7.b–c. Proportions-at-age in the 6aS, 7.b–c catch and 6aS, 7.b–c Split Malin Shelf acoustic survey (MSHAS) 2014–2021.

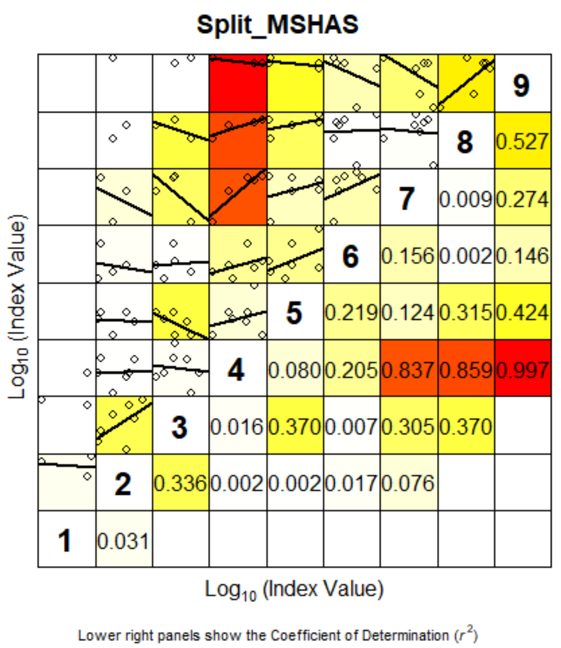
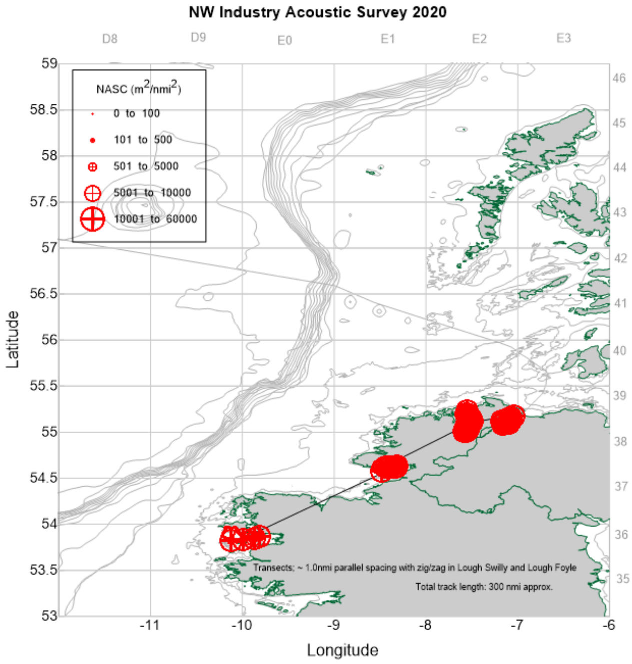


Figure 5.3.1.4 Herring in divisions 6.aS, 7.b–c. Internal consistency between ages (rings) in the Split MSHAS herring acoustic survey time-series (2014–2021).



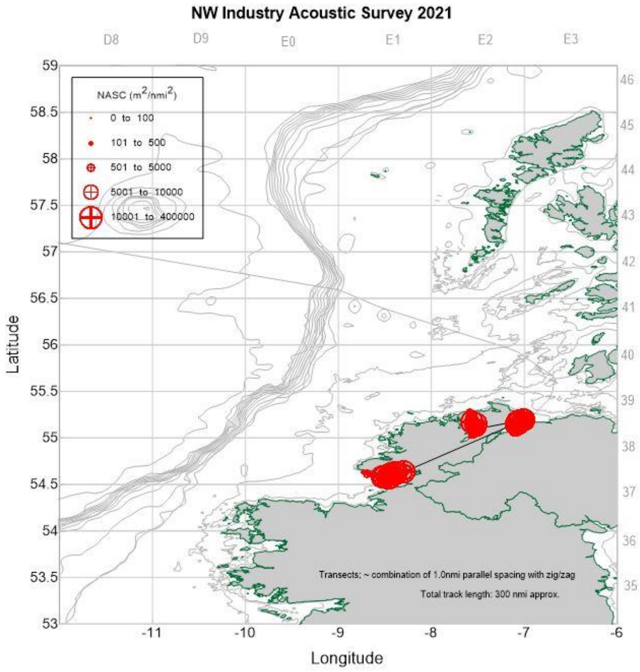


Figure 5.3.2.1. Herring in divisions 6.aS, 7.b–c. NASC distribution in the industry science surveys 2020 and 2021

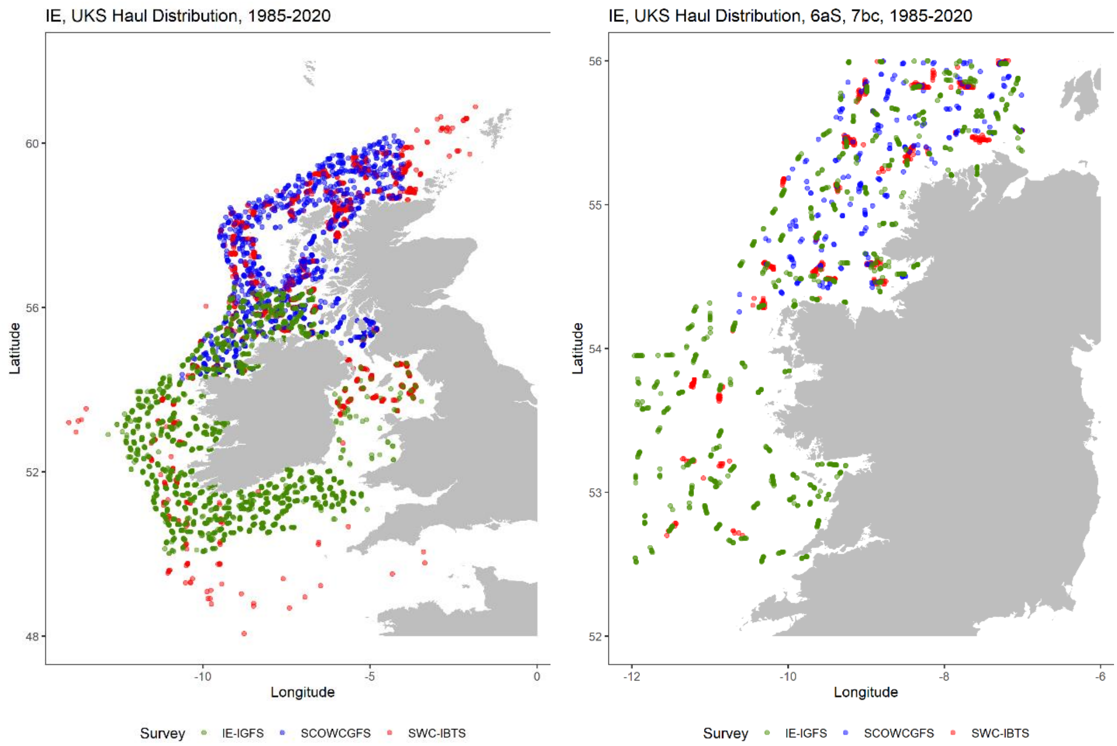


Figure 5.3.3.1 Herring in divisions 6.aS, 7.b–c . IBTS hauls positons from IE-IGFS (green), SWC-IBTS (red) and SCOWCGFS (blue) surveys, left – all hauls, right hauls in div 6a, south of 56˚N and divisions 7b and 7c

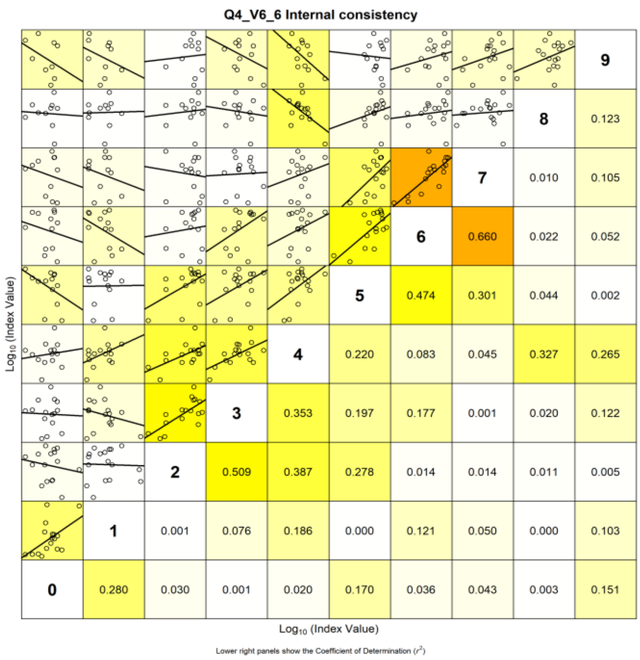


Figure 5.3.3.2. Herring in divisions 6.aS, 7.b–c. Internal consistency plot showing pairwise regressions and associated R^2 values from the IBTS Index.

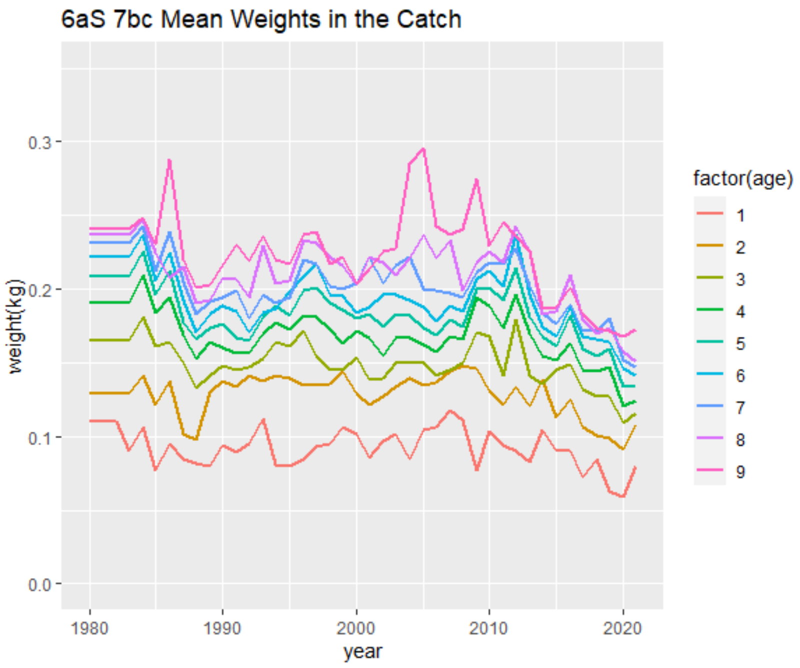


Figure 5.4.1.1. Herring in divisions 6.aS, 7.b–c. Mean weights in the catch (kg) by age in winter rings (1980–2021). Prior to 1981 weights were fixed.

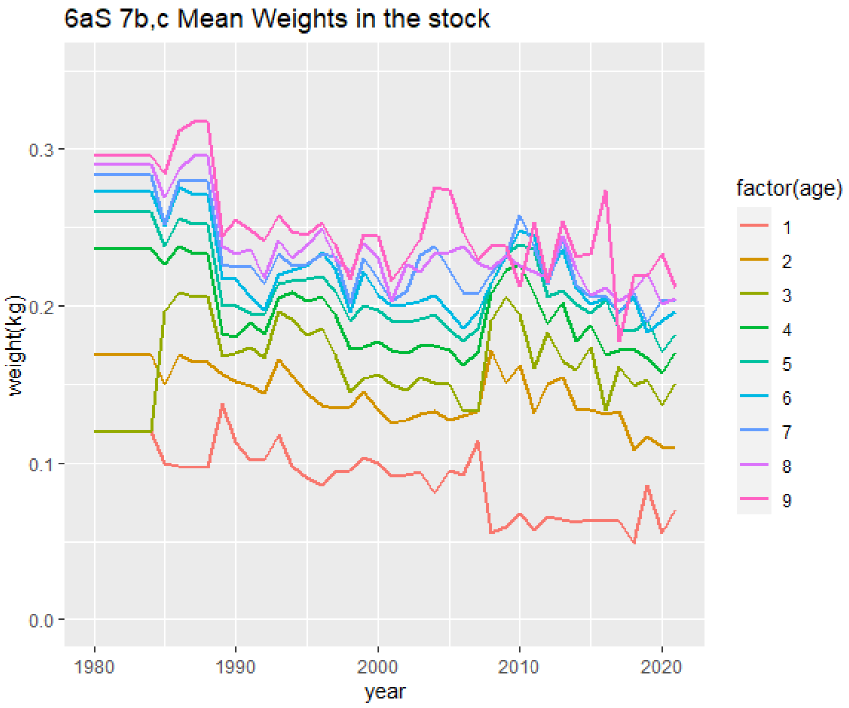


Figure 5.4.1.2. Herring in divisions 6.aS, 7.b–c. Mean weights in the stock (kg) at spawning time by age in winter rings (1980–2021). Prior to 1981 weights were fixed.

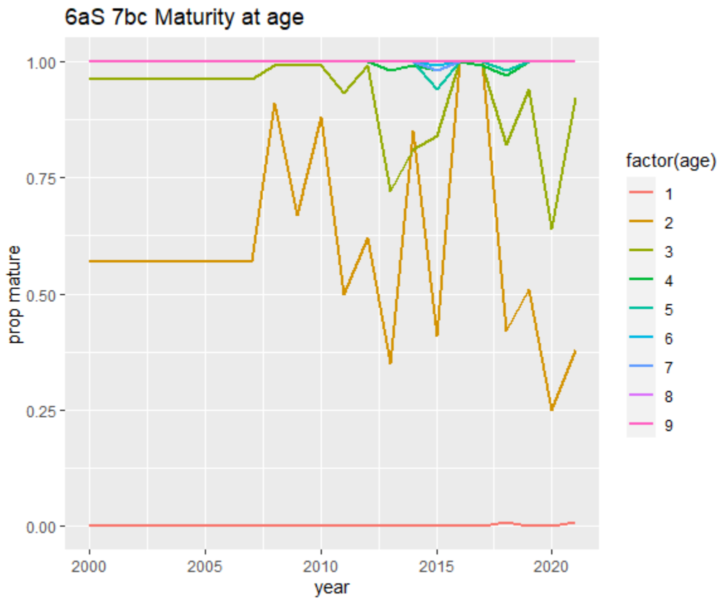


Figure 5.4.2. Herring in divisions 6.aS, 7.b–c. Maturity Ogive.

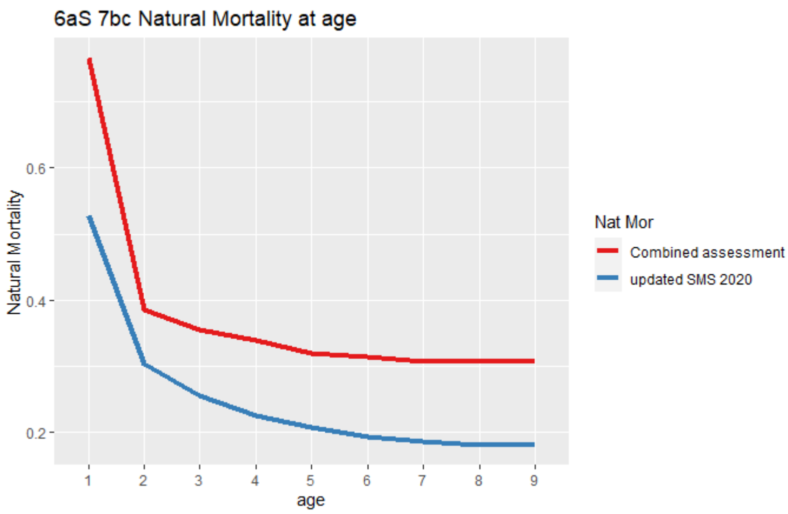


Figure 5.4.3. Herring in divisions 6.aS, 7.b–c. Natural Mortality at age updated at the benchmark in 2022 and the previously used value.

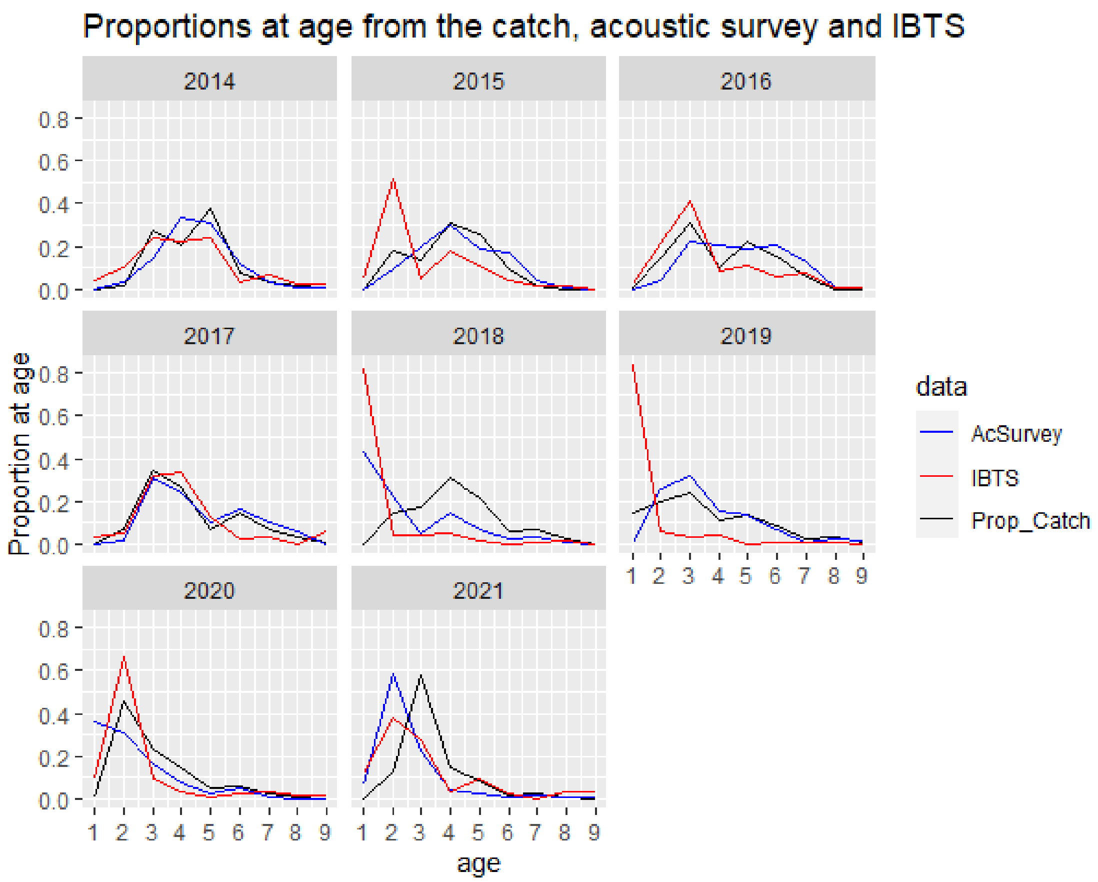


Figure 5.6.1. Herring in divisions 6.aS, 7.b–c. Proportions-at-age in the 6aS, 7.b–c catch and 6aS, 7.b–c Split Malin Shelf acoustic survey (MSHAS) and the IBTS survey 2014-2021.

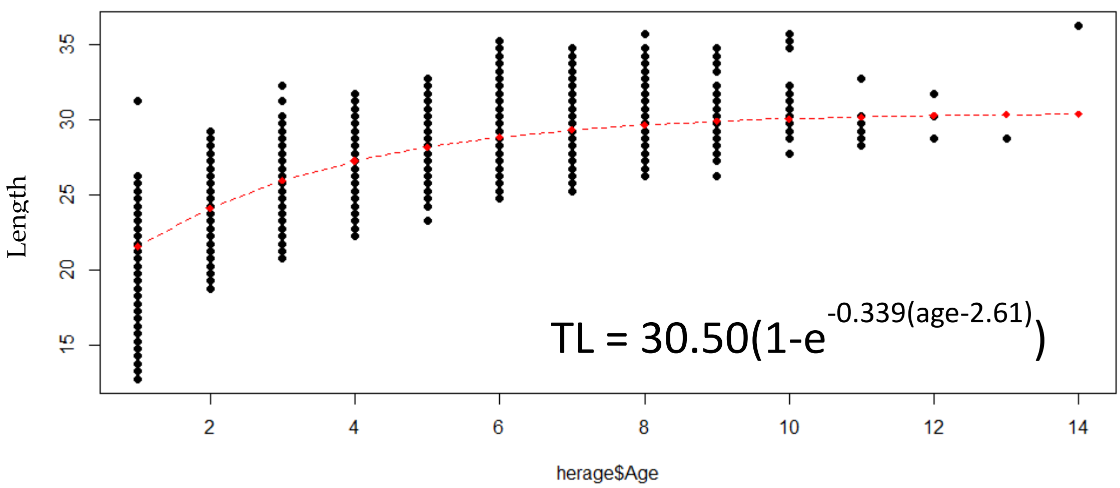


Figure 5.6.2.1. Herring in divisions 6.aS, 7.b–c. Fit of growth curve to length data from commercial catch of herring in 6aS and 7b. n = 594k.

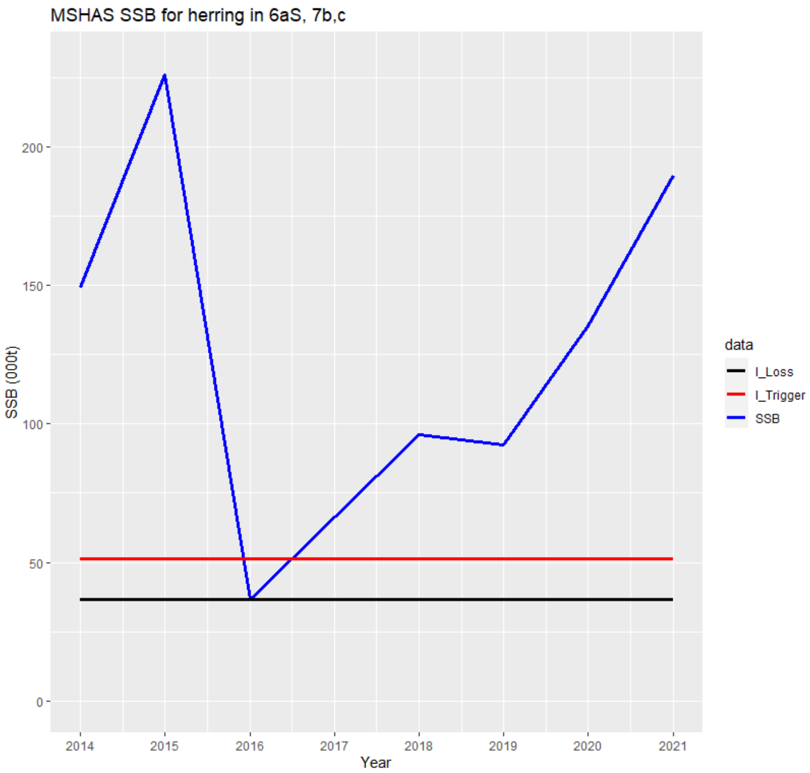


Figure 5.6.2.3.1 Herring in divisions 6.aS, 7.b–c. MSHAS 6aS Split Spawning Stock Biomass (tonnes) by year. Black line shows lowest observed value (I_{loss}); Red line shows 1.4 * I_{loss} ($I_{trigger}$).

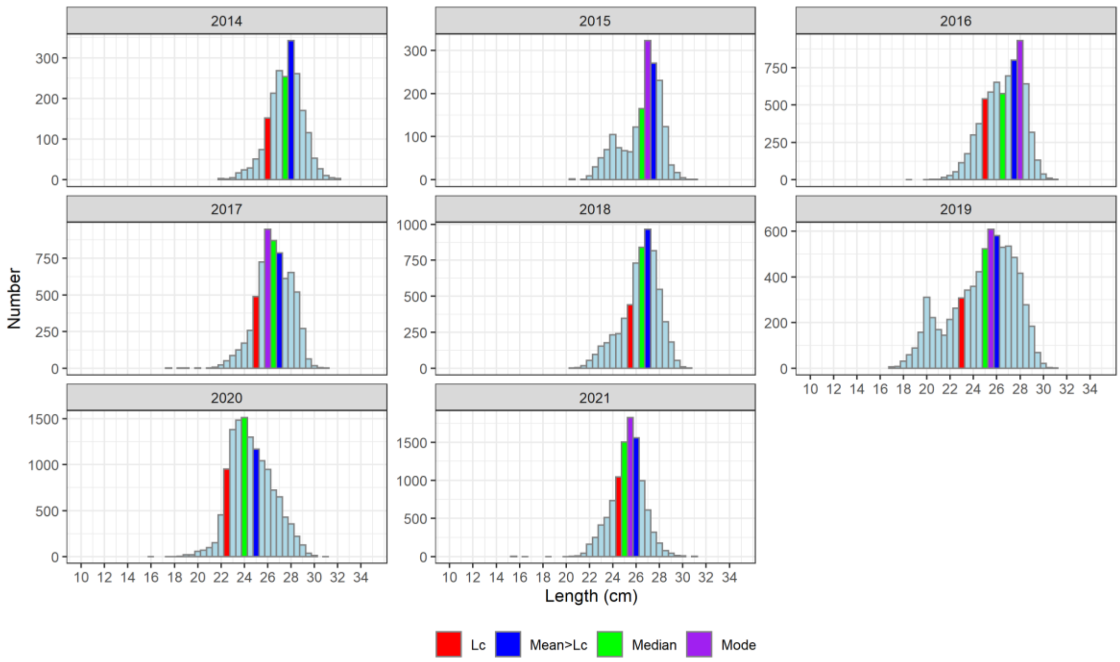


Figure 5.6.2.3.2 Herring in divisions 6.aS, 7.b–c. Length frequency distributions by year showing length at first capture (Lc), Mean length above Lc (Mean>Lc), the median and the mode from catch sampling data.

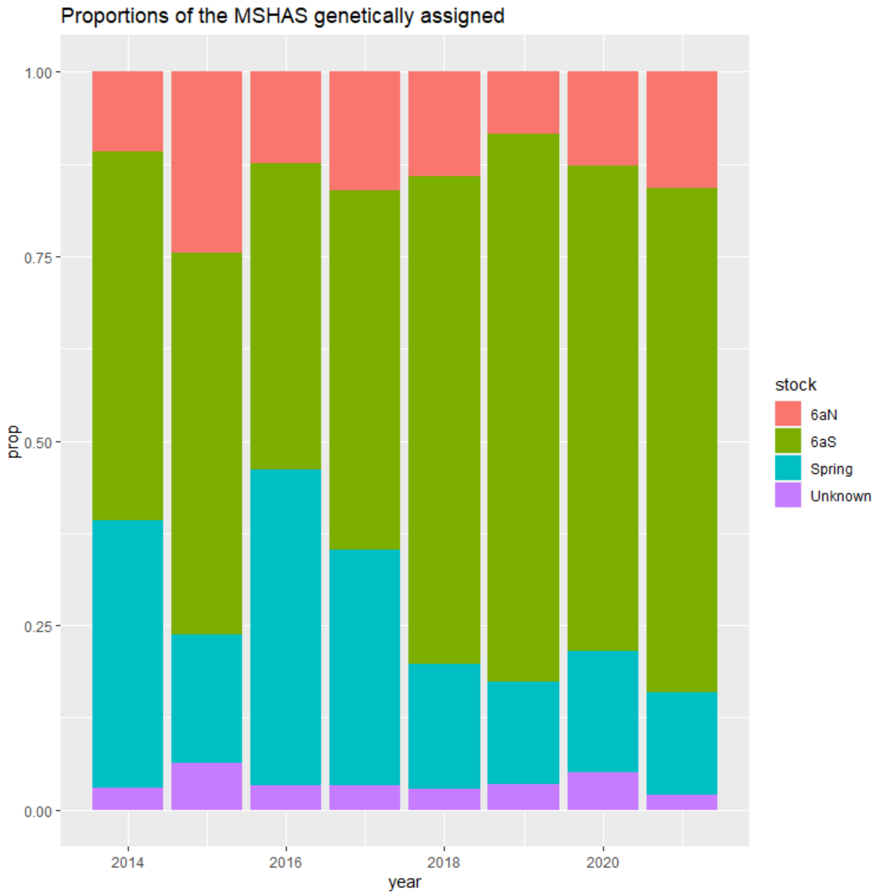


Figure 5.10.1. Herring in divisions 6.aS, 7.b–c. Proportions of the MSHAS genetically assigned.