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The 2022 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area

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Six surveys were carried out during late June and July covering most of the continental shelf in the North Sea, West of Scotland and the Malin Shelf. The surveys are presented here as a summary in the report of the ICES Working Group of International Pelagic Surveys (WGIPS), and component survey reports are available individually on request. The global estimates of herring and sprat from these surveys are reported here. The global survey results provide spatial distributions of herring and sprat and total abundance by number and biomass at age as well as mean weight and fraction mature at age.

The estimate of North Sea Autumn Spawning herring spawning stock biomass is higher than in the previous year at 1.96 million tonnes (2021: 1.50 million tonnes) with an increase in the number of mature fish from 8 170 million fish in 2021 to 10 348 million fish in 2022.

The 2022 estimate of Western Baltic Spring Spawning herring 3+ group is 77 000 tonnes and 483 million. Compared to the 2021 estimates of 82 000 tonnes and 639 million fish, this equals a decrease of 24% in biomass.

The West of Scotland herring estimate (6.a.N) of SSB in 2022 is 177 000 tonnes and 1 052 million individuals, which is a ~20% increase in biomass and abundance compared to the 147 000 tonnes and 871 million herring estimate found in this area in 2021.

The 2022 SSB estimate for the entire Malin Shelf area (6.a and 7.b, c combined) is 233 000 tonnes and 1 442 million individuals. This is lower than the 2021 estimates (278 000 tonnes and 1 827 million herring). There were again low numbers of herring found in the northernmost strata (to the north of Scotland and east to the 4˚W line) in 2022, which is similar to recent years. Herring were distributed in only a few discreet areas in 2022, to the north of Lough Swilly (south of Stanton), to the north west of Tory island around the 56°N degree line, and south of St. Kilda. There were overall less immature herring found in 2022.

For consistency, the survey results continue to be presented separately for sprat in the North Sea and Skagerrak-Kattegat in this report, although these two stocks were combined in a benchmark in 2018 (ICES, 2018).

The total abundance of North Sea sprat age 1+ (Subarea 4) in 2022 was estimated at 78 900 million individuals and the biomass at 705 000 tonnes (Table 5.10). This is an increase from the previous year, and 53% above the long-term average of the time series, in terms of both abundance and biomass. The stock is dominated by 1-year-old sprat (70% in biomass). The estimate of 0-group sprat, which only occasionally is observed in the HERAS survey, was 23% in numbers and 6% in biomass compared with the totals.

In Div. 3.a, the sprat age 1+ abundance in 2022 is estimated at 417 million individuals and the biomass at 5 200 tonnes. This is the second lowest estimate of the time series in terms of biomass, and well below the long-term average both in terms of abundance (78% below) and biomass (79% below). The estimate is dominated by 1-year-old sprat.

1 Introduction

Six surveys were carried out during late June and July covering most of the continental shelf north of 52°N in the North Sea and to the west of Scotland and Ireland to a northern limit of 62°N. The eastern edge of the survey area was bounded by the Norwegian, Danish, Swedish and German coastline and to the west by the shelf edge at around 200 m depth. Individual survey reports from participants are available on request from the nation responsible. The vessels, areas and dates of cruises are given in Table 5.1 and in Figure 5.1.

Table 5.1. Vessels, areas and cruise dates during the 2022 herring acoustic surveys.

Vessel	Period	Contributing to Stocks	Strata
Celtic Explorer (IRL) EIGB	05 - 25 July	WoS, MSHAS (6.a.N and 6.a.S)	2, 3, 4, 5, 6
Scotia (SCO) MXHR6	29 June – 19 July	MSHAS, WoS, NSAS, Sprat NS	1, 91 (north of 58°30'N), 111, 121
Johan Hjort (NOR) LDGJ	23 June – 15 July	NSAS, WBSS, Sprat NS	11, 141
Tridens (NED) PBVO	28 June - 21 July	NSAS, Sprat NS	81, 91 (south of 58°30'N), 101
Solea (GER) DBFH	1 July – 19 July	NSAS, Sprat NS	51, 61, 71, 131
Dana (DEN) OXBH	22 June – 08 July	NSAS, WBSS, Sprat NS, Sprat 3.a	21, 31, 41, 42, 151, 152

2 Methods

Survey design and acoustic data collection

The acoustic surveys were carried out and analysed in accordance with the ICES survey manual for International Pelagic Surveys (ICES, 2015) using Simrad EK60 and EK80 echosounders with transducers mounted either on the hull, drop keel or in towed bodies. Only data gathered at 38 kHz was used for the analysis. Data collected at other frequencies was used for target discrimination. Echo integration and further data analyses were carried out using either LSSS (Large Scale Survey System; Korneliussen et al., 2006) or Echoview (Echoview Software Pty Ltd, Hobart, Australia).

The survey is designed to be analysed using StoX (Johnsen et al., 2019) with a set of strata surveyed through a grid of evenly spaced parallel transects. The survey area is divided into 23 strata with a randomized starting point for the grid of transects in each stratum and with transects running perpendicular to lines of bathymetry where possible (Figures 5.1 and 5.2). The planned transect spacing in the (parallel transect) strata ranges from 10 to 30 nautical miles (n.mi.) (Table 5.18). The relative effort (and therefore the transect spacing) in each stratum was determined based on the mean abundance and variance in each of the strata during surveys in the most recent 10 years prior to the new overall survey design being implemented (2005 – 2015), and the strata had been classed as high, medium and low effort (ICES, 2016).

In 2022 a change was made to the survey design by splitting stratum 151 into a northern and a southern part. In the southern part (below 57°N) transects were changed from running in a North - South direction parallel to the Danish coast to running perpendicular to the coast and parallel to the transects in stratum 71 to the south instead. Mixed aggregations of small herring and other juvenile fish tend to concentrate towards the coast in this area, and the change in design/transect orientation is more appropriate in this situation. Additionally, the change mitigates potential bias introduced in the analysis caused by increasing amounts of mixing of WBSS and NSAS from south to north. In the southern part of stratum 151 (151_S) there is little mixing, and the herring is nearly pure NSAS. In the northern part (151_N) the proportion of WBSS in catches can be very high, and WBSS is consistently present in this part of stratum 151 (Figure 5.21).

A total of 9 225 n.mi of acoustic transects covered during the survey were used in the acoustic analysis. achieving good coverage of most of the survey area. Due to a loss of survey time through several instances of inclement weather and technical issues, stratum 131 covered by Germany had to be omitted and was left unsampled. Additionally, in stratum 51 one transect was covered by RV “Tridens” instead of RV “Solea”. Thus, full coverage of that stratum was achieved. The coverage of stratum 81 by the Netherlands was adapted due to time constraints and navigational restrictions due to wind farms. In the far south of the stratum the bathymetry did not allow sailing and fishing. The modifications and adaptions allowed full and even coverage in all strata, with the exception of stratum 131, which was not covered in 2022.

Scrutiny of acoustic data

In the Dutch, Irish, Norwegian and Scottish cruises, covering strata 1, 2, 3, 4, 5, 6, 11, 81, 91, 101, 111, 121 and 141, scrutiny of hydroacoustic data during post-processing is conducted to individual species level and species-specific NASC values are uploaded to the ICES database[1]. In strata 21, 31, 41, 42, 51, 61, 71, 131, 151, 152, covered by the German and Danish cruises, clupeids usually do not occur in single species schools but in mixed aggregations and schools that are comparatively clearly distinguishable from other schooling fishes. Post-processing of hydroacoustic data is therefore based on an aggregated CLU category consisting of a mix (in variable proportions) of clupeids herring (HER) and sprat (SPR) as well as in some occasions also anchovy (ANE) and sardines (PIL). Occasionally, spatially restricted occurrences of “clean” schools of herring, sprat or sardine are observed. Then, species-specific categories are allocated to the corresponding acoustic registrations. In cases of mixed targeted catches of clupeids together with other species (horse mackerel, mackerel, various gadoids etc.) a combined MIX category is allocated to the respective echoes. Depending on regional observations and catch composition, clupeid species can therefore also be included in the MIX category. The allocation of spatially limited but partly significant observations and catches of clupeids e.g. sardines and anchovies to a species-specific or a combined category is followed to avoid overestimating the contribution of these species in the total stratum by including them in the CLU category.

The composition of both the CLU and MIX categories in the Danish and German cruises varies according to catch compositions in trawl hauls conducted on the corresponding transects. All disaggregation steps of mixed acoustic categories to individual species in the German and Danish data are conducted using a Split-NASC process in the StoX software, where all categories employed are clearly defined (Table 5.20). In 2022, the aggregated CLU category was allocated to both German and Danish data, whereas MIX was only assigned in Danish hydroacoustic data. The disaggregated and species-specific NASC values from the Split-NASC process attributed to herring and sprat etc. are used in subsequent processes in the overall analysis.

For the Split-NASC processes as well as for further analyses of disaggregated data (stock estimates), the following target strengths were used for clupeids (ICES, 2015):

Herring, sprat, sardine, anchovy TS = 20 log L - 71.2 dB

Stock splitting

Stock splitting was conducted using genetic analysis in several parts of the survey area (See section 5 for details). For the genetic analysis, Single Nucleotide Polymorphism (SNP) panels were used including diagnostic markers to discriminate known populations (Bekkevold et al., 2022; Farrell et al., 2022; Han et al., 2020). Laboratories has developed their individual SNP panel consisting of diagnostic markers to specifically identify populations of interest in that specific region, i.e. there is no need to include markers discriminating central Baltic herring in the Malin Shelf area. However, the development of individual panels was conducted in close collaboration between laboratories. This also accounts for the establishment of reference baselines. Several reference samples that would be of interest for multiple laboratories have been exchanged. This ensures that all laboratories use identical baselines to identify known populations.

Data analysis

The 2022 disaggregated biological and acoustic data were uploaded to the ICES Acoustic trawl surveys database[1] held at the ICES data centre, and the data was analysed using the StoX analysis software (v. 3.5.2; Johnsen et al., 2019).

Acoustic and biological data were combined to provide an overall global estimate. Estimates of numbers-at-age, maturity stage and mean weights-at-age were calculated by individual survey stratum (Figure 5.1). The data were combined to provide estimates of the North Sea Autumn Spawning herring, Western Baltic Spring Spawning herring, West of Scotland (6.a.N) herring and Malin Shelf herring stocks (6.a./7. b, c) as well as sprat in the North Sea and 3.a.

1 https://www.ices.dk/ data/data-portals/Pages/acoustic.aspx

3 Stock definitions

North Sea Autumn Spawning herring (NSAS)

Includes all herring encountered in the North Sea between 4°W and 2°E and south of 56°N [56.5°N between 2-6°E] (strata 71, 81, 91, 101, 111, 121 in Figure 5.1). East of 2°E and north of 56°N [56.5°N between 2-6°E], in strata 11, 21, 31, 41, 42, 141, 151_N, 151_S and 152, herring is split into North Sea Autumn Spawning herring and Western Baltic Spring Spawning herring (Figure 5.1) based on genetic analysis (See more details in section 5).

Western Baltic Spring Spawning herring (WBSS)

The allocation to the Western Baltic Spring Spawning herring stock is limited by the geographical boundaries of strata 11, 21, 31, 41, 42, 141, 151_N, 151_S and 152. Stock splitting is only applied within these strata (Figure 5.1). Individual biological assignments of WBSS herring are based on genetic analyses (see details in section 5).

Malin Shelf Herring (MSHAS)

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 (strata 1 - 6 in Figure 5.1). The survey targets herring of 6.a.N and 6.a.S spawning origin in mixed feeding aggregations on the Malin Shelf. HAWG recommended to WGIPS in 2021 that the results of the EASME project (Farrell et al., 2021) on stock splitting be considered in future analysis and planning of the summer survey in 6.a.N and 6.a.S (also known as the Malin Shelf Herring Acoustic Survey, or MSHAS). The genetic split results were accepted at ICES WKNSCS benchmark on 6a herring in 2022 (ICES, 2023) and therefore 6.a.N and 6.a.S stocks are now assessed separately. Split indices for 6.a.N and 6.a.S stocks based on genetic analysis are now also produced from the MSHAS survey results. To maintain consistency with previous years, overall results for the MSHAS survey based on area are still presented here, and the split results for the 2014 – 2022 MSHAS surveys into the relevant stocks are presented in Annex 16. These results are generated using the method described in a working document to the WKNSCS benchmark (ICES, 2023). The differentiation between 6.a herring and North Sea herring across the 4°W line of longitude is purely based on geography.

West of Scotland herring (6.a.N)

This is a now historic subset of the Malin Shelf herring abundance and biomass estimate based on geographical location (strata 1 - 4 in Figure 5.1). All herring recorded north of the 56°N line of latitude are reported as West of Scotland (6.a.N). This distinction is kept to maintain a comparable time series of abundance of mixed stocks of herring to the West of Scotland. The area North of the 56°N line of latitude has been covered annually since 1991 whereas the extended area to include all of 6.a and 7.b and c (MSHAS index) has been covered annually since 2008.

North Sea and Div. 3a sprat

The sprat benchmark in November 2018 (ICES, 2018) decided that sprat in these two areas should be assessed as one stock from now. In this survey report, the results are still presented separately for these two areas for consistency. The indices should be summed for use in the sprat assessment.

All sprat recorded in the North Sea geographical area (ICES Subarea 4) are included in the North Sea sprat survey estimate, including the northern parts (strata 141, 91, 111 and 121), where low but recurring registrations of sprat have been observed in the preceding years (Figure 5.1).

Sprat in Div. 3.a: All sprat in strata 21, 31, 41 and 42 are included in this index.

The border between ICES Div. 3.a and Subarea 4 was revised in 2015. The new border has been used for index calculation since 2015, but prior to this the old border was used to delineate the stocks.

The survey strata used for the analysis are shown in Figure 5.1. The area and transects covered during the national acoustic surveys are given in Figure 5.2, and magnitudes of acoustic herring and sprat detections (NASC, Nautical Area Scattering Coefficients) for 5 nmi. intervals are given in Figures 5.3 and 5.4, respectively. The survey provides numbers at age, mean length as well as weight at age and maturity at age for the different herring and sprat stocks (North Sea Autumn Spawning herring, Western Baltic Spring Spawning herring, West of Scotland herring, Malin Shelf herring, sprat in the North Sea and sprat in Div. 3.a), and the time series of these are given in Figures 5.5-5.10. The time series of biomass/abundance for the four herring stocks (North Sea Autumn Spawning herring, Western Baltic Spring Spawning herring, West of Scotland and Malin Shelf herring) are given in Tables 5.6 – 5.9 and illustrated in Figures 5.11 - 5.14, respectively. The time series of biomass and abundance for sprat in the North Sea and in Div. 3.a are given in Tables 5.11 and 5.13 and Figures 5.9, 5.10, 5.15 and 5.16 respectively. In each of the figures 5.11-5.16, a 3-year running mean is included to show the general trend more clearly.

Herring

The NASC values attributed to herring throughout the HERAS survey are shown in Figure 5.3. As in previous years, the largest aggregations of adult herring in the North Sea were concentrated in the areas to the east of the Shetland Isles, between 2°W and 2°E and app. 57.5°N - 61.5°N (Figures 5.3 & 5.17). Adult herring were also distributed in larger concentrations in the Norwegian Trench into the deeper parts of Skagerrak. Juvenile herring were primarily in the usual distribution in the shallower south and eastern parts of the North Sea and in the Skagerrak and Kattegat (Figure 5.18). The central North Sea (stratum 131) was not surveyed in 2022.

The estimate of **North Sea** Autumn Spawning herring spawning stock biomass has increased by 28% from 1.50 million tonnes in 2021 to 1.96 million tonnes this year (Table 5.6, Figure 5.11). The abundance of mature fish has increased from 8 170 million in 2021 to 10 348 million in 2022 (Table 5.2). The mean weight of mature fish is only slightly higher than last year at 189.7g, and the increase in biomass of mature fish is due to higher abundance rather than change in condition of individual fish. The 2012- and 2013- year classes (age 8 and 9 winter rings (wr) now) continue to be stronger than the long-term average (especially the 2013 year class). The 2014 year class which was age 7-wr in 2022, is also emerging as a stronger than average size year class. These stronger year classes still contribute 17% to the overall biomass in 2022 and it should be noted that all year classes since 2015 are well below the average level since 2010 (and the long term average). The 2016 year class (5-wr in 2022) is particularly weak with abundance at only 56% of the average level since 2010.

The abundance of immature fish in the stock has decreased by 15% from 23 311 million in 2021 to 19 780 million this year..

At 70%, the proportion mature at 2 winter rings in 2022 is again at the high end in the time series – compared to e.g. the all-time low of 37% in 2018. Maturities for ages 3 and above were comparable to the long-term average with 95% maturity of 3 winter ringers, 97% of 4-wr and 99% of 5-wr and 100% maturity for all ages 5 and above (Table 5.2). Since 2015, actual observed maturities are reported for all age groups. Prior to 2015 maturity was fixed at 100% for ages above 4 wr.

The 2022 estimate of **Western Baltic** Spring Spawning herring 3+ group is 77 000 tonnes and 483 million herring (Table 5.3). This is a 24% decrease in biomass (6% decrease in abundance) compared to 2021, and continues to be well below the average from 2009 to the present (2009 – 2021; 706 million herring). The 2021 estimate was 639 million. In comparison, the 2017 estimate was the highest level observed since 2008 (1 353 million) and was comparable to the stock size prior to the low levels observed after 2008 (Table 5.8). In 2021 the stock was dominated by 2 and 3 winter ring fish (Table 5.3, Figure 5.6). In 2022 these same two year classes, now at 3 and 4 winter rings together still account for 33% of the total stock. The single largest age component in 2022 however was 2 winter ring fish that accounted for 32% despite the almost complete lack of 1 winter ring fish in 2021. The numbers of older herring (3+ group) accounted for 62% of the total stock in 2022. Although this is a decrease from 2021, where the 3+ group accounted for 70% of total stock, it is a higher contribution than was observed in the period 2009 to 2020 where the 3+ group on average accounted for 37% of the stock. Compared with 2021, mean weights were about 26 % lower for 1 year old fish but higher for 2, 3 and 4 year olds by 33, 23 and 22% respectively.

The **Malin Shelf** (6.a and 7.b, c) herring estimate of SSB is 233 400 tonnes and 1 442 million individuals (Table 5.5), is a decrease compared to the 278 100 tonnes and 1 827 million individual herring found in 2021. The estimate is the second largest since 2015 when it was 430 000 tonnes (Table 5.9, Figure 5.14). In 2022, 73% of the total biomass (TSB) and 76% of the SSB was observed north of 56°N (the geographic area that forms the historic **West of Scotland** (6.a.N) index). Herring were distributed in a few discreet areas in 2022, north west of Tory island, West of the Hebrides (south of St. Kilda) and north of Lough Swilly (Malin Head). The **West of Scotland** (6.a.N) herring estimate of SSB is 177 000 tonnes and 1052 million individuals (Table 5.4) is an increase compared to the 147 000 tonnes and 871 million herring estimate in 2021. The time-series of indices of abundance per age class for West of Scotland herring are provided in Table 5.8 and Figure 5.7. The estimates since 2016 are still the lowest in the time series. The distribution of herring schools was broadly similar to 2021 except that the distribution was more contracted (Figure 5.3) in smaller areas meaning that biological sampling was difficult. There were some herring marks found to the south of St. Kilda in 2022, but generally less than found historically in this area.

Immature herring were found north west of Tory island, north of Malin Head and west of the Hebrides, but in lower numbers than recent years (Figure 5.18). Adult herring schools were mainly found in deeper, cooler water to the north west of Tory Island and west of the Outer Hebrides (Figure 5.17). Most of the herring in Stratum 1 to the north of Scotland were found in the north east of the stratum near the 4°W line. Herring has in the past been found in high densities to the east of the 4°W line to the north of Scotland 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. This has not been the case for the last number of years. Relatively large schools for the strata are usually seen in the North east however smaller marks are also seen in the south east, however in 2022 there were not as many as in previous years.

The Malin Shelf survey estimate was dominated by 2-, 3- and 4- winter ringers, making up 68% of the total abundance and 71% of the total biomass. Immature herring made up 10% of the total biomass (Table 5.5). Age disaggregated survey abundance indices for Malin Shelf herring since 2008 are given in Table 5.9.

Sprat in the North Sea and Div. 3.a

In the North Sea, sprat were observed in strata 51, 61, 71, 81, 91, 101, 141 and 151_N (Table 5.17). Stratum 131, where sprat is also usually observed, was not covered in 2022. Highest sprat densities were measured in the southern part (below 54.5° N) of the survey area (strata 51, 61, and 81) (Figure 5.4). The southern limit of the surveyed area is at 52° N. There is no indication that the southern limit of the sprat stock distribution has been reached; it is likely that sprat distribution extends further south into the English Channel.

The sprat distribution in the North Sea and Div. 3.a in terms of abundance and biomass per stratum is shown in Table 5.17. The NASC values attributed to sprat in the survey are shown in Figure 5.4. The age 0 indices are not used in the stock assessment for sprat.

The total abundance of sprat 1+ in the North Sea (Subarea 4) in 2022 was estimated at 78 889 million individuals and the biomass at 705 000 tonnes (Table 5.10). This is 53% above the long-term average of the time series in terms of both abundance and biomass. Compared to the 2021 estimate, abundance and biomass are 44% and 69% higher, respectively (Table 5.11, Figure 5.9). The 1+ estimate was dominated by 1-year-old sprat (70% of biomass), and 75% of the sprat were found to be mature (Table 5.10).

An age-disaggregated time-series of abundance and biomass of sprat in the North Sea (ICES Subarea 4), as obtained from the acoustic survey, is given in Table 5.11.

In Div. 3.a, sprat in stratum 21 (Kattegat) dominated the estimate (97% of both the abundance and biomass), but sprat were also found in stratum 42 of the Skagerrak area (comprising strata 31, 41, 42). In some years (2018 and 2013), sprat had exclusively been found in the Kattegat. The age 1+ abundance was estimated at 417 million individuals, 33% lower than the 623 million individuals in 2021 (Table 5.13). The biomass was 16% lower than in 2021, at 5 200 tonnes. 1-year-old sprat dominate the stock (63% in numbers and 55% in biomass). The age-disaggregated time-series of sprat abundance and biomass in Div. 3.a are given in Table 5.13 and Figure 5.10.

5 Quality considerations

The 2022 HERAS global survey estimates of abundance were calculated using StoX (Johnsen et al., 2019) version 3.5.2 with Rstox Framework 3.5.2, with input files (ICES XML format) generated via the ICES Acoustic database[2]. Version 3.5.2 is comparable with version 3.5.1 used for the 2021 survey estimates. The delivery of disaggregated acoustic and biological data to the group continues to be considered an improvement to the survey analysis as it allows a level of transparency and discussion on data collection and standardisation issues not readily achieved before.

The 2022 survey covered all but one planned strata, and survey effort, timing and coverage were largely comparable to previous years. All main aggregations of herring are considered to have been sampled sufficiently.

Due to a loss of survey time originating from inclement weather and technical issues, stratum 131 could not be covered by RV "Solea" (Germany) as planned, but had to be completely omitted. Since 2017, the contribution of this stratum to the total NSAS abundance was on average 4%, while the contribution to the NSAS spawning stock estimates was insignificant. Given the distribution of herring in the North Sea in the 2022 survey surrounding the omitted stratum there is no indication to expect any significant deviation from this pattern. The 2022 survey results for North Sea Autumn Spawning herring is therefore not considered to be significantly impacted by the loss of coverage in stratum 131. Although a small underestimation of the abundance of small juvenile herring is likely this is not expected to impact the assessment, since the 0-ringer information is not practically used.

For sprat, the omission of stratum 131 is however likely to have led to an underestimate of the total abundance in 2022. In recent years this stratum has contributed up to 13% of total abundance (average 7% over the period 2016-2021). Given the similarities in distribution over the time series, a similar contribution from stratum 131 in the survey in 2022 would be a reasonable expectation.

A detailed discussion of potential effects of the loss of stratum 131 in the 2022 survey to the NSAS and sprat estimates can be found in a Working document to HAWG 2023 (Annex 17, WGIPS 2023).

Parts of stratum 81 covered by the Netherlands are not accessible anymore due to the building of wind farms requiring a slight modification in transect orientation. Additionally, the southern part of stratum 81 does not allow sailing and pelagic fishing due to topographical constraints. As these restrictions are permanent it may be necessary to consider a permanent modification to this stratum in the future. The modifications carried out this year are typical for this stratum and are not thought to have a significant effect to the overall results.

Stock containment

In previous years, herring had been observed in the most northern HERAS transects, suggesting that North Sea herring may now be distributed further north than the area covered by the HERAS survey. The amount is not currently considered significant, and as in previous years, the northward extension of herring appeared to be largely contained within the survey strata covered in 2022. Other surveys covering the area north of the HERAS area have also detected small amounts of herring in recent years, and genetic sampling of herring in the Norwegian Sea surveys in May and July has also confirmed the presence of NSAS herring north of 62°N.

To ensure containment of North Sea herring in the northern part of the HERAS survey we suggest using data from summer surveys covering the most northern part of the North Sea and areas further north. In particular, the Norwegian acoustic saithe survey (NORACU) where the first part co-occurs with the Norwegian part of HERAS, and the second part covers the area between 59-62°N and 1°W to 2°E. NORACU allocate herring for the acoustics, but since herring is not the target species there are no targeted hauls. The trawl hauls targeting

2 https://www.ices.dk/data/data-portals/Pages/acoustic.aspx

saithe though occasionally have good samples of herring, and this survey thus can be used to add an exploratory stratum north of the northern boundary of if the HERAS to monitor the containments (or lack thereof) of North Sea herring. In 2022, NORACU had eight bottom tows at the margin of or north of the HERAS survey area, whereof five had very small herring catches (less than two kg).

Good containment of the adult stock was achieved in the Malin Shelf area in 2022, biomass that is sometimes observed straddling the 4˚W line was not a significant issue in 2022.

Stock splitting methods

Since 2021 a common genetic analysis method has been applied for stock splitting, replacing the two traditional methods of otolith microstructure and shape (used in strata 21, 31, 41, 42, 151, 152) or vertebrae counts (used in stratum 11 and 141). The advantage of genetic data is a more fine-scale discrimination down to the population level compared to the previously used methods. The results of the genetic analysis revealed that several populations that were previously not considered occur in the survey area. In total, 8 different herring populations have been identified (Figure 5.21). Aside from the 3 identified with previous methods (NSAS, Downs (included in NSAS indices) and WBSS), the genetic method also identified herring from several adjacent populations in the survey area: WBSS Skagerrak herring (WBSS-SK) which can be discriminated from other WBSS herring, Norwegian Spring Spawning (NSS) herring, Central Baltic herring (CBH), Baltic Autumn Spawning (BAS) herring, and Icelandic Summer Spawning herring (ISSH, only 1 individual). This increased resolution of stock discrimination at individual level provides challenges to the index calculation and warrants a larger discussion with the assessment working group (HAWG) for the way forward. In terms of consistency in the calculation of the indices for NSAS and WBSS, individuals were only assigned to either the NSAS or WBSS herring stock as was done previously. Their assignments to either stock was based on the genetic result, and where this indicated a different stock than NSAS or WBSS, the assignment was mapped to how the previously used splitting methods would have assigned them (Table 5.21). So, in strata 11 and 141, where the vertebrae counts were previously used, NSS and WBSS Skagerrak herring would be mapped to NSAS, whereas in strata 21, 31, 41, 42, 151 and 152, where the otolith microstructure method was used, these would be mapped to WBSS and so forth following linkages in table 5.21. This allows us to provide estimates abundance of NSAS and WBSS herring that are comparable to previous years and therefore compatible with the time series. We do however now have firm evidence that these indices contain several more herring stocks than previously considered in the splitting process and need to discuss a way forward. The indices used for NSAS and WBSS are "contaminated" by other stocks, however we cannot estimate by how much each year going back in time, or how variable this has been between years. There is likely a high inter-annual variability in mixing proportion both due to the migratory behavior of herring in these areas and also to differences in year class strength between the different stocks in the mix.

In addition, herring outside the stock splitting area for NSAS and WBSS are assumed to be 100% NSAS herring. Small scale investigations over recent years have indicated that other stocks may be encountered in these areas, albeit in relatively small numbers. A recent study identified Norwegian Spring Spawning herring (NSS) in the survey area by using length-at-age differences between NSAS and NSS (WD Annex 18). The study indicated that some individual catches contained up to as much as 25% of NSS herring. The applied method is very conservative and most likely underestimating the amount of NSS herring present in the northern part of the HERAS survey area. We recommend that genetic analysis also be applied in other strata to quantify potential mixing with other stocks and that Norwegian Spring Spawning herring should be considered in a future splitting scenario.

Occasionally, Germany has also conducted analysis of otoliths to deduct stock membership of herring in strata 51, 61, 71 and 131. Only very small amounts of spring spawning herring have been found during this exercise (2 in 2015, 1 in 2016, 3 in 2017, 1 each in 2018, 2019 and 2020, most in strata 71 or bordering it). These are suspected to be from local spring spawning populations in the adjacent Ringkøbing Fjord, but this has not been genetically verified. Historically splitting has not been carried out in these strata, and given the very small amount of spring spawning herring detected since the start of this investigation in 2015, no splitting of the acoustic abundances is conducted in the southern area.

Malin Shelf (6.a/7.b, c) splitting: A benchmark for the herring stocks contained in 6.a, 7.b, c was held in 2022 (ICES, 2023). A split index for the survey back to 2014 using results from the EASME project (Farrell et al., 2021) was accepted at the benchmark. Methods used to split the MSHAS index using genetics were published in Farrell et al. (2022). The splitting of the herring found on the MSHAS relies on continued maintenance of baseline spawning data from the individual 6.a.N and 6.a.S stocks, but also from other stocks known to be in the MSHAS area during the survey. For instance, there are spring spawning herring and other herring of unknown origin known to be in the MSHAS area during the summer and although these are accounted for in the split index of the MSHAS, there is a lot of uncertainty around the life history of these smaller stocks and how vulnerable they are to fishing or environmental pressures.

Survey uncertainty

The use of the StoX software for survey abundance estimation, concurrent availability of disaggregated survey data, and application of a transect-based approach allows for an estimate of survey uncertainty. With the development of automatic routines, CVs have been estimated for abundance at age in each stratum. Results are shown for the period 2017-2020 for the NSAS and WBSS herring estimates in Figure 5.19 and 5.20, respectively. Overall, there is consistency in CV estimates since 2017 for both NSAS and WBSS herring. For 2021 and 2022 the procedure has not yet been realised in the new version of StoX. The survey group anticipates CVs to be estimated again in 2023 and forward for these stocks also.

As a consequence of the contracted distribution of herring and fewer herring found on transects (including 2 strata with no herring), the CV on the estimate for the Malin Shelf survey in 2022 was 0.51, much higher than the 2021 estimate of 0.26 and higher than the CV found on the surveys in recent years. There has been an increase in the juvenile/immature herring occurring in the trawls in the Malin Shelf area in recent years, particularly in the southern area, but these were not evident on the survey in 2022. However, juvenile/immature herring are not considered reliably estimated with this survey design.

Biological sampling

It was difficult to obtain biological samples in the Malin Shelf survey area in 2022. Because the stock was so contracted in terms of area compared to recent years, opportunities to sample herring were fewer. Conditions were good on the survey and there was adequate trawling effort, however samples were only obtained in the areas where herring were found in high concentrations acoustically. There were samples obtained in all the relevant strata, including genetic sampling which was used for stock splitting a requirement after the 6.a benchmark (ICES, 2023). Overall trawling in 2022 provided good confidence in school recognition and supporting biological data for age stratified abundance estimation of herring in most strata, however there were still low numbers of hauls in some strata. With the continued low stock size in recent years in the Malin Shelf area it has been difficult to secure catches in some years, potentially affecting the accuracy of the stock composition estimates for West of Scotland and Malin Shelf herring.

The biological sampling strategy (how many individual fish of the target species are measured and aged and how they are selected) is not standardised amongst participants in the HERAS survey, mainly due to historical differences in analysis methods used to work up the partial results from each area. The strategies vary, with some collecting a fixed total number of fish from the catch to sample for age, maturity and stock ID, for others a fixed number of fish from each length class are sampled (either the same across the length distribution, or further stratified by length class with a larger number (but still pre-determined) selected from the larger lengths to resolve the age structure better (see Table 5.19 for an overview of sampling strategies used in HERAS).

There is concern that biological sampling effort in some strata is inadequate to satisfy the increasing demands on the survey to provide results for an increasing number of sub-categories with the increased focus on stock splitting using genetic results.

We suggest a review of the different strategies used and that an analysis is carried out in the survey group to determine the effect of the different strategies on the accuracy and precision of the final results (the abundance indices delivered to the assessment procedure for the stocks). Furthermore, it should be explored what the optimal sampling strategy and level is, given the present situation, but also what is needed with the increased demand for splitting the survey results in the near future.

We suggest a workshop with the nations participating in the HERAS survey as a way forward on this issue. This has been discussed during the 2022 WGIPS meeting and is currently being planned.

Scrutiny of acoustic data

In the Dutch, Irish, Norwegian, and Scottish survey, scrutiny of hydroacoustic data during post-processing is taken to species level. Based on scattering characteristics of echo-traces as well as catch composition of corresponding targeted trawl catches, a robust allocation of e.g. herring and sprat to echoes originating from detected fish schools and aggregations is feasible. The acoustic categories HER (herring) and SPR (sprat) are therefore allocated to these echo-traces and corresponding NASC values are exported from integration results.

The group recommend mixed-species acoustic categories should only be used when there is no other alternative, i.e. when species level scrutiny is not possible due to herring and sprat occurring in truly inseparable mixed aggregations with other species. In general, it is recommended to scrutinize to the highest resolution where possible and to improve species allocation to mixed aggregations through more directed trawling on aggregations.

In the German and Danish survey area, clupeids mostly occur in mixed schools of "typical" appearance that based on hydroacoustic characteristics and corresponding catch composition from trawl haul rarely allows allocation of a single species category to echo-traces. However, clupeid schools in the area are comparatively clearly distinguishable and an allocation of a general aggregated CLU (clupeid) category is typically feasible. Where Clupeids are found in aggregations with other species, a category of MIX is assigned in the post-processing, the precise mix of species being determined from the composition of relevant trawl hauls. In 2022, no MIX category was allocated in the German acoustic data due to mostly "clean" clupeid catches. In the Danish acoustic data, the MIX category was applied due to partly high species diversity in catch samples with notable contributions of other than the target species and the expectable contribution of those fishes to the echo registrations recorded. This is partly expected to result from different trawl gear employed as well as the areas visited. In general, this approach followed in the adjacent Danish and German survey areas with a high degree of mixed aggregations is considered to give a robust estimate of the disaggregated, species-specific and spatially explicit NASC distribution of both target and non-target species in the corresponding strata. The allocations of trawl hauls to acoustic samples used for the split-NASC processes are documented in the final StoX project.

Maturity

Since the 2015 survey no assumptions have been made about expected full maturity above a certain age, and those actually observed in the surveys are reported in this report. In the past (prior to 2015), fish 5-wr or older were all assumed mature by definition in the reported result from the HERAS survey. This is a decision that should be made in the assessment working group for each assessment, as the underlying data should be collected and reported as actually observed.

From 2017 the proportion mature at age of WBSS is not reported. Due to the timing of the survey in relation to the spawning time of this spring spawning stock, it would be erroneous to calculate SSB based on observations since first-time spawners might not have started their maturation development (switch from immature to mature) at this time of the year.

6 Further improvements to survey

1) Efforts to further standardise the HERAS survey should continue.
    a. Assess the various biological sampling strategies used in the survey by different laboratories and develop a commonly agreed strategy to achieve adequate resolution of stock, age and maturity composition
2) Continue monitoring of stock containment to the north of stratum 111. This informs whether it is necessary to expand the survey area further north.
3) Provide sardine and anchovy occurrence at the south of the survey coverage.
4) Extensive check of the national data incl. check of compliance with the ICES acoustic trawl database format requirements to be performed prior to the post-cruise meetings. This includes also thorough checks of the reporting format for e.g. age: All ages for herring must be provided in winter rings to be used by the assessment working group.
5) Further work to incorporate genetic sampling and analysis of herring throughout the HERAS area to facilitate splitting the survey estimates into the component stocks using a commonly agreed set of techniques and procedures. This includes the evaluation of NSAS/WBSS stock splitting but also mixing with other herring stocks. This will require extra resources from national laboratories and possibly a series of workshops to agree on methods for collecting and analysing genetics as well as agreements on sampling levels needed to achieve adequate precision.

References

Bekkevold D., Berg F., Polte P., Bartolino V., Ojaveer H., Mosegaard H., Farrell E.D., Fedotova J., Hemmer-Hansen J., Huwer B., Trijoulet V., Moesgaard Albertsen C., Fuentes-Pardo A.P., Gröhsler T., Jansen T., Folkvord A., and Andersson L., 2023. Mixed-stock analysis of Atlantic herring (*Clupea harengus*): a tool for identifying management units and complex migration dynamics. ICES Journal of Marine Science 0, 1-12. https://doi.org/10.1093/icesjms/fsac223

Farrell, E.D., Campbell, N., Carlsson, J., Egan, A., Gras, M., Lusseau S.M., Nolan, C., O'Connell, S., O'Malley, M., and White, E. 2021. Herring in Divisions 6.a, 7.b and 7.c: Scientific Assessment of the Identity of the Southern and Northern Stocks through Genetic and Morphometric Analysis. Final Report. European Commission. Service Contract EASME/EMFF/2017/1.3.2.1/SI2.767459. 251 pp.

Farrell E.D., Andersson L., Bekkevold D., Campbell N., Carlsson J., Clarke M.W., Egan A., Folkvord A., Gras M., Lusseau S.M., Mackinson S., Nolan C., O'Connell S., O'Malley M., Pastoors M., Pettersson M.E., White E., 2022. A baseline for the genetic stock identification of Atlantic herring, *Clupea harengus*, in ICES Divisions 6.a, 7.b–c. Royal Society Open Science 9:220453.

Han, F., Jamsandekar, M., Pettersson, M.E., Su, L., Fuentes-Pardo, A., Davis, B., Bekkevold, D., Berg, F., Casini, M., Dahle, G., Farrell, E.D., Folkvord, A., and Andersson, L., 2020. Ecological adaptation in Atlantic herring is associated with large shifts in allele frequencies at hundreds of loci. eLife 9, e61076.

Hatfield, E.M.C., and Simmonds, E.J. 2010. Revisions to acoustic survey derived data for the west of Scotland – VIa (North) - herring stock. Working Document to the ICES Herring Assessment Working Group, 2010.

ICES. 2015. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES. 2016. Report of the Working Group of International Pelagic Surveys (WGIPS), 18-22 January 2016, Dublin, Ireland. ICES CM 2016/SSGIEOM:05. 433pp.

ICES. 2018. ICES WKSPRAT REPORT 2018. Benchmark workshop on sprat (WKSPRAT 2018), 5-9 November 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:35. 60 p.

ICES. 2023. Benchmark Workshop on North Sea and Celtic Sea stocks (WKNSCS). ICES Scientific Reports. 4:85. 324 pp. https://doi.org/10.17895/ices.pub.21558681

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., and Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods in Ecology and Evolution, 10(9), 1523–1528. https://doi.org/10.1111/2041-210x.13250

Lusseau, S., O'Malley, M., Egan, A., Clarke, M. 2015. Working document 2: Revisions to VIa, VIIbc combined FLSAM assessment input data. Working Document to WKWEST 2015.

Tables and Figures

Table 5.2. North Sea Autumn Spawning herring: Total numbers (millions) and biomass (thousands of tonnes) in the area surveyed in the acoustic surveys June - July 2022. Mean weights, mean length and fraction mature by age (winter ring).

Age (ring)	Numbers	Biomass	Maturity	Weight(g)	Length (cm)
0	14 746	78	0.00	5.3	9.0
1	3 711	149	0.00	40.3	16.9
2	3 814	503	0.70	132.0	24.2
3	3 043	541	0.95	177.8	26.7
4	1 743	340	0.97	194.9	27.3
5	822	172	0.99	209.7	27.9
6	662	154	1.00	232.2	29.0
7	718	176	1.00	244.4	29.3
8	619	151	1.00	243.5	29.2
9+	249	67	1.00	268.8	30.4
Immature	19 780	367		18.6	11.5
Mature	10 348	1 963		189.7	26.8
Total	30 127	2 330	0.34	77.4	16.8

Table 5.3. Western Baltic spring spawning herring: Total numbers (millions) and biomass (thousands of tonnes) in the area surveyed in the acoustic surveys June-July 2022. Numbers, biomass, mean weight and mean length by age (winter ring).

Age (ring)	Numbers	Biomass	Weight (g)	Length (cm)
0	0	0		
1	45	2	40.2	17.5
2	246	28	115.6	23.2
3	129	17	132.6	24.5
4	124	17	137.2	24.9
5	100	16	163.1	26.3
6	58	11	183.2	27.7
7	36	7	198.5	28.7
8+	37	9	230.2	29.6
3+	483	77	158.5	26.0
Total	774	107	138.0	24.6

Table 5.4. Autumn spawning West of Scotland herring: Total numbers (millions) and biomass (thousands of tonnes) in the area surveyed in the acoustic surveys June-July 2022. Mean weights, mean lengths and fraction mature by age (winter ring).

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.0	0.0	0.0
1	2	0.1	0.0	53.4	19.0
2	230	28.4	0.7	123.7	24.0
3	378	60.2	1.0	159.2	25.8
4	276	48.8	1.0	176.7	26.7
5	121	22.2	1.0	182.7	27.1
6	52	10.3	1.0	197.3	27.9
7	24	5.6	1.0	236.1	29.3
8	30	6.2	1.0	207.3	29.0
9+	5	1.4	1.0	273.5	33.4
Immature	94	11.2		119.5	23.7
Mature	1 052	177.0		168.3	26.3
Total	1 147	188.2	0.9	164.2	26.1

Table 5.5. Malin Shelf herring (6.a./7. b, c): Total numbers (millions) and biomass (thousands of tonnes) in the area surveyed in the acoustic surveys June-July 2022. Mean weights, mean lengths and fraction mature by age (winter ring).

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.0	0.0	0.0
1	232	12.5	0.0	53.8	18.9
2	316	37.8	0.7	119.7	23.8
3	543	82.8	1.0	152.5	25.5
4	362	62.6	1.0	172.9	26.6
5	162	29.3	1.0	180.6	27.1
6	63	12.3	1.0	193.9	27.8
7	29	6.4	1.0	223.4	29.1
8	40	8.2	1.0	202.3	29.1
9+	5	1.4	1.0	273.5	33.4
Immature	337	24.8		73.6	20.4
Mature	1 442	233.4		161.9	26.1
Total	1 793	258.2	0.8	144.0	24.9

Table 5.6. North Sea Autumn Spawning herring: Numbers (millions) at age (winter rings) and spawning stock biomass (SSB) from acoustic surveys 1986–2022. For 1986 the estimates are the sum of those from the Div. 4.a summer survey, the Div. 4.b autumn survey, and the Div. 4.c, 7.d winter survey. The 1987 to 2022 estimates are from summer surveys in Div. 4.a-c and 3.a excluding estimates of Western Baltic Spring Spawning herring. For 1999 and 2000, the Kattegat was excluded from the results because it was not surveyed. Prior to 2008 there is no information on 0-ringers.

Year / Age (ring)	0	1	2	3	4	5	6	7	8	9+	Total	SSB ('000t)
1986		1 639	3 206	1 637	833	135	36	24	6	8	7 542	942
1987		13 736	4 303	955	657	368	77	38	11	20	20 165	817
1988		6 431	4 202	1 732	528	349	174	43	23	14	13 496	897
1989		6 333	3 726	3 751	1 612	488	281	120	44	22	16 377	1 637
1990		6 249	2 971	3 530	3 370	1 349	395	211	134	43	18 262	2 174
1991		3 182	2 834	1 501	2 102	1 984	748	262	112	56	12 781	1 874
1992		6 351	4 179	1 633	1 397	1 510	1 311	474	155	163	17 173	1 545
1993		10 399	3 710	1 855	909	795	788	546	178	116	19 326	1 216
1994		3 646	3 280	957	429	363	321	238	220	132	13 003	1 035
1995		4 202	3 799	2 056	656	272	175	135	110	84	11 220	1 082
1996		6 198	4 557	2 824	1 087	311	99	83	133	206	18 786	1 446
1997		9 416	6 363	3 287	1 696	692	259	79	78	158	22 028	1 780
1998		4 449	5 747	2 520	1 625	982	445	170	45	121	16 104	1 792
1999		5 087	3 078	4 725	1 116	506	314	139	54	87	15 107	1 534
2000		24 735	2 922	2 156	3 139	1 006	483	266	120	97	34 928	1 833
2001		6 837	12 290	3 083	1 462	1 676	450	170	98	59	26 124	2 622
2002		23 055	4 875	8 220	1 390	795	1 031	244	121	150	39 881	2 948
2003		9 829	18 949	3 081	4 189	675	495	568	146	178	38 110	2 999
2004		5 183	3 415	9 191	2 167	2 590	317	328	342	186	23 722	2 584
2005		3 113	1 890	3 436	5 609	1 211	1 172	140	127	107	16 805	1 868
2006		6 823	3 772	1 997	2 098	4 175	618	562	84	70	20 199	2 130
2007		6 261	2 750	1 848	898	806	1 323	243	152	65	14 346	1 203
2008	6 869	3 714	2 853	1 709	1 485	809	712	1 749	185	270	20 355	1 784
2009	13 554	4 655	5 632	2 553	1 023	1 077	674	638	1 142	578	31 526	2 591
2010	12 227	14 577	4 237	4 216	2 453	1 246	1 332	688	1 110	1 619	43 705	3 027
2011	2 530	10 119	4 166	2 534	2 173	1 016	651	688	440	1 207	25 524	2 431
2012	2 936	7 437	4 718	4 067	1 738	1 209	593	247	218	478	23 641	2 269
2013	17 786	6 388	2 683	3 031	2 895	1 546	849	464	250	592	36 484	2 261
2014	34 864	11 634	4 918	2 827	2 939	1 791	1 236	669	211	250	61 339	2 610
2015	386	6 714	9 495	2 831	1 591	1 549	926	520	275	221	24 508	2 280
2016	20 314	9 034	12 011	5 832	1 273	822	909	395	220	146	51 686	2 648
2017	14 259	3 054	1 761	6 095	3 142	787	365	298	153	140	30 055	1 943
2018	7 480	9 938	4 254	1 692	5 150	2 440	719	529	293	111	32 606	2 337
2019	4 573	10 146	1 303	2 345	1 212	3 506	1 657	395	252	172	25 560	1 919
2020	7 178	7 130	2 736	1 156	1 371	1 674	1 666	504	164	188	23 766	1 717
2021	17 500	5 196	2 803	1 800	773	877	915	1 021	388	208	31 481	1 501
2022	14 746	3 711	3 814	3 043	1 743	822	662	718	619	249	30 127	1 963

Table 5.7. Western Baltic Spring Spawning herring: Numbers (millions) at age (winter rings) from acoustic surveys 1992 to 2022. The 1999 survey was incomplete due to the lack of participation by RV "Dana".

Year/Age (ring)	1	2	3	4	5	6	7	8+	Total	3+ group
1992	277	2 092	1 799	1 593	556	197	122	20	10 509	4 287
1993	103	2 768	1 274	598	434	154	63	13	5 779	2 536
1994	5	413	935	501	239	186	62	34	3 339	1 957
1995	2 199	1 887	1 022	1 270	255	174	39	21	6 867	2 781
1996	1 091	1 005	247	141	119	37	20	13	2 673	577
1997	128	715	787	166	67	69	80	77	2 088	1 245
1998	138	1 682	901	282	111	51	31	53	3 248	1 428
1999	1 367	1 143	523	135	28	3	2	1	3 201	691
2000	1 509	1 891	674	364	186	56	7	10	4 696	1 295
2001	66	641	452	153	96	38	23	12	1 481	774
2002	3 346	1 576	1 392	524	88	40	18	19	7 002	2 081
2003	1 833	1 110	395	323	103	25	12	5	3 807	864
2004	1 668	930	726	307	184	72	22	18	3 926	1 328
2005	2 687	1 342	464	201	103	84	37	21	4 939	910
2006	2 081	2 217	1 780	490	180	27	10	0.1	6 791	2 487
2007	3 918	3 621	933	499	154	34	26	14	9 200	1 661
2008	5 852	1 160	843	333	274	176	45	44	8 839	1 715
2009	565	398	205	161	82	85	39	65	1 602	638
2010	999	511	254	115	65	24	28	34	2 030	519
2011	2 980	473	259	163	70	53	22	46	4 067	614
2012	1 018	1 081	236	87	76	33	14	60	2 605	505
2013	49	627	525	53	30	12	8	15	1 319	643
2014	513	415	176	248	28	37	26	42	1 798	556
2015	1 949	1 244	446	224	171	82	89	115	4 322	1 127
2016	425	255	381	99	40	40	12	28	1 483	600
2017	696	424	661	401	94	53	52	92	2 474	1 353
2018	106	224	271	175	169	50	35	44	1 075	745
2019	418	591	315	109	67	52	19	13	1 585	574
2020	815	274	225	180	74	77	64	46	1 764	667
2021	26	245	275	203	52	49	22	39	911	639
2022	45	246	129	124	100	58	36	37	774	483

Table 5.8. West of Scotland herring: Numbers (millions) at age (winter rings) and SSB (thousands of tonnes) from acoustic surveys 1993 to 2022. In 1997 the survey was carried out one month early in June as opposed to July when all the other surveys were carried out. A revision of the period 1991 to 2007 was carried out in 2010 and is incorporated in this table (Hatfield and Simmonds, 2010).

Year/Age (ring)	1	2	3	4	5	6	7	8	9+	SSB:
1993	2	579	690	689	565	900	296	158	161	845
1994	494	542	608	286	307	268	407	174	132	534
1995	441	1 103	473	450	153	187	169	237	202	452
1996	41	576	803	329	95	61	77	78	115	370
1997	792	642	286	167	66	50	16	29	24	175
1998	1 222	795	667	471	179	79	28	14	37	376
1999	534	322	1 388	432	308	139	87	28	35	460
2000	448	316	337	900	393	248	200	95	65	445
2001	313	1 062	218	173	438	133	103	52	35	359
2002	425	436	1 437	200	162	424	152	68	60	549
2003	439	1 039	933	1 472	181	129	347	114	75	739
2004	564	275	760	442	577	56	62	82	76	396
2005	50	243	230	423	245	153	13	39	27	223
2006	112	835	388	285	582	415	227	22	59	472
2007	0	126	294	203	145	347	243	164	32	299
2008	48	233	912	669	340	272	721	366	264	788
2009	346	187	264	430	374	219	187	500	456	579
2010	425	489	398	150	143	95	63	48	188	253
2011	22	185	733	451	204	220	199	113	263	458
2012	792	179	729	471	241	107	107	56	105	375
2013	0	137	320	600	162	69	61	24	37	256
2014	1 031	243	218	469	519	143	30	19	11	272
2015	0	122	325	650	378	442	83	23	2	387
2016	0	30	108	88	112	79	62	6	1	88
2017	0	22	324	144	97	109	44	18	5	139
2018	964	323	92	331	153	51	72	27	13	152
2019	3	50	77	41	137	86	14	16	20	76
2020	657	579	274	150	83	178	38	13	10	158
2021	61	511	282	97	54	41	80	26	23	147
2022	2	230	378	276	121	52	24	30	5	177

Table 5.9. Malin Shelf acoustic survey (6.a./7. b, c): Numbers (millions) at age (winter rings) and SSB (thousands of tonnes) from acoustic survey time series 2008-2022. This table has been revised in 2015, details can be found in Lusseau et al., 2015.

Year/Age (ring)	1	2	3	4	5	6	7	8	9+	SSB:
2008	50	267	996	720	363	331	744	386	274	845
2009	773	265	274	444	380	225	193	500	456	592
2010	133	375	374	242	173	146	102	100	297	370
2011	63	257	900	485	213	228	205	113	264	498
2012	796	548	832	517	249	115	111	57	105	434
2013	0	209	434	672	195	71	61	29	37	284
2014	1 012	278	242	502	534	148	33	19	13	280
2015	0	212	397	747	423	476	90	24	2	430
2016	0	30	108	88	112	79	62	6	1	88
2017	0	25	339	155	106	110	47	13	5	145
2018	1 289	447	106	343	153	52	72	27	13	159
2019	24	231	225	123	169	95	14	17	21	128
2020	1 175	1 226	609	235	110	209	42	18	10	226
2021	227	1 808	711	177	81	48	83	27	23	278
2022	232	316	543	362	162	63	29	40	5	233

Table 5.10. Sprat in the North Sea (ICES Subarea 4): Abundance, biomass, mean weight and mean length by age and maturity (i = immature, m = mature) from the summer 2022 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (1000 t)	Mean weight (g)	Mean length (cm)
0i	23 317	45	1.9	6.3
1i	16 228	90	5.6	8.9
1m	43 733	403	9.2	10.6
2i	2 516	17	6.9	9.6
2m	13 551	158	11.7	11.3
3i	600	4	7.1	10.1
3m	2 067	29	14.0	12.0
4m	194	4	18.9	13.2
Immature	42 662	157	3.7	7.6
Mature	59 546	594	10.0	10.8
Total	102 208	751	7.3	9.5

Table 5.11. Sprat in the North Sea (ICES Subarea 4): Time-series of abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2000-2022. The surveyed area has expanded over the years. Only figures from 2004 and onwards are broadly comparable. In 2003, information on sprat abundance is available from one nation only.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
2022	23 317	59 961	16 067	2 861	**102 206**	45	493	175	37	**750**
2021	1 345	46 595	6 793	1 467	**56 200**	4	315	82	20	**420**
2020	12 869	34 717	17 505	1 963	**67 055**	13	278	208	32	**531**
2019	574	93 503	26 512	4 410	**124 999**	0	413	393	74	**880**
2018	3 409	107 083	9 061	588	**120 141**	1	717	106	10	**834**
2017	2 941	38 124	3 518	1 374	**45 956**	2	280	48	24	**354**
2016	24 792	58 599	33 318	7 880	**124 588**	24	500	453	141	**1118**
2015	198	26 241	22 474	9 799	**58 711**	0	239	312	161	**712**
2014	5 828	58 405	20 164	3 823	**88 219**	9	429	228	62	**728**
2013	454	9 332	6 273	1 600	**17 660**	2	71	74	25	**172**
2012	7 807	21 912	12 541	3 205	**45 466**	27	177	150	55	**409**
2011	0	26 536	13 660	2 430	**42 625**	0	212	188	44	**444**
2010	1 991	19 492	13 743	798	**36 023**	22	163	177	14	**376**
2009	0	47 520	16 488	1 183	**65 191**	0	346	189	21	**556**
2008	0	17 165	7 410	549	**25 125**	0	161	101	9	**271**
2007	0	37 250	5 513	1 869	**44 631**	0	258	66	29	**353**
2006*	0	21 862	19 916	760	**42 537**	0	159	265	12	**436**
2005*	0	69 798	2 526	350	**72 674**	0	475	33	6	**513**
2004*	17 401	28 940	5 312	367	**52 019**	19	267	73	6	**366**
2003*	0	25 294	3 983	338	**29 615**	0	198	61	6	**266**
2002	0	15 769	3 687	207	**19 664**	0	167	55	4	**226**
2001	0	12 639	1 812	110	**14 561**	0	97	24	2	**122**
2000	0	11 569	6 407	180	**18 156**	0	100	92	3	**196**

*** re-calculated using FishFrame (https://www.ices.dk/data/data-portals/Pages/RDB-FishFrame.aspx)**

Table 5.12. Sprat in ICES Div. 3.a: Abundance, biomass, mean weight and length by age and maturity from the summer 2022 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (tonnes)	Mean weight (g)	Mean length (cm)
0i	0	0	-	-
0m	0	0	-	-
1i	6.0	54	9.0	10.2
1m	256.6	2 754	10.7	10.5
2i	1.6	22	14.1	11.9
2m	131.1	1 970	15.0	12.3
3m+	21.2	415	19.6	13.8
Immature	8.0	76	10.0	10.5
Mature	409.0	5 139	12.5	11.2
Total	416.0	5 215	12.5	11.2

Table 5.13. Sprat in ICES Div. 3.a: Time-series of sprat abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2006-2022.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
2022	0.0	262.6	132.7	21.2	**416.5**	0.0	2.9	2.0	0.4	**5.3**
2021	0.0	323.2	258.0	42.0	**623.2**	0.0	2.6	2.9	0.8	**6.2**
2020	3.5	3698.2	488.1	92.1	**4 281.9**	0.0	31.7	6.5	1.6	**39.9**
2019	0.7	271.5	1 508.0	865.1	**2 645.3**	0.0	2.7	19.8	16.0	**38.4**
2018	98.2	2 096.9	1 051.6	191.0	**3 437.7**	0.3	17.7	11.7	3.7	**33.4**
2017	0.0	10.9	146.3	90.5	**247.7**	0.0	0.1	2.3	1.7	**4.1**
2016	0.0	5.4	671.2	280.0	**956.5**	0.0	0.0	8.7	4.8	**13.5**
2015	0.3	840.8	202.0	342.6	**1 385.8**	0.0	9.6	2.7	6.2	**18.5**
2014	29.6	614.5	109.8	159.4	**913.3**	0.1	4.8	1.8	3.4	**10.1**
2013	1.4	14.5	68.8	448.6	**533.3**	0.0	0.2	1.2	9.6	**10.9**
2012	0.3	123.9	290.1	1 488.0	**1 902.3**	0.0	1.2	5.0	31.4	**37.6**
2011	0.0	45.4	546.9	981.9	**1 574.2**	0.0	0.5	9.1	17.8	**27.5**
2010	0.0	836.1	343.8	376.3	**1 556.2**	0.0	7.3	4.9	6.4	**18.6**
2009	0.0	169.5	432.4	1 631.9	**2 233.8**	0.0	1.8	6.5	28.3	**36.6**
2008	0.0	23.0	457.8	291.2	**772.0**	0.0	0.2	6.3	5.8	**12.3**
2007	0.0	5 611.9	323.9	382.9	**6 318.7**	0.0	47.9	3.8	6.5	**58.2**
2006	86.0	61.3	1 451.9	653.0	**2 252.2**	0.3	0.6	21.2	11.5	**33.6**

Table 5.14. North Sea Autumn Spawning herring: Total abundance, biomass, mean weight and percent mature (in numbers) by stratum, last year and present survey. Stratum numbers correspond to numbering in Figure 5.1.

	2021				2022			
Strat.	Abundance (mill)	Biomass (kt)	Mean weight (g)	Pro-portion mature	Abundance (mill)	Biomass (kt)	Mean weight (g)	Pro-portion mature
11	567	123.1	217.2	1.00	556	135	242.4	0.96
21	11 605	67.2	5.8	0.00	292	6	21.7	0.01
31	439	16.3	37.1	0.00	436	23	52.7	0.03
41	208	12.9	62.0	0.06	572	73	128.3	0.72
42	922	37.0	40.2	0.01	910	36	39.1	0.02
51	250	1.8	7.4	0.00	6 382	31	4.9	0.00
61	2 995	6.4	2.1	0.00	2 647	11	4.1	0.00
71	2 910	15.3	5.3	0.00	3 127	18	5.8	0.00
81	189	7.8	41.2	0.01	9	0	54.5	0.22
91	5 251	623.8	118.8	0.62	3 058	516	168.9	0.89
101	0	0	-	-	0	0	-	-
111	3 724	781.0	209.7	0.99	4 773	981	205.5	0.98
121	349	65.4	187.6	1.00	608	130	214.1	1.00
131	94	1.4	14.3	0.00	0	0	-	-
141	1 223	85.7	70.1	0.16	2 829	232	81.9	0.29
151	651	24.8	38.1	0.05	*	*	*	*
151_N	*	*	*	*	180	24	133.9	0.77
151_S	*	*	*	*	3 224	44	13.8	0.00
152	102	9.8	96.0	0.37	526	70	132.5	0.71

*In 2022 stratum 151 was divided into 151_N and 151_S.

Table 5.15. Western Baltic Spring Spawning herring: Total abundance, biomass, and mean weight by stratum. Stratum numbers correspond to numbering in Figure 5.1.

	2021			2022		
Stratum	Abundance (mill)	Biomass (kt)	Mean weight (g)	Abundance (mill)	Biomass (kt)	Mean weight (g)
11	128	24.9	194.5	93.0	18.6	200.2
21	12	0.5	46.0	23.4	1.2	52.1
31	25	1.3	52.2	84.2	7.0	83.3
41	204	18.8	92.3	215.9	25.1	116.3
42	6	0.6	105.3	12.0	1.1	91.4
141	442	48.2	108.9	238.1	39.9	167.4
151	21	2.5	118.3	*	*	*
151_N	*	*	*	17.4	2.5	145.3
151_S	*	*	*	5.6	0.1	22.5
152	74	8.2	109.7	84.0	11.2	133.3

*In 2022 stratum 151 was divided into 151_N and 151_S.

Table 5.16. Malin shelf and West of Scotland (6.a.N) herring: Total abundance, biomass, mean weight, and percent mature by stratum. Stratum numbers correspond to numbering in Figure 5.1. The 6.a.N herring geographic subset is comprised of strata marked with *.

	2021				2022			
Stratum	Abun-dance (mill)	Bio-mass (kt)	Mean weight (g)	Proportion mature	Abun-dance (mill)	Bio-mass (kt)	Mean weigh t (g)	Proportion mature
1*	126.5	25.6	202.6	0.95	61.5	12.2	198.3	0.9
2*	15.5	0.8	54.1	0.00	0.0	0.0	0.0	0.0
3*	593.9	93.8	158.0	0.82	695.6	113.9	163.8	0.9
4*	438.7	56.6	128.9	0.60	389.4	62.1	159.4	1.0
5	1 875.8	219.4	117.0	0.48	646.9	70.0	108.2	0.6
6	135.6	15.5	114.3	0.42	0.0	0.0	0.0	0.0

Table 5.17. Sprat in the North Sea and Div. 3.a: Total abundance, biomass, mean weight, and percent mature by stratum. Stratum numbers correspond to numbering in Figure 5.1.

		2021				2022			
ICES area	Stratum	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature
Div. 3.a	21	530	5 381	10.1	99	405	5 069	12.5	98
	31	15	134	8.7	54	0	0	-	-
	41	0	0	-	-	0	0	-	-
	42	77	672	8.7	47	11	146	13.3	1
North Sea	11	0	0	-	-	0	0	-	-
	51	27 630	209 846	7.6	54	63 332	401 417	6.3	45
	61	13 509	75 126	5.6	17	12 248	86 542	7.1	61
	71	5 805	44 863	7.7	98	8 155	73 998	9.1	92
	81	709	7 074	10.0	100	15 459	162 184	10.5	89
	91	2 274	23 915	10.5	100	64	451	7.0	70
	101	233	1 833	7.9	100	42	359	8.5	1
	111	0	0	-	-	0	0	-	-
	121	0	0	-	-	0	0	-	-
	131	5 113	47 408	9.3	99	0	0	-	-
	141	168	2 347	14.0	100	740	625	0.8	0
	151	759	7 822	10.3	100	*	*	*	*
	151_N	*	*	*	*	2 166	25 233	11.6	100
	151_S	*	*	*	*	0	0	-	-
	152	0	0	-	-	0	0	-	-

*In 2022 stratum 151 was divided into 151_N and 151_S.

Table 5.18. Length of track used in analysis, number of fish ages used in estimates and transect spacing for each stratum in the 2021 and 2022 survey. Number of ages cannot be summed for all strata to give total number of ages for the survey as haul information may have been used in more than one stratum. * zig zag. ** Stratum 131 was not covered in 2022. * Stratum 151 was divided in 151_S and 151_N in 2022.**

	2021				2022			
Stratum	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)
1	481.4	234	-	15	415	156	-	15
2	154.9	47	-	*	150	0	-	*
3	303	232	-	15	270	101	-	15
4	223.3	286	-	15	265	100	-	15
5	393.5	516	-	10	380	227	-	10
6	224	191	-	15	205	0	-	15
11	942	316	0	15	920	808	0	15
51	594	304	269	25	565	476	572	25
61	240	147	265	23	230	384	388	23
71	293	306	233	17.5	285	400	332	17.5
81	475	57	34	*	470	29	146	*
91	1692	1104	21	15	1550	399	12	15
101	61	57	24	15	90	0	21	15
111	711.6	1398	0	15	705	1046	0	15
121	484.9	166	0	15	415	96	0	15
131	462	277	359	40	**	**	**	**
141	999.4	450	24	18.75	1230	574	30	15
21	209.2	274	203	13	245	490	378	13
31	153.3	363	107	10	150	417	0	10
41	156.8	268	-	17.5	160	560	0	17.5
42	85.8	383	79	17.5	75	209	70	17.5
151	384.2	717	326	15	***	***	***	***
151_N	***	***	***	***	150	194	0	15
151_S	***	***	***	***	185	139	205	17.5
152	118.2	368	0	15	115	238	0	15

Table 5.19. Biological sampling of trawl hauls in the HERAS survey by country and species.

Country	Species	Full biological sample	Length and weight	Total
SCO	Herring	2 per 1/2 cm class below 22 cm, 5 per 1/2 cm class from 22 1/2-27 1/2 cm and ten per 1/2 cm class for 28 cm and above	400-500	400-500
SCO	Sprat	5 per 1/2 cm length group from the pool that are length measured	150	150
NL	Herring	5 per 1/2 cm length group from the pool that are length measured	350	350
NL	Sprat	5 per 1/2 cm length group from the pool that are length measured	250	250
IRL	Herring	100 random fish aged, length, weight, sex, maturity and genetic sample. Additional 100 random fish for length and weight only. Length frequency only continued until 60 individuals is reached in one length class.	200 (length and weight). Up to 600 lengths	~600
IRL	Sprat	100 random fish for length and weight. Length frequency only continued until 60 individuals is reached in one length class.	100 (length and weight) 200-300 lengths	200-300
GER	Herring	10 fish per ½ cm length group per stratum from length frequency measurements. Sampling from length measurements continued until length group sample is full.	>750 (all strata combined)	Catches allowing, a sample of at least 200 fish is measured (length frequency) per haul
GER	Sprat	10 fish per ½ cm length group per stratum from length frequency measurements. Sampling from length measurements continued until length group sample is full.	>750 (all strata combined)	Catches allowing, a sample of at least 200 fish is measured (length frequency) per haul
DK	Herring	3 per ½ cm length group up to 16cm, 6 per ½ cm length group from 16.5 – 19cm and 10 per 1/2cm length group for 19.5 and above from the pool that are length measured.	450-500	450-500
DK	Sprat	10 per ½ cm length group from the pool that are length measured	200	200
NOR	Herring	50, random	50, random	100
NOR	Sprat	30, random	70, random	100

Table 5.20. Defining acoustic categories uploaded to ICES database by Denmark and Germany in 2022. The table shows the category name used in the ICES Database, which acoustic (split) categories and associated species are contained in these mixed categories, and the TS relationship used to split the NASC where a and m refer to the values in the standard formula: TS = m* log L – a, where L is length in cm.

Acoustic category in database	Country	Name in StoX project	AcousticSplit category	Species name	Aphia code	(a) dB	(m)
CLU	GER, DEN	CLU	HER	*Clupea harengus*	126417	-71.2	20
			SPR	*Sprattus sprattus*	126425	-71.2	20
			PIL	*Sardina Pilchardus*	126421	-71.2	20
			ANE	*Engraulis encrasicolus*	126426	-71.2	20
MIX	DEN	MIX	HER	*Clupea harengus*	126417	-71.2	20
			SPR	*Sprattus sprattus*	126425	-71.2	20
			PIL	*Sardina Pilchardus*	126421	-71.2	20
			ANE	*Engraulis encrasicolus*	126426	-71.2	20
			WHB	*Micromesistius poutassou*	126439	-65.2	20
			GUG	*Eutrigla gurnardus*	150637	-67.5	20
			HAD	*Melanogrammus aeglefinus*	126437	-67.5	20
			COD	*Gadus morhua*	126436	-67.5	20
			GSE	*Hyperoplus lanceolatus*	126756	-81.5	21.7
			HKB	*Merluccius merluccius*	126484	-67.5	20
			NOP	*Trisopterus esmarkii*	126444	-67.5	20
			POK	*Pollachius virens*	126441	-67.5	20
			MSE	*Ammodytes marinus*	126751	-81.5	21.7
			WHG	*Merlangius merlangus*	126438	-67.5	20

Table 5.21. Assignment of herring populations to either North Sea Autumn Spawning herring or Western Baltic Spring Spawning (WBSS) herring based on genetic analysis, mean vertebral counts, or otolith microstructure.

Genetics	*ICES stock code*	*Vertebral counts*	*Otolith microstructure*
North Sea autumn spawners (NSAS)	her-47d3	NSAS	NSAS (autumn)
Downs	her-4c7d	NSAS	NSAS (winter)
Western Baltic spring spawners (WBSS)	her-3a22	WBSS	WBSS (spring)
Western Baltic spring spawners Skagerrak	her-3a	NSAS	WBSS (spring)
Norwegian spring spawners (NSS)	her-noss	NSAS	WBSS (spring)
Baltic Autumn spawners (BAS)	her-riga	WBSS	NSAS (autumn)
Central Baltic spring spawners	her-2532-gor	WBSS	WBSS (spring)

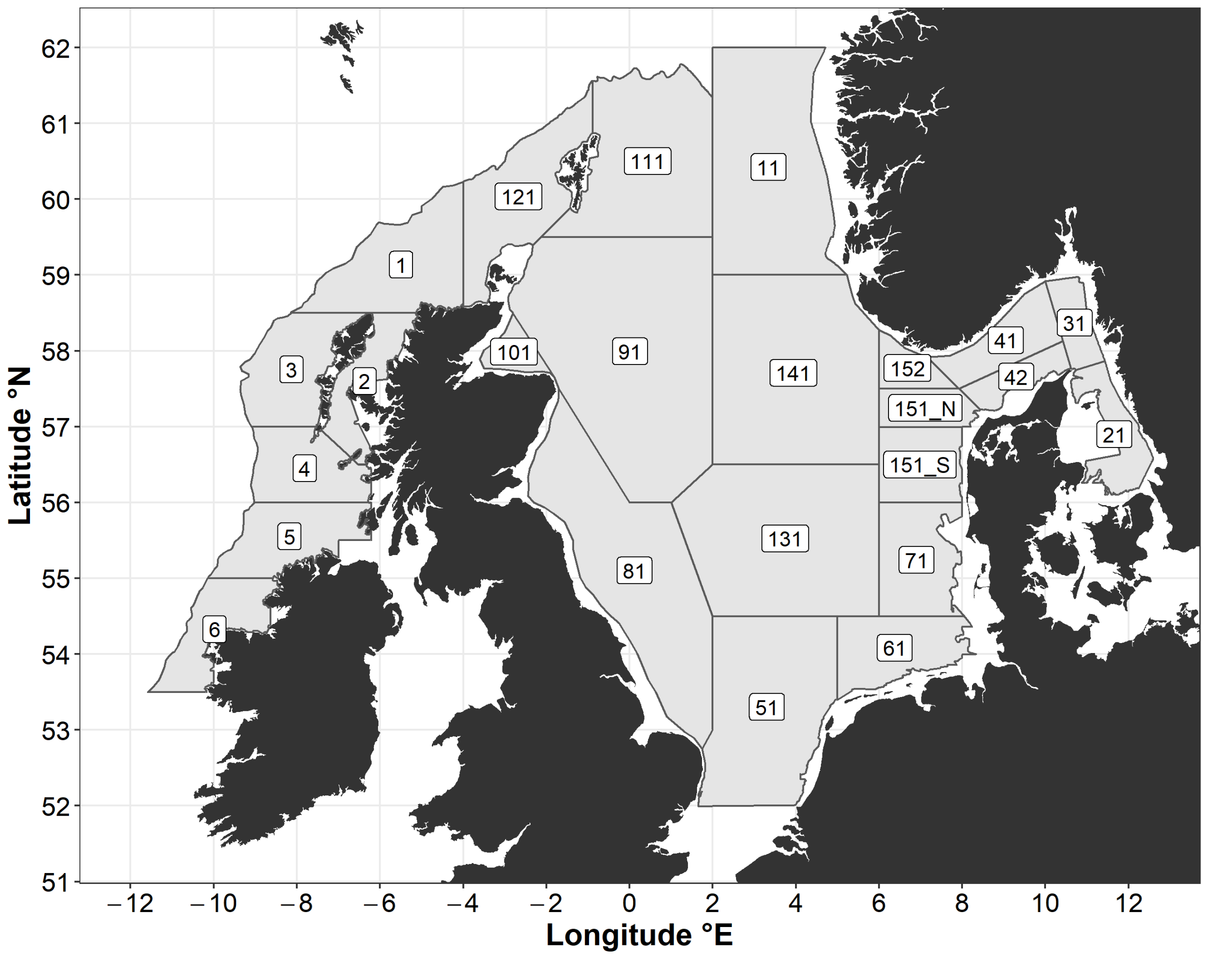


Figure 5.1. Strata used in the HERAS survey 2022.

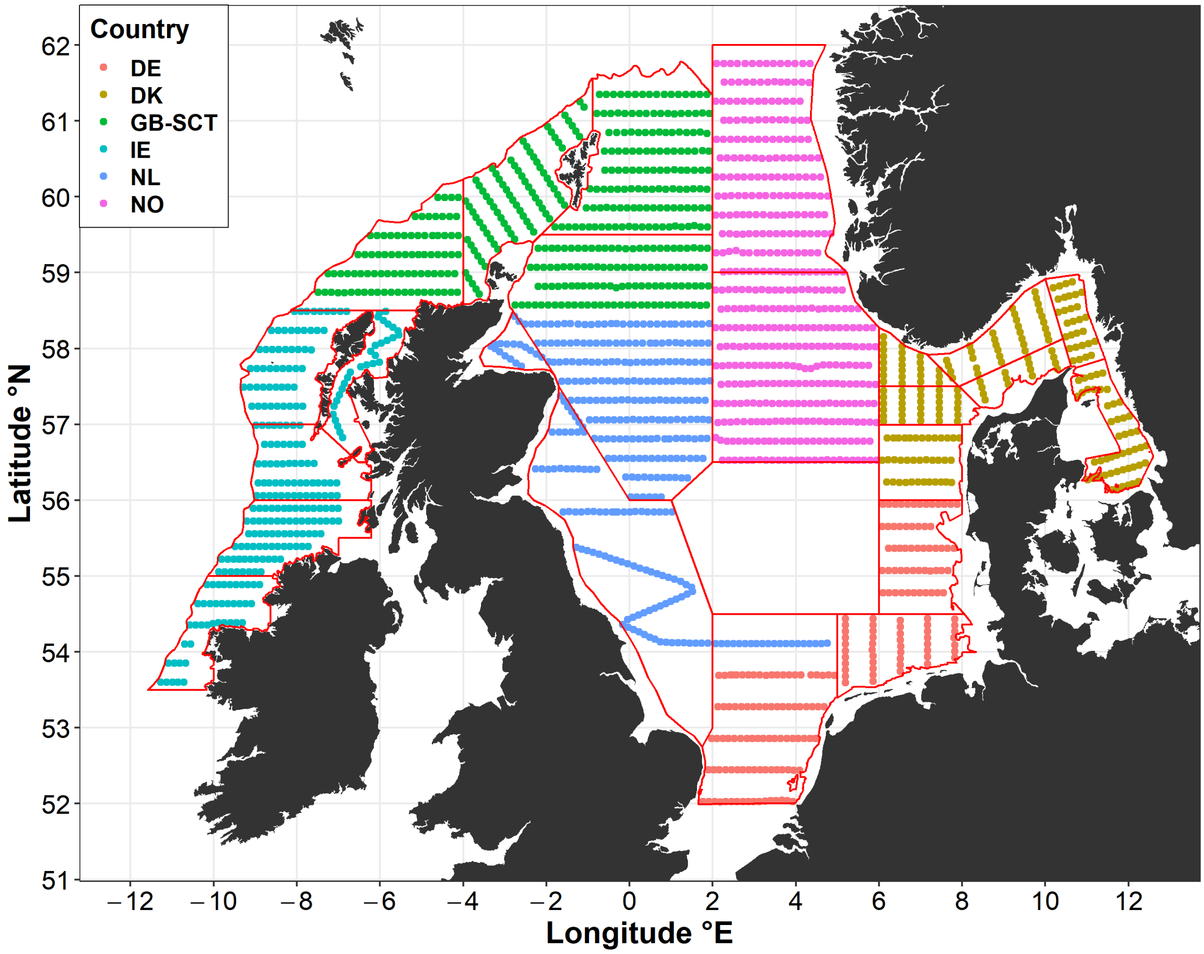


Figure 5.2. Survey area coverage in the 2022 HERAS survey and individual vessel tracks by nation.

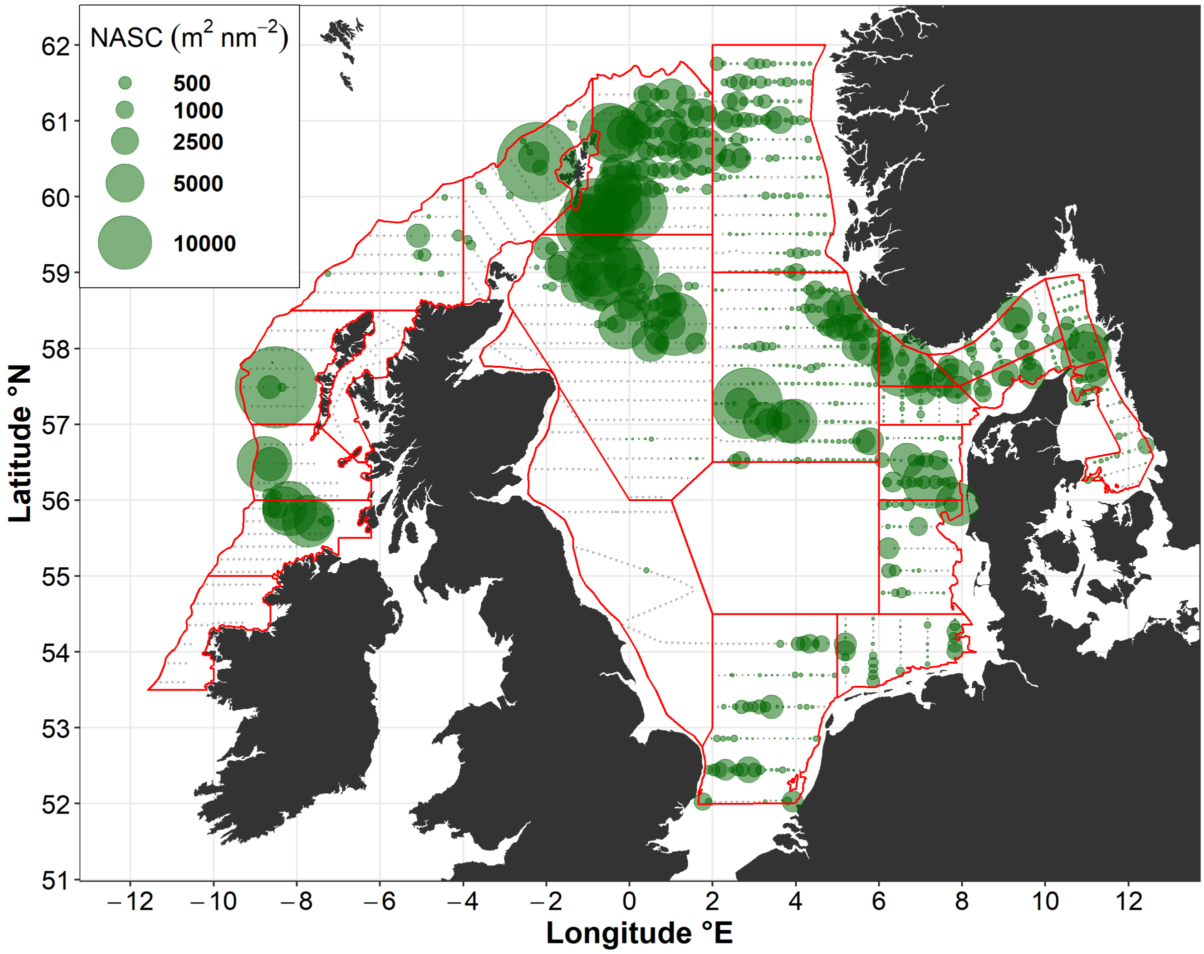


Figure 5.3. Distribution of NASC attributed to herring in the 2022 HERAS survey. Acoustic intervals represented by light grey dots, with green circles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track. The red lines indicate stratum boundaries.

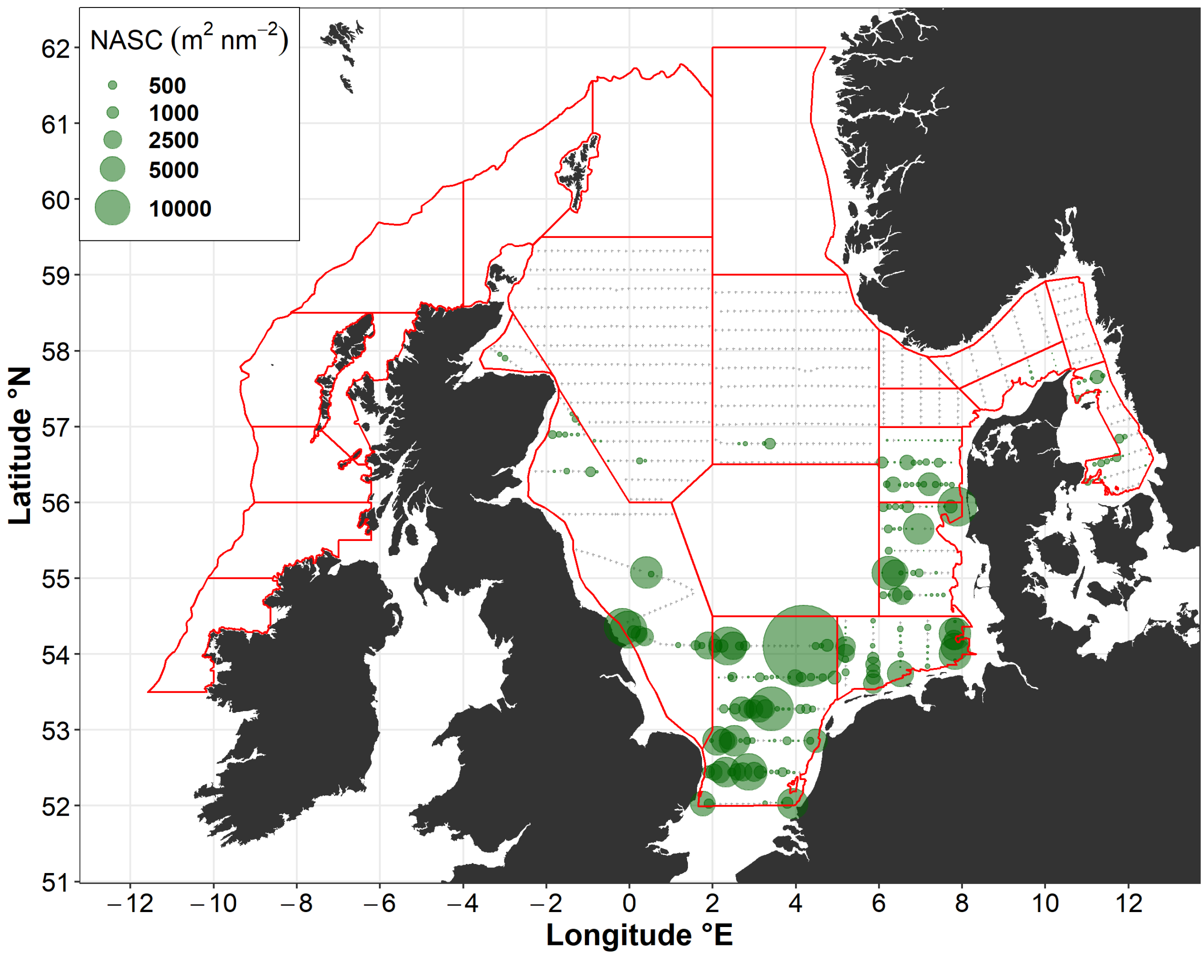


Figure 5.4. Distribution of NASC attributed to sprat in the 2022 HERAS survey. Acoustic intervals represented by light grey dots, with green circles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track. The red lines indicate stratum boundaries.

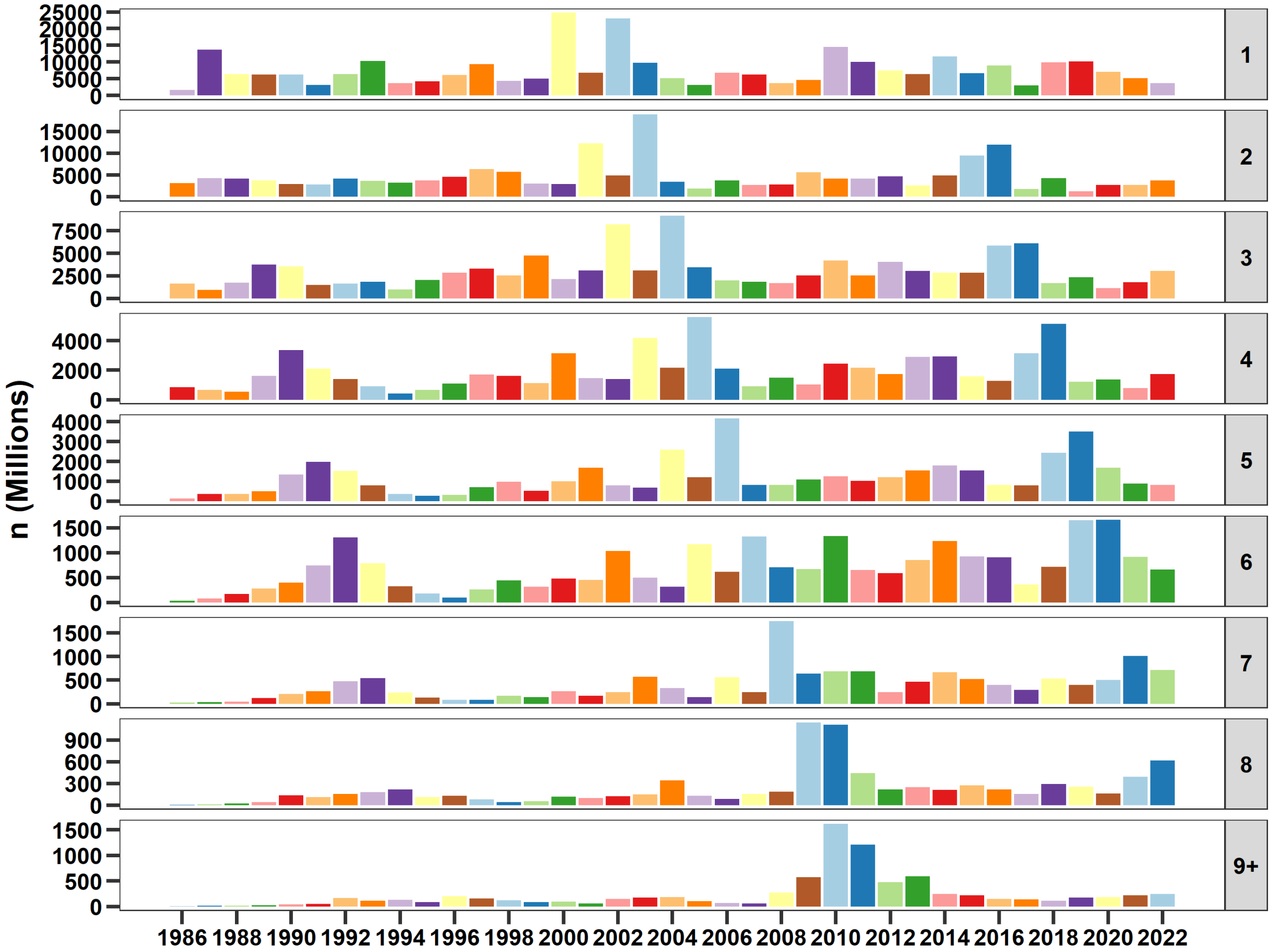


Figure 5.5. North Sea Autumn Spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1986-2022. Note diverging scales of abundance between ages.

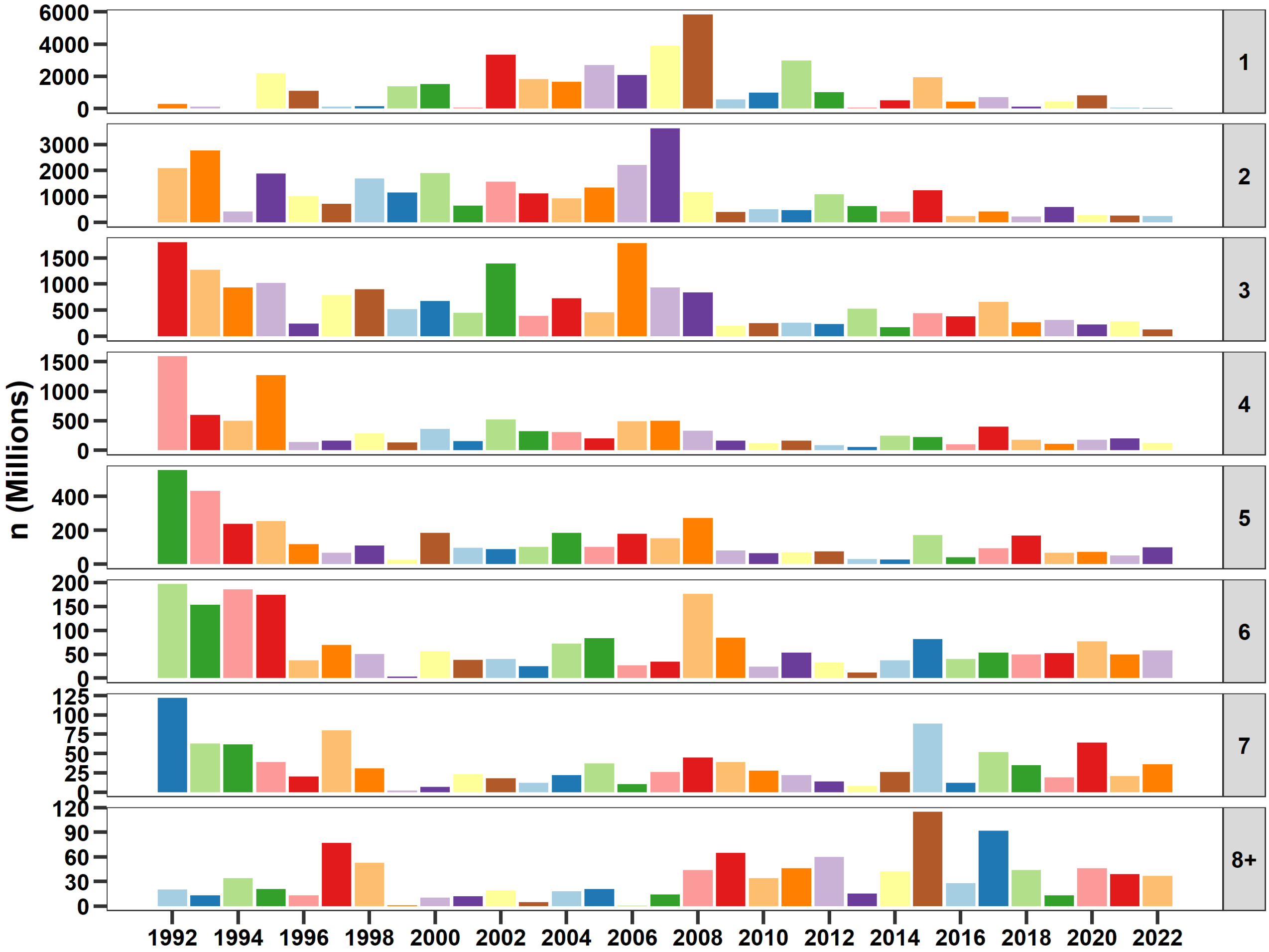


Figure 5.6. Western Baltic Spring Spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1992-2022. Note diverging scales of abundance between ages.

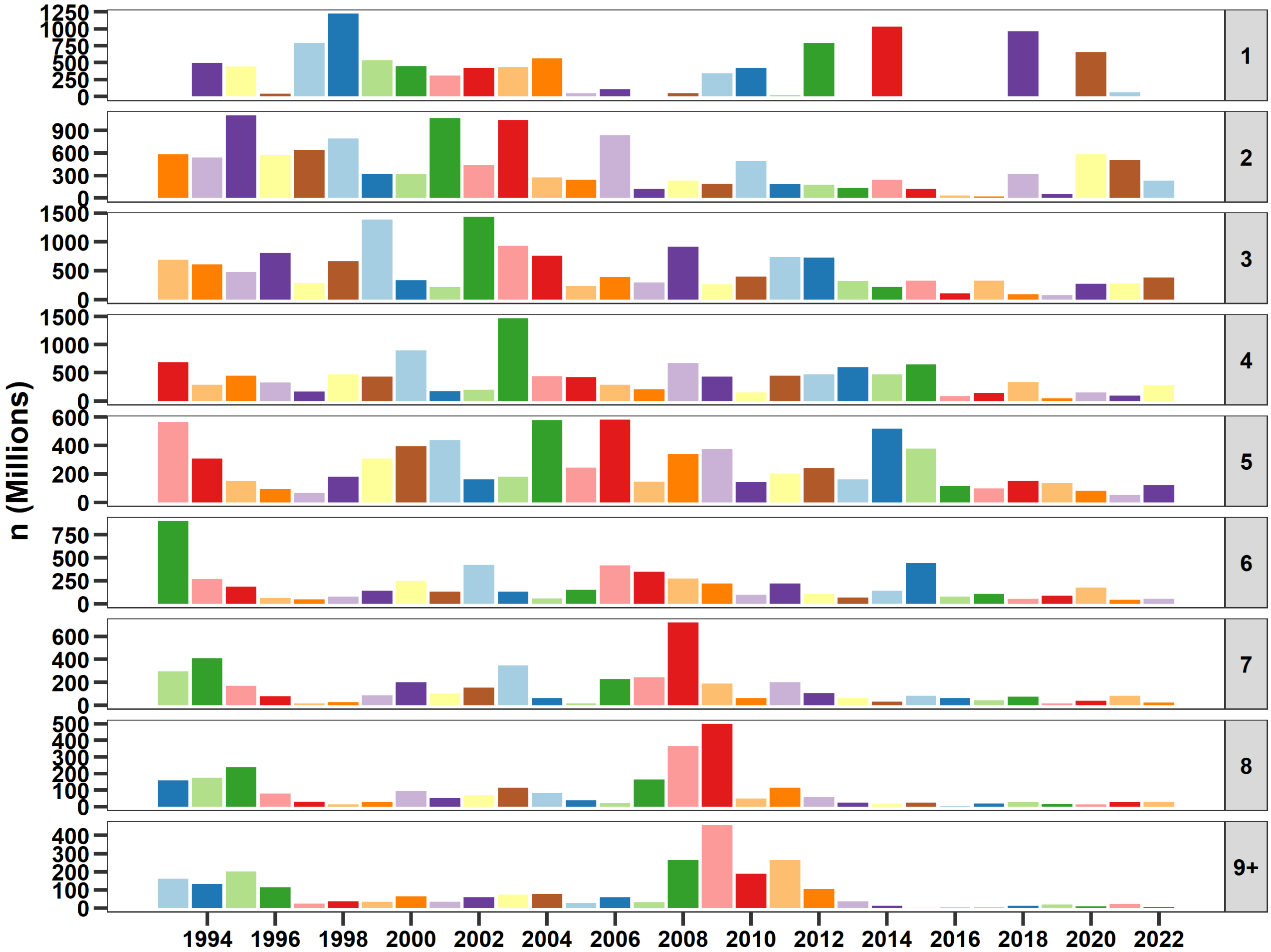


Figure 5.7. West of Scotland (6.a.N) herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1993-2022.

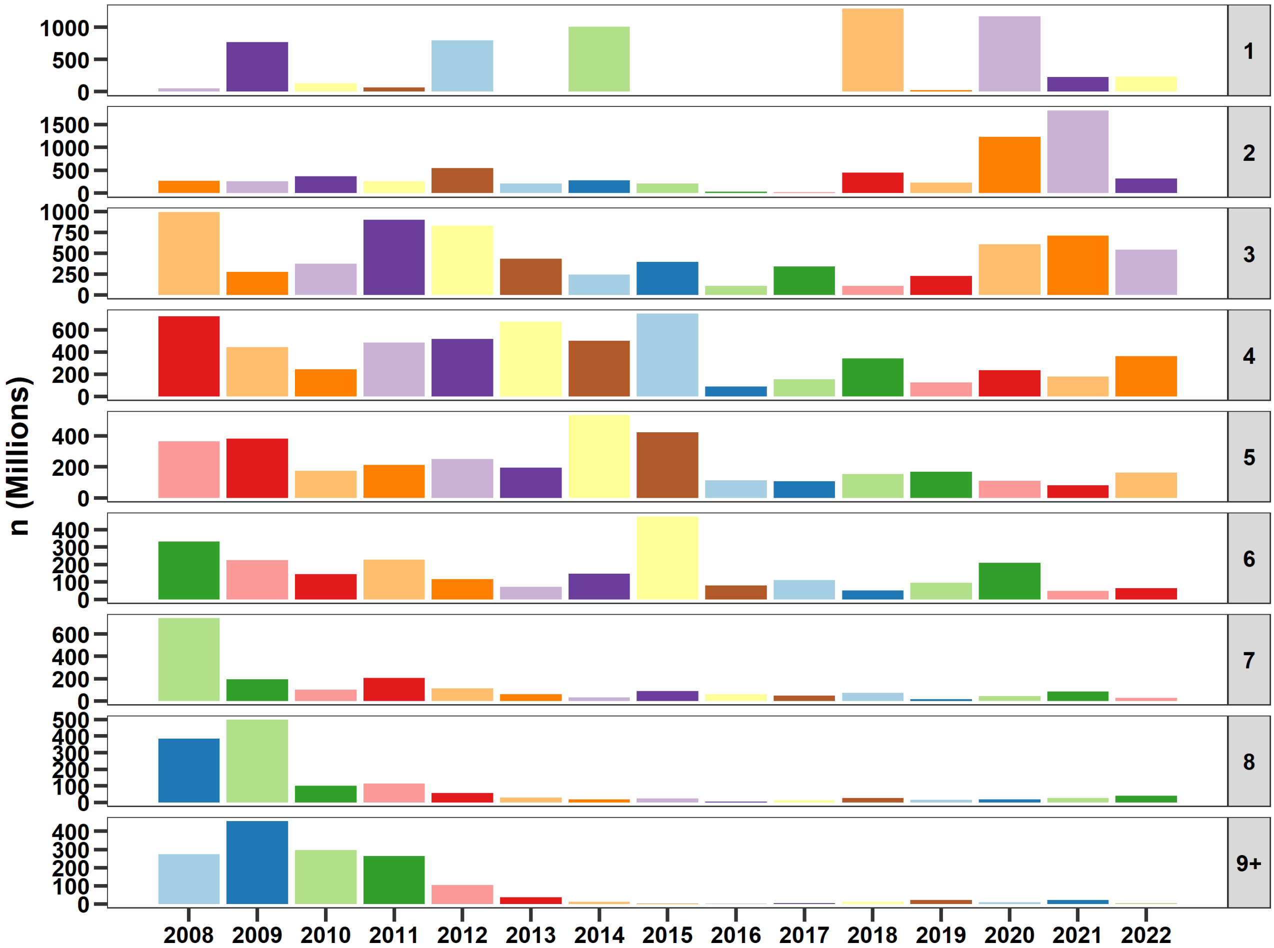


Figure 5.8. Malin Shelf Herring (6.a./7. b, c): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2008-2022.

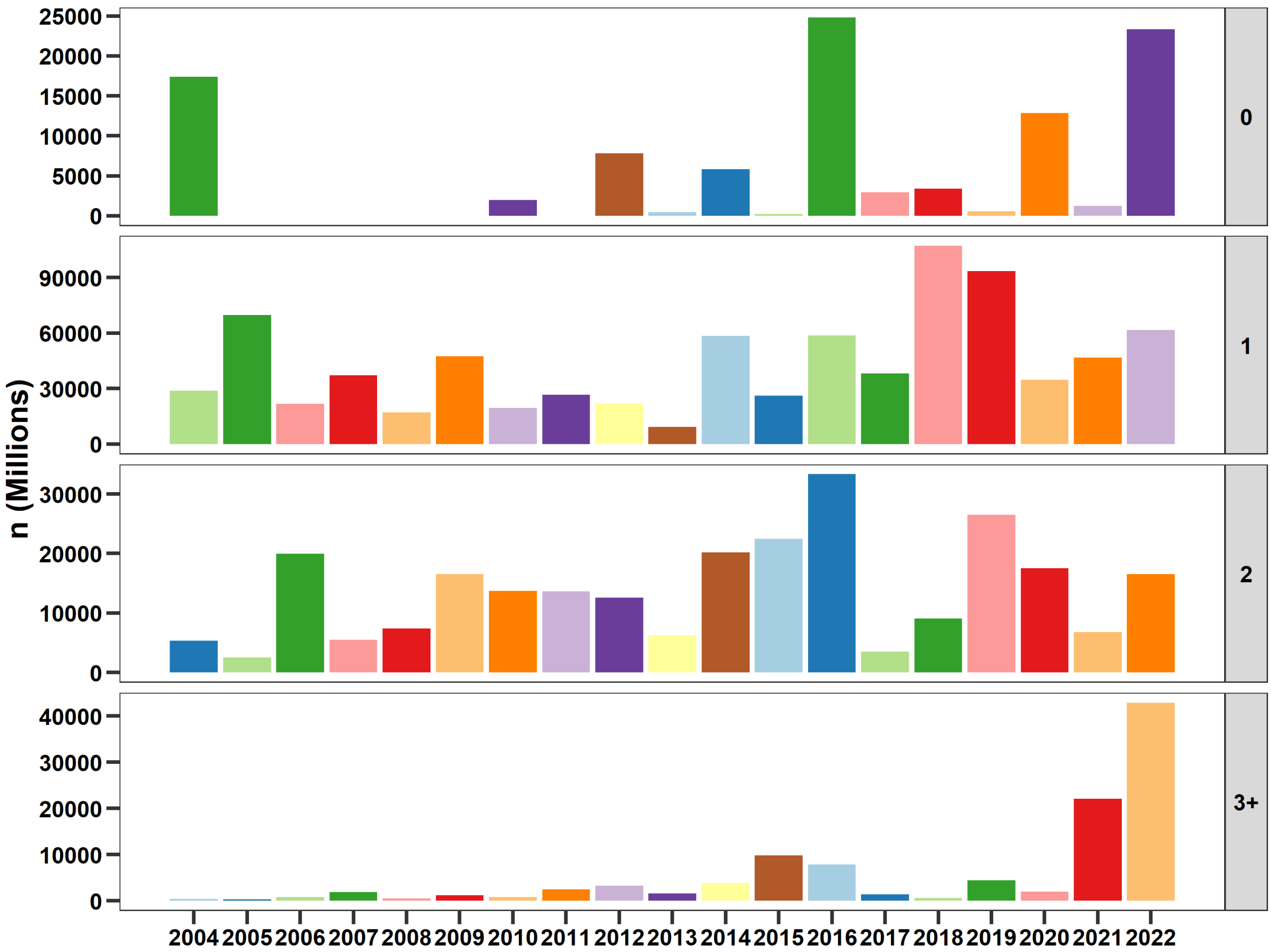


Figure 5.9. North Sea Sprat (ICES Subarea 4): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2004-2022. Note diverging scales of abundance between ages.

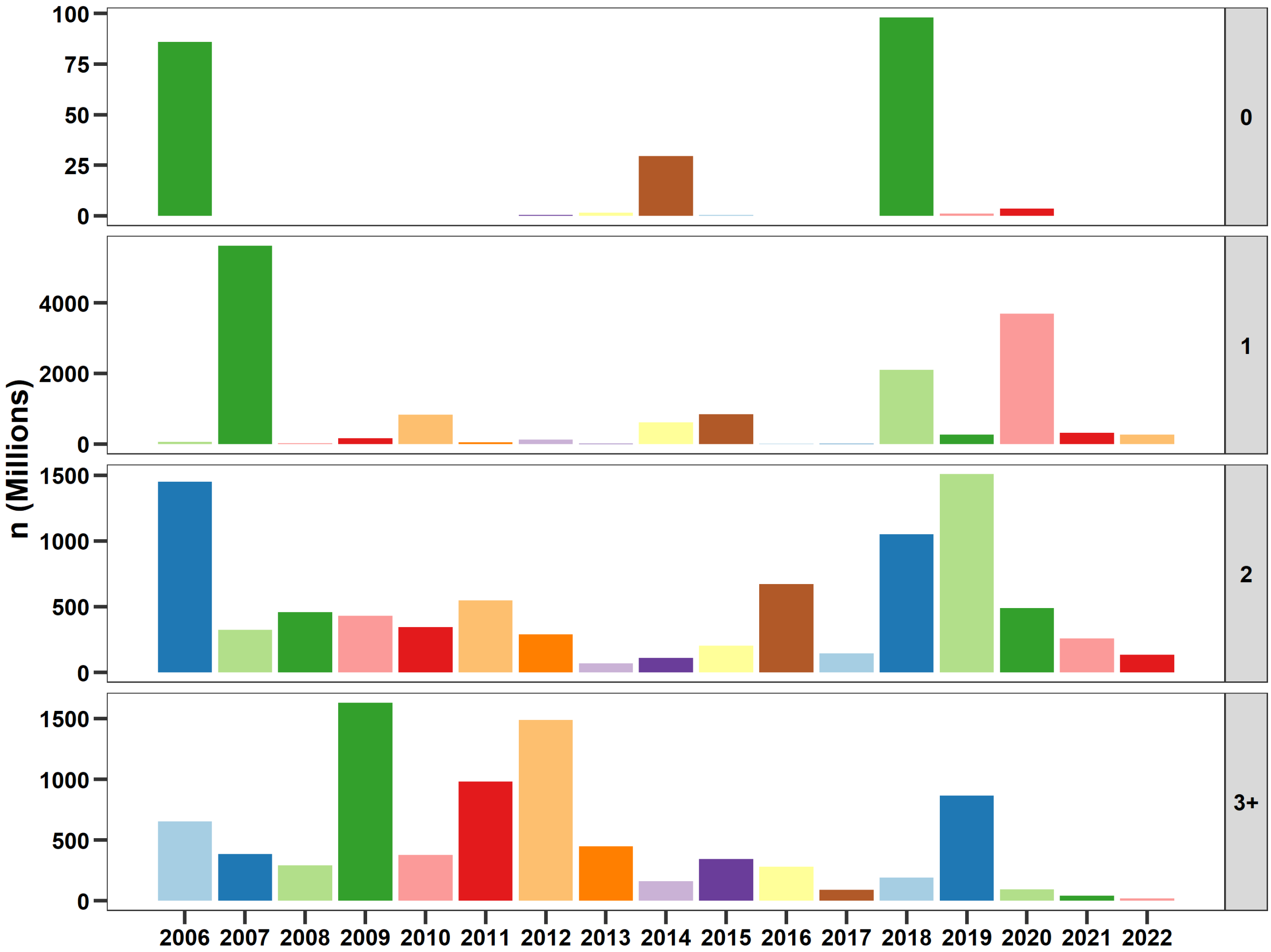
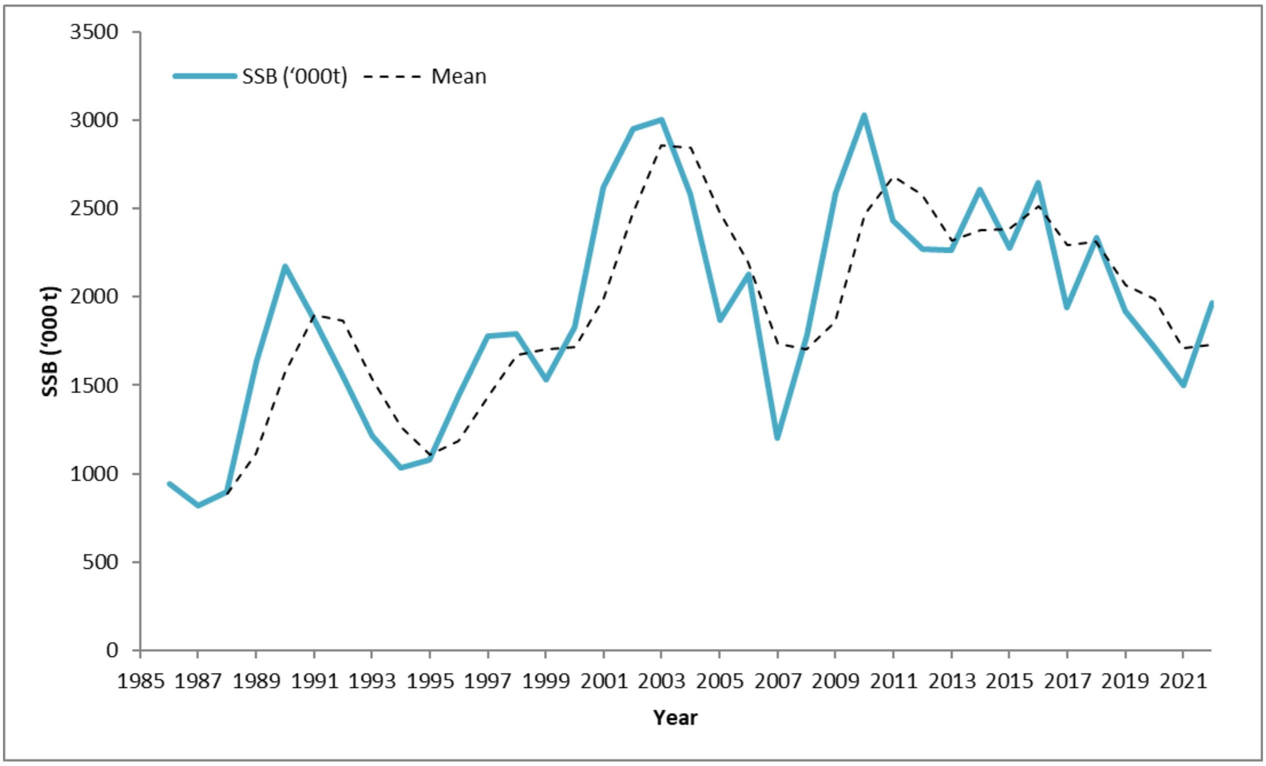


Figure 5.10. Sprat in Div. 3.a: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2006-2022. Note diverging scales of abundance between ages.

(a)



(b)

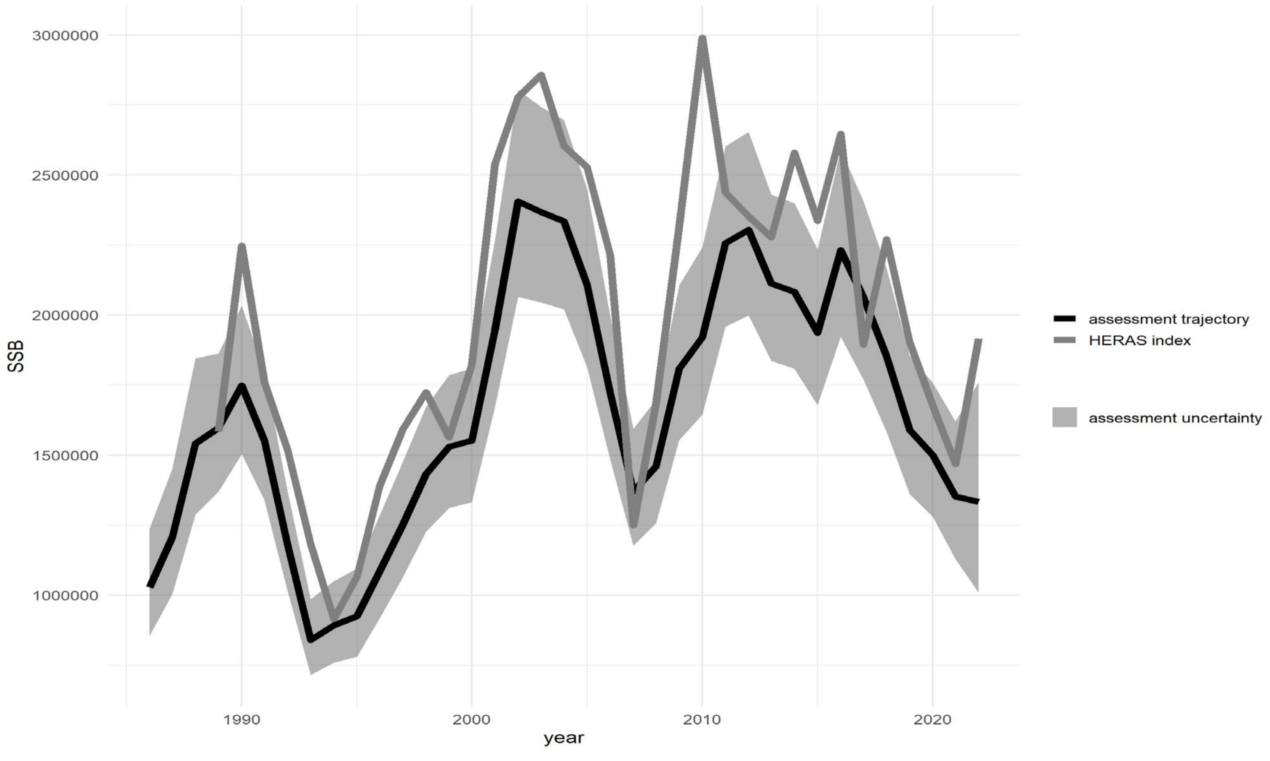


Figure 5.11. North Sea Autumn Spawning Herring: (a) Time series of SSB for the period 1986 – 2021 with three year running mean. (b) Comparison of the HERAS index for 1986 – 2022 with the 2022 NSAS herring assessment (HAWG 2022).

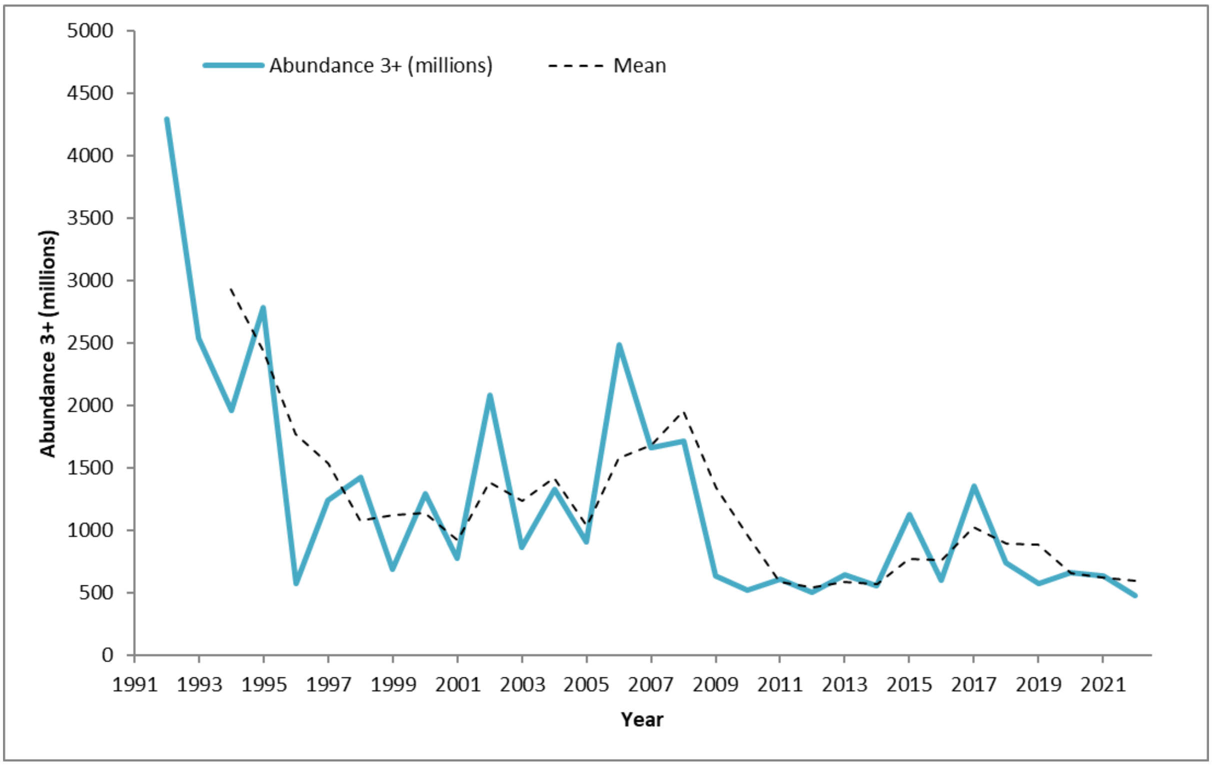


Figure 5.12. Western Baltic spring spawning herring: Time series of 3+ abundance with three year running mean.

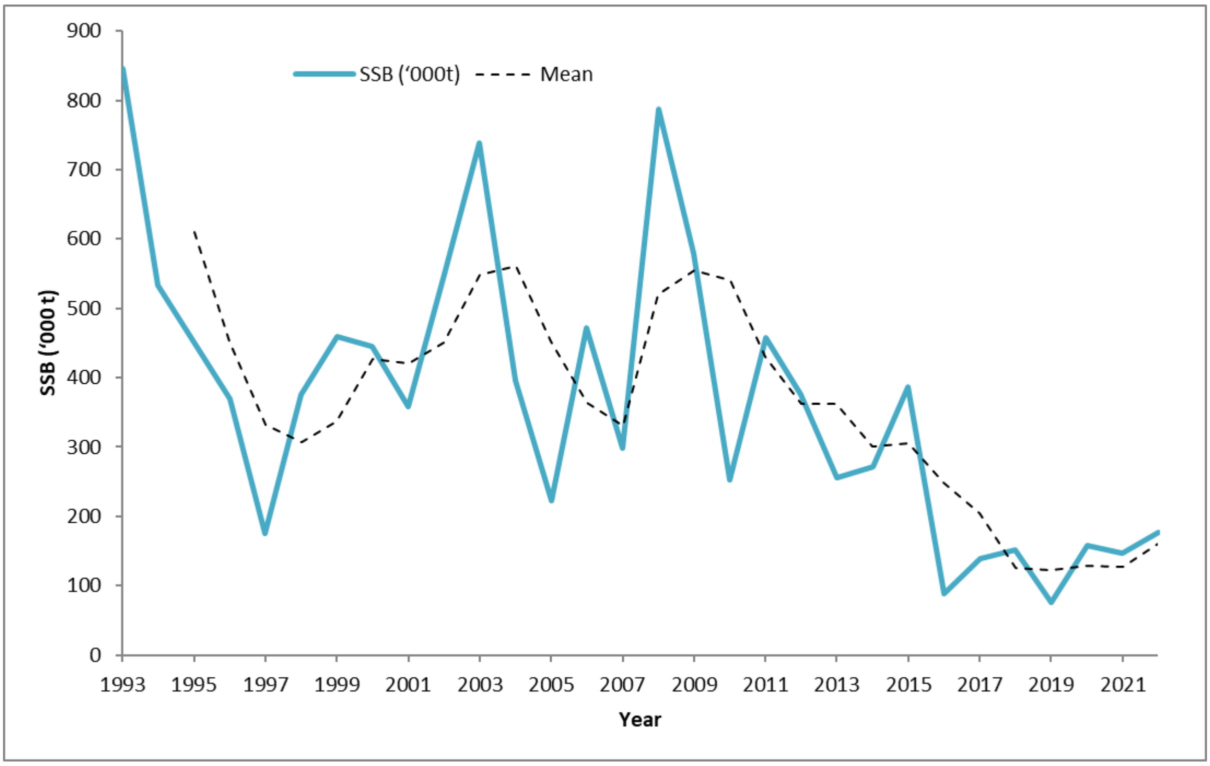


Figure 5.13. West of Scotland herring (geographical subset of Malin Shelf herring): Time series with three year running mean.

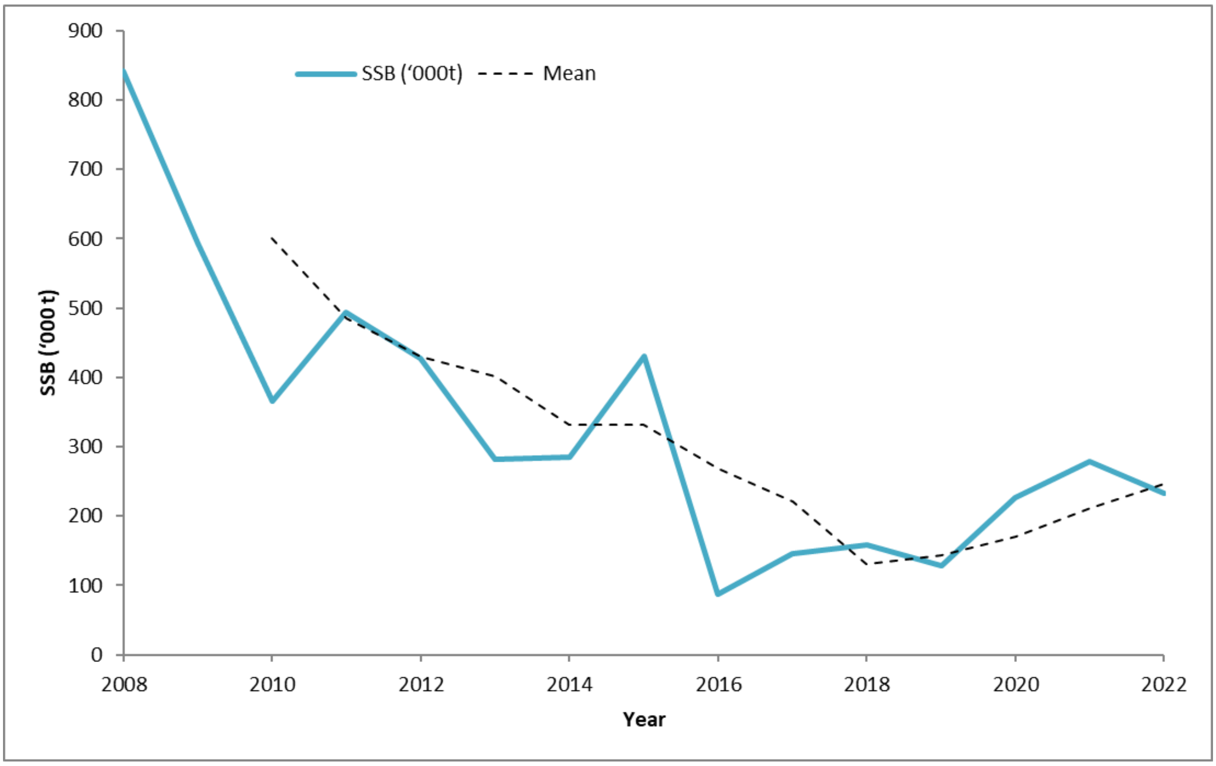


Figure 5.14. Malin Shelf herring: Time series of SSB with three year running mean.

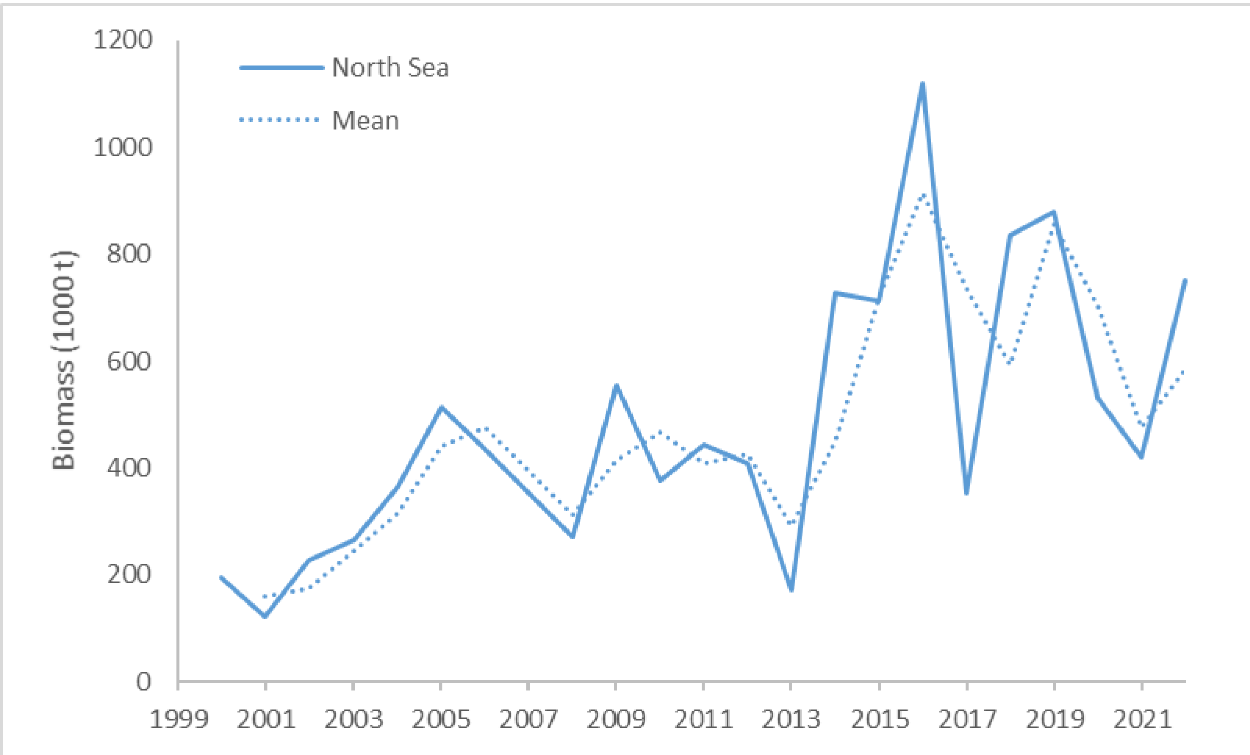


Figure 5.15. North Sea sprat (ICES Subarea 4): Time series of SSB with three year running mean.

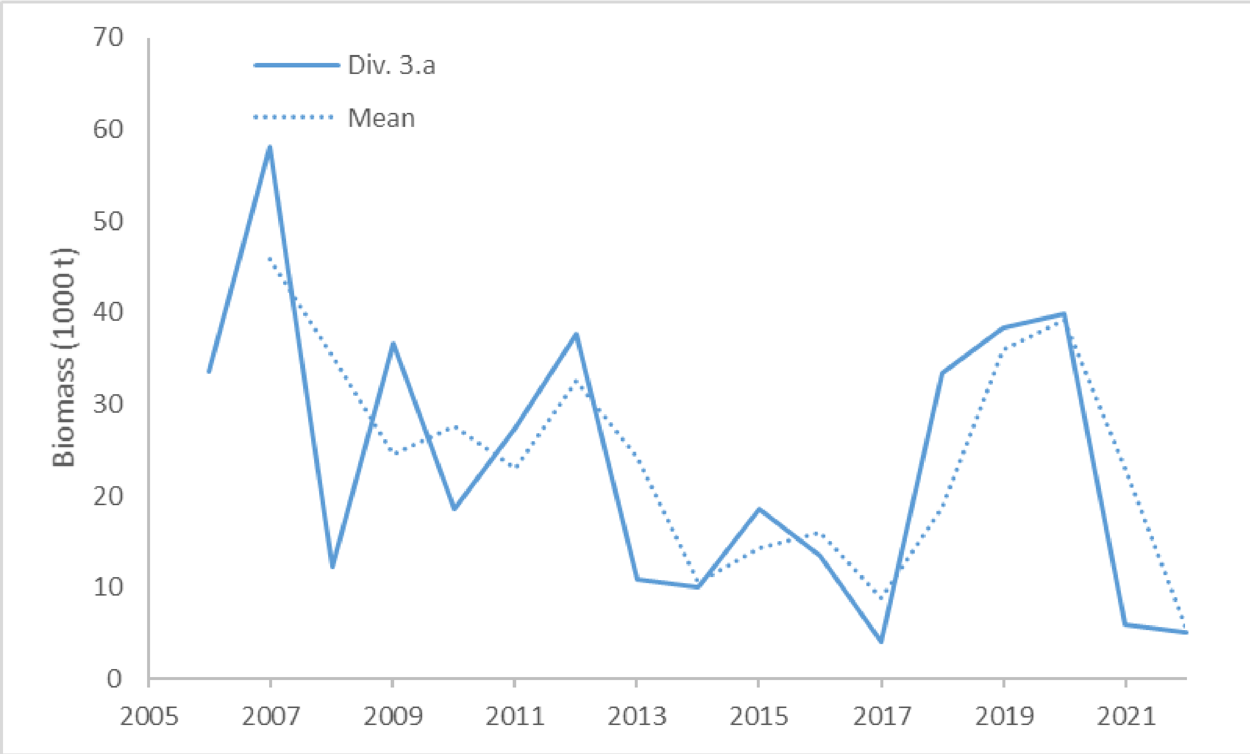


Figure 5.16. Sprat in Div. 3.a: Time series of SSB with three year running mean.

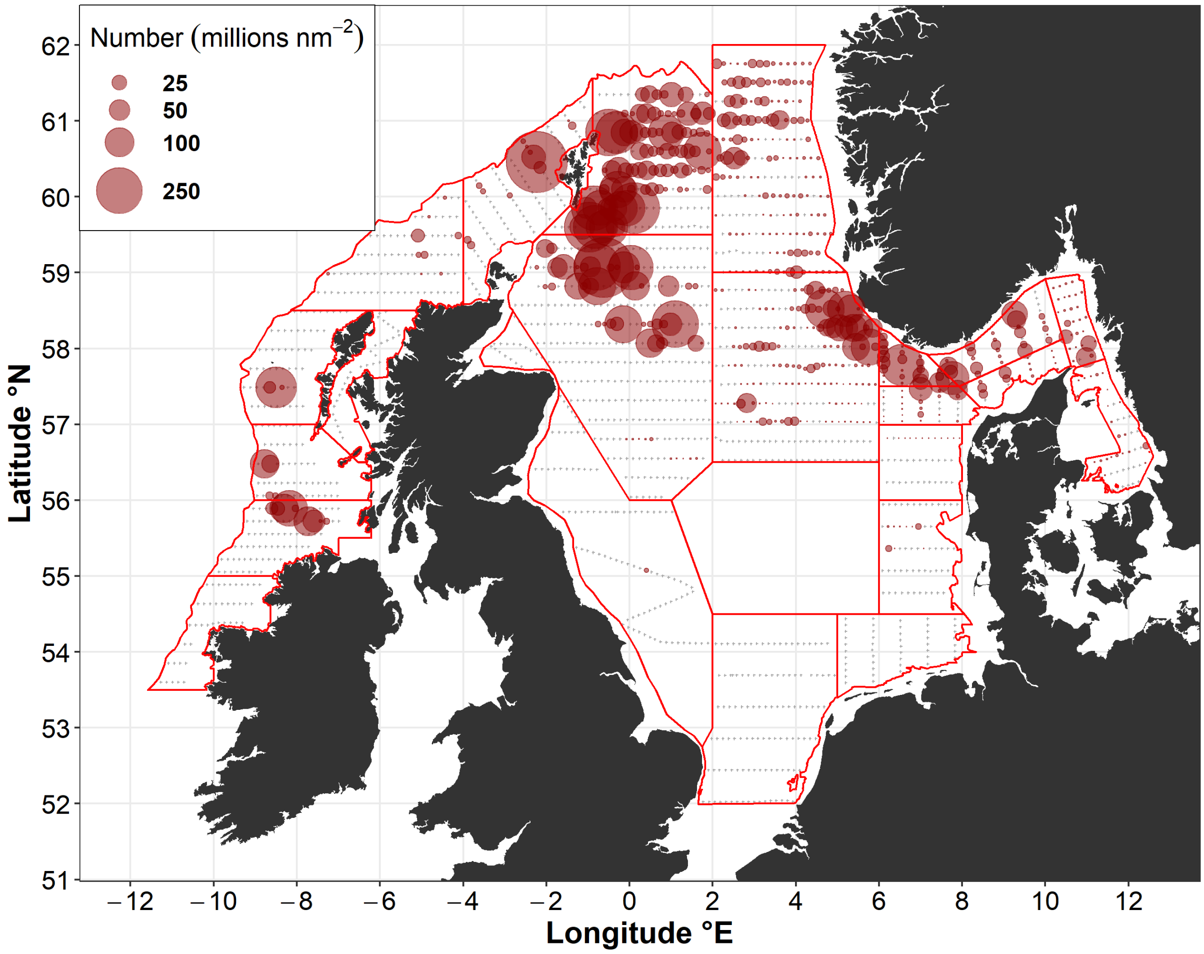


Figure 5.17. Distribution of NASC attributed to mature herring in HERAS 2022. Acoustic intervals represented by light grey dots with red bubbles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track and split into mature and immature within each stratum following the proportion of mature herring in the stratum. The red lines show the strata system.

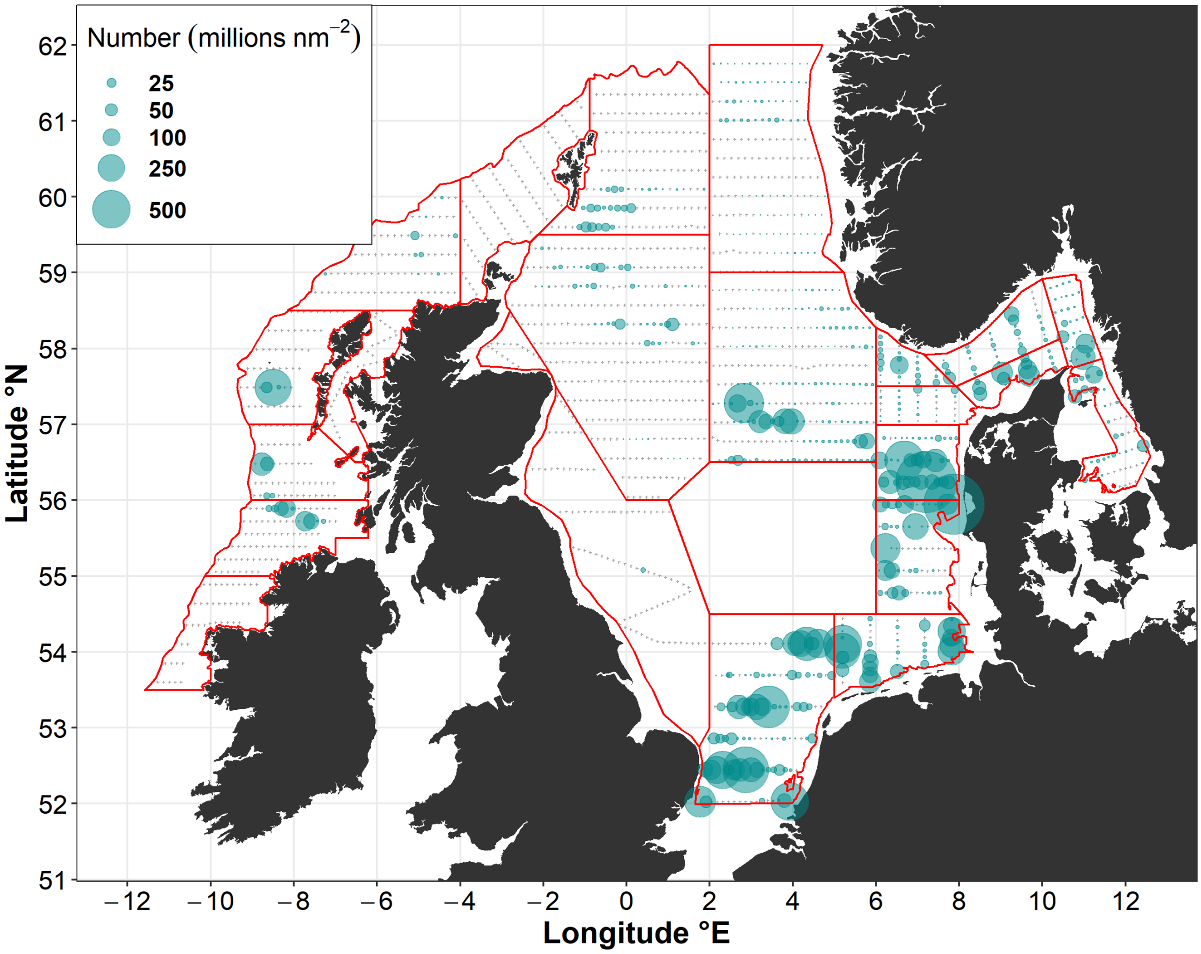


Figure 5.18. Distribution of NASC attributed to immature herring in HERAS 2022. Acoustic intervals represented by light grey dots with red bubbles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track and split into mature and immature within each stratum following the proportion of mature herring in the stratum. The red lines show the strata system.

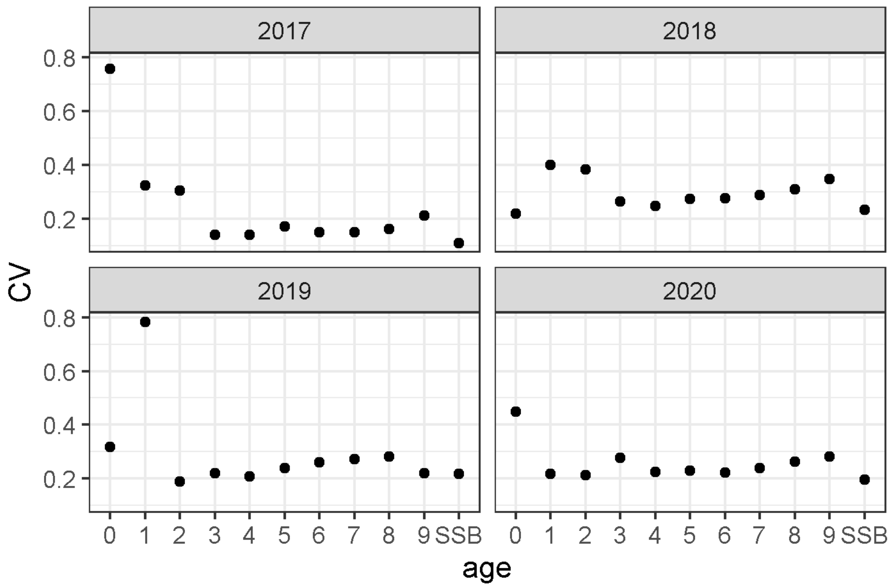


Figure 5.19. NSAS herring Coefficient of Variation (CV) for abundance at age and SSB as estimated using bootstrapping results from StoX. Data are shown for the 2017-2020 period for comparison.

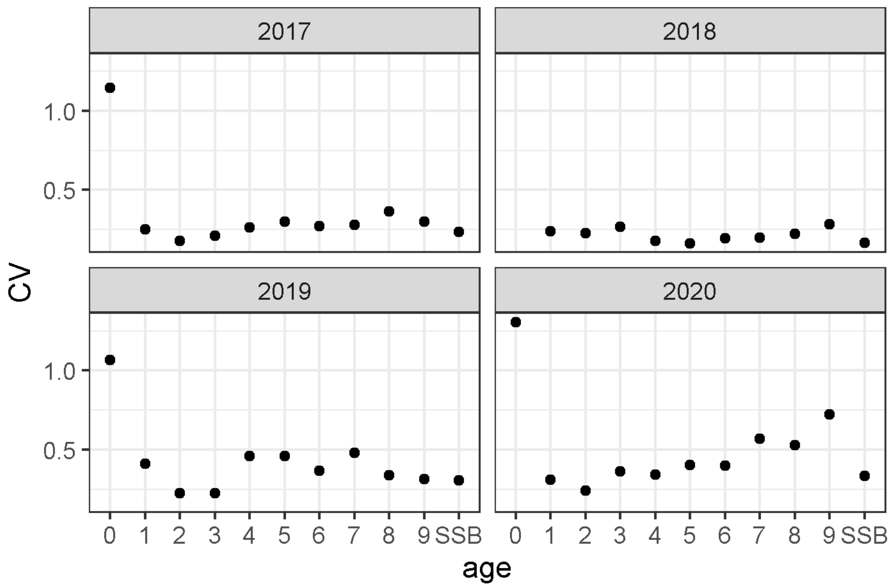


Figure 5.20. WBSS herring Coefficient of Variation (CV) for abundance at age and SSB as estimated using bootstrapping results from StoX. Data are shown for the 2017-2020 period for comparison.

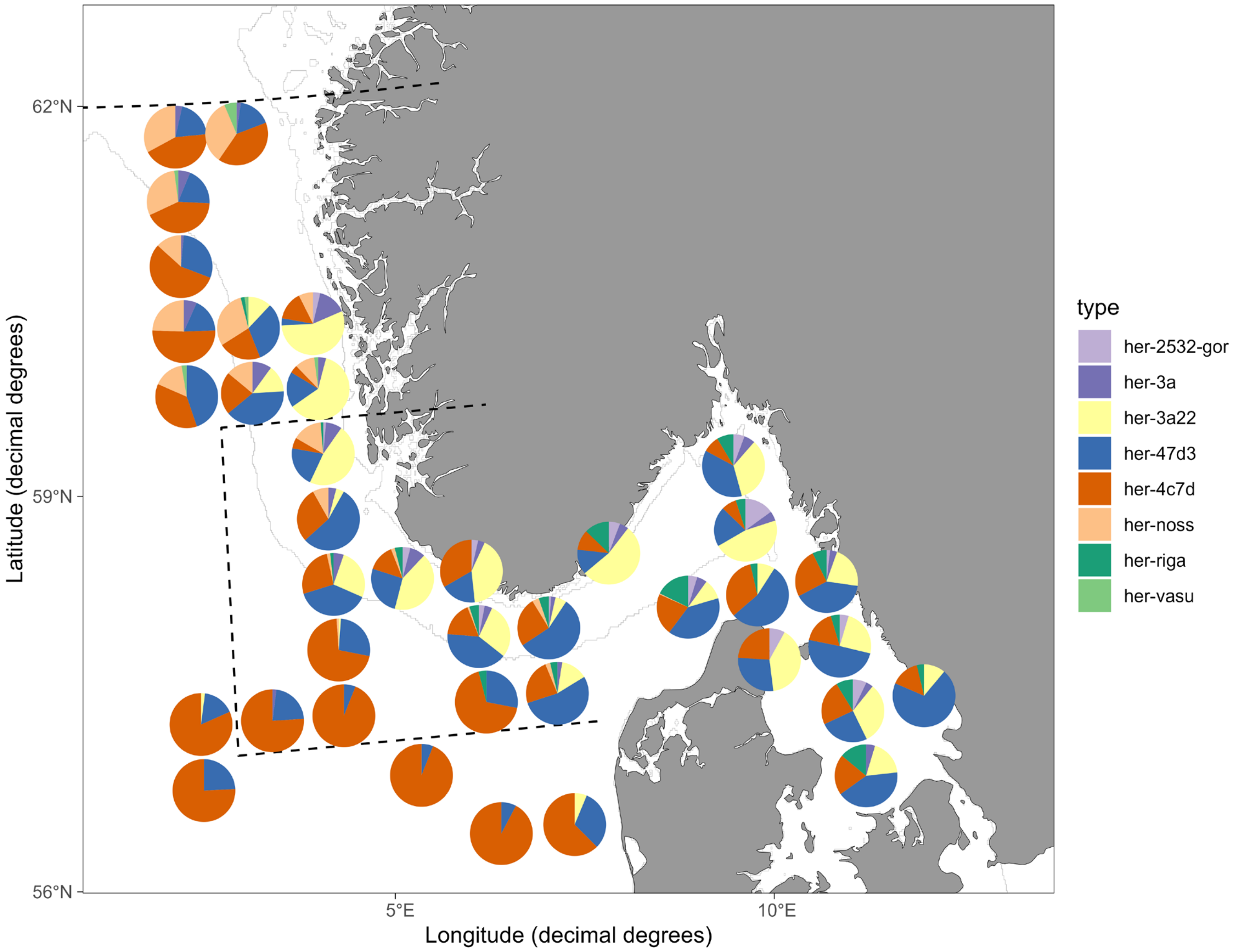


Figure 5.21. Results of genetic analyses (Single Nucleotide Polymorphism panels; Bekkevold et at., 2022; Farrell et al., 2021; Han et al., 2020) for stock splitting. The analysis was conducted in areas where previously North Sea Autumn Spawning (NSAS = her-47d3, and Downs = her-4c7d) and Western Baltic Spring Spawning (WBSS = her-3a22) herring had been identified using otolith microstructure and vertebrae counts. Aside from 3 populations identified with the previous methods (NSAS, Downs –included in NSAS indices-, and WBSS), the genetic method also identified herring from several adjacent populations in the survey area: WBSS Skagerrak herring (her-3a), CBH – Central Baltic herring (her-2532-gor), BAS – Baltic Autumn Spawning herring (her-riga), NSS – Norwegian Spring Spawning herring (her-noss), ISSH – Icelandic Summer Spawning herring (her-vasu; 1 individual).