Annex 4c: The 2015 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area

Susan Lusseau[1], Eric Armstrong[1], Phil Copland[1], Sascha Fässler[2], Cormac Nolan[3], Ciaran O'Donnell[3], Norbert Rohlf[4], Matthias Schaber [4], Cecilie Kvamme[5] and Karl Johan Staehr[6].

[1] Marine Scotland Science, Marine Laboratory, Aberdeen, Scotland, UK
[2] Wageningen-IMARES, IJmuiden, The Netherlands
[3] Marine Institute, Galway, Ireland
[4] Thünen- Institute of Sea Fisheries, Hamburg, Germany
[5] Institute of Marine Research, Bergen, Norway
[6] DTU-Aqua, Hirtshals, Denmark

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 for 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 slightly lower than previous year at 2.3 million tonnes but is comprised of a similar number of fish (2015: 14 222 mill. fish, 2014: 14 392 mill. fish).

The 2015 estimate of Western Baltic spring-spawning herring SSB is 207 000 tonnes and 1 447 million herring. This is nearly a doubling of the 2014 estimates of 128 000 tonnes and 791 million fish and brings the stock back in line with abundances observed in the period prior to 2009.

The West of Scotland estimate (VIaN) of SSB is 387 000 tonnes and 1 935 million herring, a considerable increase over the 2014 estimate of 272 000 tonnes and 1 400 million fish.

The SSB estimate for the Malin Shelf area (divisions VIaN-S and VIIb,c) is 430 000 tonnes and 2 181 million herring. This is a significant increase on 2014 estimates of 285 000 tonnes and 1471 million fish.

The total abundance of North Sea sprat (Subarea IV) in 2015 was estimated at 58 745 million individuals and the biomass at 712 000 tonnes (Table 5.10). This is the fourth and second highest estimate observed in the time series, in terms of abundance and biomass, respectively. The stock is dominated by 1- and 2-year-old sprat.

In Division IIIa, the sprat abundance is estimated at 1 394 million individuals and the biomass at 18 515 tonnes. This is below average both in terms of abundance and biomass. The stock is dominated by 1-year-old sprat.

The Irish Sea survey program is reported separately in the WGIPS report (Annex 5b).

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 2015 herring acoustic surveys.

Vessel	Period	Area	Rectangles
Celtic Explorer (IRL)	24 June – 14 July	53°30'-58°30'N ,12°-4°W	36D8-D9, 37D9-E1, 38D9-E1, 39E0-E2, 40E0-E2,41E0-E3, 42E0-E3, 43E0-E3, 44E0-E3, 45E0-E4, 46E2-E5, 47E3-E6, 48E4-E5, 49E5
Scotia (SCO)	25 June – 14 July	58°30'-62°N, 4°W-2°E	46E6-F1, 47E6-F1, 48E6-F1, 49E6-F1, 50E7-F1, 51E8-F1
Johan Hjort (NOR)	25 June – 15 July	56°30'-62°N, 2°-6°E	42F2-F5, 43F2-F5, 44F2-F5, 45F2-F5, 46F2-F4, 47F2-F4, 48F2-F4, 49F2-F4, 50F2-F4, 51F2-F4, 52F2-F4
Tridens (NED)	22 June – 17 July	54°25'– 58°24'N, 3° W–5°E	37E9-F1, 38E8-F1, 39E8-F1, 40E8-F4, 41E7-F4, 42E7-F1, 43E7-F1, 44E6-F1, 45E6-F1
Solea (GER) DBFH	26 June – 16 July	52°-56.5°N, Eng to Den/Ger coasts	33F1-F4, 34F2-F4, 35F2-F4, 36F2-F7, 37F2-F8, 38F2-F7, 39F2-F7, 40F6-F7, 41F5
Dana (DEN) OXBH	25 June – 8 July	Kattegat and North of 56°N, east of 6°E	41F6-F7, 41G1-G2, 42F6-F7, 42G0-G2, 43F6-G1, 44F6-G1, 45F8-G1, 46F9-G0

Methods

Survey design and acoustic data collection

The acoustic surveys were carried out using Simrad EK60 38 kHz echosounders with transducers mounted either on the hull, drop keel or in towed bodies. Echo integration and further data analyses were carried out using either LSSS (Large Scale Survey System), Myriax Echoview or Echoann software. The survey tracks were selected to cover the whole area with sampling intensities based on the herring densities of previous years. Transect spacing of 7.5, 15 and 30 nautical miles were used in various parts of the area according to perceived abundance and variance from previous years' surveys. The survey was designed to be analysed using rectangle based estimation with ICES rectangles as the analysis unit. Tracks were planned to ensure a minimum of one length of track in each ICES rectangle covered.

The following target strength to fish length relationships were used to analyse the data:

herring TS = 20 log L - 71.2 dB
sprat TS = 20 log L - 71.2 dB
gadoids TS = 20 log L - 67.5 dB
mackerel TS = 21.7 log L - 84.9 dB

Data analysis

Due to the cessation of support for the FishFrame database and analysis tool traditionally used by the group to combine acoustic and biological data from individual surveys into global estimates a move to using a new analysis tool had to be taken in 2015 (ICES 2015).

The 2015 disaggregated biological and acoustic data were delivered to an interim database held at the ICES data centre and the data was analysed using the newly developed analysis software StoX (Annex 9).

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 strata (Figure 5.2). The data were combined to provide estimates of the North Sea autumn spawning herring, Western Baltic spring-spawning herring, West of Scotland (VIaN) herring and Malin Shelf herring stocks (VIaN-S and VIIb-c) as well as North Sea sprat and sprat in IIIa.

Stock definitions

North Sea Autumn Spawning herring

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 6 – 8 and 11 – 21 in Figure 5.2). East of 2°E and north of 56°N [56.5°N between 2-6°E], in strata 1 – 5 and 9 – 10, herring is split into North Sea autumn spawners and Western Baltic spring spawners (Figure 5.2). In strata 9 – 10 this is done based on analysis of number of vertebrae and in strata 1 – 5 this is done based on otolith shape analysis.

Western Baltic spring spawning herring:

The allocation to the Western Baltic spring spawning stock is partly a geographical assignment and partly a biological assignment based on the vertebrae and otolith shape analysis mention above. The stock splitting methodologies are only applied within strata 1 – 5 and 9 – 10 (Figure 5.3). Recently Germany has also conducted analysis of otoliths to deduct stock membership of herring in the southern area, and in 2015 two herring from 41F5 was allocated as WBSS. As this rectangle previously has not been included in the stock split this was ignored in the 2015 analysis to preserve continuity with the time series, but opens a discussion on the geographical limits of the application of the stock splitting analysis.

Malin Shelf Herring:

Includes all herring in the stock complex located in ICES areas VIa and VIIb. 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 22 – 27 in Figure 5.2). It surveys herring of VIaN and VIaS spawning origin in mixed feeding aggregations on the Malin Shelf. Work is in progress to split the abundance and biomass estimations by spawning origin (VIaN vs VIaS) but this has been as yet unsuccessful. The differentiation between VIa herring and North Sea herring across the 4°W line of longitude is purely geographically based. In 2015 one vessel covered the entire Malin Shelf area so no combining of data was required in StoX.

West of Scotland (VIaN) herring

This is simply a subset of the Malin Shelf herring abundance\biomass estimate based purely on geographical location (strata 22 – 24 in Figure 5.2). All herring recorded north of the 56°N line of latitude and east of the 7°W line of longitude are reported as West of Scotland (VIaN). The remainder of the estimated abundance\biomass is considered VIaS + VIIbc. As mentioned previously, work is underway to improve on this geographical split.

VIaS and VIIbc are not reported separately but can be calculated by subtracting the West of Scotland estimates from the Malin Shelf estimates.

North Sea sprat:

All sprat recorded in the North Sea geographical area (ICES area IV) are included in the North Sea sprat stock. Sprat is however very rarely recorded in the northern part in strata 9 – 10 and 14 – 21 (Figure 5.2). Strata 3 and 4 straddles the border between sprat in the North Sea and IIIa sprat and only the half of each of these strata contained within ICES area IV contributes to the sprat in the North Sea estimate.

Div. IIIa Sprat

Sprat in IIIa is also a geographically delimited stock. All sprat in strata 1 – 2 are include and any sprat in strata 3 – 4 recorded to the east of the border between ICES Subarea IV and ICES Div. IIIa are included.

Acoustic Survey Results for 2015

Herring

The NASC values attributed to herring in the HERAS surveys are shown in Figure 5.3.

The estimate of North Sea autumn spawning herring spawning stock biomass has decreased from 2.6 million tonnes in 2014 to 2.3 million tonnes this year (Table 5.6, Figure 5.11).

The abundance of mature fish of 14 222 million in 2015 is comparable to the 2014 estimate of 14 392 million (Table 5.2). The drop in SSB is caused by a significant decrease in the mean weight of the mature fish from 181.4 g in 2015 to 160.3 g this year. This is due to a combination of two factors. The mean weight is decreased for all ages apart from 1 winter ringers this year compared to last year. In addition the stock has seen a large increase in 2 winter ring fish and a small decrease in abundance of all older ages in effect shifting the abundance to a larger amount of smaller fish.

The abundance of immature fish in the stock has decreased dramatically this year from 46 947 million in 2014 to 10 285 in 2015. This drop is caused mainly by an almost complete absence of 0 winter ring fish. The 1 winter ring abundance is also reduced to approximately half of last year's estimate bringing it back in line with the long term average. (Table 5.6, Figure 5.5).

Maturities were lower than last year with 70% of 2 winter ringers and 90% of 3 winter ringers mature. 100% maturity was only reported above age 7 (Table 5.2). The presence of immature fish above age 4 indicates a shift in reporting by the group. Previously all fish above age 4 has been assumed mature. This year however it was agreed that observed maturities would be reported and it would be left to the assessment working group to decide whether to assume 100% maturity above a certain age.

The 2008 and 2009 year classes (5 and 6-winter ringers this year) continues to be strong and are consistent with the high estimate of 1-wr fish in 2010 and 2011 (Table 5.6). The 2007 year class (7-winter rings this year) continues to grow very slow and mean weight continues to be below that of the following year class (Table 5.2).

The distribution of adult herring in the North Sea is still concentrated in the areas east and north of Scotland (Figure 5.3). Similarly to last year the distribution is stretching south in the western North Sea.

The 2015 estimate of Western Baltic spring-spawning herring SSB is 207 000 tonnes and 1 447 million herring (Table 5.3). In terms of biomass the spawning stock nearly doubled and increased by 79 000 tonnes. The amount of mature fish also was twice as high as the numbers measured in 2014 (791 million). The stock is dominated by 1 and 2 ring fishes. The abundance of 1 and 2 ringers increased by a factor of 4 and 3

respectively when compared to last year's estimate, and is in a comparable order of magnitude as it has been in the past (Table 5.7, Figure 5.6). The numbers of older herring (3+ group) in the stock has continued to be relatively low, but numbers have increased from the low values that had been observed for six years in a row before. When compared to 2014, the mean weight at age has increased considerably for herring aged 0 but decreased for all ages above (exception age 3 with similar weight at age between years).

The West of Scotland (VIaN) estimate of SSB is 387 000 tonnes (1 935 million herring) (Table 5.4), a 115 000 tonne increase over the 2014 estimate. In 2014 4 and 5 winter-ring fish dominated the age composition of the standing stock and these cohorts have been successfully tracked in 2015 with 5 and 6 winter-ring fish comprising 19% and 22% of the total abundance, respectively. However, the largest proportion of herring observed in 2015 were the 4 winter-ring fish, which accounted for 32% of the total abundance. No 1 winter-ring herring were recorded. Long-term indices of abundance per age class for West of Scotland herring are provided in Table 5.8 and Figure 5.7.

The SSB estimate for the Malin Shelf area (divisions VIa and VIIb,c) is 430 000 tonnes and 2 181 million herring (Table 5.5). This is a 145 000 tonnes increase on 2014, which was the second lowest SSB estimate in the time series (Figure 5.1). The estimate is also dominated by 4, 5, and 6 winter ringed fish. The overall maturity ratio was 0.96. The similarities between the West of Scotland and Malin Shelf indices reflect the fact that so few herring were observed in VIaS and VIIb,c. Age disaggregated survey abundance indices for Malin Shelf herring since 2008 are given in Table 5.9 and Figure 5.8.

The area covered during the individual acoustic surveys is given in Figure 5.1. The survey strata used for the analysis are shown in Figure 5.2, and magnitudes of acoustic herring and sprat detections (nautical area scattering coefficients) for 15 nmi intervals are given in Figures 5.3 and 5.4, respectively. The survey provides numbers at age for the different herring and sprat stocks (North Sea autumn-spawners, Western Baltic spring-spawners, West of Scotland, Malin Shelf herring, North Sea sprat and Div. IIIa sprat) and the time series of these are given in Figures 5.5-5.10. The time series of abundance for the four herring stocks (North Sea autumn-spawners, Western Baltic spring-spawners, West of Scotland and Malin Shelf herring) are given in Tables 5.6 – 5.9 and illustrated in Figures 5.11 -5.14, respectively. In each of them, a 3 year running mean is included to show the general trend more clearly.

Estimated survey uncertainty per numbers at age by survey participant for both herring and sprat are shown in Figures 5.15. and 5.16.

Sprat in the North Sea and Division IIIa

Sprat data were available from RV "Solea", RV "Tridens", and RV "Dana". No sprat were observed in the northern part of the North Sea surveyed by MRV "Scotia" and RV "Johan Hjort". In the Dutch survey sprat was found in coastal areas: the Moray Firth and south of 56°, in particular off Flamborough (37F0). In 2014, no sprat was found in this part of the survey, and the coastal distribution of sprat probably explains the high variability in abundances between years. In the German survey area, sprat as in previous years were distributed throughout the whole survey area. Highest sprat densities were measured in the German Bight (especially around Helgoland Island) but also in the south-eastern part of the covered survey area along the UK and Dutch coast. However, sprat were not present in all catches (as in 2014) but in 39 out of 55 hauls (71 %). Sprat was also found in small amounts in the North Sea areas surveyed by the Danish survey. In the 2015 acoustic surveys, sprat was found further north than in 2014, but concentrated in the southern part of the North Sea, with the highest abundances and biomass in an area below 55° N. 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 can be found even further south in the English Channel. The sprat distribution in the North Sea and Division IIIa in terms of abundance and biomass per strata is shown in

Table 5.17. The NASC values attributed to sprat in the Danish, Dutch and German survey are shown in Figure 5.4.

The total abundance of North Sea sprat (Subarea IV) in 2015 was estimated at 58 745 million individuals and the biomass at 712 000 tonnes (Table 5.10). This is the fourth and second highest estimate observed in the time series, in terms of abundance and biomass, respectively. Compared to the 2014 estimate, the historic high of the time series, abundance and biomass have decreased by 33 and 2%, respectively (Table 5.11, Figure 5.9). Both the 2015 and the 2014 sprat biomass are about twice as high as the long term average for the survey time series. The stock was dominated by 1- and 2-year-old sprat (77% of biomass), and most sprat were found to be mature (82%) (Table 5.10).

An age-disaggregated time-series of North Sea sprat abundance and biomass (ICES Subarea IV), as obtained from the acoustic survey, is given in Table 5.11. Note that for 2003, information on the sprat distribution in the North Sea is available from one nation only.

In Division IIIa, sprat were mostly found in the Kattegat (highest concentration on the border between 44G0 and 43G0) and, in smaller amounts, in the Skagerrak area (44F9-G0), as in 2014. This is in contrast to 2013, when sprat was only seen in the Kattegat. The abundance is estimated at 1386 million individuals, increased by 52% compared to the 913 million individuals in 2014 (Tables 5.12-5.13). The biomass has increased by 83% to 18 500 tonnes. 1-year-old sprat dominate the stock (61% in numbers and 52% in biomass), while also the 3+ group was a large proportion of the stock. The age-disaggregated time-series of sprat abundance and biomass in Division IIIa are given in Table 5.13 and Figure 5.10.

Quality considerations

Changing analysis tool

The global estimates for 2015 were for the first time calculated based on disaggregated acoustic and biological data delivered to the group allowing a level of transparency and discussion on data collection and standardisation issues not readily achieved before.

The effect of changing from one analysis method to another was investigated and reported in full in Annex 9 of this report. The nationally calculated total abundances at age and maturity, which would previously have been collated to produce global estimates in FishFrame, were contrasted to the number at age and maturity calculated independently for each nation in the StoX software. The settings applied there were then used to calculate the overall abundances.

It was shown that the effect of changing the calculation method to StoX had very little effect on the resulting indices carried forward to the stock assessment process. The group is therefore confident that the latest index at age is comparable to the existing time series.

Scrutiny of Danish acoustic data

The StoX software has a function to partition mixed species echotraces based on splitting by species specific target strength (TS). This functionality was used in the 2015 analysis to partition German and Danish data to sprat and herring. In the German survey area, mixed aggregations of clupeids makes scrutiny to species level difficult and necessitates the use of allocation of echotraces to a mixed clupeid class for partitioning in the post processing. In the Danish area scrutiny however is only taken to the level of distinguishing between fish or not fish, and the echo traces are then partitioned based entirely on composition of trawl catches. This approach is not compatible with best practice anymore and it should be possible to use modern acoustics species discrimination techniques to narrow the allocation to at least clupeid or pelagic fish mixes. Denmark

has agreed to work with Norway and Germany that survey bordering strata and therefore encounter echotraces similar to those encountered in the Danish area to standardise Danish scrutiny methods to align with those used by all other participants.

Stock splitting methods

At the present two different methods are used within the survey to assign herring in the splitting area (strata 1 – 5 and 9 – 10) to the North Sea autumn spawning stock or the Western Baltic spring spawning stock. These methods have been developed independently within national laboratories, but have not been calibrated against each other so far. To ensure resilience in the consistency over the time series the two methods should be calibrated against each other. But ideally, the method should be standardised across the surveys to use one common method for all splitting between the two stocks.

In addition, the method used by Norway does not provide stock information at the individual fish level and it is therefore not at the present possible to analyse the Norwegian component of the survey within an overall StoX project for the two herring stocks. This means that at the present time it is still not possible to routinely produce uncertainty estimates for the herring stocks.

VIaN and VIaS: Work has been ongoing for a number of years to split the Malin Shelf herring survey into VIaN and VIaS spawning components using morphological (body and otolith) differences. To date, the successful classification rate has been unsatisfactory so both stocks of herring are reported as one from this survey. Genetic techniques are now being investigated to facilitate this split.

Maturity

This year, portions of immature fish > age 3 were reported. This is because for the first time no assumptions were made about constant maturity and those actually observed in the surveys are reported in this report. In the past, fish 5 wr or older were all assumed mature by definition in the reported result. 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.

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 allowed for an estimate of survey uncertainty. These were provided by survey participant and age group for both herring and sprat (Figures 5.15. and 5.16.). While observed uncertainties for herring were generally expectedly higher for youngest and oldest ages, indices provided by some participants also had a high uncertainty level for intermediate ages. This was especially true for Danish, German and Dutch observations on North Sea autumn spawning herring, where CV values above 40% were estimated. This may suggest that the historic transect design proposed a decade ago and still used may not be representative of the current distribution pattern anymore. To reduce the CVs the design and methodology should be adapted for example by optimising transect design (spacing) in areas covered by these nations. CVs observed for sprat were generally higher than for herring, but more similar among nations. This may suggest that the survey design, which is geared towards optimally sampling herring, may be less suitable for sprat.

Recommendations:

1) Danish acoustic data scrutiny review to be carried out and brought in line with rest of group. Bordering nations with experience of similar conditions (Norway and Germany) to work with Denmark.

2) Stock splitting procedures to be reviewed and common protocol to be developed for WBSS and NSAS – at individual fish level. Ask HAWG to put forward a recommendation for a joint work shop to accomplish this.

3) Reporting format. In this interim period the reporting outputs are restricted compared to usual. Visualisations of adult versus juvenile distributions and distribution by age groups and maturity levels cannot be easily produced at the present, but standard methods for producing such maps should be developed by the group for use with the new analysis outputs.

References

ICES (2015). Report of the Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL), 24-28 August 2015, ICES Headquarters, Copenhagen, Denmark. ICES CM 2015/SSGIEOM:16. 48 pp.

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

Tables and Figures

Table 5.2. Total numbers (millions) and biomass (thousands of tonnes) of North Sea autumn spawning herring in the area surveyed in the acoustic surveys June - July 2015 with mean weights and mean lengths by age in winter rings.

Age (ring)	Numbers	Biomass	Maturity	Weight(g)	Length (cm)
0	386	2	0.00	4.0	8.1
1	6 714	331	0.00	49.3	18.2
2	9 495	1 148	0.70	120.9	24.0
3	2 831	414	0.90	146.4	25.6
4	1 591	292	0.96	183.5	27.5
5	1 549	309	0.98	199.6	28.1
6	926	204	0.99	220.1	29.0
7	520	107	1.00	205.4	28.9
8	275	58	1.00	210.0	29.3
9+	221	51	1.00	229.1	30.2
Immature	**10 285**	**635**		**61.7**	**19.1**
Mature	**14 222**	**2 280**		**160.3**	**26.2**
Total	**24 508**	**2 915**	**0.58**	**119.0**	**23.2**

Table 5.3. Total numbers (millions) and biomass (thousands of tonnes) of Western Baltic spring spawning herring in the area surveyed in the acoustic surveys June-July 2015, with mean weights, mean length and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	2	0	0.00	14.2	13.3
1	1 949	61	0.01	31.5	16.1
2	1 244	106	0.37	85.4	21.7
3	446	55	0.74	122.7	24.5
4	224	34	0.85	150.9	26.2
5	171	30	0.97	177.1	27.5
6	82	17	0.97	202.3	28.7
7	89	18	1.00	198.9	28.8
8+	115	25	1.00	218.9	29.6
Immature	**2 875**	**139**		**48.4**	**17.8**
Mature	**1 447**	**207**		**143.1**	**25.5**
Total	**4 322**	**346**	**0.33**	**80.1**	**20.4**

Table 5.4. Total numbers (millions) and biomass (thousands of tonnes) of autumn spawning West of Scotland herring in the area surveyed in the acoustic surveys July 2015, with mean weights, mean lengths and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0		154.8	25.8
1	0	0		183.4	27.3
2	122	19	0.58	195.3	27.9
3	325	60	0.92	204.7	28.4
4	650	127	0.99	211.3	28.9
5	378	77	0.98	217.3	29.4
6	442	93	1.00	215.3	29.1
7	83	18	0.97	220.0	30.0
8	23	5	1.00	154.8	25.8
9+	2	0	1.00	183.4	27.3
Immature	**89**	**12**		**137.9**	**25.1**
Mature	**1935**	**387**		**200.1**	**28.2**
Total	**2024**	**399**	**0.96**	**197.4**	**28.0**

Table 5.5. Total numbers (millions) and biomass (thousands of tonnes) of Malin Shelf herring (VIaN-S, VIIb,c) June-July 2015. Mean weights, mean lengths and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0			
1	0	0			
2	212	30	0.48	139.9	25.0
3	397	70	0.85	176.7	26.9
4	747	144	0.99	192.9	27.7
5	423	86	0.98	202.3	28.3
6	476	100	1.00	210.4	28.8
7	90	19	0.97	215.8	29.3
8	24	5	1	214.5	29.1
9+	2	0	1	220.0	30.0
Immature	190	25		130.9	24.6
Mature	2181	430		197.1	28.0
Total	2372	455	0.92	191.8	27.7

Table 5.6. Estimates of North Sea autumn spawners (millions) at age and SSB from acoustic surveys, 1986–2015. For 1986 the estimates are the sum of those from the Division IVa summer survey, the Division IVb autumn survey, and the Divisions IVc, VIId winter survey. The 1987 to 2014 estimates are from summer surveys in Divisions IVa,b,c and IIIa excluding estimates of Western Baltic spring spawners. For 1999 and 2000, the Kattegat was excluded from the results because it was not surveyed. Total numbers include 0-ringers from 2008 onwards.

Years / Age (rings)	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	3,714	2,853	1,709	1,485	809	712	1,749	185	270	20,355	1,784
2009	4,655	5,632	2,553	1,023	1,077	674	638	1,142	578	31,526	2,591
2010	14,577	4,237	4,216	2,453	1,246	1,332	688	1,110	1,619	43,705	3,027
2011	10,119	4,166	2,534	2,173	1,016	651	688	440	1,207	25,524	2,431
2012	7,437	4,718	4,067	1,738	1,209	593	247	218	478	23,641	2,269
2013	6,388	2,683	3,031	2,895	1,546	849	464	250	592	36,484	2,261
2014	11,634	4,918	2,827	2,939	1,791	1,236	669	211	250	61,339	2,610
2015	6,714	9,495	2,831	1,591	1,549	926	520	275	221	24,508	2,280

Table 5.7. Numbers at age (millions) of Western Baltic spring spawning herring at age (winter rings) from acoustic surveys 1992 to 2015. The 1999 survey was incomplete due to the lack of participation by RV "Dana".

Year/Age	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

Table 5.8. Numbers at age (millions) and SSB (thousands of tonnes) of West of Scotland autumn spawning herring at age (winter rings) from acoustic surveys 1993 to 2015. In 1997 the survey was carried out one month early in June as opposed to July when all the other surveys were carried out.

Year/Age	1	2	3	4	5	6	7	8	9+	SSB:
1993	3	750	681	653	544	865	284	152	156	866
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	577	803	329	95	61	77	78	115	370
1997	792	642	286	167	66	50	16	29	24	141
1998	1,221	795	667	471	179	79	28	14	37	376
1999	534	322	1,389	432	308	139	87	28	35	460
2000	448	316	337	900	393	248	200	95	65	500
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	168
2006	112	835	388	285	582	415	227	22	59	472
2007	0	126	294	202	145	347	243	163	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	1031	243	218	469	519	143	30	19	11	272
2015	0	122	325	650	378	442	83	23	2	387

Table 5.9. Numbers at age (winter rings, millions) and SSB (thousands of tonnes) of the Malin Shelf acoustic survey (VIaN-S, VIIb,c) time seriesfrom 2008 to 2015.

Year/Age	1	2	3	4	5	6	7	8	9+	SSB:
2008	312	290	998	720	363	331	744	386	274	842
2009	928	265	274	444	380	225	193	500	456	593
2010	300	376	374	242	173	146	102	100	297	366
2011	63	257	900	485	213	228	205	113	264	494
2012	796	548	832	518	249	115	111	57	105	427
2013	0	212	435	672	195	71	61	29	37	282
2014	1031	281	243	502	534	148	33	19	13	285
2015	0	212	397	747	423	476	90	24	2	430

Table 5.10. Sprat in the North Sea (Subarea IV): Abundance, biomass, mean weight and mean length by age and maturity (i = immature, m = mature) from the summer 2015 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (1000 t)	Mean weight (g)	Mean length (cm)
0i	198	0	1.2	5.9
1i	8,915	56	6.3	9.5
1m	17,326	183	10.5	11.1
2i	1,483	16	10.9	11.3
2m	20,991	296	14.1	12.3
3i	102	1	11.3	11.4
3m	9,247	152	16.4	13.0
4m	441	8	18.0	13.5
5m	9	0	19.6	13.5
6m	0	0	-	-
Immature	10,698	74	6.9	9.7
Mature	48,014	638	13.3	12.0
Total	58,745	712	12.1	11.6

Table 5.11. Time-series of sprat abundance and biomass (ICES Subarea IV) as obtained from the summer North Sea acoustic survey (HERAS) time series 2000-2015. 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
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.**

Table 5.12. Sprat in Division IIIa: Abundance, biomass, mean weight and length by age and maturity from the summer 2015 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (tonnes)	Mean weight (g)	Mean length (cm)
0i	0.3	1	2.9	7.5
1i	547.4	5421	9.9	10.7
1m	293.5	4149	14.1	12.0
2i	112.7	1385	12.3	12.0
2m	89.3	1320	14.8	12.1
3m+	342.6	6176	18.0	13.7
Immature	660.4	6806	10.3	10.9
Mature	725.4	11646	16.1	12.8
Total	1393.7	18515	13.3	11.9

Table 5.13. Time-series of sprat abundance and biomass (ICES Div. IIIa) as obtained from the summer North Sea acoustic survey (HERAS) time series 2006-2015.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
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	1451.9	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 by strata. Strata numbers corresponds to numbering in Figure 5.2.

Strata	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature
1	244	6	25	0%
2	271	11	42	0%
3	475	27	57	1%
4	524	20	38	1%
5	165	6	38	4%
6	3 825	395	103	56%
7	5 442	660	121	75%
8	1 062	72	68	22%
9	4 383	426	97	34%
10	705	130	185	77%
11	398	10	25	0%
12	439	5	12	0%
13	11	0	17	0%
14	998	206	206	100%
15	39	8	206	100%
16	937	207	221	98%
17	415	58	139	74%
18	2 267	378	167	89%
19	1 483	194	131	69%
20	369	85	231	100%
21	55	9	171	90%

Table 5.15. Western Baltic spring spawning herring. Total abundance, biomass, mean weight and percent mature by strata. Strata numbers corresponds to numbering in Figure 5.2.

Strata	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature
1	708	20	28.9	8%
2	503	18	35.3	12%
3	348	17	48.7	17%
4	648	36	55.0	20%
5	832	57	68.4	37%
9	592	85	143.6	68%
10	690	113	164.3	63%

Table 5.16. Malin shelf and VIaN herring. Total abundance, biomass, mean weight and percent mature by strata. The VIaN herring geographic subset is comprised of strata marked with *.

Strata	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature
22*	0	0		
23*	1 624	325	200	97%
24*	400	75	186	88%
25	103	17	160	68%
26	115	18	159	75%
27	129	20	158	70%

Table 5.17. North Sea sprat and Div. IIIa sprat. Total abundance, biomass, mean weight and percent mature by strata. Strata numbers corresponds to numbering in Figure 5.2. Strata 3 and 4 are divided into East (E) and West (W) along the border between ICES Divisions IVa and IIIa.

Stock	Strata	Abundance (mill)	Biomass (t)	Mean weight (g)	% Mature
Div. IIIa sprat	1	576	7 277	12.6	48%
	2	531	6 637	12.5	50%
	3E	279	4 538	16.3	65%
	4E	576	7 277	12.6	48%
North Sea sprat	3W	333	4 160	12.5	28%
	4W	3 224	43 436	13.5	99%
	5	17 626	275 347	15.6	98%
	6	17 829	185 252	10.4	79%
	7	15 203	157 460	10.4	64%
	8	4 042	39 504	9.8	82%
	11	228	3 495	15.3	59%
	12	226	3 456	15.3	59%
	13	333	4 160	12.5	28%

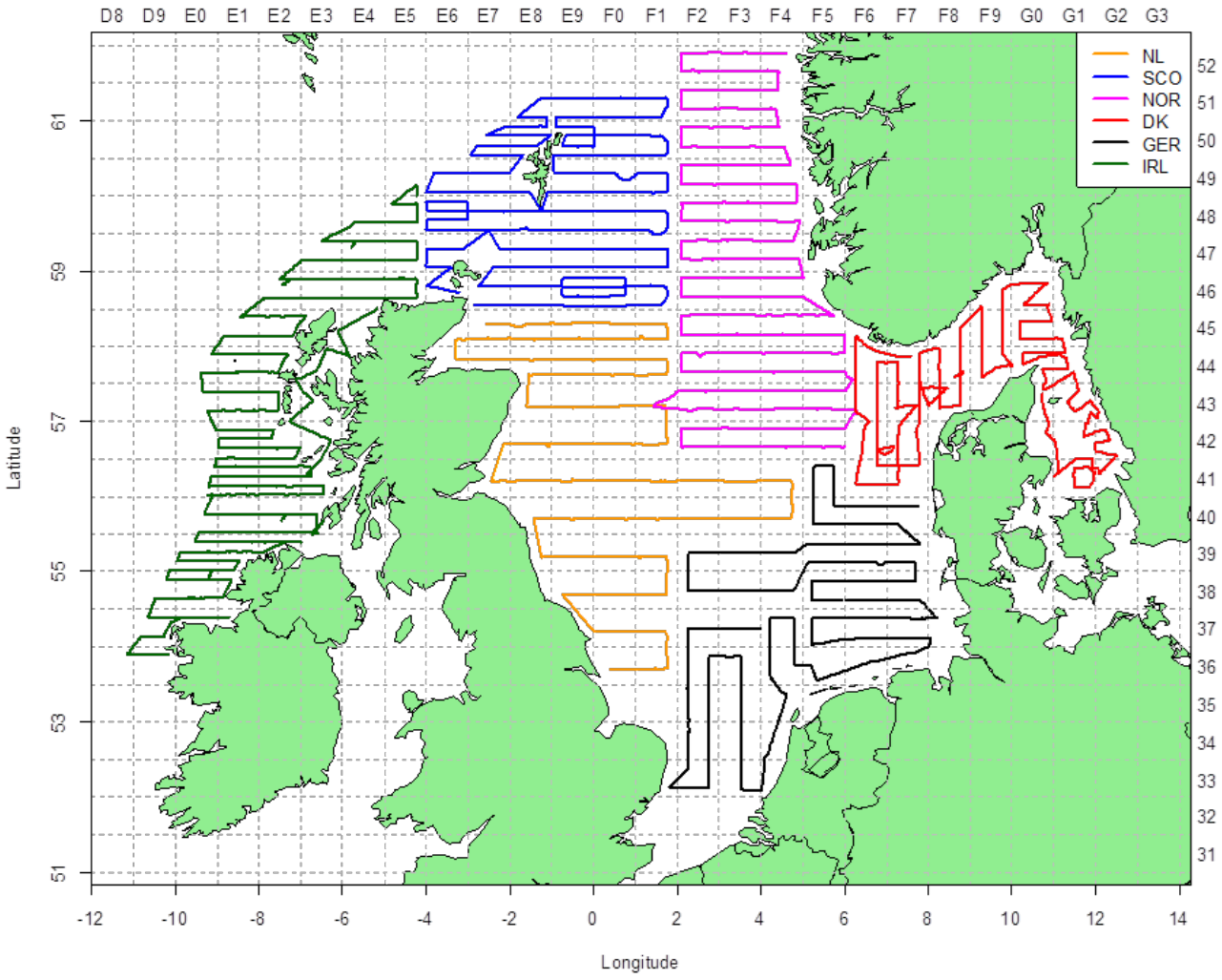

Figure 5.1. Survey area coverage in the pelagic acoustic surveys in 2015 and individual vessel tracks by nation (IRL = Celtic Explorer; SCO = Scotia; NOR = Johan Hjort; DK = Dana; NL = Tridens; GER = Solea).

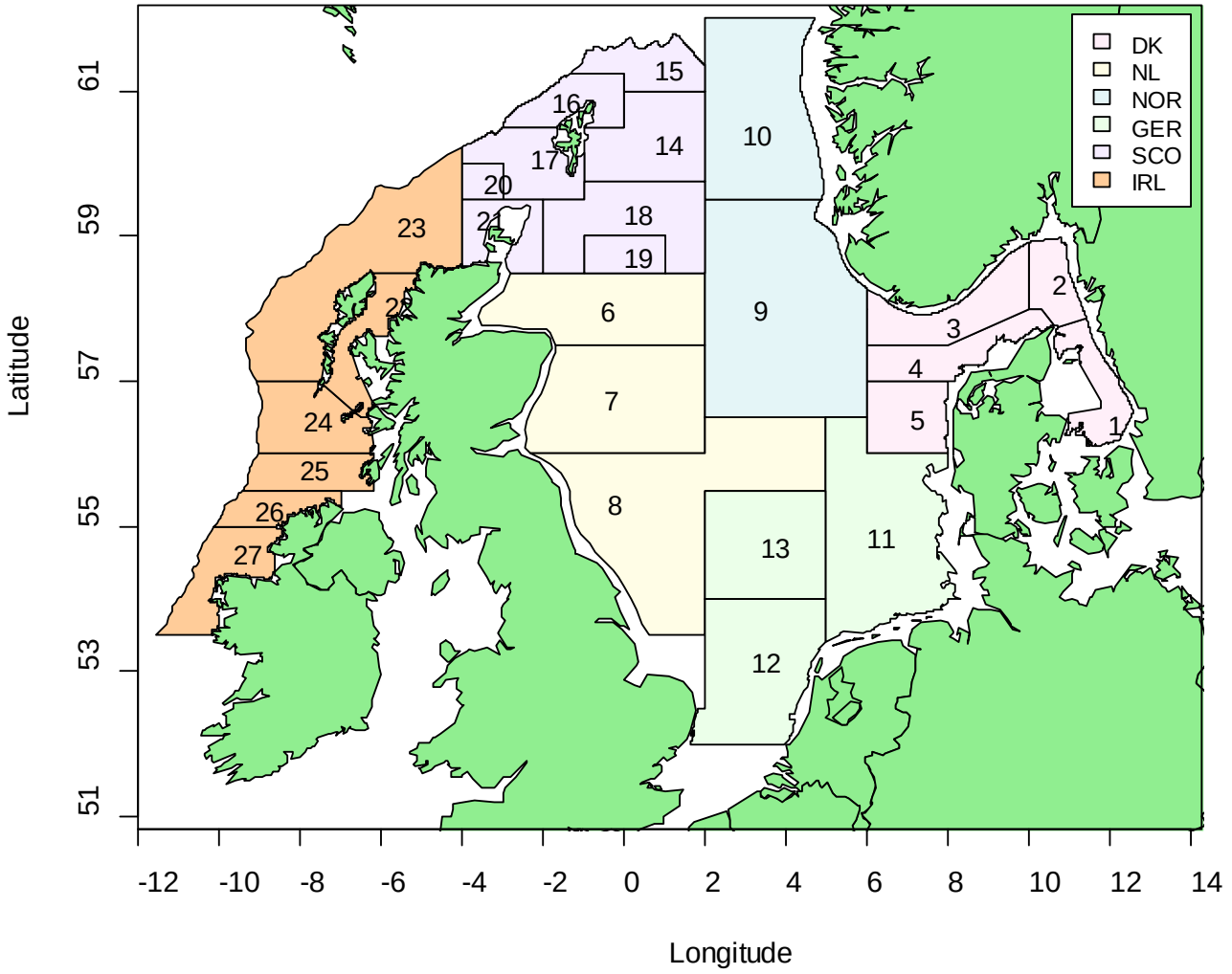

Figure 5.2. Stratification used in the StoX analysis of the HERAS survey 2015. Strata covered by different vessels are indicated by colour coding.

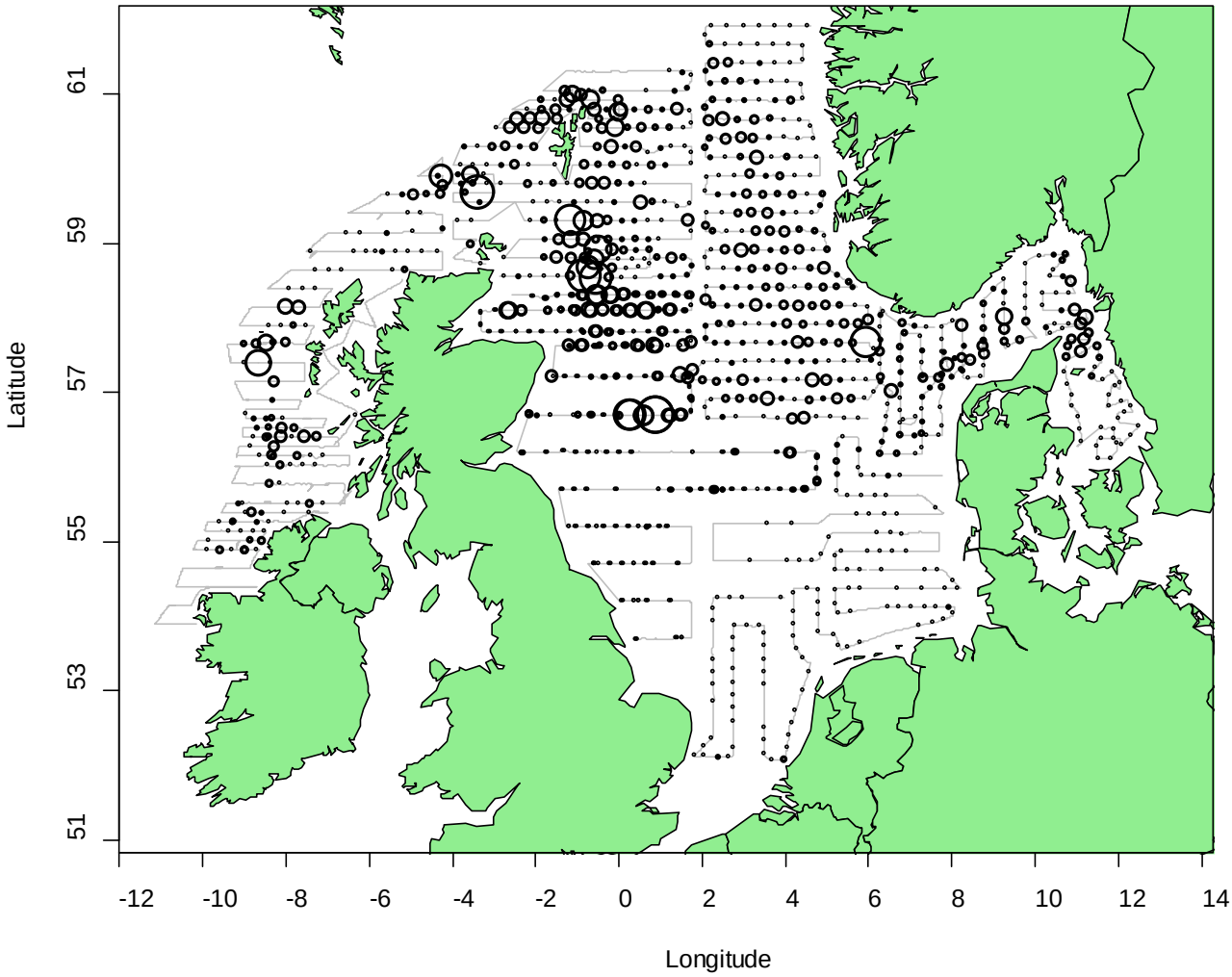

Figure 5.3. Distribution of NASC attributed to herring in HERAS in 2015. Cruise tracks are outlined in light grey with circles representing size and location of herring aggregations. NASC values are resampled at 15 nm intervals along the cruise track.

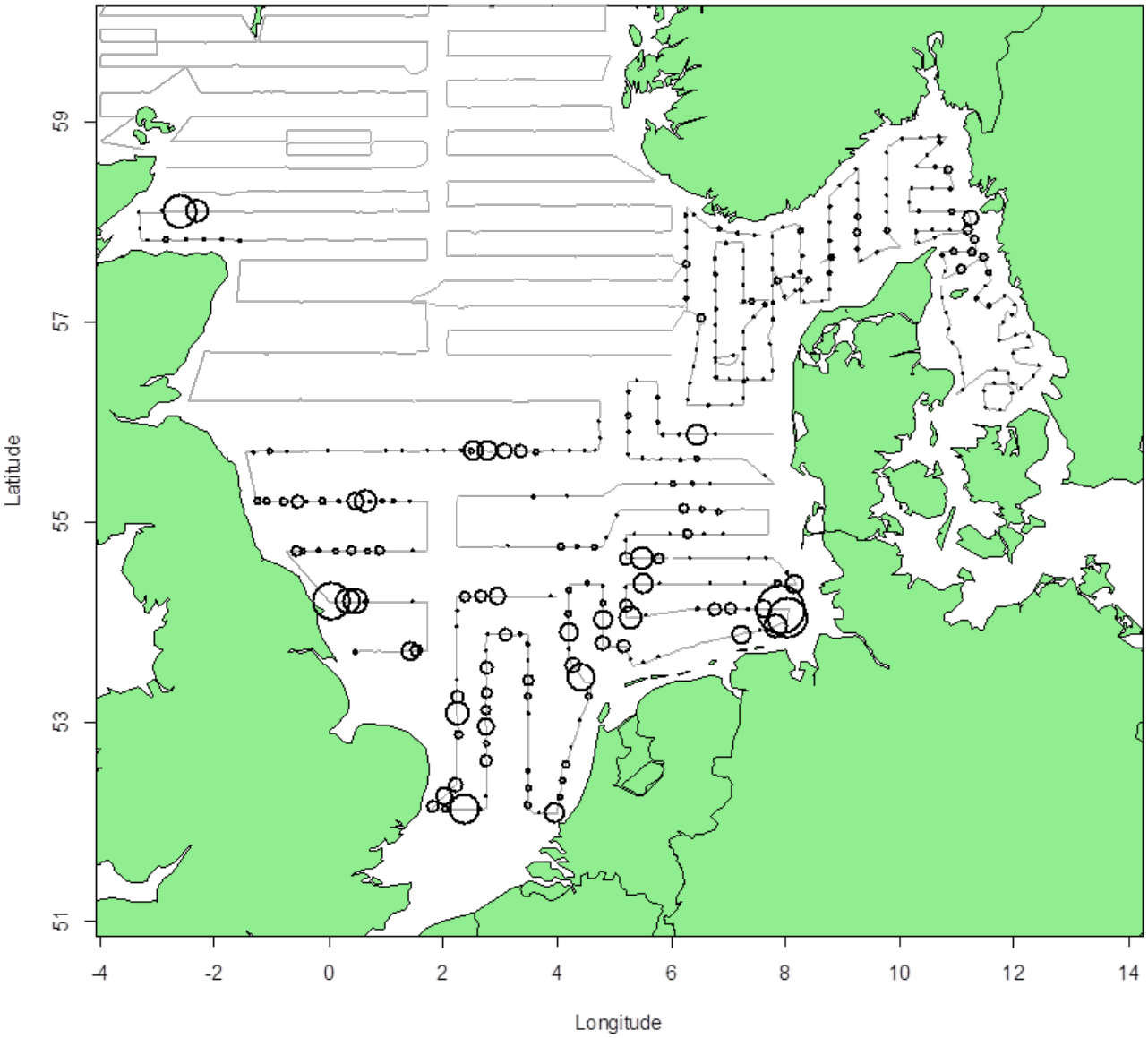

Figure 5.4. Distribution of NASC attributed to sprat in HERAS in 2015. Cruise tracks are outlined in light grey with circles representing size and location of sprat aggregations. NASC values are resampled at 10 nm intervals along the cruise track.

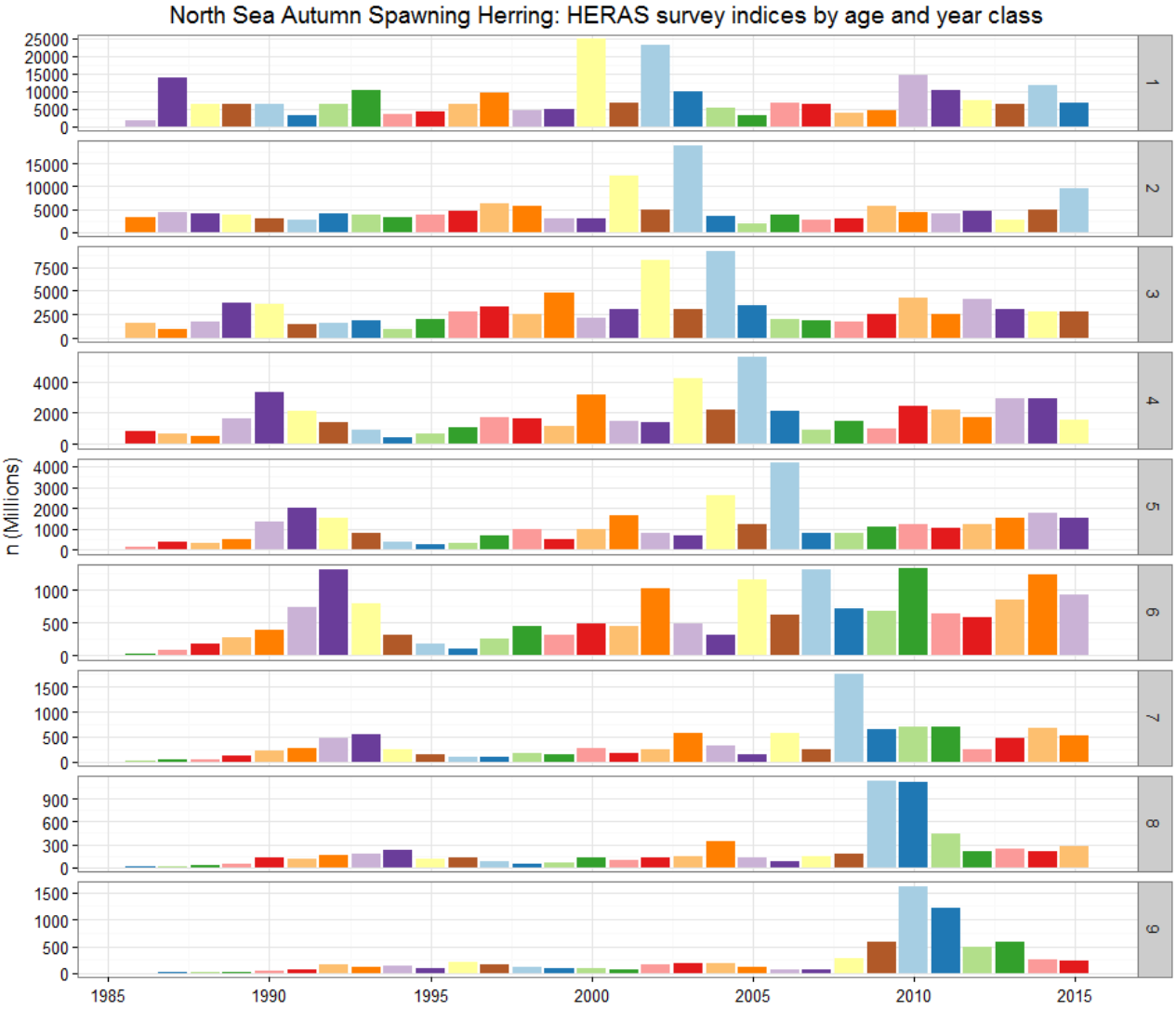

Figure 5.5. North Sea autumn spawning Herring: HERAS indices (millions) by age (winter rings) and year class from the acoustic surveys 1986-2015. Age 9 includes ages 9 and older. Note diverging scales of abundance between ages.

Figure 5.6. Western Baltic spring spawning Herring: HERAS indices (millions) by age (winter rings) and year class from the acoustic surveys 1992-2015. Age 8 includes ages 8 and older. Note diverging scales of abundance between ages.

Figure 5.7. West of Scotland (VIaN) autumn spawning herring: HERAS indices (millions) by age (winter rings) and year class from the acoustic surveys 1993-2015. Age 9 includes ages 9 and older.

Figure 5.8. Malin Shelf Herring (VIaN-S, VIIb,c): HERAS indices (millions) by age (winter rings) and year class from the acoustic surveys 2008-2015. Age 9 includes ages 9 and older.

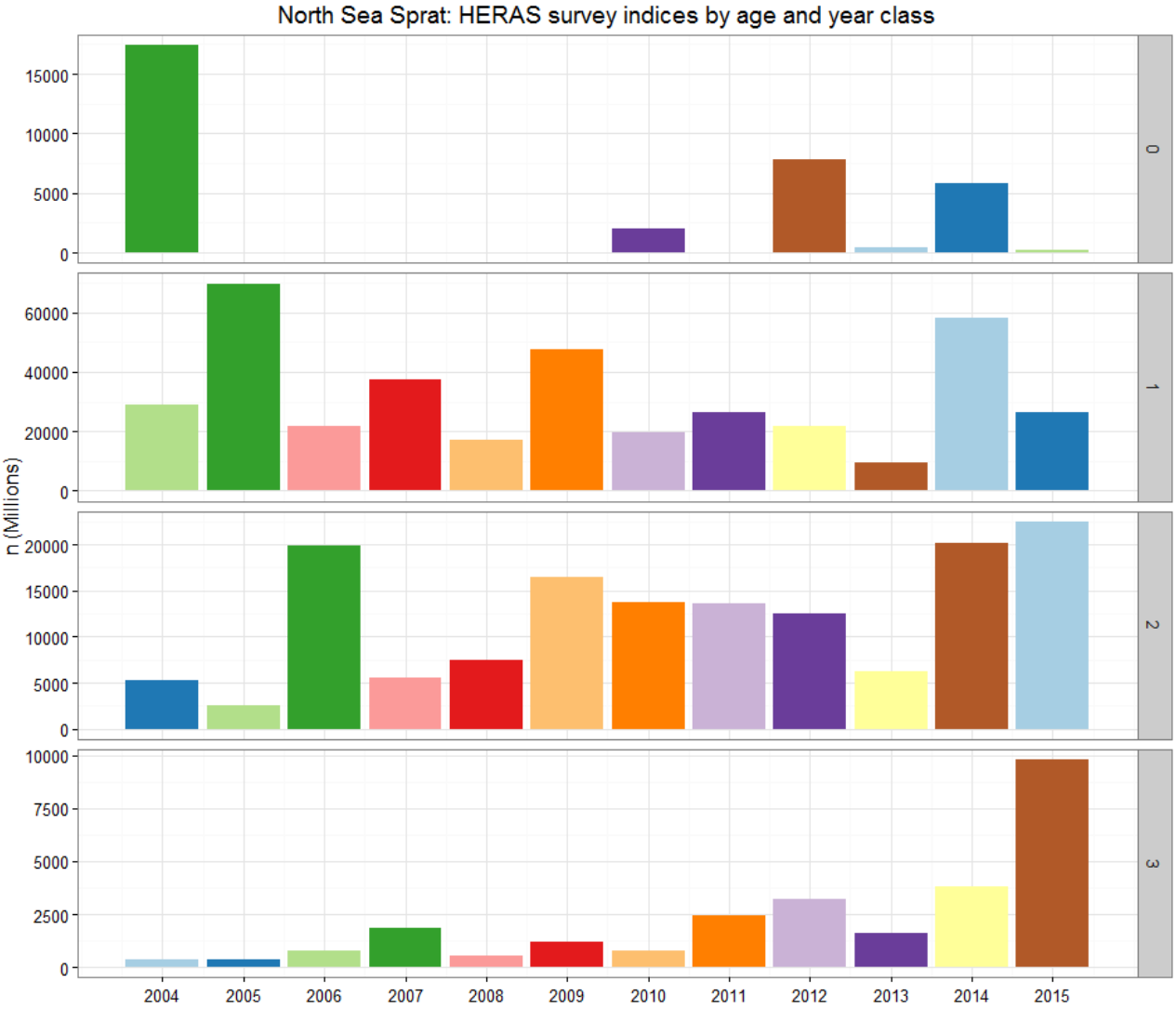

Figure 5.9. North Sea Sprat: HERAS indices (millions) by age (winter rings) and year class from the acoustic surveys 2004-2015. Age 3 includes ages 3 and older. Note diverging scales of abundance between ages.

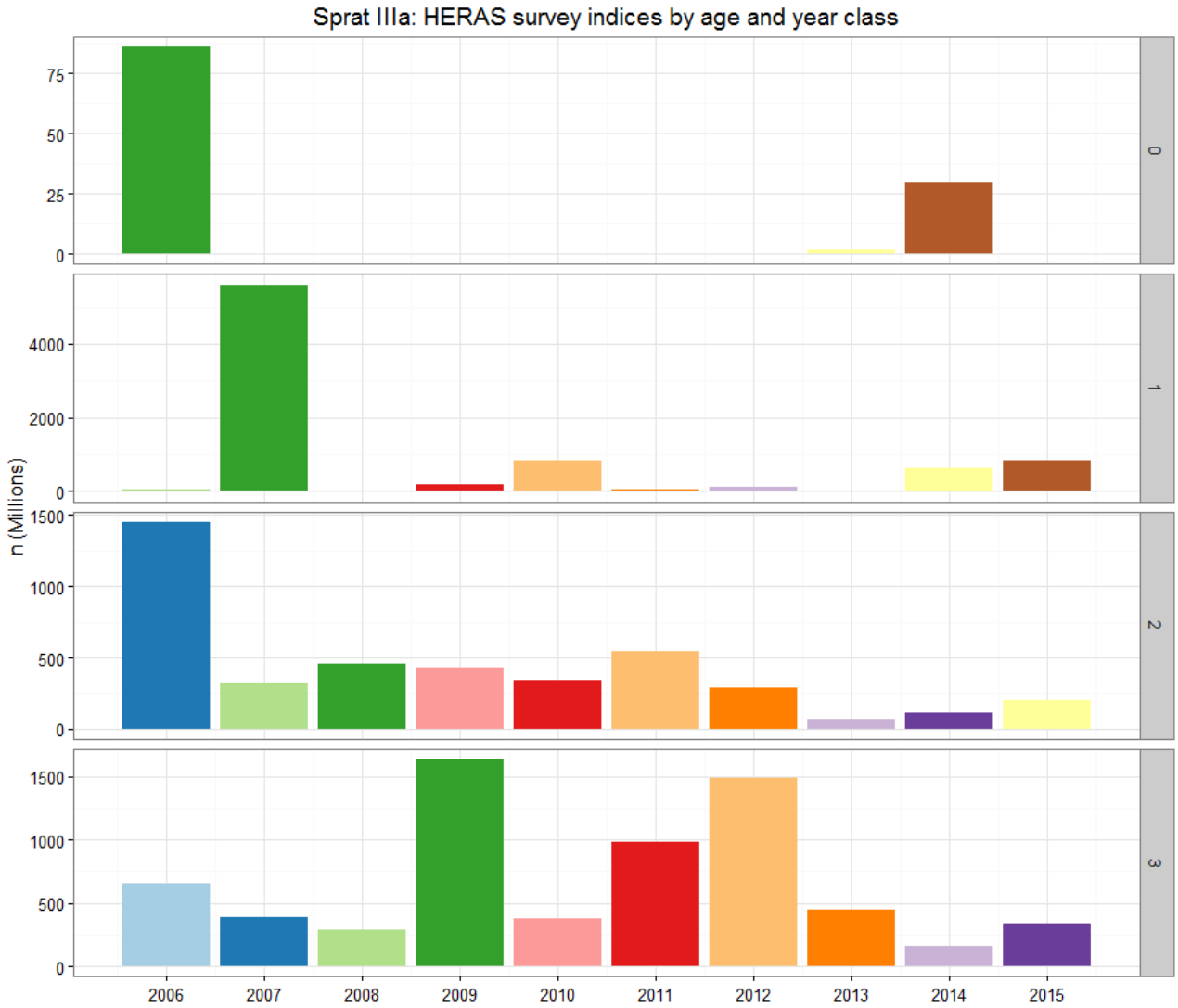

Figure 5.10. Sprat in Division IIIa: HERAS indices (millions) by age (winter rings) and year class from the acoustic surveys 2006-2015. Age 3 includes ages 3 and older. Note diverging scales of abundance between ages.

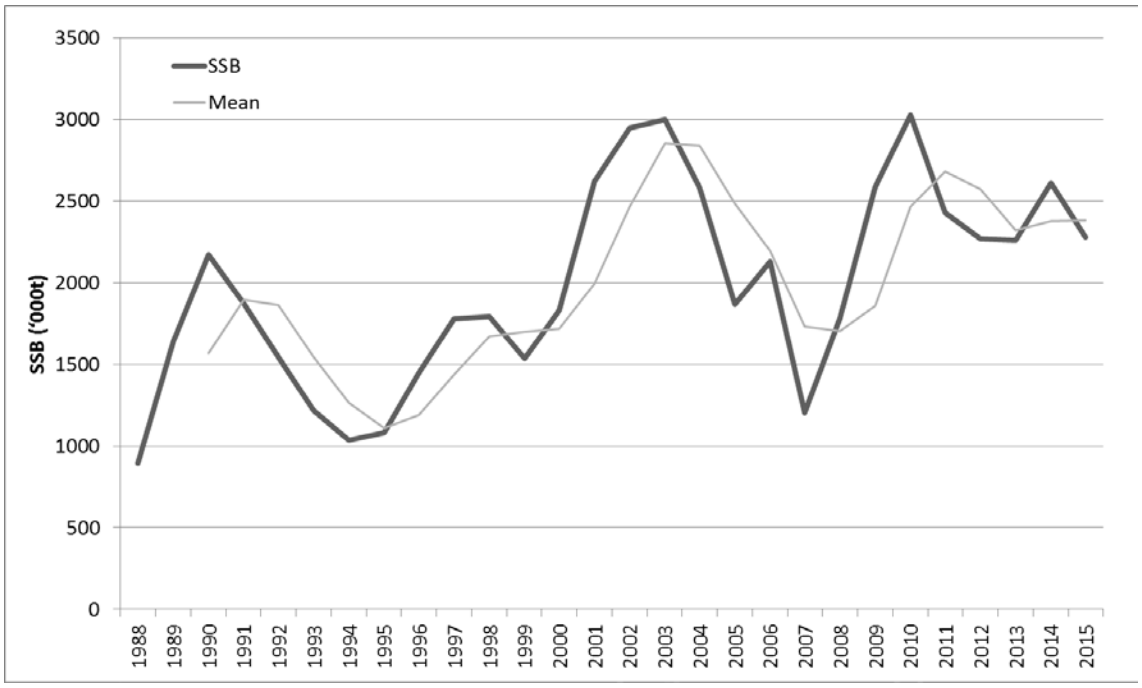

Figure 5.11. Time series of SSB of North Sea autumn spawning herring with three year running mean.

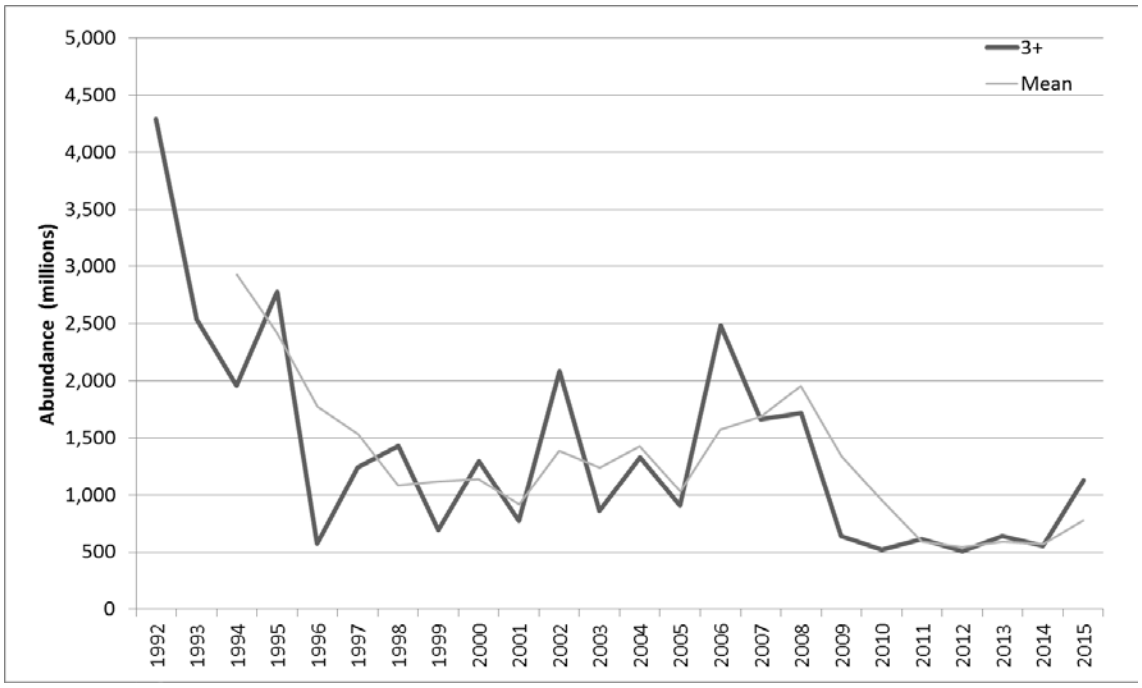

Figure 5.12. Time series of 3+ abundance of Western Baltic spring-spawning herring with three year running mean.

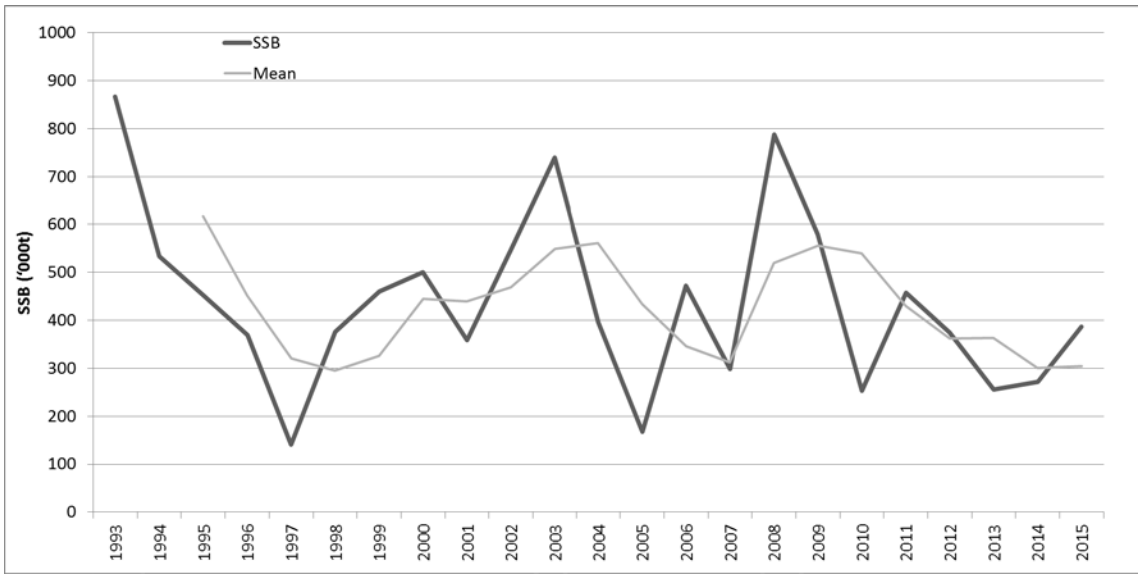

Figure 5.13. Time series of SSB of West of Scotland herring (geographical subset of Malin Shelf herring) with three year running mean.

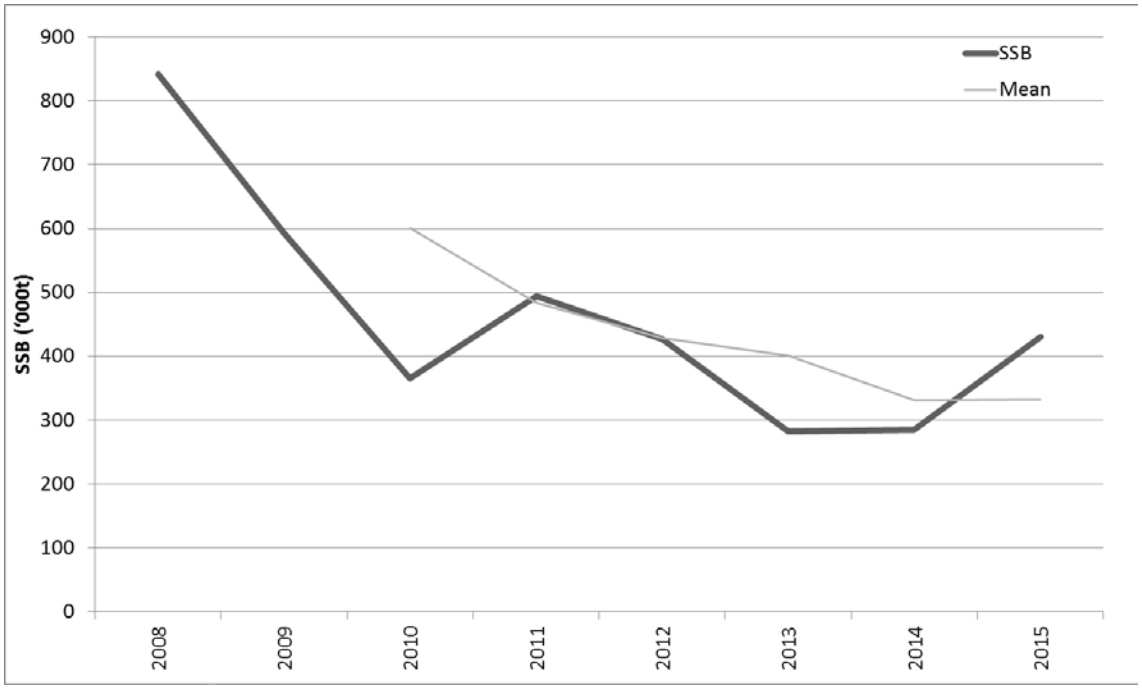

Figure 5.14. Time series of SSB of Malin Shelf herring with three year running mean.

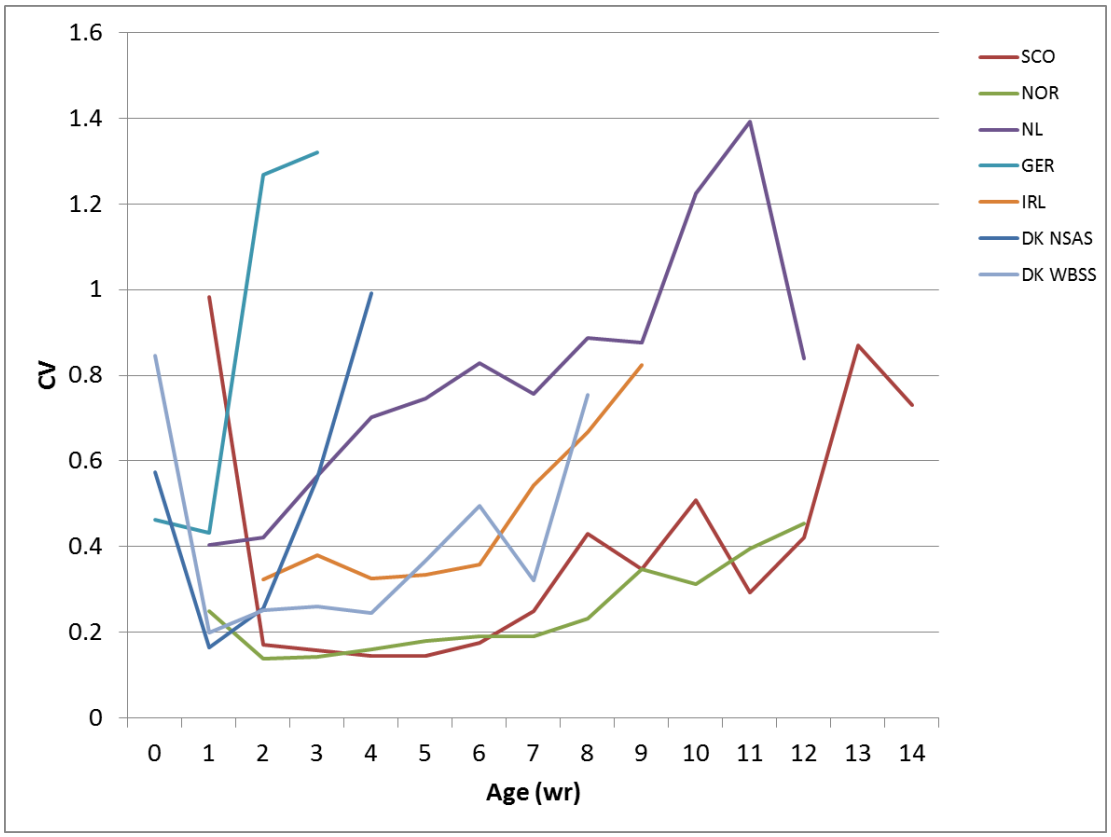

Figure 5.15. CV on abundance at age for herring in each national survey from the analysis in StoX.

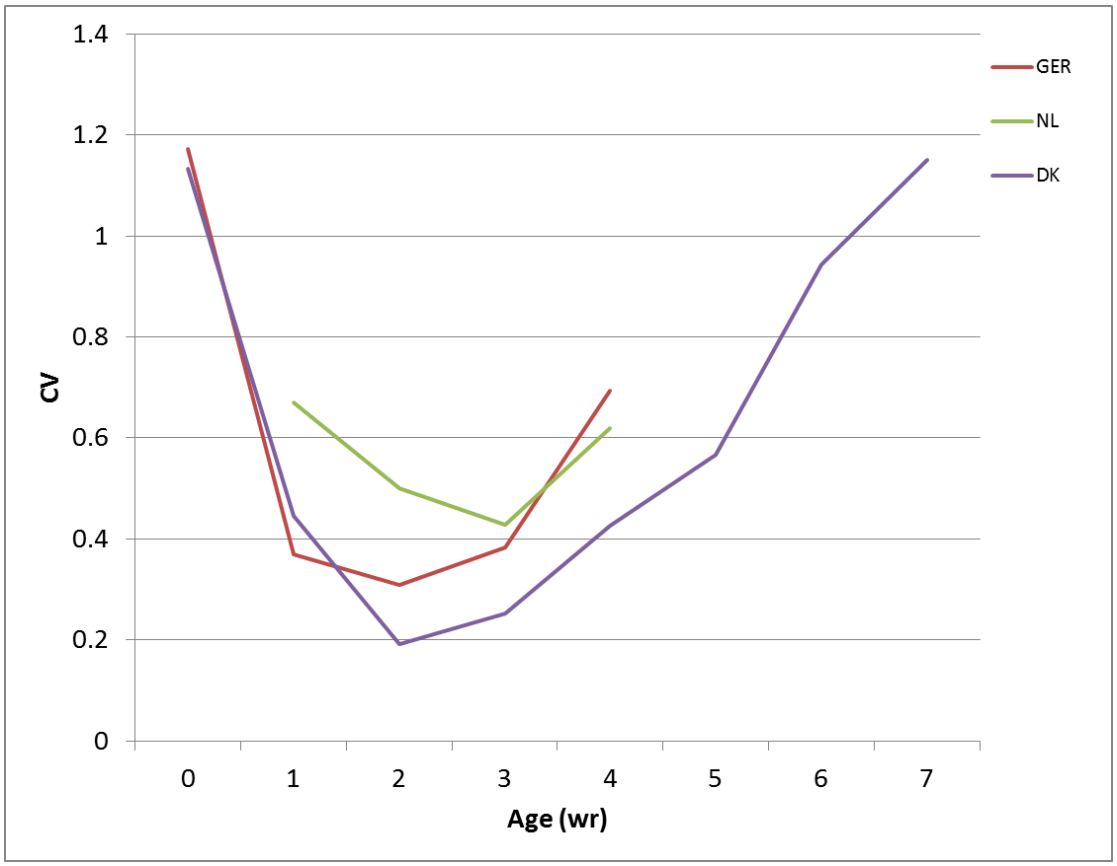

Figure 5.16. CV on abundance at age for sprat in each national survey from the analysis in StoX.