4 Herring (*Clupea harengus*) in division 6.a (North), autumn spawners (West of Scotland)

Herring in division 6.aN existed as a distinct management unit from 1982 to 2014. Following the WKWEST benchmark meeting (ICES, 2015a) this stock was combined with herring in 6.aS 7.b-c, as the survey indices could not be successfully split between the two areas. From 2015 to 2021 the two stocks were assessed together as a meta-population (ICES, 2021a) despite continuing to be considered by HAWG as discrete stocks. Following genetic work (Farrell, *et al.*, 2021), the survey indices have been successfully split, and the combined stock was separated back into its components at the WKNSCS benchmark in 2022 (ICES, 2022a).

The location of the area occupied by the stock is shown in Figure 4.1. For assessment purposes this stock is considered as an autumn spawning stock only despite spring-spawning populations occurring in the area.

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.

4.1 The Fishery

4.1.1 Advice and management applicable to 2016–2021

ICES gave separate advice for herring in 6.aN up to 2015, and advice for the combined stocks since 2016. After the benchmarking process in early 2015 (ICES 2015a), the stocks were assessed together. The management plans in place for either stock were no longer applicable for the combined stocks. Considering the low SSB and low recruitment estimated for the combined stocks in recent years, ICES advised in 2016 that it was not possible to identify any non-zero catch that would be compatible with the MSY and precautionary approach. There were no catch options consistent with the combined stocks recovering to above B_{lim}, and consequently, ICES advised that the TAC be set at 0 t. 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. ICES advised on a scientific monitoring TAC of 4840 t (with a TAC split of 3480 t to be taken in 6.aN and 1360 t in 6.aS and 7.b–c (ICES 2016g). Furthermore, the data should be collected in a way that (i) satisfied standard length, age, and reproductive monitoring purposes by EU Member States for ICES, and (ii) ensured that sufficient spawning-specific samples were available for morphometric and genetic analyses as agreed by the Pelagic Advisory Council monitoring scheme 2016 (Pelagic Advisory Council, 2016).

The European Commission set a monitoring TAC slightly higher than this advice, at 5800 t (TAC split of 4170 t in 6.aN and 1630 t in 6.aS and 7.b–c; (EU, 2016), and the same for 2017, 2018 and 2019 (EU, 2017; 2018; 2019). This was reduced to 4840 t, split of 3480 t in 6.a.N and 1360 t in 6.a.S and 7.b-c for 2020 and 2021 (EU 2020; 2021).

Following the benchmark meeting in early 2022 (ICES 2022a), ICES has returned to providing separate advice for herring in 6.aN, although now this advice only covers the autumn spawning population in 6.aN.

4.1.2 Changes in the fishery

There have been no significant changes in the fishing technology of the fleets in this area in recent years. In 6.aN, the fishery has become restricted to the northern part of the area since 2006, focusing on the autumn spawning population. Prior to 2006 there was a much more even distribution of effort, both temporally and spatially. In 6.aN there were three fisheries prior to 2016, (i) a Scottish domestic pair trawl fleet and the Northern Irish fleet; (ii) the Scottish single boat trawl and purse-seine fleets and (iii) an international freezer-trawler fishery.

Since 2016 the fishery has been restricted to a monitoring fishery with a TAC of 4170 t between 2016 – 2019, and 3480 t in 2020-2022, a significant reduction on the 2015 TAC of 22 690 t for 6.aN.

4.1.3 The monitoring fishery

The industry–science survey aim is to improve the knowledge base for the spawning components of herring in 6.aN and 6.aS 7.b–c and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan.

Utilizing ICES advice on the monitoring fishery (ICES, 2016g) together with the experience from 2016 a review of spawning areas and timing and discussions with fishing skippers four areas were selected for surveying in 6.aN. Areas 2 and 4 are considered to be active spawning areas and Area 1 a pre-spawning aggregation area that contains an unknown mixture of stocks of Western and potentially North Sea herring where a large proportion of catches has been taken in the years prior to 2016 (ICES 2016g). Area 5 was a new addition for 2018 and 2019 based on evidence from 2017 from local creel fishers catches of herring on the east side of the North Minch.

Following the guidance arising from WKHASS (ICES 2020c), the survey area from 2020 onwards has focused on two principal spawning areas (Figure 4.1.3.1), with timing planned to coincide with the known spawning period. Strata 1 and 2 are reduced version of previous area 2 and 3 and correspond to regions that have been covered consistently since 2016. Moreover, refocusing the survey to these new strata means that it is now possible to provide a consistency the survey time-series, which will be necessary for developing time-series indices relevant for assessment purposes.

Following a proposal from industry to ensure that commercial catches in 6.aN in 2020 were reduced to a bare minimum, the removal of herring was limited to sample hauls during the acoustic surveys. Details of the survey are reported in WGIPS (ICES 2021b) and Mackinson *et al*. (2021). In total only 177 tonnes of herring were caught in 6.aN during 2020. Following continued concern over the poor state of the stock, industry reiterated their wish to minimise commercial catches in 6.aN in 2021 to a bare minimum, proposing that the only removal of herring from 6.aN should be limited to sample hauls during the acoustic surveys (Mackinson *et al*. 2022). In 2021 1 115 tonnes of herring were caught in division 6.aN. The low uptake of the monitoring TAC in 2020 and 2021 was due to a combination of the industry taking pro-active measures to avoid commercial catch when the stock is low, a change in management measures and difficulties in catching allocated monitoring quotas.

4.1.4 Stock recovery plan

The Pelagic Advisory Council submitted a revised proposed rebuilding plan for both 6.aN and 6.aS 7.b–c stocks combined which was reviewed by HAWG 2018 (ICES 2018b, Annex 9). However, ICES ACOM considered that further quantitative evaluation would be required to be used as the basis for advice. ICES advice in 2019 stated *'ICES still considers it important to develop a stock recovery plan for herring in divisions 6.a and 7.b–c, but given the large changes in perception of the stock, fishing pressure and recruitment together with the continued uncertainty in the quality of the assessment, the requirement for a rebuilding plan (or plans) are considered to be better addressed during a full benchmark, anticipated for 2021'.* There is no specific stock recovery plan in place for herring in 6.aN.

4.1.5 Regulations and their affects

The 4° meridian divides 6.aN from the North Sea stock. It is not clear if this boundary is appropriate, as it bisects some of the spawning grounds and evidence suggests 6.aN autumn spawning herring are genetically identical to North Sea autumn spawning herring (NSAS). Historically area misreporting is known to have occurred across the boundary. The north–south boundary between 6.aN and 6.aS (56° parallel) is also 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.

4.1.6 Catches in 2021

The Working Group's best estimate of removals from the stock is shown in Table 4.1.6.

4.1.7 Length Frequency information

Length frequency information are available from commercial market sampling from 2014 to 2015 before the introduction of the monitoring TAC and from commercial hauls under the monitoring TAC from 2016 to 2021 (Figure 4.1.7.1). In 2018 length frequency data from Dutch vessels were only collected to 1 cm bins, so all data were binned to this resolution for this year. In 2020 catches in 6.aN were reduced to a minimum and removals were limited to survey hauls only, therefore commercial length frequency data are not available for this year. In 2021 the length frequency data come from commercial hauls by one vessel (Chris Andra) only.

4.2 Biological Composition of the Catch

Catch and sample data by country and by period (quarter) in 2021 are detailed in Table 4.2.1. Although the current assessment does not require data on numbers or weights at age in the catch, these data are detailed in tables 4.2.2 and 4.2.3 and displayed in figures 4.2.1 and 4.2.2. Biological data sampled from commercial hauls (n = 2) were used to allocate the age distribution for the 6.aN catches. The allocation of age distributions to un-sampled catches and the calculation of total international catch-at-age and mean weight-at-age in the catches were done following established raising methods. A detailed description of the process can be found in (WD02 HAWG 2017). The principles described in that document were followed in 2021 as far as possible. The number of samples in 2021 does not meet the requirements of the monitoring fishery as advised by ICES (ICES 2016g), and caution should be applied when comparing trends in biological composition of the catch with other years when sampling was more comprehensive.

4.3 Fishery-independent Information

4.3.1 Acoustic surveys (A9481)

An acoustic survey has been carried out in Division 6.aN by Marine Scotland Science in June–July since 1991. It originally covered an area bounded by the 200 m depth contour in the north and west, to the 4°W in the east and extended south to 56°N; it had provided an age-disaggregated index of abundance as the sole tuning index for the analytical assessment of 6.aN herring since 2002. In 2008, it was decided that this survey should be expanded into a larger coordinated summer survey on recommendation from WESTHER, HAWG and SGHERWAY (Hatfield *et al.*, 2005; ICES 2007; ICES, 2010). The Scottish 6.aN survey was augmented with the participation of the Irish Marine Institute and the area was expanded to cover all of ICES divisions 6.a and 7.b. The Malin Shelf Herring Acoustic Survey (MSHAS), as it is now known, has covered this increased geographical area in the period 2008 to 2020 as well as maintaining coverage of the original survey area in 6.aN. Genetic work (Farrell *et al.*, 2021) has allowed estimates from this survey to be split between populations (ICES 2022a), but these only go back to 2014.

The Malin Shelf herring estimate of SSB for autumn spawning herring in 6.aN in 2021 is 43 886 tonnes and 341 million individuals (Table 4.3.1), an increase compared to 2020. Although estimates appear to be improving from the minimum value in 2019, it should be noted that numbers of herring to the West of Scotland are very low compared to historical estimates prior to the genetic split (ICES 2021a).

Herring has in the past been found in high densities to the east of the 4°W line in association with a specific bathymetric feature and the occurrence of these herring west of the line in some years has the ability to strongly influence the annual estimate of abundance of the Malin Shelf/West of Scotland estimates. There is some evidence that this was the case in 2019. It appears that the increase in the 2017 and 2018 estimates compared to 2016 were a result of a greater spread in the distribution of herring rather than distributions occurring around the 4°W line. The stock in 2021 is dominated by 2-winter ringers (39.7% of the abundance, 2019 year class). Age disaggregated survey abundance indices for 6.aN autumn spawning herring since 2014 are given in Table 4.3.2 and displayed in Figure 4.3.1.1.

The stock is highly contagious in its spatial distribution, which explains some of the high variability in the time-series. The survey covers the area at the time of year when aggregations of herring from both the 6.aN and 6.aS, 7.b–c stocks are offshore feeding (i.e. not at spawning time). These distributions of offshore herring aggregations are considered to be more available to the survey compared to surveying spawning aggregations, which aggregate close to the seabed and are generally found inshore in areas unsuitable for the large vessels carrying out summer acoustic surveys. Genetic analyses outlined in Farrell *et al.*, 2021 split these indices into 6.aN autumn spawning herring and 6.aS, 7b-c winter spawning herring for use in assessments.

4.3.1.1 Industry–Science Acoustic survey

From 2016 to 2021 industry acoustic surveys of herring during the spawning and pre-spawning period were undertaken as part of the monitoring fishery on this stock. The surveys cover known active spawning grounds in both 6.aN and 6.aS,7b at spawning time and aim to provide estimates of minimum spawning stock size in each of the areas. Two industry vessels were used to undertake acoustic surveys on the spawning ground in September to collect acoustic data and information on the size and age of herring required to generate an age-disaggregated acoustic estimate of the biomass of prespawning/ spawning herring in 6.aN.

Full results from the surveys can be found in (ICES 2022b), who conclude that the survey in 2021 provides a reliable estimate of the minimum biomass of mature herring at age and the minimum

spawning biomass observed in survey areas during the survey period. The limited sampling by one vessel involved in the survey in 2021 and some uncertainty over the quality of acoustic data recorded using the Furuno FCV-30 on another led to the decision to combine biological samples from both vessels in the acoustic analysis. While this practice is not uncommon, the temporal lag was not optimal.

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

4.4.1 Mean weight-at-age

Weights-at-age in the stock are obtained from the genetically split acoustic survey and are given in Table 4.3.1 (for the current year) and Table 4.4.1.1 (for the time-series). The weights-at-age in the stock have been steadily declining since 2014 (Figure 4.4.1.1). Weights-at-age in the catches are presented in Table 4.2.3.

There have been fluctuations in catch weights over time. In several years no 1 winter ring fish have been taken in the 6.aN fishery. In 2021 the catch weights have increased across age classes compared to 2020.

4.4.2 Maturity ogive

The maturity ogive is obtained from the acoustic survey (Table 4.4.2.1). The genetically split Malin Shelf Acoustic Survey (MSHAS) provides estimated values for the period 2014 to 2021, but in some years no estimates are available at younger ages. The proportion mature of ages 2 and 4-wr in 2021 were similar to 2020.

4.4.3 Natural mortality

The natural mortality used in previous assessments of several herring stocks to the West of Scotland, including 6.aN, were based on the results of a multispecies VPA for North Sea herring calculated by the ICES multispecies working group in 1987 (ICES 1987). From 2012 onwards the assessment of North Sea herring has used variable estimates of M-at-age derived from a new multispecies stock assessment model, the SMS model, used in WGSAM (Lewy and Vinther, 2004).

The benchmark of herring in Division 6.a and 7.b–c (ICES 2015) agreed to use the natural mortalities for North Sea herring from the current North Sea multispecies model, as it is deemed the best available proxy for natural mortality of herring in 6.a and 7.b–c. The input data to the assessment of herring in divisions 6.a and 7.b–c are averaged annual M values from the 2011 SMS key run (period 1974–2010) for each age. This approach is similar to the pre-benchmarked assessment in that it is time invariant and age variant. This time-series reflects the most recent period of stability in terms of M from the North Sea SMS as it excludes the gadoid outburst of the 1960 which is of little relevance to present day conditions.

In 2020, the SMS model from the North Sea was updated (ICES 2021c), and new values for natural mortality became available (Table 4.4.3.1). At the latest benchmark (ICES 2022a) it was agreed that these values were the most suitable for herring in 6.aN. For the category three methods, the value of M was taken from ages 3-6.

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

4.5 Recruitment

There are no specific recruitment indices for this stock. Although both the catch and the surveys generally have some catches at 1-wr, both the fishery and survey encounter this age group only incidentally. The first reliable appearance of a cohort appears at 2-wr in both the catch and the stock.

4.6 Assessment of 6.aN autumn spawning herring

The assessment presented here follows the procedure agreed by the most recent benchmark (ICES 2022a). The tool for the assessment of herring in 6.aN follows the category 3 WKLIFE guidelines (ICES 2021d; ICES 2021e).

Data Exploration

For category three stocks, advice is provided using biomass or abundance trends-based assessments. The latest ICES guidance on applying these methods recommends that a Surplus Production in Continuous Time model (SPiCT, Pedersen and Berg, 2017) should be attempted first. If an acceptable SPiCT model is not possible, other data-limited approaches should be attempted, based on the von Bertalanffy growth parameter *k* for the population being assessed (ICES 2021d).

A SPiCT model using various model settings was attempted for herring in 6.aN at the 2022 benchmark, but no suitable model could be developed for this stock (ICES 2022a). Following the recommendations of WKLIFE, (ICES 2021d), the growth parameter *k* was calculated for this stock.

At the benchmark meeting in 2022, length-at-age data from the commercial fishery were not available for the calculation of growth parameters, and the calculations were done using the biological data from the acoustic survey. Biological data from the 6.aN genetically split acoustic survey were extracted from DATRAS and analysed to calculate *k* and asymptotic length (ICES 2022a). These fish are unquestionably 6.aN autumn spawning herring (compared to catch/IBTS data where we don't have genetic samples available). Guidelines indicate that calculations of growth parameters should come from commercial data (ICES 2021d), and this calculation was updated for HAWG in 2022.

Commercial market sampling data from 2000-2015 and data from commercial hauls under the monitoring TAC were used to recalculate growth parameters. This assessment includes 6.aN autumn spawning herring only, and individuals thought to be from the spring-spawning component should be removed. Therefore samples taken from the South Minch area (Figure 4.6.1) were removed from the market sampling data prior to the calculation of growth parameters.

Von Bertalanffy growth parameters were calculated from the combined commercial data for autumn spawning herring in 6.aN from 2000-2021 (Figure 4.6.2), and gives and estimated L_∞ value of 30.51cm and an associated *k* value of 0.335. Given that $0.32 \leq k \leq 0.45$, the Constant Harvest Rate should be used to provide advice.

Assessment

The constant harvest rate (CHR) applies a constant harvest rate ($F_{MSY\ proxy}$ calculated from catch length frequency data) that is considered a proxy for MSY harvest rate, and applies this to the biomass index. This rule is being applied using the genetically split acoustic survey index, so runs from 2014 onwards. The $F_{MSY\ proxy}$ used in applying this rule is calculated from the length frequency data.

$F_{MSY\ proxy}$ is calculated as the average of the ratio of catch C to the biomass index I, calculated across all years for which mean length / target reference length >1. The target reference length ($L_{F=M}$) is calculated from the length frequency data and is key to the $F_{MSY\ proxy}$ value calculation. Target reference length is usually calculated using the following equation:

$L_{F=M} = (0.75*L_{c(y)}) + (0.25*L_{inf})$

This calculation assumes that the M/k ratio is equal to 1.5. When the actual M/k ratio is calculated for 6.aN herring the value comes to 0.65, which is considerably different to the assumed value. Using the assumed method with an M/k ratio of 1.5 would suggest a natural mortality estimate of 0.51 for herring in 6.aN. This value contrasts with the values taken from the 2020 SMS key run. ICES technical guidelines (ICES 2018b) state that stock specific M/k values can be applied by using an alternative $L_{F=M}$ calculation from Jardim *et al*. 2015. This alternative method for calculating the target reference length was approved at the benchmark meeting in 2022 (ICES 2022a), using the following equation:

$L_{F=\gamma M,K=\theta M} = \theta\ L_{inf} + L_c\ (\gamma + 1)/\ \theta + \gamma + 1$

As per ICES, 2021d, advised catch is calculated as follows:

$Cy+1 = Iy\text{-}1 \times F_{MSY\ proxy} \times b \times m$

The components of this formula were estimated as follows.

- I_y is the biomass index for year y. In this case, using the 6.aN autumn spawning herring from the Malin Shelf Herring Acoustic Survey , $\boldsymbol{I_y = 43\ 866}$.
- $F_{MSY\ proxy}$ is the average of the ratio of catch C to the biomass index I, calculated across all years for which $L_{mean}/L_{F=M} > 1$. The comparison between L_{mean} and $L_{F=M}$ is shown in Table 4.6.1, from which it can be seen that 2014 - 2018 should be used in the calculation of $F_{MSY\ proxy}$. The ratio C/I is shown in Figure 4.6.3, and the average is $\mathbf{0.335}$.
- $b = min\{1, I_y/I_{trigger}\}$. The value used for $I_{trigger}$, 14 711, is $1.4I_{loss}$, where $I_{loss} = 10\ 508$ is the lowest observed biomass index value. Doing so results in $\boldsymbol{b = 1.0}$.
- m is a multiplier intended to avoid biomass declining below B_{lim}. In this situation WKLIFE recommends that $\boldsymbol{m = 0.5}$.

Using these estimates the formula gives:

$Cy+1 = 43866 \times 0.335 \times 1 \times 0.5 = 7\ 362$ tonnes

Under WKLIFE guidelines (ICES 2021d) a stability clause of +20% and -30% is recommended relative to the previous year's advised catch. Herring in 6.aN is a new stock so the 'previous year's advice' does not apply in this case. Therefore, the stability clause should be applied against a mean of the past three year's catch (1010 tonnes). When the stability clause is applied, the advised catch for herring in 6.aN under the CHR rule is 1 212 tonnes.

4.6.1 Final Assessment for 6.aN autumn spawning herring

In accordance with the method set out in the Stock Annex, the final assessment of 6.aN autumn spawning herring was carried out using the Constant Harvest Rate (CHR) rule. This follows on from the benchmark in early 2022 (ICES 2022a).

4.6.2 State of the stock

Fishing mortality has been reduced since the introduction of zero catch advice and in line with the monitoring TAC in 2016. SSB remains at very low levels relative to the long term trend,

despite improvements since 2019. Recruitment has been low, with no big cohorts evident in recent years. Recent catches have been among the lowest in the time-series.

4.7 Quality of the Assessment

This assessment is now for herring in 6.aN only, following 7 years of a combined assessment with herring in 6.aS, 7.b-c. Unlike prior assessments for 6.aN herring, this assessment only includes the Cape Wrath autumn spawning component, as the Minch spring spawners cannot currently be split out from the acoustic index using genetic information. Further information on this population of herring is detailed in section 8.2 of this report.

Herring in 6.aN have been under zero advice and a monitoring TAC since 2016 under the combined assessment. Despite and increasing trend in recent biomass estimates, the survey biomass for this stock remains at low levels compared to historical values.

There have been indications that the autumn spawning herring population in 6.aN are genetically identical to the North Sea autumn spawning population. These unresolved stock identity issues should be investigated in the future.

4.8 Management Considerations

Recruitment has been at a low level since 1998 and even lower since 2013. There is almost complete absence in the stock of 7,8, and 9+ winter ring fish in both the catches and the acoustic survey in recent years

The survey index across the whole Malin Shelf Herring Acoustic Survey has been steadily decreasing since 2008 (ICES 2022b). Although the 2021 estimates for autumn spawning 6.aN herring indicate increases since 2019, the stock remains at very low levels compared to long term trends.

A monitoring TAC of 4 170 t was implemented from 2016-2019, and reduced to 3480 t in 2020-2022 to allow sampling for each stock separation and maintain the time-series of catch composition.

The assessment for herring in 6.aN includes only the autumn spawning component around Cape Wrath. The spring-spawning herring in the Minch area have not yet been split out from the acoustic survey and are no longer assessed by HAWG.

4.9 Ecosystem Considerations

Herring constitute some of the highest biomass of forage fish to the west of Scotland and Ireland, and are thus an integral part of the ecosystem. As a dominant planktivore, herring link zooplankton production with higher trophic level predators that eat them, including fish, sea mammals and birds. Ecosystem models of the West of Scotland (Bailey *et al*., 2011; Alexander *et al*., 2015) show herring to be an important mid-trophic level species along with sprat, sandeel, and horse mackerel. They can also act as predators on other fish species by their predation on fish eggs at certain times of year (ICES, 2014a). Work using a length-based ecosystem modelling, suggests a link between herring biomass and North Sea cod (Speirs *et al*., 2010), via the predation of cod eggs by herring.

As herring constitute an important part of the overall biomass of plankton feeding and forage fish in the west of Scotland and Ireland ecosystem, impacts from changes in productivity from environmental drivers are likely to be widely felt.

4.10 Changes in the Environment

Temperatures in this area have been increasing over the last number of decades, and there are indications that salinity is also increasing (ICES 2006). It is considered that this may have implications for herring. 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). With environmental changes predicted to continue, the impacts on herring in 6.aN are uncertain.

Table 4.1.6. Herring in division 6.aN. ICES estimated catches by country. Units: Tonnes

Year	Denmark	Faroe Islands	France	Germany	Ireland	Netherlands	Lithuania	Norway	UK	Unallocated	Discards*	Total	Area misreported	ICES estimate
1992	0	0	119	5640	7985	8000	0	2389	32730	-5485	200	51578	-22593	28985
1993	0	0	818	4693	8236	6132	0	7447	32602	-3735	0	56175	-24397	31778
1994	0	274	5087	7938	6093	8183	0	30676	-4287	700	0	54664	-30234	24430
1995	0	0	3672	3733	3548	7808	0	4840	42661	-4541	0	61271	-32146	29575
1996	0	0	2297	7836	9721	9396	0	6223	46639	-17753	0	64359	-38254	26105
1997	0	0	3093	8873	1875	9873	0	4962	44273	-8015	62	64995	-29766	35233
1998	0	0	1903	8253	11199	8483	0	5317	42302	-11748	90	65799	-32446	33353
1999	0	0	463	6752	7915	7244	0	2695	36446	-8155	0	61514	-23623	29736
2000	0	0	870	4615	4841	4647	0	0	22816	0	0	37789	-14627	23162
2001	0	0	760	3944	4311	4534	0	0	21862	277	0	35688	-10437	25251
2002	0	800	1340	3810	4239	4612	0	0	20604	6244	0	41649	-8735	32914
2003	0	400	1370	2935	3581	3609	0	0	16947	2820	0	31622	-3581	28081
2004	0	228	625	1046	1894	8232	0	0	17706	3490	123	33344	-6885	26459
2005	0	1810	613	2691	2880	5132	0	0	17494	0	772	31392	-17263	14129
2006	0	570	701	3152	4352	7008	0	0	18284	0	163	34230	-6884	27346
2007	0	484	703	1749	5129	8052	0	0	17618	0	0	33735	-4119	29616
2008	0	927	564	2526	3103	4133	0	0	13963	0	0	25216	-9162	16054

Year	Denmark	Faroe Islands	France	Germany	Ireland	Netherlands	Lithuania	Norway	UK	Unallocated	Discards*	Total	Area misreported	ICES estimate
2009	0	1544	1049	27	1935	5675	0	0	11076	0	0	21306	-2798	18508
2010	0	70	511	3583	2728	3600	0	0	12018	0	95	22510	-2728	19877
2011	0	0	504	3518	3956	1684	0	0	11696	0	0	21358	-3599	17759
2012	0	0	244	1829	3451	3523	0	0	12249	0	0	21296	-2780	18516
2013	0	0	586	4025	3124	1775	0	0	15906	0	30	25446	-2468	22978
2014	0	360	589	3354	2632	1641	770	0	16769	0	0	26115	-4088	22027
2015	0	0	0	3292	1799	956	0	1	15260	0	0	21307	-2506	18801
2016	23	0	0	1028	569	300	0	0	3254	0	0	5174	-450	4724
2017	0	0	0	0	10	835	0	0	3356	0	0	4200	0	4201
2018	39	0	7	17	84	1000	0	4	2911	0	0	4063	0	4063
2019	71	0	46	2	37	653	0	3	928	0	0	1739	0	1739
2020	0	4	0	0	116	85	0	0	51	0	0	256	-79	177
2021	0	0	0	0	242	5	0	0	974	0	0	1221	-106	1115

*unraised discards

Table 4.2.1. Herring in division 6.aN. Catch and sampling effort by nation in the fishery in 2021

Country	Quarter	Sampled catch (t)	Official Catch (t)	No. Hauls	No. of samples	No. measured	No.aged	SOP
UK (SCO)	1	0	39	-	-	-	-	0%
	3	671	751	2	2	182	43	112%
UK (NI)	3	0	180	-	-	-	-	0%
UK (ENG)	1	0	5	-	-	-	-	0%
Ireland	1	0	137	-	-	-	-	0%
Netherlands	4	0	5	-	-	-	-	0%
Total		671	1115	2	2	182	43	112%

Table 4.2.2. Herring in division 6.aN. Catch in number. Units: Thousands

Year	1	2	3	4	5	6	7	8	9+
1957	6496	74622	58086	25762	33979	19890	8885	1427	4423
1958	15616	30980	145394	39070	24908	27630	17405	9857	7159
1959	53092	67972	35263	116390	24946	17332	16999	7372	8595
1960	3561	102124	60290	22781	48881	11631	10347	6346	4617
1961	13081	45195	61619	33125	22501	12412	5345	4814	2582
1962	55048	92805	22278	67454	44357	19759	24139	6147	7082
1963	11796	78247	53455	11859	40517	26170	8687	13662	6088
1964	26546	82611	70076	26680	7283	24227	18637	8797	15103
1965	299483	19767	62642	59375	22265	5120	22891	18925	19531
1966	211675	500853	33456	60502	40908	19344	5563	17811	27083
1967	207947	27416	218689	37069	39246	29793	11770	5533	25799
1968	220255	94438	20998	159122	13988	23582	15677	6377	10814
1969	37706	92561	71907	23314	211243	21011	42762	26031	26207
1970	238226	99014	253719	111897	27741	142399	21609	27073	24082
1971	207711	335083	412816	302208	101957	25557	154424	16818	31999
1972	534963	621496	175137	54205	66714	25716	10342	55763	16631
1973	51170	235627	808267	131484	63071	54642	18242	6506	32223
1974	309016	124944	151025	519178	82466	49683	34629	22470	21042
1975	172879	202087	89066	63701	188202	30601	12297	13121	13698
1976	69053	319604	101548	35502	25195	76289	10918	3914	12014

Year	1	2	3	4	5	6	7	8	9+
1977	34836	47739	95834	22117	10083	12211	20992	2758	1486
1978	22525	46284	20587	40692	6879	3833	2100	6278	1544
1979	247	142	77	19	13	8	4	1	0
1980	2692	279	95	51	13	9	8	1	0
1981	36740	77961	105600	61341	21473	12623	11583	1309	1326
1982	13304	250010	72179	93544	58452	23580	11516	13814	4027
1983	81923	77810	92743	29262	42535	27318	14709	8437	8484
1984	2207	188778	49828	35001	14948	11366	9300	4427	1959
1985	40794	68845	148399	17214	15211	6631	6907	3323	2189
1986	33768	154963	86072	118860	18836	18000	2578	1427	1971
1987	19463	65954	45463	32025	50119	8429	7307	3508	5983
1988	1708	119376	41735	28421	19761	28555	3252	2222	2360
1989	6216	36763	109501	18923	18109	7589	15012	1622	3505
1990	14294	40867	40779	74279	26520	13305	9878	21456	5522
1991	26396	23013	25229	28212	37517	13533	7581	6892	4456
1992	5253	24469	24922	23733	21817	33869	6351	4317	5511
1993	17719	95288	18710	10978	13269	14801	19186	4711	3740
1994	1728	36554	40193	6007	7433	8101	10515	12158	10206
1995	266	82176	30398	21272	5376	4205	8805	7971	9787
1996	1952	37854	30899	9219	7508	2501	4700	8458	31108
1997	1193	55810	34966	31657	23118	17500	10331	5213	9883
1998	9092	74167	34571	31905	22872	14372	8641	2825	3327
1999	7635	35252	93910	25078	13364	7529	3251	1257	1089
2000	4511	22960	21825	51420	15504	9002	3897	1835	576
2001	147	83318	15368	9569	25175	9544	6813	4741	1028
2002	992	38481	93975	9014	18113	28016	9040	1547	1422
2003	56	33331	46865	53766	7462	4344	12818	9187	1407
2004	0	7235	23483	29421	48394	4151	8100	9023	4265
2005	182	9632	23236	20602	10237	9783	1014	1194	1430

Year	1	2	3	4	5	6	7	8	9+
2006	132	6691	9186	13644	41067	27781	20972	3041	5088
2007	130	34326	17754	6555	14264	30566	21517	13585	4242
2008	0	7898	13039	5427	3219	5688	14832	8142	8968
2009	1923	11508	10475	16586	8332	5688	7514	11793	9443
2010	10074	20339	16331	9957	14608	6322	4322	5388	13199
2011	1667	40587	15782	10333	7190	5071	3164	2611	7225
2012	979	14952	46647	9704	8097	6311	3873	1129	4013
2013	0	13681	18181	53116	11681	7093	5098	4324	5031
2014	0	8705	15144	21063	42229	7130	2944	2854	3511
2015	231	10854	13937	15716	19386	21621	6397	1932	1250
2016	12	8148	3341	3197	2791	2821	3148	739	431
2017	0	1122	11929	4082	2075	1443	1416	767	273
2018	0	1508	3215	6873	5253	3068	844	852	680
2019	1504	1333	1035	2007	3100	1003	214	79	42
2020	145	110	206	234	156	191	118	11	20
2021	0	3188	1748	378	378	449	295	35	83

Table 4.2.3. Herring in division 6.aN. Weights at age in the catch. Units: kilograms

Year	1	2	3	4	5	6	7	8	9+
1957	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1958	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1959	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1960	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1961	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1962	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1963	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1964	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1965	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1966	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185

Year	1	2	3	4	5	6	7	8	9+
1967	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1968	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1969	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1970	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1971	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1972	0.079	0.104	0.13	0.158	0.164	0.17	0.18	0.183	0.185
1973	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1974	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1975	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1976	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1977	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1978	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1979	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1980	0.09	0.121	0.158	0.175	0.186	0.206	0.218	0.224	0.224
1981	0.08	0.14	0.175	0.205	0.231	0.253	0.270	0.284	0.295
1982	0.08	0.14	0.175	0.205	0.231	0.253	0.270	0.284	0.295
1983	0.08	0.14	0.175	0.205	0.231	0.253	0.270	0.284	0.295
1984	0.069	0.103	0.134	0.161	0.182	0.199	0.213	0.223	0.231
1985	0.113	0.103	0.173	0.196	0.215	0.23	0.242	0.251	0.258
1986	0.073	0.143	0.183	0.211	0.22	0.238	0.241	0.253	0.256
1987	0.08	0.112	0.157	0.177	0.203	0.194	0.24	0.213	0.228
1988	0.082	0.142	0.145	0.191	0.19	0.213	0.216	0.204	0.243
1989	0.079	0.129	0.173	0.182	0.209	0.224	0.228	0.237	0.247
1990	0.084	0.118	0.16	0.203	0.211	0.229	0.236	0.261	0.271
1991	0.091	0.119	0.183	0.196	0.227	0.219	0.244	0.256	0.256
1992	0.089	0.128	0.158	0.197	0.206	0.228	0.223	0.262	0.263
1993	0.083	0.142	0.167	0.19	0.195	0.201	0.244	0.234	0.266
1994	0.106	0.142	0.181	0.191	0.198	0.214	0.208	0.277	0.277
1995	0.081	0.134	0.178	0.21	0.23	0.233	0.262	0.247	0.291

Year	1	2	3	4	5	6	7	8	9+
1996	0.089	0.136	0.177	0.205	0.222	0.223	0.219	0.238	0.263
1997	0.097	0.138	0.159	0.182	0.199	0.218	0.227	0.212	0.199
1998	0.076	0.13	0.158	0.175	0.191	0.21	0.225	0.223	0.226
1999	0.1084	0.1327	93910	25078	13364	7529	3251	1257	1089
2000	0.0834	0.1373	0.1637	0.1829	0.2014	0.2147	0.2394	0.2812	0.2526
2001	0.0490	0.1398	0.1628	0.1828	0.1922	0.1959	0.2047	0.2245	0.2716
2002	0.1066	0.1464	0.1625	0.1728	0.1595	0.1780	0.1863	0.2449	0.2802
2003	0.0609	0.1448	0.1593	0.1690	0.1852	0.1997	0.1942	0.1854	0.2938
2004	0	0.1541	0.1732	0.1948	0.2160	0.2197	0.1986	0.1885	0.3030
2005	0.1084	0.1327	0.1632	0.1845	0.2108	0.2258	0.2341	0.2556	0.2496
2006	0.0908	0.158	0.1676	0.1929	0.2076	0.2251	0.2443	0.2615	0.275
2007	0.1152	0.1667	0.1881	0.1968	0.2105	0.2214	0.2161	0.2618	0.303
2008	0	0.1705	0.206	0.231	0.2309	0.2489	0.2529	0.284	0.2877
2009	0.1121	0.1726	0.2141	0.2379	0.2457	0.2535	0.2599	0.2549	0.273
2010	0.0818	0.1549	0.1883	0.2129	0.2337	0.2394	0.2369	0.2400	0.2549
2011	0.0613	0.155	0.1894	0.2178	0.234	0.2388	0.247	0.2463	0.2522
2012	0.0725	0.1469	0.1894	0.2076	0.2161	0.2261	0.2408	0.2817	0.2467
2013	0	0.1441	0.1746	0.1965	0.202	0.2124	0.2304	0.2343	0.2476
2014	0	0.1451	0.1877	0.203	0.2279	0.2449	0.2608	0.2614	0.2835
2015	0.0769	0.1425	0.1795	0.2059	0.2136	0.2307	0.2386	0.2454	0.2685
2016	0.1	0.144	0.178	0.204	0.219	0.229	0.237	0.251	0.257
2017	0	0.137	0.167	0.187	0.204	0.213	0.221	0.233	0.249
2018	0	0.126	0.151	0.174	0.190	0.208	0.218	0.238	0.246
2019	0.089	0.129	0.148	0.182	0.199	0.210	0.220	0.257	0.244
2020	0.074	0.125	0.115	0.147	0.180	0.192	0.210	0.140	0.222
2021	0	0.137	0.158	0.178	0.202	0.201	0.214	0.278	0.238

Table 4.3.1. Herring in division 6.aN. Total numbers (millions) and biomass (thousands of tonnes) of 6.aN autumn spawning herring from the Malin Shelf Survey June-July 2021. Mean weights, mean lengths and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.00	0.0	0.0
1	20.5	1.3	0.00	63.1	19.5
2	140.0	15.3	0.45	109.5	23.0
3	57.4	9.2	1.00	160.9	25.8
4	41.9	7.0	1.00	166.1	26.1
5	14.0	2.8	1.00	198.0	27.9
6	14.6	4.0	1.00	272.4	30.9
7	33.7	8.4	1.00	248.8	30.0
8	10.2	2.8	1.00	269.9	31.5
9+	9.1	2.2	1.00	239.5	30.1

Immature	98.0	9.0		91.8	21.8
Mature	243.4	43.9		180.3	26.7
Total	341.4	52.9	0.71	154.9	25.3

Table 4.3.2. Herring in division 6.aN. Numbers-at-age (millions) and SSB (thousands of tonnes) of 6.aN autumn spawning herring from the Malin Shelf herring acoustic survey time-series. Age (rings) from acoustic surveys 2014 to 2021.

Year\Age (Rings)	1	2	3	4	5	6	7	8	9	SSB
2014	0.00	2.75	13.50	21.36	85.13	20.39	5.35	2.41	6.65	32.46
2015	0.00	35.56	139.03	127.40	97.37	106.38	24.68	3.81	5.76	107.11
2016	0.00	5.81	15.50	13.62	11.15	8.83	5.22	0.06	0.73	10.87
2017	0.00	0.71	35.75	25.40	26.44	11.41	9.93	2.48	1.86	21.86
2018	92.96	41.07	14.27	48.31	16.67	3.34	10.05	5.49	2.28	20.66
2019	0.00	17.17	17.32	15.80	20.17	4.64	0.16	0.00	0.51	10.51
2020	59.05	103.81	49.51	14.96	12.44	28.21	11.01	0.00	0.00	26.07
2021	20.48	140.01	57.44	41.87	13.98	14.57	33.73	10.25	9.07	43.89

Table 4.4.1.1. Herring in division 6.aN. Mean weights-at-age (kg) of 6.aN autumn spawning herring from the Malin Shelf herring acoustic survey time-series. Age (rings) from acoustic surveys 2014 to 2021.

Year\Age (Rings)	1	2	3	4	5	6	7	8	9
2014		0.142	0.179	0.182	0.212	0.216	0.229	0.226	0.255
2015		0.159	0.184	0.198	0.214	0.220	0.219	0.198	0.220
2016		0.147	0.154	0.174	0.195	0.209	0.201	0.219	0.225
2017		0.130	0.175	0.184	0.197	0.207	0.211	0.238	0.221
2018	0.051	0.103	0.164	0.181	0.203	0.206	0.200	0.232	0.217
2019		0.121	0.140	0.175	0.208	0.214	0.204		0.212
2020	0.050	0.112	0.149	0.168	0.198	0.199	0.220		
2021	0.063	0.110	0.161	0.166	0.198	0.272	0.249	0.270	0.239

Table 4.4.2.1. Herring in division 6.aN. Maturity at age of 6.aN autumn spawning herring from the Malin Shelf herring acoustic survey time-series. Age (rings) from acoustic surveys 2014 to 2021.

Year\Age (Rings)	1	2	3	4	5	6	7	8	9
2014		0.98	1	0.95	1	1	1	1	1
2015		0.88	0.99	0.99	1	1	1	1	1
2016		1	0.98	1	1	1	1	1	1
2017		1	1	1	1	1	1	1	1
2018	0	0.37	0.97	1	1	1	1	1	1
2019		0.51	0.48	1	1	1	1		1
2020	0	0.47	0.97	1	1	1	1		
2021	0	0.45	1	1	1	1	1	1	1

Table 4.4.3.1. Natural mortality estimates for herring in 6.aN.

Age (Rings)	1	2	3	4	5	6	7	8	9	3 to 6
	0.528	0.303	0.255	0.225	0.207	0.193	0.186	0.180	0.180	0.220

Table 4.6.1. $F_{MSY\ proxy}$ calculation for herring in 6.aN under the constant harvest rate rule.

Year	Survey Index	ICES landings	Modal Catch	Lc	Mean>Lc	LF=M	f	Cy/Iy	$F_{MSY\ proxy}$
2014	32460	22027	28.5	27.5	29.448	28.801	1.022	0.679	0.335
2015	107113	18801	29	27.5	29.208	28.801	1.014	0.176	0.335
2016	10870	4724	29.5	25.5	28.691	27.666	1.037	0.435	0.335
2017	21863	4200	27	25.5	27.702	27.666	1.001	0.192	0.335
2018	20663	4063	27	25	27.595	27.382	1.008	0.197	0.335
2019	10508	1739	23.5	20	23.982	24.543	0.977	0.165	0.335
2020	26070	177	NA	NA	NA	NA	NA	0.007	0.335
2021	43886	1115	25.5	24	26.084	26.814	0.973	0.025	0.335

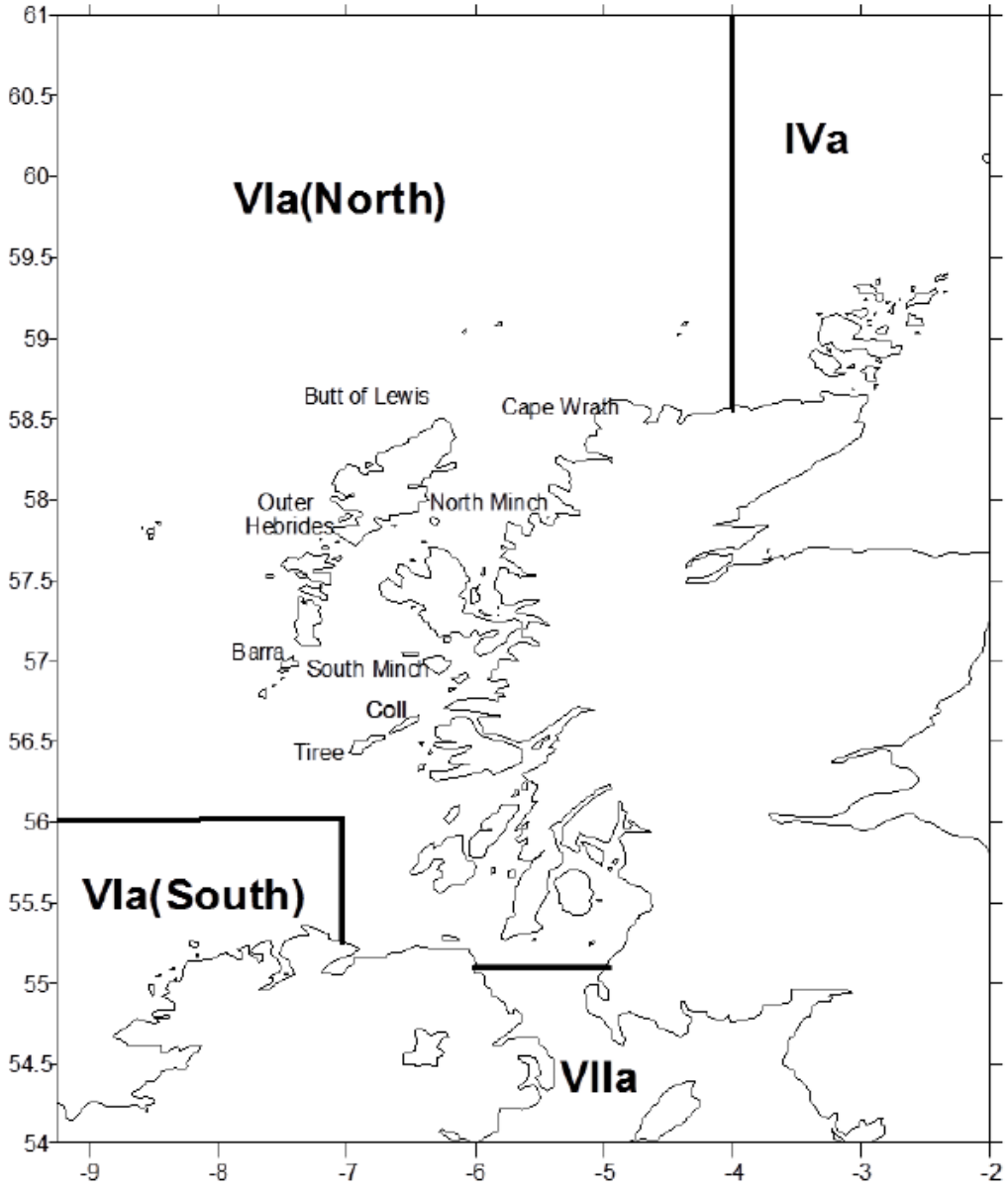

Figure 4.1. Location of ICES area 6.a (North) and adjacent areas with place names.

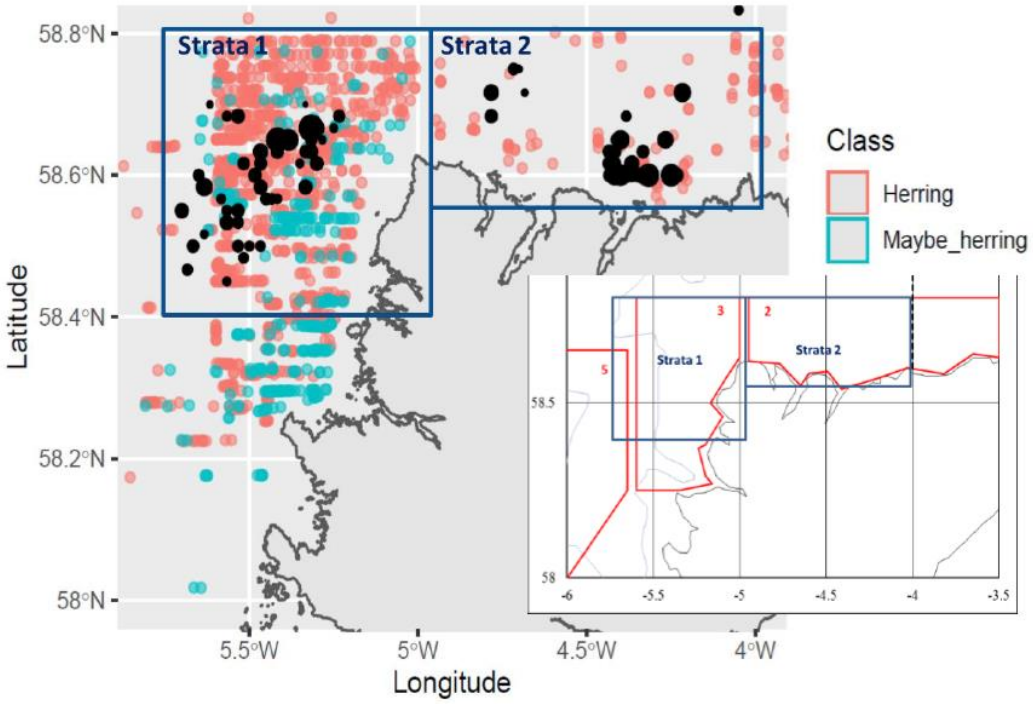

Figure 4.1.3.1. Acoustic survey recordings of herring and 'maybe herring' marks and locations of commercial catches 2016-2019 in defined Strata 1 and 2, showing overlap with previous survey Areas 2,3,5 (inset) and noting that the distribution of catches reflect spawning grounds. Catches (black dots) scaled proportionally. Acoustic marks are not scaled and denote location only.

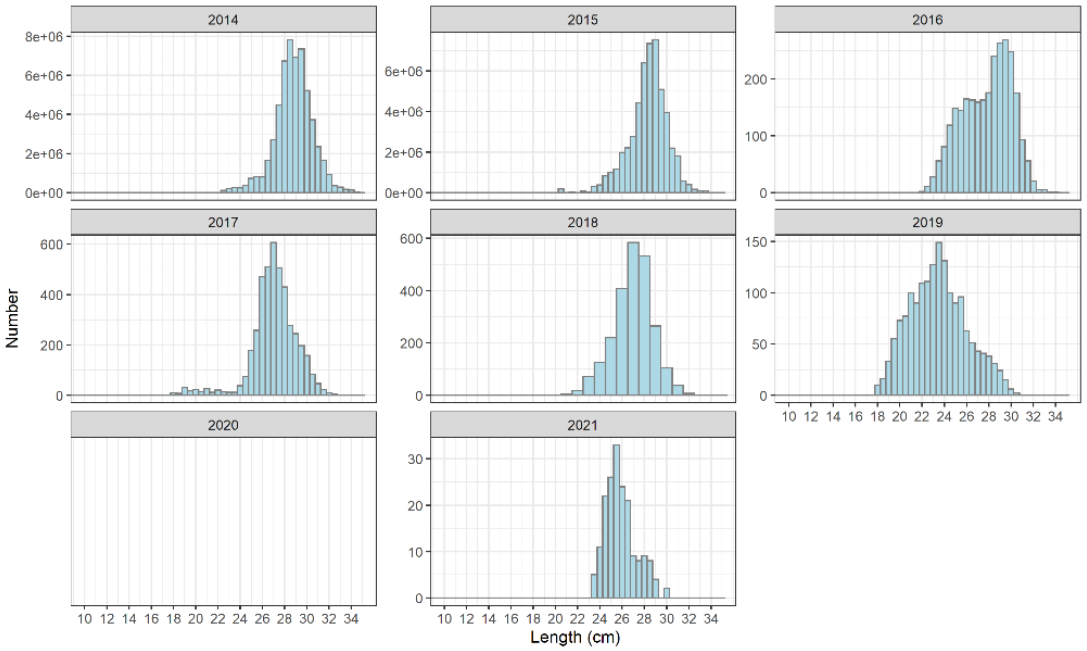

Figure 4.1.7.1. Length-frequency of commercial catches in division 6.aN. Since 2016 a monitoring TAC has been in place for this area. Some data in 2018 were reported to a 1cm resolution, and therefore all data in this year have been binned to this level in this year. No length data from commercial hauls are available for 2020.

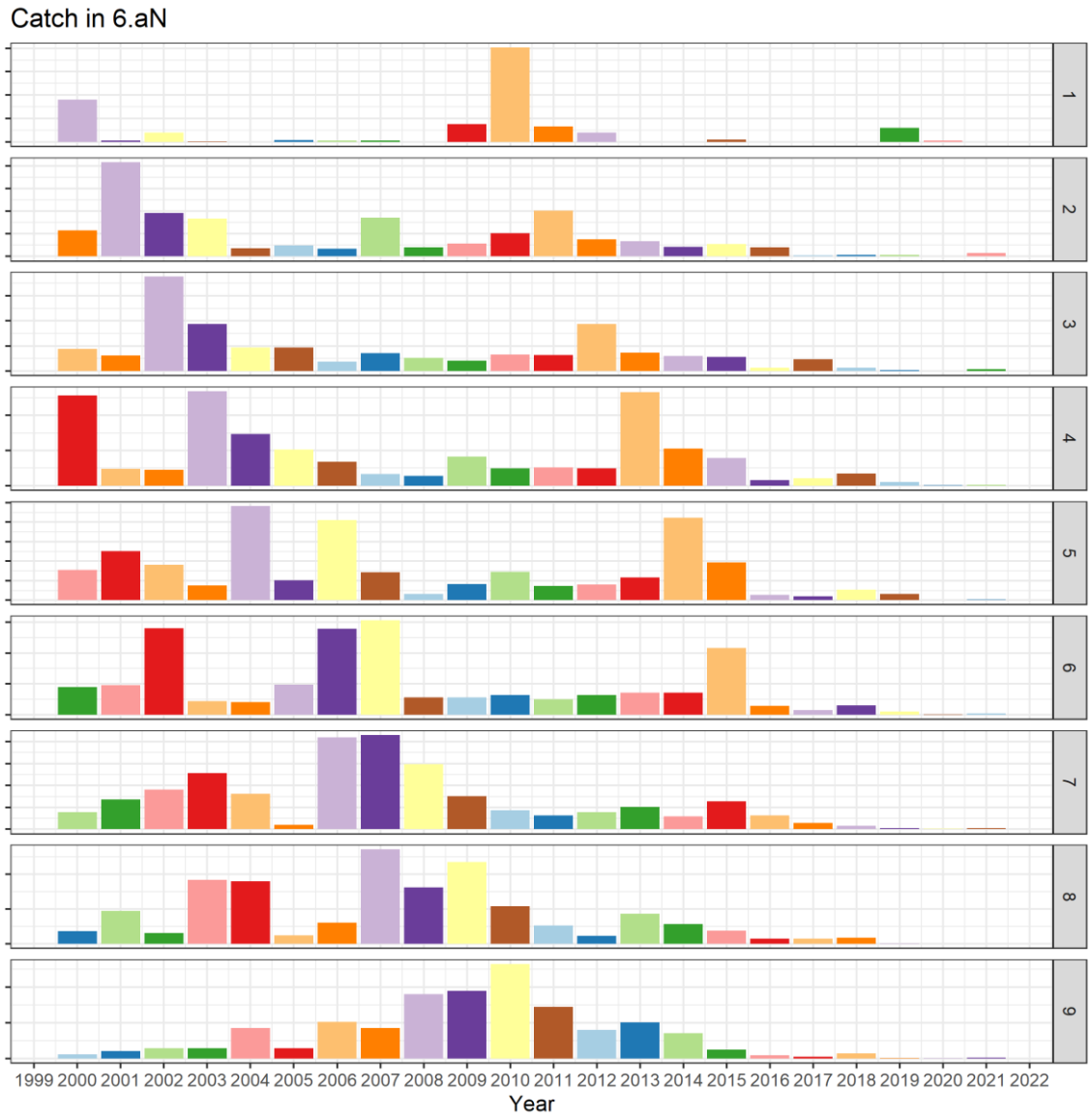

Figure 4.2.1. Catch numbers at age for herring in division 6.aN.

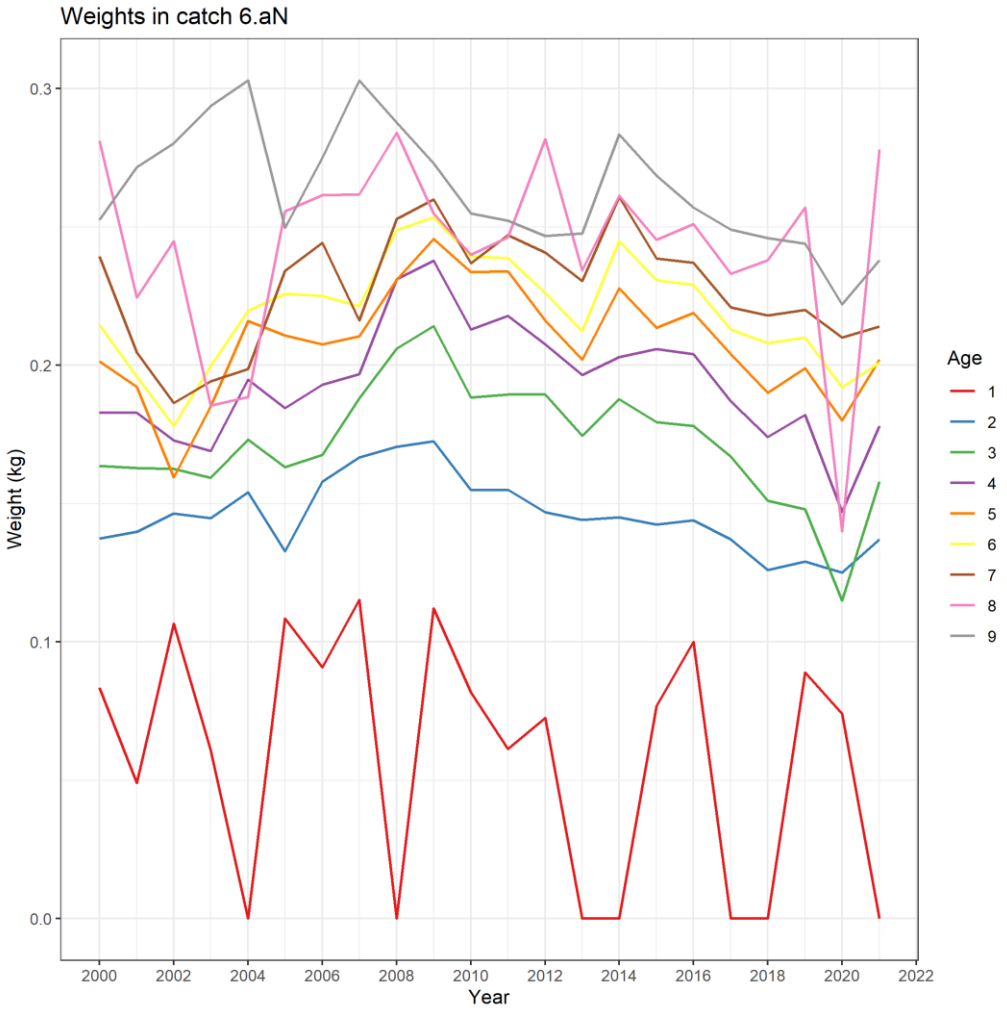

Figure 4.2.2. Weights at age in the catch for herring in 6.aN.

Figure 4.3.1.1. Catch numbers at age for 6.aN autumn spawning herring from the Malin Shelf herring acoustic survey.

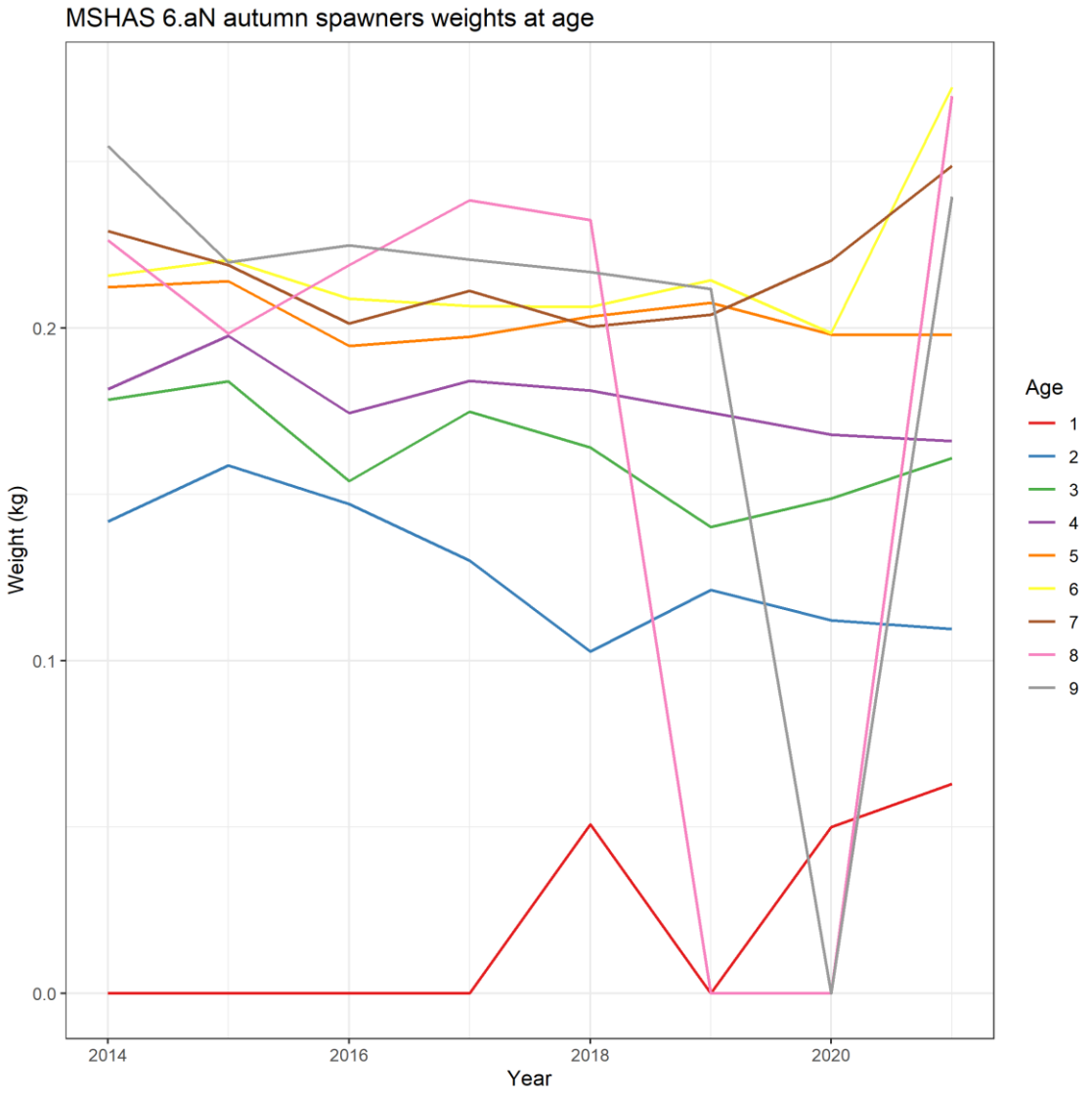

Figure 4.4.1.1. Weights-at-age for 6.aN autumn spawning herring from the genetically split Malin Shelf Herring acoustic survey.

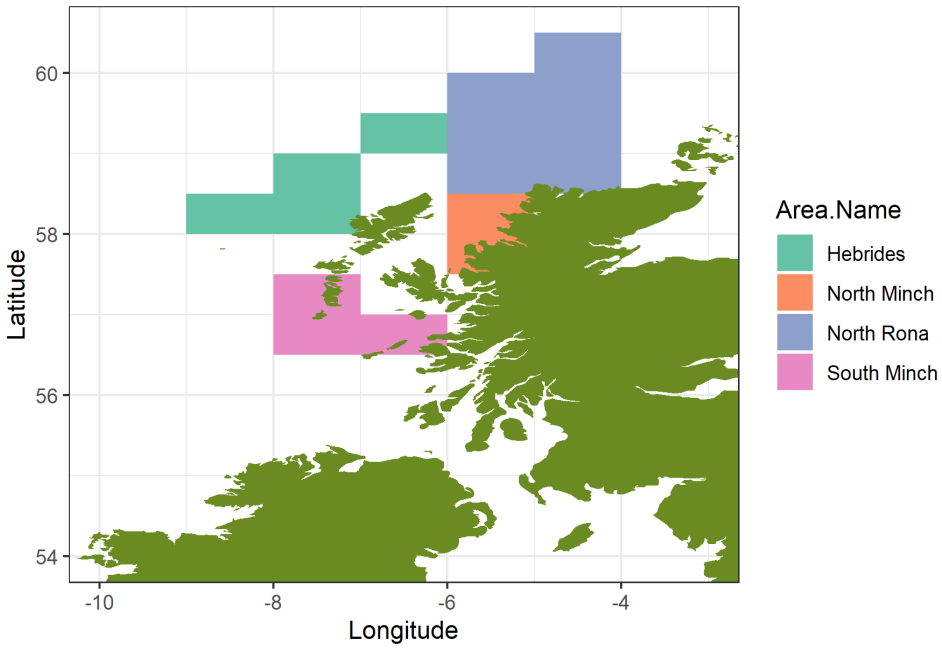

Figure 4.6.1. ICES rectangles where market sample data have been collected from 2000-2015.

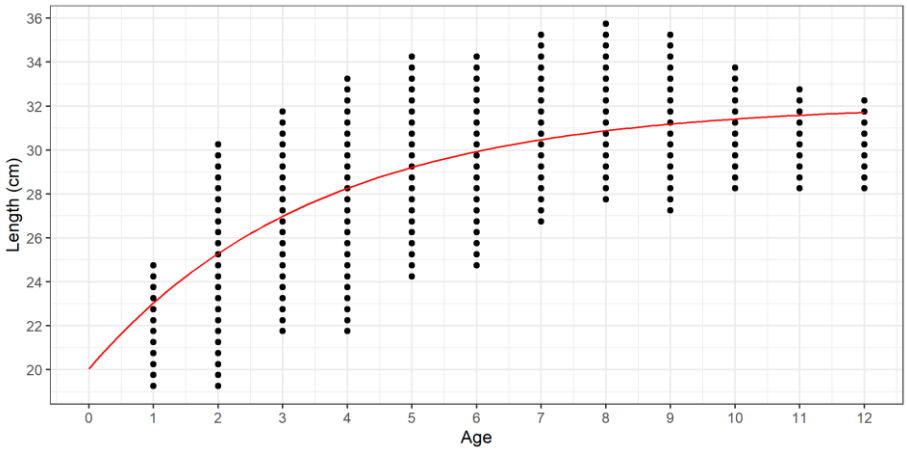

Figure 4.6.2. Growth curve calculated from commercial catches in division 6.aN, and gives an estimated L_∞ value of 30.51cm with an associated *k* value of 0.335

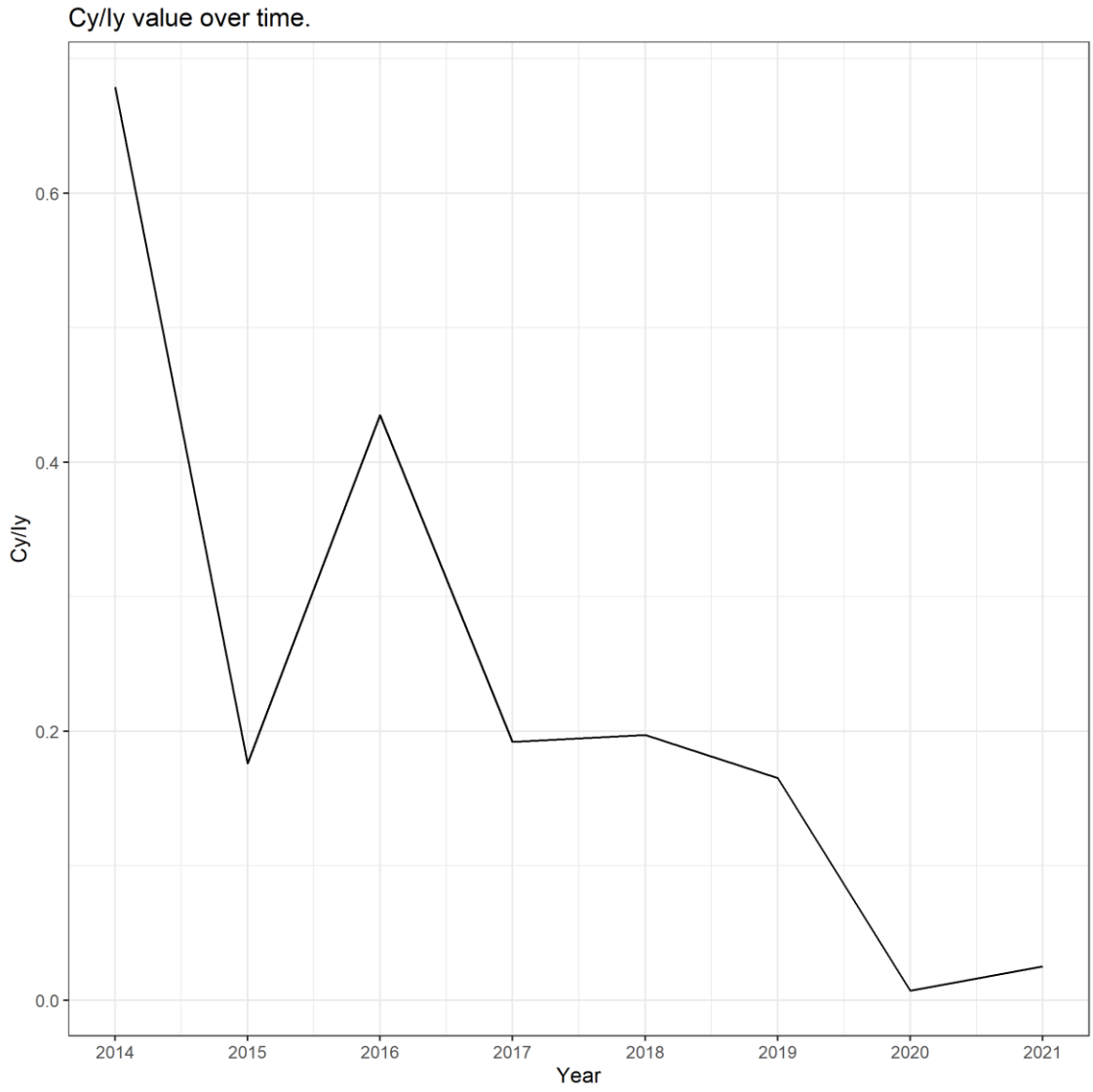

Figure 4.6.3. The ratio C/I for 6.aN herring 2014-2021, from which the $F_{MSY\ proxy}$ value is calculated.