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Survey report

MS *Libas*, MS *M.Ytterstad* and MS *Vendla* 2.-14.02.2016

Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2016

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Contents

Summary

During the period 2-14th of February 2016 the spawning grounds from Møre (62ºN) to Troms (70º) were covered acoustically by the commercial vessels MS *Libas* and *M.Ytterstad*. MS *Vendla* covered the western area from 65ºN to 69º30N and limited to 1ºW and 1000 m depth contours in the east based on information from the scouting vessels. In 2015 the herring was distributed all along the coast from Ålesund (62.5ºN) to Malangsgrunnen off Troms (70ºN). In 2016, the situation was very different; the herring was about 2 weeks later in the migration compared and it appeared in a real high density bulk within a small area 66-67ºN, and to some extent at lower densities further north. High densities of herring were also observed over very small areas inside the wintering fjords. The spawning stock biomass index was 4.3 million t in 2016 with a really high uncertainty (CV) of 40%. This was a drop in the index of 30.5% from 6.2 million t estimate in 2015, and at the same time the CV in 2015 was much lower at 11%. The drop in the index and the huge CV in 2016 could be related to the fact that the main bulk of herring was only measured over a few transect, compared to 2015 when the herring was distributed over much larger area. As much as 94.9% of the estimate in 2016 was found between 65-69ºN, most of it within a limited area 66-67ºN. Such densities over a small area is the main reason to the high CV. As in 2015, the estimate of 2016 was dominated by three year classes; 2004 most abundant, with 2006 and 2009 coming next, which demonstrates the problem with no large year classes recruiting to the spawning stock in recent years. The western area constituted only 1.3% of the biomass, and here 50% of the herring appeared to be summer spawners in a resting or very early maturation stage. The most common year class among the summers spawners was 2009, whereas the spring spawners mixing with the summer spawners had a comparable year class composition as at the coast with the 2004 year class being most abundant. The size of the herring was relatively stable all over the area, except north of 68ºN where more small herring appeared in the samples, and in the northernmost area the 2011year class was most abundant with 38%. Sonar investigations in 2016 indicated that that echo sounder biomass estimations were not seriously biased by unaccounted fraction of herring in the upper layers, and that no significant fraction of herring was distributed in the echo sounder blind zone. Moreover, a comparison between the general estimate with echo sounders, and a combined estimate between echo sounder and sonar, showed estimates that were not significantly different in the western strata.

Survey participants:

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Aril Slotte	Survey coordinator	2 -14.02.2016
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Valantine Anthonypillai	Biology	2 -14.02.2016

Introduction

Acoustic surveys on NSS herring during the spawning season has been carried out regularly since1988, with some breaks (in 1992-1993, 1997, 2001-2004 and 2009-2014). In 2015 the survey was initiated again based on the pressure from fishermen and fishermen's organizations that IMR should conduct more surveys on this commercially important stock. The Norwegian Sales Organization for Pelagic fish also decided to support the survey in 2015 financially, covering the full costs of three commercial vessels over two weeks. The survey was considered a success with a really good design and coverage of herring migrating southwards along the coastline from wintering grounds in the north towards spawning ground further south. The survey was carried out according to good scientific standards for abundance estimation of fish, and several specialists in fisheries acoustics were onboard. It was decided to continue the survey also in 2016, hoping that the survey could be a contribution to future stock assessment and advice of NSS herring.

Despite effort put on coverage in 2015, fishermen were worried that the survey did not cover herring migrating to the Norwegian coast from wintering grounds in the Norwegian Sea. Hence, in 2016 it was decided to put effort covering also this potential immigration directly from the west. The Norwegian Sales Organization for Pelagic decided to cover the expenses for this extension of the survey westwards into the Norwegian Sea in 2016 with a third vessel. This organization also covered expenses for a pilot survey with four smaller scouting vessels for five days in order to limit and focus the effort needed in the western area to where the herring was actually distributed.

With this basis the main objective of the NSS spawning survey 2016 was to estimate indices of year class abundance and spawning stock biomass during the period of spawning migration from wintering areas at/off the northern Norwegian coast and in the Norwegian Sea towards the coastal spawning ground further south. Other sub-objectives were to compare estimation with or without the inclusion of sonar data in the western area, using sonar data to estimate migration speeds and measuring target strength (TS) of the pre-spawning herring.
Finally, it was also a purpose that the results of the survey should be compared with the 2015 survey, which was carried out in a similar manner at the exact same time period.

Material and methods

Survey design

During the period 2-14th of February 2016 the spawning grounds from Møre (62ºN) to Troms (70º) were covered acoustically by the commercial vessels MS *Libas* and *M.Ytterstad*. MS *Vendla* covered the western area from 65ºN to 69º30N and limited to 1ºW and 1000 m depth contours in the east based on information from the scouting vessels (Figure 1).

The survey design followed a standard stratified design (Jolly and Hampton 1990), where the survey area was stratified before the survey start according to the expected density and age structures of herring. Within each stratum, parallel east-west transects with a constant distance and a random starting position was used as the primary sampling unit (Simmonds and MacLennan 2008). The distance between transects were 10 nm in the eastern stratas and 15 nm in the western strata (Figure 1). It was further decided that all vessels should sail as close as possible to the coast, and that the western limits of the offshore transects should end when no herring was observed for about 10 nmi. These rules made small changes to the predefined stratum polygons during the survey. In addition, fivespecial strata with zigzag transect design were predefined for the wintering fjords in the north, where herring were still observed by fishing vessels at the start of and during the survey (Figure 2).

Biological sampling

The following variables of individual herring were analysed for each of the 32 trawl stations with herring catch: Total weight (W) in g and total length (L_T) in cm (measured to nearest 0.5 cm below) on up to 100 individuals per sample and totally 2971 individuals, and in addition the sex, maturity stage, stomach fullness and gonad weight (W_G) in g (given maturity stage<7) were measured in 50 individuals per sample and totally in 1394 individuals. The maturity stages were determined by visual inspection of gonads as recommended by ICES (Anon. 1962): immature = 1 and 2, maturing = 3 to 4, ripe = 5, spawning = 6, spent = 7 and recovering = 8. Extra attention was paid to potential infection of ichtyophonus, given recent occurrence in North Sea herring, but only 2 individuals out of the 1334 were found to be infected.

Echo sounder data

Multifrequency (18, 38, 70, 120, 200 kHz) acoustic data were recorded with a SIMRAD EK 60 echo sounder and echo integrator onboard all three vessels. All three vessels were calibrated at the tip of the fishing pier in Ålesund prior to the survey according to standard methods (Foote et al., 1987), adjusted for split beam methods as described in Ona (1999). All vessels were satisfactorily calibrated, and the calibration reports with new gain estimates and raw data are stored on the survey disc at NMD.

LSSS, Large Scale Survey System (Korneliussen et al., 2006) was applied in the interpretation of the data. The recorded area echo abundance, i.e. the nautical area backscattering coefficient (NASC), s_A (MacLennan et al., 2002), was interpreted and distributed to herring and 'other' items. The data were stored with a resolution of 1 nmi on the horizontal scale and 10 m intervals.

Abundance estimation methods

The acoustic density values were stored by species category in nautical area scattering coefficient (NASC) [m^2 n.mi.$^{-2}$] units (MacLennan et al. 2002) in a database with a horizontal resolution of 1 nmi and a vertical resolution of 10 m, referenced to the surface. To estimate the mean and variance of NASC, we use the methods established by Jolly and Hampton (1990) and implemented in the software StoX. The primary sampling unit is the sum of all elementary NASC samples of herring along the transect multiplied with the resolution distance. The transect (*t*) has NASC value (*s)* and distance length *L*. The average NASC (S) in a stratum (*i*) is then:

$$\hat{S}_i = \frac{1}{n_i} \cdot \sum_{i=1}^{n_i} w_{it} s_{it} \qquad (1)$$

where $w_{it} = L_{it} / \overline{L}_t$ (t= 1,2,.. n_i) are the lengths of the n_i sample transects, and

$$\overline{L}_i = \frac{1}{n_i} \sum_{t=1}^{n_i} L_{it} \qquad (2)$$

The final mean NASC is given by weighting by stratum area, A;

$$\hat{S} = \frac{\sum_i A_i \hat{S}_i}{\sum_i A_i} \qquad (3)$$

Variance by stratum is estimated as:

$$\hat{V}\left(\hat{S}_i\right) = \frac{n}{n_i - 1} \sum_{t=1}^{n} w_{it}^2 \left(s_t - \bar{s}\right)^2 \quad \text{with } \bar{s}_i = \frac{1}{n_i} \cdot \sum_{t=1}^{n_i} s_t \qquad (4)$$

Where $w_{it} = L_{it} / \overline{L}_t$ (t= 1,2,.. n_i) are the lengths of the n_i sample transects.

The global variance is estimated as

$$\hat{V}(\hat{S}) = \frac{\sum_i A_{i=1}^2 \hat{V}(\hat{S})}{\left(\sum_i A\right)^2} \qquad (5)$$

The global relative standard error of NASC

$$RSE = 100 \sqrt{\frac{\hat{V}(\hat{S})}{N}} \bigg/ \hat{S} \qquad (6)$$

where N is number of strata.

In order to verify acoustic observations and to analyse year class structure over the surveyed area, trawling was carried out at a total of 32 stations (Figure 3). All trawl stations were used to derive a common length distribution for all transect within the respective strata. All stations had equal weight.

Relative standard error by number of individuals by age group was estimated by carrying out a by combining Monto Carlo selection from estimated NASC distributions by stratum with a bootstrapping techniques of the assigned trawl stations.

The acoustic estimates presented in this report use the 38 kHz NASC, and the mean was calculated for data scrutinized as herring and collected along the transects (acoustic recordings taken during trawling, etc are excluded). The number of herring (*N*) in each length group (*l*) within each stratum (*i*) is then computed as:

$$N_l = \frac{f_l \cdot \hat{S}_i \cdot A_i}{\langle \sigma \rangle}$$

Where

$$f_l = \frac{n_l L_i^2}{\sum_{l=1}^{m} n_l L_l}$$

is the ”acoustic contribution” from the length group L_l to the total energy. <s_A>is the mean backscattering coefficient [m^2/nmi.2] (NASC). A is the area of the stratum [nmi.2] and σ is the mean backscattering cross section at length L_l.

The target strength (TS) is used for the conversion where $\sigma = 4\pi\ 10^{(TS/10)}$ is used for estimating the backscattering cross section. Traditionally, TS = 20logL – 71.9 (Foote 1987) has been used for herring during the spawning surveys, however, several papers question this target strength. Ona (2003) describes how the target strength of herring changes with depth, and measured the target strength of herring to be TS = 20logL – 2.3 log(1 + z/10) – 65.4 where z is depth in meters. Still, given that previous surveys were estimated using Foote (1987), the estimation this year was also done with this TS, for direct comparison and possible inclusion in ICES WGWIDE 2016 as another year in the time series.

The conversion from number of fish by length group (*l)* to number by age is done by estimating an age ratio from the individuals of length group (*l*) with age measurements. Similar, the mean weight by length and age grouped is estimated.

StoX software developed by IMR were used in the abundance estimation in 2016 just as in 2015. StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application build with Java for easy sharing and further development in cooperation with other institutes. The underlying high resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Accessing StoX from external software may be an efficient way to process time series or to perform boot-strapping on one dataset, where for each run, the content of the parameter dataset is altered. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990)[i] is implemented.

Sonar data and analyses

Data from Simrad SIMRAD low frequency sonars were logged onboard all vessels. In this survey report focus has been on the combination of sonar data with echo sounder data to estimate the abundance in the western area relative to the coastal area, due to the general schooling behaviour of herring in the western area. This data, methods and results are described in Annex 1. The plan is also to use the sonar data to check for migration speeds along the coast, which can be used to correct the estimates at a later stage.

Results and discussion

Distribution and density

As opposed to the situation in 2015 when the herring was more evenly distributed, the bulk herring in 2016 appeared in a real high density bulk within a small area 66-67ºN, in the northern part of strata 3 and southern part of strata 4 from Træna to Røst, and to some extent at lower densities further north (Figure 3). In 2016 the herring was about 2 weeks late in the migration compared with 2015. In fact no herring was observed in the two southern strata 1-2. . High densities of herring were also observed over very small areas inside the wintering fjords around Kvaløya.

Index of abundance and biomass

The official estimate of a spawning stock biomass index using StoX, to be treated as a relative one, was 4.3 million t in 2016 (Table 1) with a really high uncertainty (CV) of 40%. This was a drop of 30.5% from 6.2 million t estimate in 2015, and at the same time the CV in 2015 was much lower at 11%. The drop in the index and the huge CV in 2016 could be related to the fact that the main bulk of herring was only measured over a few transect, compared to 2015 when the herring was distributed over much larger area. As much as 94.9% of estimate in 2016 was found in strata 3-4 (Annex 2) (Figure 4), most of which between 66-67ºN (Figure 3). Clearly, with such densities over a small area the estimate could vary with the design and coverage.

As in 2015, the estimate of 2016 was dominated by three year classes; 2004 most abundant, with 2006 and 2009 coming next (Table 1) (Figure 5), which clearly confirm the problem with no large year classes recruiting to the spawning stock in recent years. In 2015 the 2011 year class appeared more strong relative to the other year classes then in 2016, where it appears less significant. This could indicate that it was overrepresented in the samples in 2015 or underrepresented in 2016 due to wintering or spawning outside the covered area.

The western area constituted only 1.3% of the biomass, and here 50% of the herring appeared to be summer spawners in a resting or very early maturation stage. The most common year class among the summers spawners was 2009, whereas the spring spawners mixing with the summer spawners had a comparable year class composition as at the coast with the 2004 year class being most abundant (Figure 6).

There was still herring left in the wintering fjords, when the survey finished: 3.4% of the total biomass was found here in very dense aggregations over small areas in the fjord system (Figure 7). These appeared to be even more delayed in the maturation then the rest of the herring measured further south.

Sonar observations

Sonar investigations in 2016 indicated that that echo sounder biomass estimations were not seriously biased by unaccounted fraction of herring in the upper layers, and that no significant fraction of herring was distributed in the echo sounder blind zone. Moreover, a comparison between the general estimate with echo sounders, and a combined estimate between echo sounder and sonar , showed estimates that were not significantly different in the western strata. See Annex 1 for more information about the sonar results.

Geographical variations in age, length, weight

The size of the herring was relatively stable all over the area, except north of 68ºN where more small herring appeared in the samples (Figures 8-9), and in the northernmost area (strata 5) the 2011 year class was most abundant with 38%. This size dependent distribution pattern is in accordance with the observations in earlier years, which has been thoroughly discussed in Slotte and Dommasnes, 1997, 1998, 1999, 2000; Slotte, 1998*b*; Slotte, 1999*a*, Slotte 2000, Slotte et al. 2000, Slotte & Tangen 2005, 2006). The main hypothesis is that this could be due to the high energetic costs of migration, which is relatively higher in small compared to larger fish (Slotte, 1999*b*). Large fish and fish in better condition will have a higher migration potential and more energy to invest in gonad production and thus the optimal spawning grounds will be found farther south (Slotte and Fiksen, 2000), due to the higher temperatures of the hatched larvae drifting northwards.

Quality of the commercial vessels for abundance estimation

The survey must be considered to be a success, as the overall the acoustic data recorded were of real high quality. Compared with 2015, when the vessels did not have drop keels, the acoustic data were of better quality in 2016. In 2016 all vessels were equipped with multifrequency equipment, resulting in easier scrutiny of the acoustic data. In addition, in 2016 all vessels were able to trawl (in 2015 only one vessel could trawl), which resulted in more sampling on acoustic registrations and more quality of the scrutiny process into herring and other targets. Still, despite the really good quality of the survey, the surprising late migration and very patchy distribution of the herring lead to a high uncertainty in the estimate of herring. This is something that need to have implications for next year, for instance to have scouting vessels at the coast to give limitations of distribution, so that the survey could put more effort into high density areas.

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Tables

Table 1. The overall areas estimate of abundance (TSN), total biomass (TSB) and spawning stock biomass (SSB) of Norwegian spring spawning herring during the spawning season 2-14.February 2016.

	Age																				
Length (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number	Biomass	MeanW (g)
11-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65	65	0.5	8
14-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65	65	1.8	27
15-16	391	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	391	8	20.5
16-17	1303	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1303	34.6	26.6
17-18	2540	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2540	76.7	30.21
18-19	6710	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6710	203.6	30.35
19-20	651	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	716	28.9	40.36
20-21	-	2705	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2705	138.6	51.25
21-22	5342	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5342	299.2	56
22-23	-	12927	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12927	852.3	65.94
23-24	-	19053	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19053	1494.9	78.46
24-25	-	6379	13562	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19942	1764.6	88.49
25-26	-	31529	18622	3847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53997	5467.7	101.26
26-27	-	31839	21609	7576	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61025	7276.6	119.24
27-28	-	8453	16385	34465	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59303	8056.6	135.86
28-29	-	13028	49769	95223	-	-	-	-	-	-	-	-	-	-	-	-	-	-	158020	24569.7	155.49
29-30	-	39084	52499	86226	553	-	-	-	-	-	-	-	-	-	-	-	-	-	178361	31168.7	174.75
30-31	-	226	53465	100628	5784	226	-	-	-	-	-	-	-	-	-	-	-	-	160327	32429.4	202.27
31-32	-	52341	26745	51371	8996	17140	-	-	-	-	459	-	-	-	-	-	-	-	157052	35969.1	229.03
32-33	-	-	652	92659	50318	194480	7979	-	-	-	-	-	652	-	-	-	-	-	346739	91928.4	265.12
33-34	-	-	-	49967	135739	613153	78168	6868	26933	39084	45678	-	-	-	-	-	-	-	995591	290711	292
34-35	-	-	-	16974	107047	1074109	3310	109361	705062	140168	534302	21116	182391	-	-	-	414	-	2894253	918358	317.3
35-36	-	-	-	-	95013	351511	142070	432001	1247246	332994	1501884	39859	277961	204	409	-	-	-	4421151	1492850	337.66
36-37	-	-	-	-	-	37583	682	18030	648194	140506	1499683	101922	315028	455	26511	3371	-	-	2791963	987241	353.6
37-38	-	-	-	-	443	221	9895	2868	164348	28161	548140	26263	175612	14521	1332	3153	-	-	974957	362399	371.71
38-39	-	-	-	-	-	-	-	-	185	185	14066	1482	16953	741	51415	556	-	-	85583	34710.2	405.57
39-40	-	-	-	-	-	-	-	-	-	-	-	6411	13028	-	3455	-	-	-	22894	10054.9	439.2
41-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	186	-	-	186	81.7	440
TSN(1000)	16937	217629	253307	538935	403892	2288422	242103	569128	2791968	681097	4144213	197053	981624	15921	83121	7266	414	130	**13433160**	-	-
TSB(1000 t)	648.8	32535.4	40944.9	111236	120816	703254	76080.4	191031	949494	225012	1434427	70907.2	340354	5958.7	32673.2	2675.5	126.4	2.3	-	**4338176**	-
MeanL (cm)	18.83	27.36	28.41	30.3	33.82	34	34.54	35.05	35.32	35.2	35.67	36.1	35.82	37.14	37.56	36.88	34.25	13	-	-	-
MeanW (g)	38.31	149.5	161.64	206.4	299.13	307.31	314.25	335.66	340.08	330.37	346.13	359.84	346.72	374.26	393.08	368.22	305.5	17.5	-	-	322.95
% mature	0	35	86	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100			
SSB (1000 t)	0	11387	35213	111236	120816	703254	76080	191031	949494	225012	1434427	70907	340354	5959	32673	2676	126	2		**4310647**	

Figures

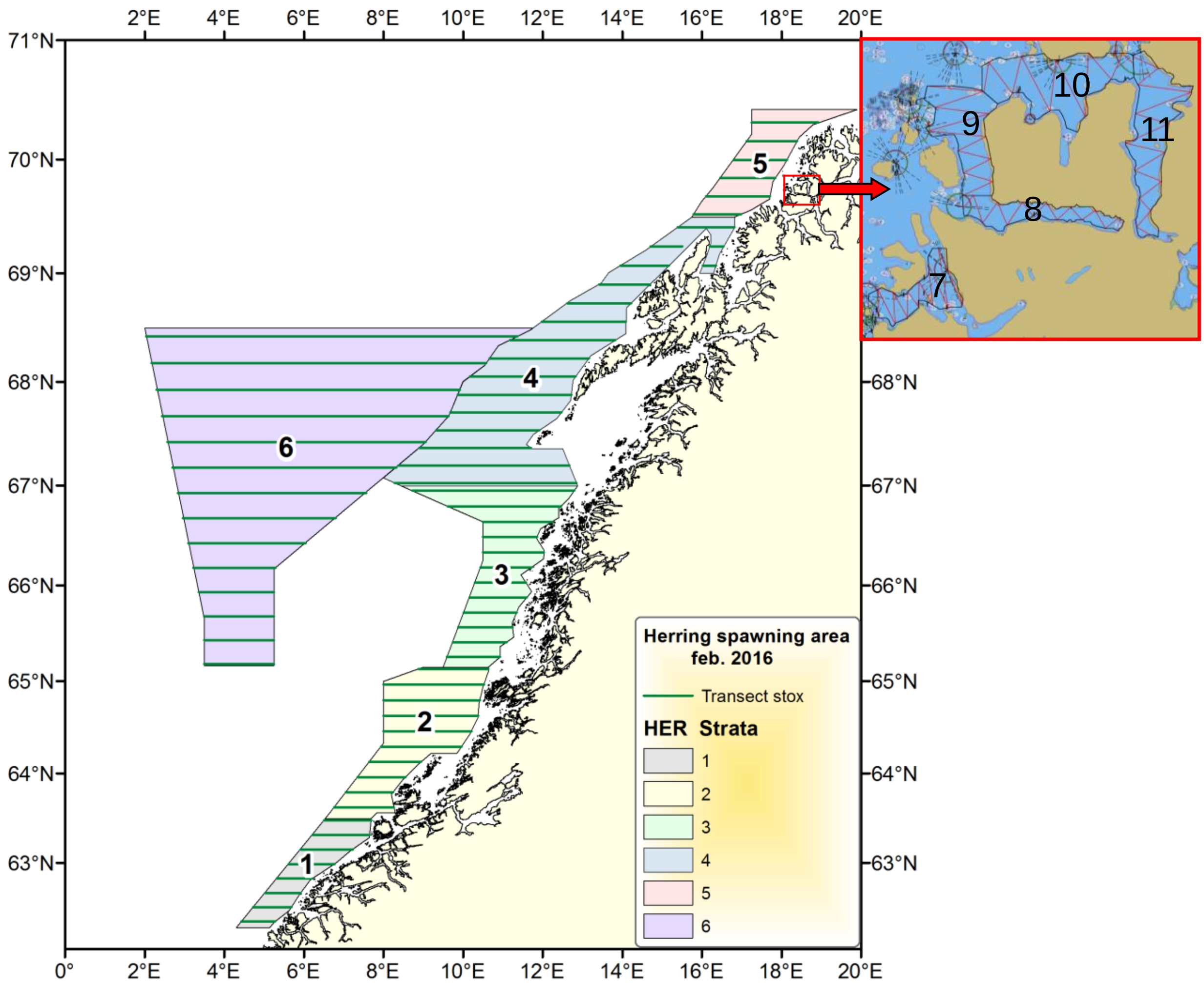

Figure 1. Strata and transects covered during 2-14. February 2016 with *Libas, M.Ytterstad* and *Vendla.*

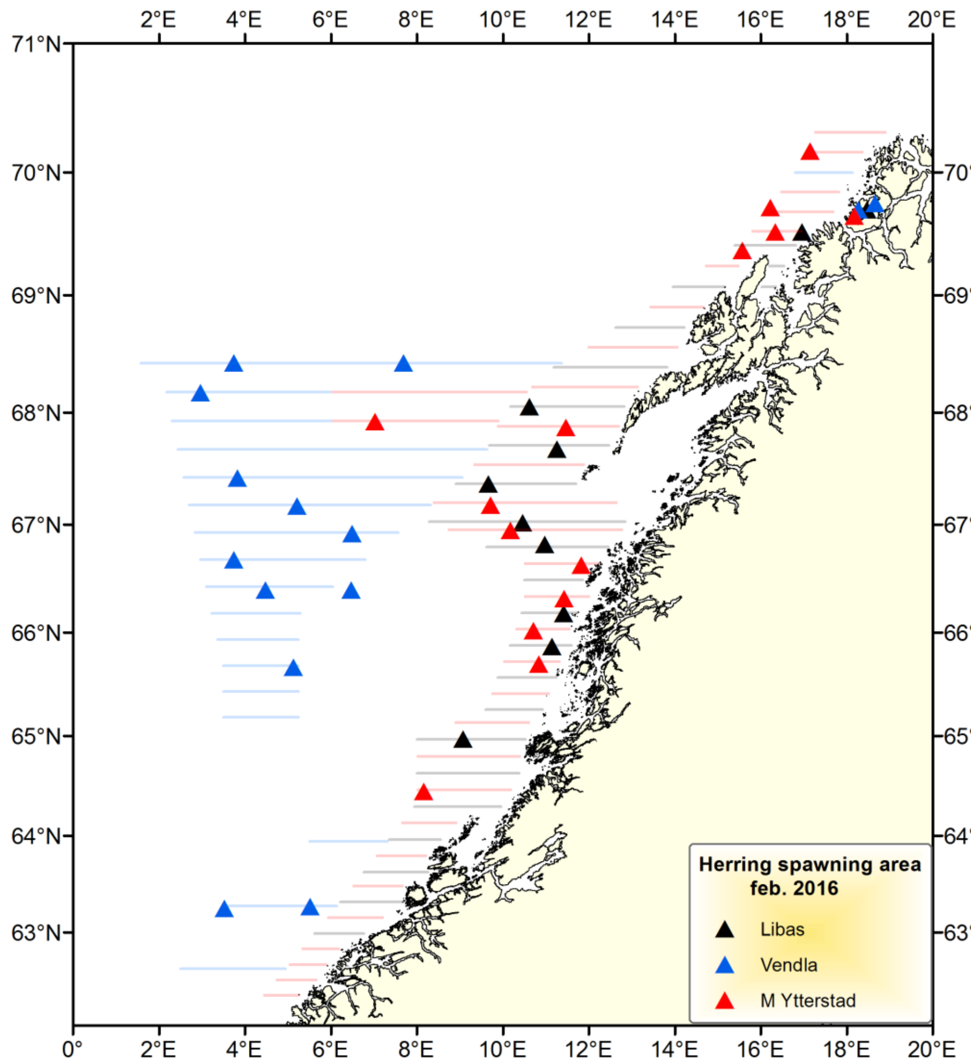

Figure. 2. Trawl stations with *Libas*, *M.Ytterstad* and *Vendla* taken at acoustic registrations 2-14 February 2016.

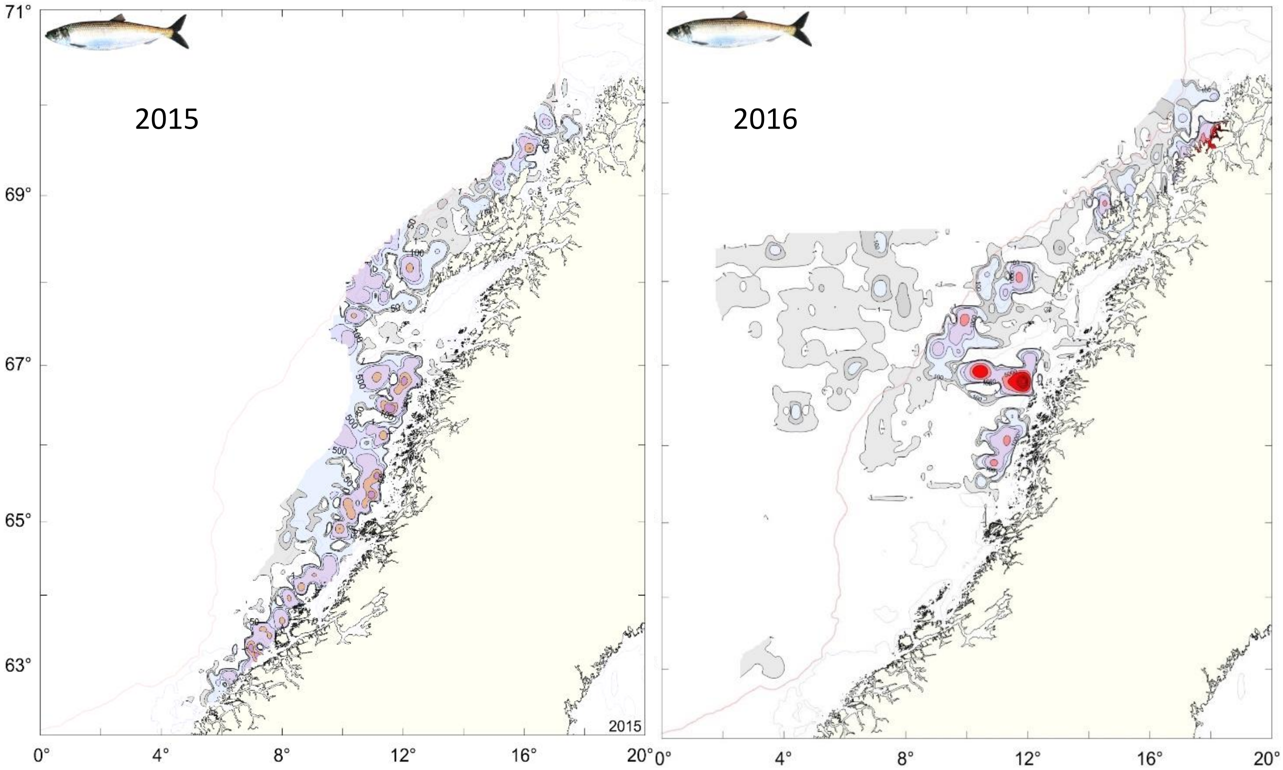

Figure 3. Distribution and acoustic density of herring recorded during 2-14.February 2015 and 2016.

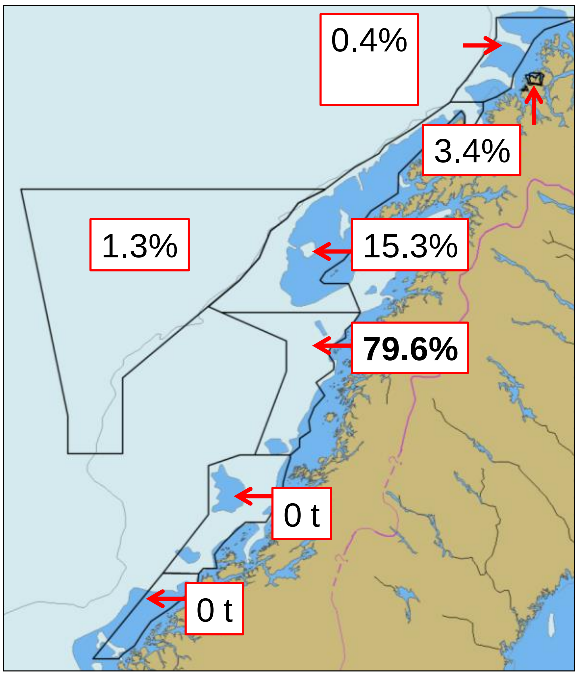

Figure 4. Percent of biomass 4.3 mill t by the different strata surveyed.

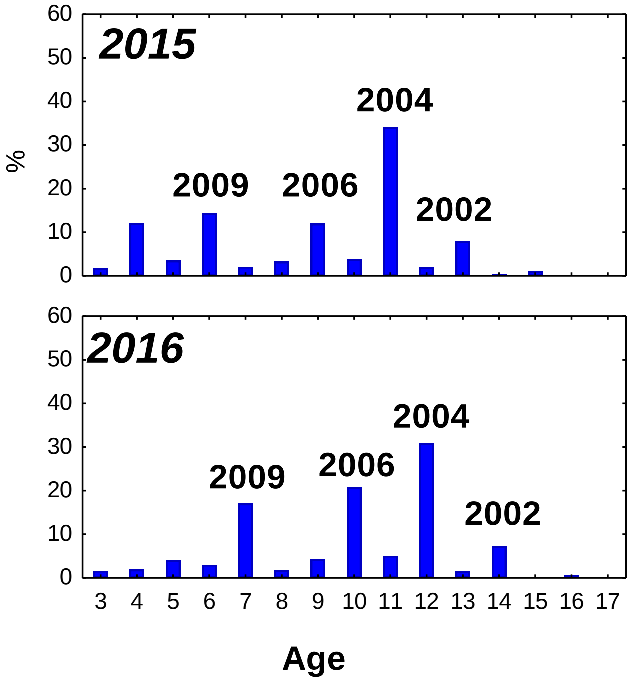

Figure 5. Comparison of relative year class composition between survey during the spawning season 2015 and 2016.

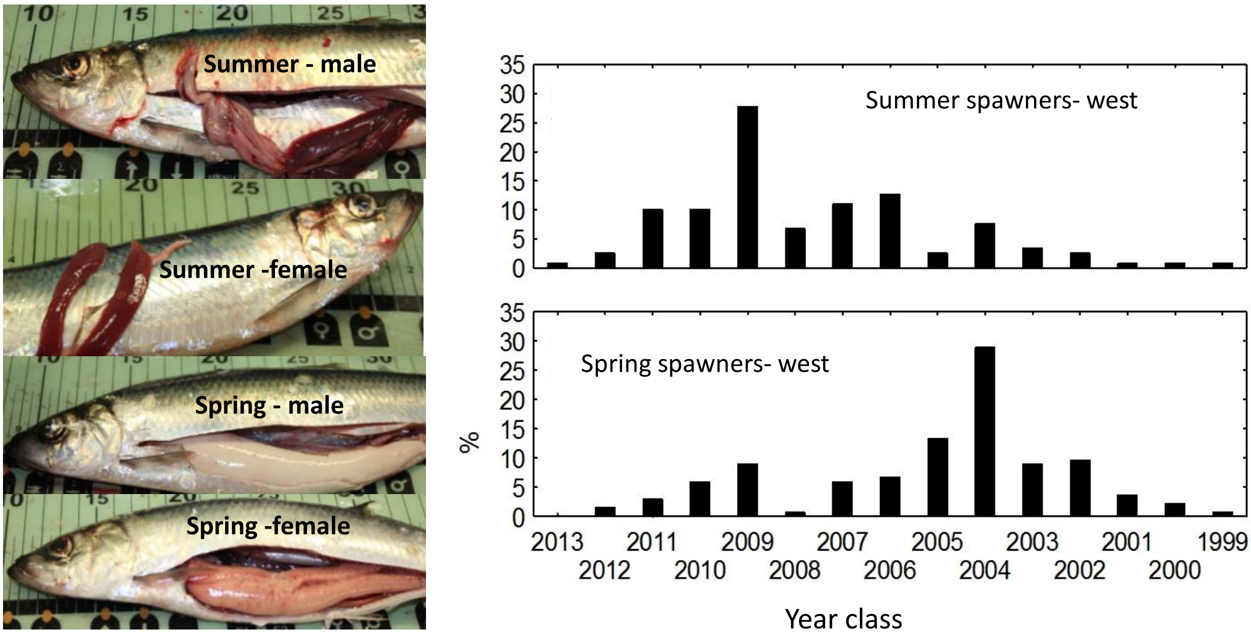

Figure 6. Comparison of relative year class composition between summer and spring spawners in the western area during the spawning season 2016.

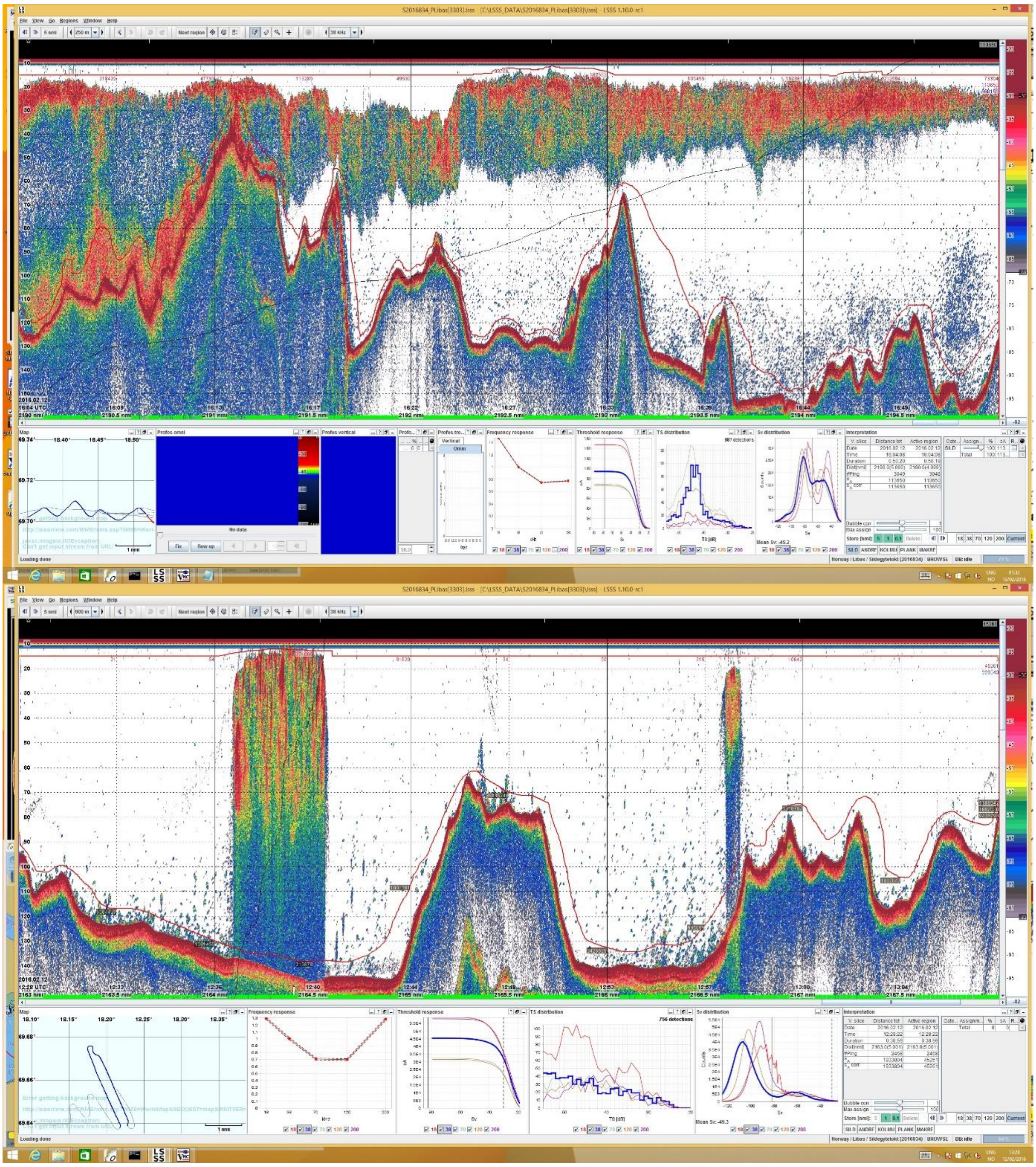

Figure 7. Examples of dense herring registrations in thw wintering areas (Ersfjorden upper and Kattfjorden bottom) during the spawning survey 2016.

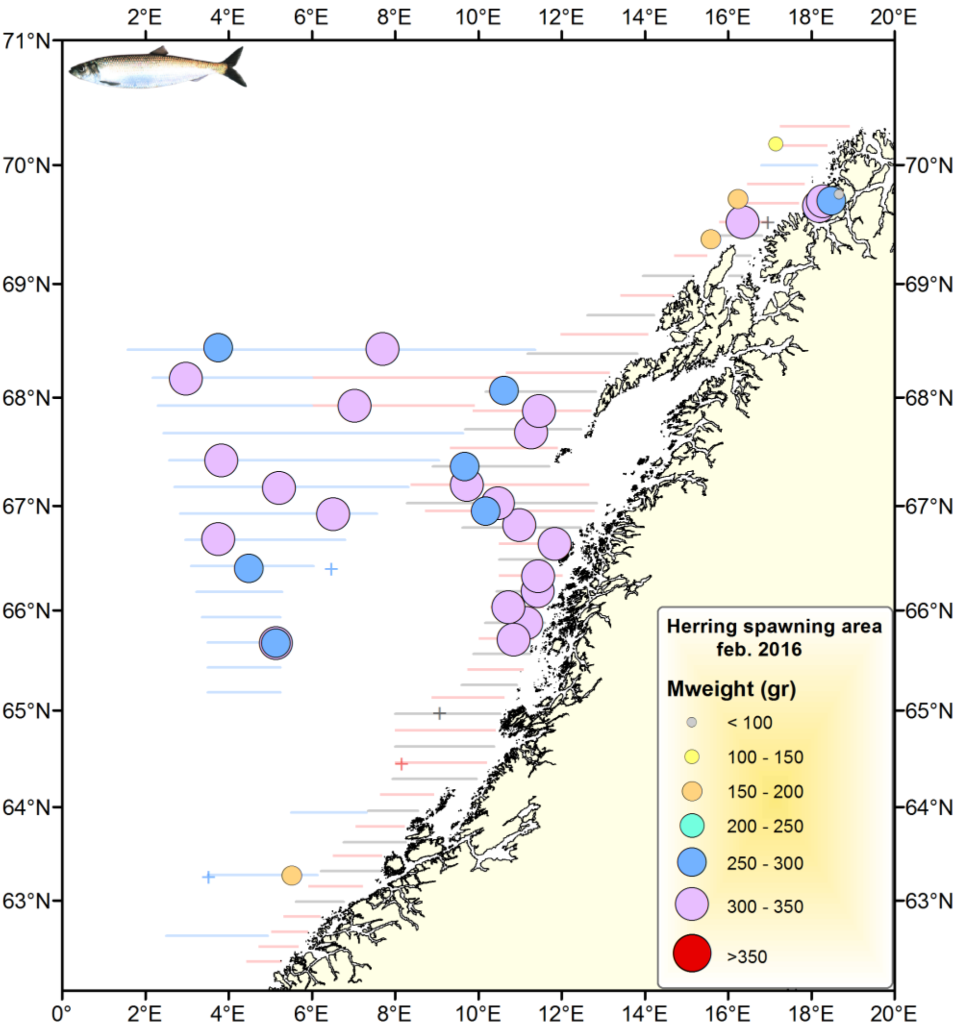

Figure 8. Spatial differences in mean herring weight (g) in the survey during the spawning season 2016.

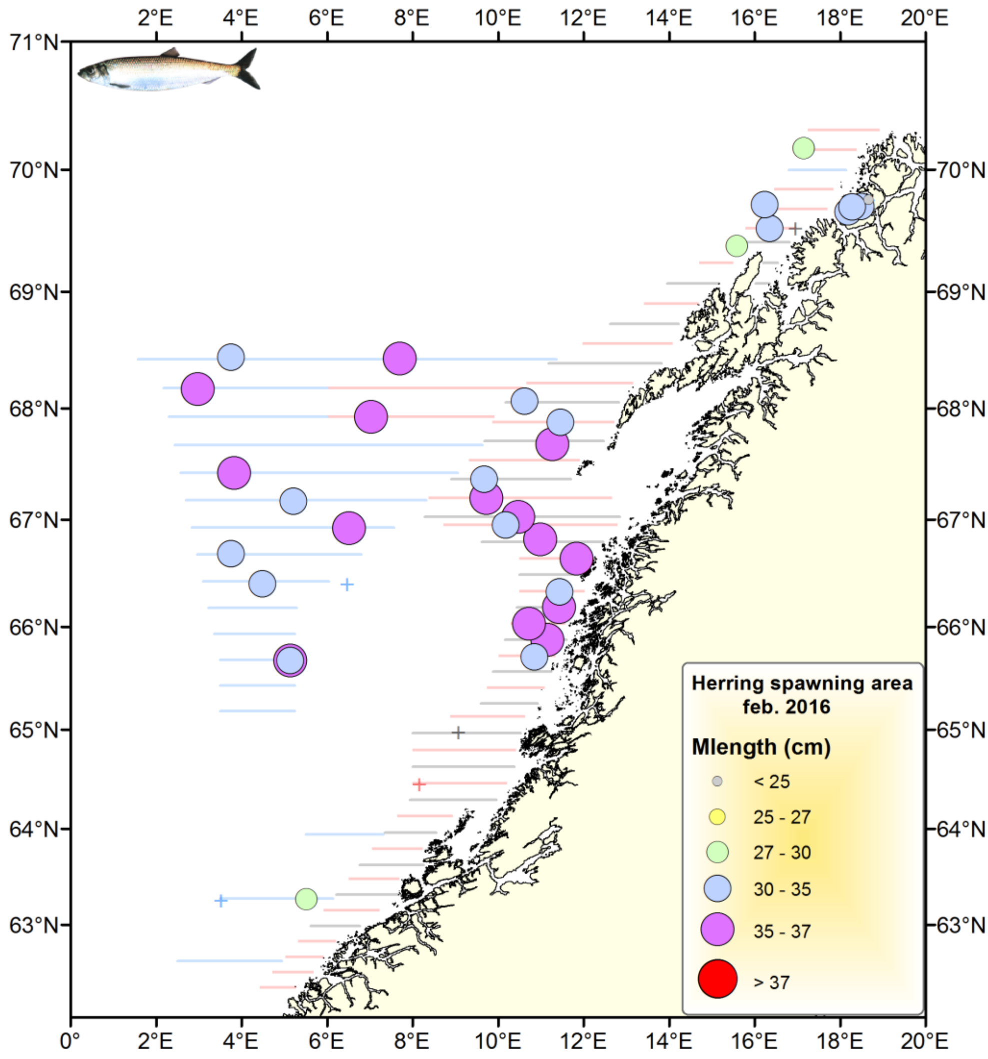

Figure 9. Spatial differences in mean herring body length (cm) in the survey during the spawning season 2016.

Annex 1. Sonar investigations

Sonar investigations during the acoustic evaluation of the spawning stock of Norwegian spring spawning (NSS) herring

Héctor Peña, Sindre Vatnehol and Arne Johannes Holmin

Introduction

Omnidirectional fisheries sonars (namely "sonars") have been used for scientific purposes at the Institute of Marine Research (IMR) for several years. This instrument has the potential to investigate fish close to the sea surface, school patchiness during systematic surveying and to evaluate single school biomass during purse seining. Although the information derived from sonar data is valuable, no standard methodology has been established for biomass estimation during surveying, as exists for the echosounder echo integration method (Simmonds and MacLennan, 2002).

In spring 2016, fisheries sonars were utilized on all three fishing vessels used to carry out a survey of NSS herring ("Vendla", "M. Ytterstad" and "Libas"), with the aim of complementing the echosounder estimation. “Vendla” was surveyed offshore strata, while the two other vessels surveyed the coastal strata (map with strata in main report).

The sonar survey objectives were:

1. To evaluate the presence of NSS herring in echosounder blind zone in the coastal strata
2. To evaluate NSS herring migrating from the offshore strata towards the coastal strata
3. To investigate the migration speed and direction of herring schools in all strata

Due to limited time for acoustic data analysis, only the analysis and results from the data collected in the offshore strata are included here. Sonar data from the coastal strata will be reported on at a later stage and a new version of this report produced.

Methods

The low frequency sonars on all three vessels were prepared for data acquisition at the beginning of the survey (2 February 2016, Ålesund). The sonar models were a Simrad SX93, a Simrad SX90, and a Simrad SU90 on "Vendla", "Libas" and "M. Ytterstad", respectively.

Raw sonar data were stored continuously. The sonar was operated with a near-horizontal and a vertical cross-section beam, alternating at a frequency of about 1 Hz. The vertical cross-section was orientated perpendicular to the vessel heading. Several hours of sonar data were lost on “Vendla” due to a sonar malfunction. This loss was taken into consideration in the subsequent analysis and results.

Calibration of the sonars was not prioritized during the survey preparations due to the focus on calibrating the echosounders. A post-survey calibration of the sonar systems can be conducted if deemed necessary.

When monitoring herring migration in offshore transects, the sonar onboard "Vendla" used an FM signal with a centre frequency of 26 kHz, 3000 m detection range and a beam tilt angle of 3 degree below horizontal. The pulse duration with this configuration is 85 ms, corresponding to a pulse length of 127 m at a sound speed of 1490 ms^{-1}. The width of the beams at a range of 2000 m is 280 m.

All sonar data from "Vendla" were scrutinized onboard, using the Profos (Processing system for omnidirectional fisheries sonar) module in the LSSS post-processing software. This was used to extract the total number of schools observed. An automatic school detection algorithm was used, where the parameters used for the school-segmentation were optimized for this particular survey. The quality of the segmentation was manually evaluated, and adjustments made if necessary. The maximum range for school segmentation was set to 2000 m. Beyond this range, the background noise level was too high for reliable school detection.

A combined analysis of the echosounder and sonar was done for the data collected by "Vendla". Echosounder schools were sorted by depth from the surface to 400 m, being the same depth used in the sonar analysis. The ratio between the numbers of schools detected by each system was estimated.

To investigate possible echosounder bias due to school avoidance, school patchiness, or schools located in the echosounder blind zone, a theoretical ratio between the detection probability of a 100 m length school in the sonar and the echosounder was computed. The sampling volume of the sonar and echosounder used in the theoretical computations correspond to the volume covered by the sonar and echosounder beams during the survey.

A simple model for computing the total biomass (TBM) using the sonar is proposed, where

$$TBM = \bar{M}_{school} \cdot K_{school} \cdot \frac{A_{survey}}{A_{transect}}$$

$\bar{M}_{school}$ is the mean biomass of a single school, K_{school} is the number of schools registered on the sonar, A_{survey} is the total area of the survey and $A_{transect}$ is the area sampled by the sonar. $A_{transect}$ was compensated for the loss of data due to the sonar malfunction on “Vendla”. Since the sonar was set to a “search mode”, and not calibrated, an accurate sonar estimate of school volume and density and consequent single school biomass was not possible. As an alternative approach, the density and the volume of a several selected schools were measured using the echosounder, and the school biomass computed. The school selection criteria were those selected for trawling (with low vessel speed) in areas with several schools, and for which the school structure was considered to be undisturbed (Figure 1). When computing the biomass of a single school, the number of fish within the school was estimated using

$$N_{fish} = \frac{s_A}{\sigma_{bs}} \cdot \left(\frac{L}{1852}\right)^2$$

where S_A is the area backscattering coefficient, σ_{bs} is the backscattering cross-section and L is the measured length of the school. Both S_A and L were measured using the echosounder. The biomass of a single school is then

$$M_{school} = \overline{w}_i N_{fish}$$

where the $\overline{w}_i$ is the mean weight of individual fish. The weight was estimated from several trawl catches. The fish density within the single school is then estimated from

$$\rho = \frac{N_{fish}}{V}.$$

For simplicity, the school shape is assumed to be cylindrical, where

$$V = \pi \left(\frac{L}{2}\right)^2 H$$

and H is the height measured with the echosounder.

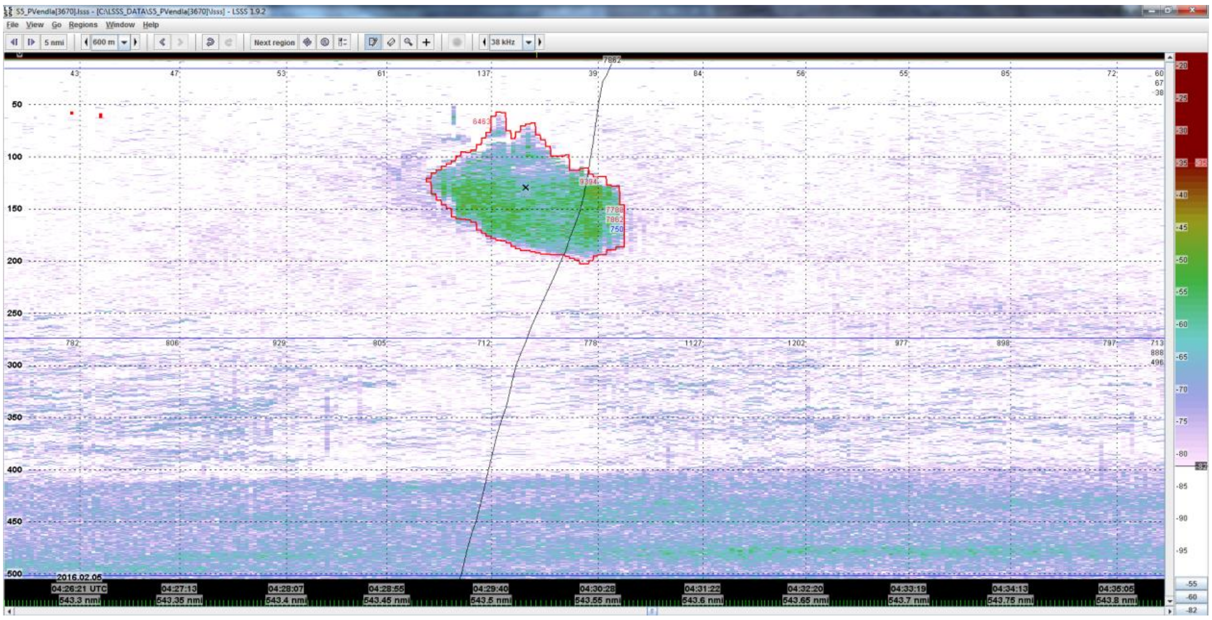

Figure 1. An echogram showing a single herring school. Similar schools were individually scrutinized and the length, height, density and number of fish estimated. The length of this example school was 181 m, the height was 114 m and the mean Sv was -57.2 dB.

Results

Herring schools were observed on the sonar as isolated echoes at ranges of up to 2000 m. When transmitting a horizontal fan of beams, the background noise level was sufficiently low within this range. In the vertical beams, schools were also recognised as isolated targets when the depth of the school was less than 400 m (Figure 2). Below this depth, a layer of blue whiting made it difficult to identify herring schools.

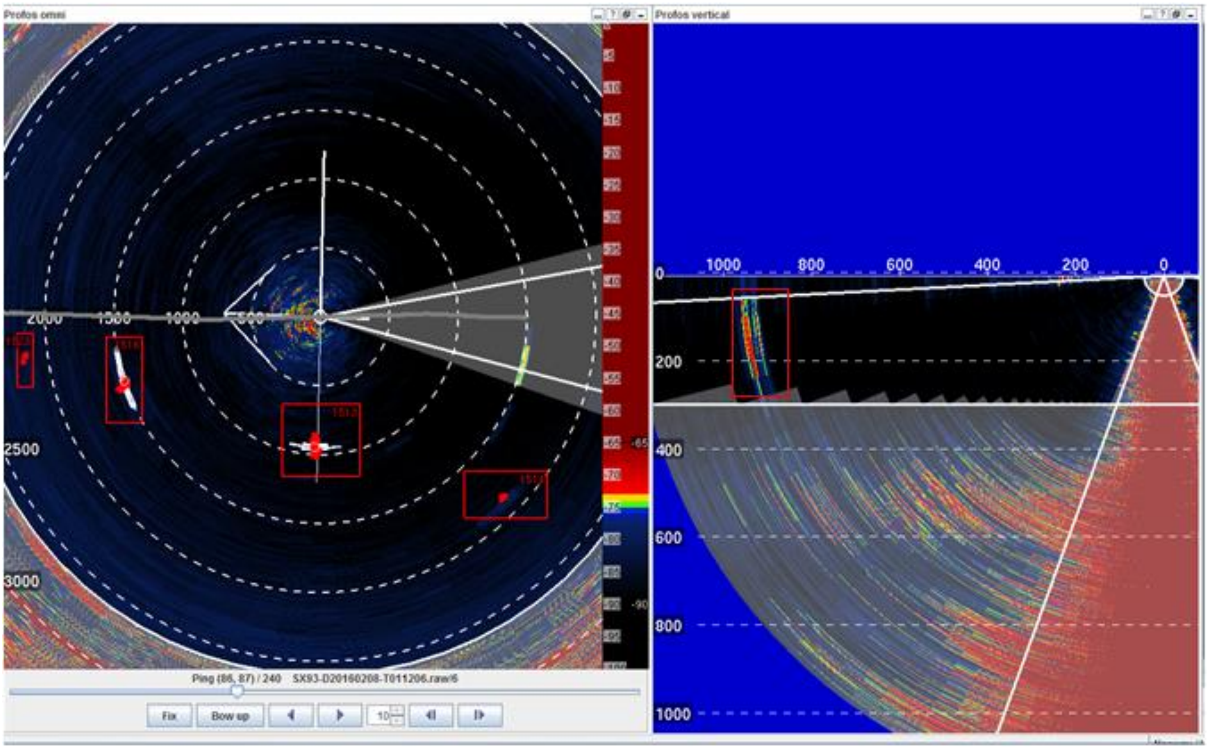

Figure 2. Sonar images of herring schools. Left panel: detected schools in the horizontal beams displayed with a white overlay and surrounded by a red square. Right panel: one school detected in the vertical beams. The same school was observed in the horizontal beams at a range of 1000 m on the port side of the vessel.

Although the sonar on “Vendla” was not calibrated, the mean volume backscattering coefficient (Sv) of the schools were between -80 and -70 dB. For comparison, outside this strata, and closer to the coast, the largest school measured by Vendla had an Sv between -60 and -50 dB. This relative difference indicates schools in the offshore strata were less dense than in the coastal area.

Schools along the vessel track were sampled both by sonar operating horizontally at long range, and later sampled with the echosounder (Figure 3). Schools were observed at depths between 150 to 400 m (Figure 4). During night the schools were mostly observed between 150 - 250 m.

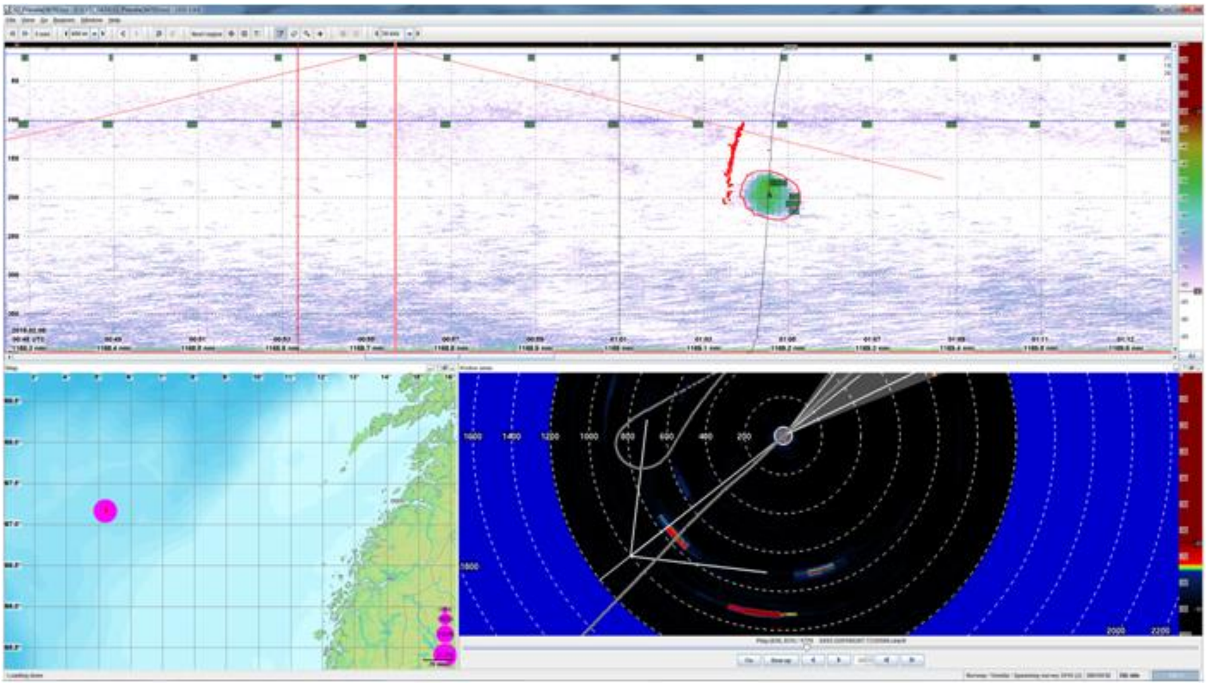

Figure 3. An echogram (upper panel) and sonar image (lower right panel) showing a herring school. The geographical location is shown in the lower left panel. The school was first detected by the sonar at 800 m, and later crossed by the vessel and measured with the echosounder.

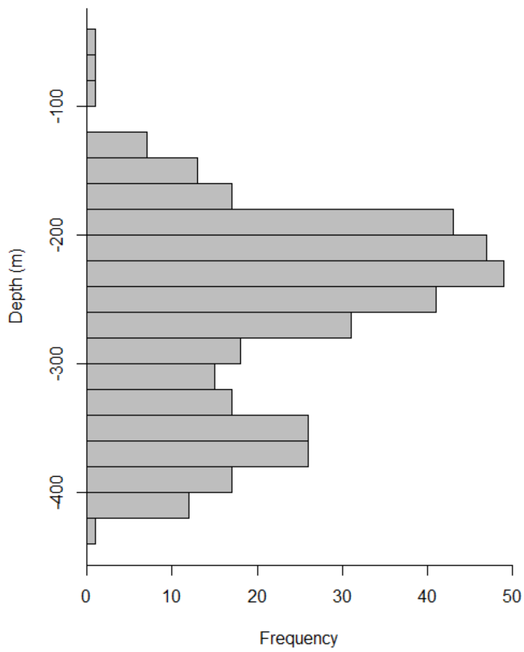

Figure 4. Depth of school observed with vertical sonar beams

The spatial distribution of the herring schools agreed well between the sonar and the echosounders along the survey transects. In most areas where schools were detected with sonar, schools were also detected with the echosounder (Figure 5).

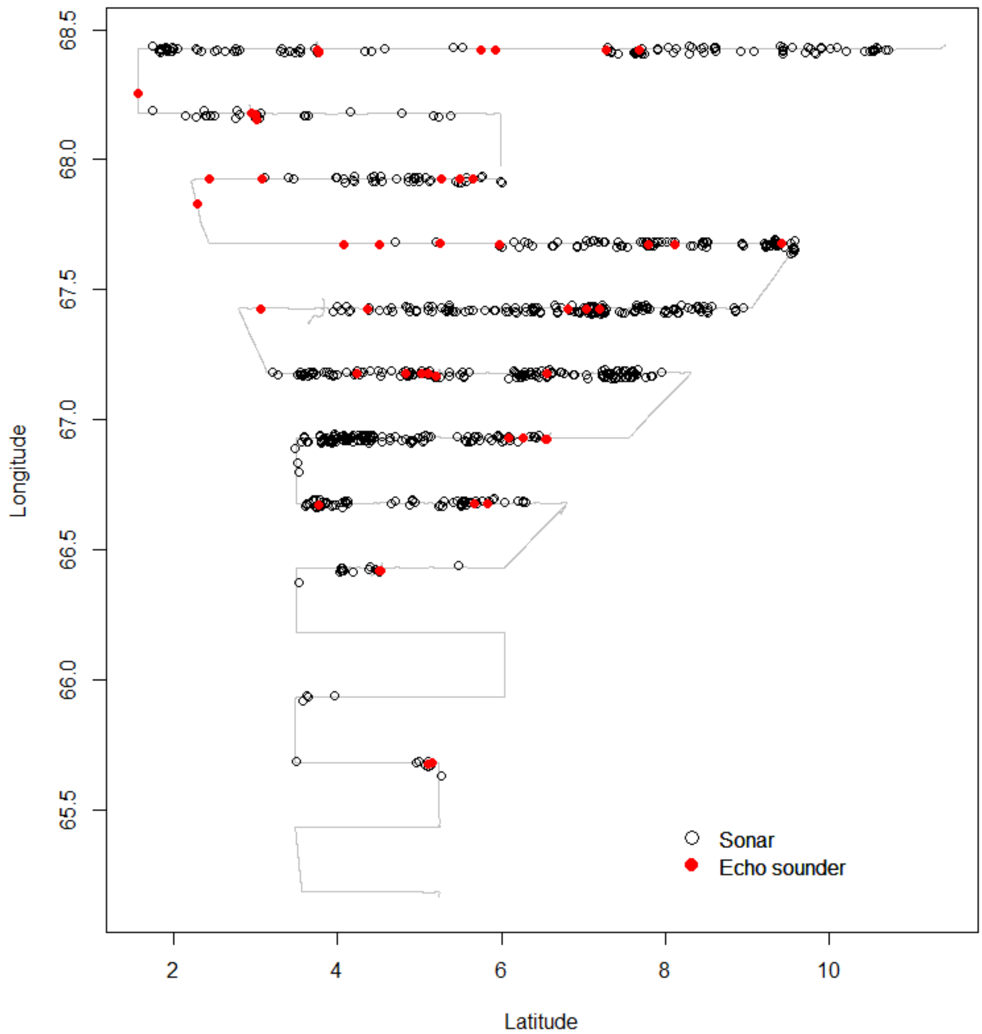

Figure 5. Spatial distribution of herring schools detected by sonar (open black circles) and echosounder (solid red circles), from the surface to 400 m depth.

Schools shallower than 400 m depth were scrutinized, both in the horizontal and vertical sonar cross-sections. A total of 825 schools were observed on the sonar; 442 in the horizontal cross-section, and 383 in the vertical. Schools observed in both the horizontal and vertical beams were only counted in one of the beams. In the echosounder, 46 schools shallower than 400 m depth were observed. The ratio between the observed schools in the sonar and echosounder was hence 17.9. The theoretical expected ratio computed for the sonar and echosounder settings in normal operation during the survey was 19.8. The close agreement between these two values indicates that the number of schools detected by the echosounder is consistent with the number observed by the sonar, with no bias caused either by fish avoidance or fish located in the echosounder blind zone.

A total of 26 schools were selected from the echosounder data for the biomass estimation. The mean school size was estimated to be have a length of 103.0 m (s. d. = 32.5), height of 49.7 m (s. d. = 19.8), density of 0.1 fish/m^3 (s. d. = 0.1) and a mean nautical area backscattering coefficient, S_A, of 10233.2 m^2 nmi^{-2} (s. d. = 7458.5). The mean school biomass of the selected schools was 10.3 ton.

The total area sampled by the sonar was estimated to be 3126 nmi^2. The density of schools was 0.26 schools per nmi^2. The total area of the offshore strata was 21 789 nmi^2. Using the mean school biomass and estimated spatial school density, the estimated biomass in the offshore survey area is 59 200 t.

Visual evaluation of the sonar survey data, in both the coastal and offshore strata, found no schools in the echosounder blind zone, from surface to 50 m.

Summary

- The sonars operation was optimized for school detection of up to 2000 m.
- The large sonar sampling volume does not allow for accurate school volume estimates.
- The uncalibrated sonar does not allow for accurate school density estimates.
- Schools shallower than 400 m depth were detected in both the horizontal and vertical beams.
- A total of 825 schools were detected by sonar along the transects in the offshore strata.
- The ratio between the sonar and echosounder school counts was 17.9. The theoretical ratio, based on sampling volume, was 19.8.
- The schools had a mean length of 103 m and a mean density of 0.1 fish per m^3.
- Mean school biomass from selected echosounder registrations was 10 t.
- The density of schools was 0.26 schools per nmi^2.
- Total NSS herring biomass estimate for the offshore strata was 59 200 t.
- In both the coastal and the offshore strata, no schools were observed in the echosounder blind zone, from surface to 50 m.

References

Simmonds, E. J., and MacLennan, D. N. 2005. Fisheries Acoustics, 2nd edn. Blackwell Science, Oxford, UK. 437 pp.

Annex 2. Index of abundance estimates and biomass by strata

Variable: Abundance
EstLayer: 1
Stratum: 3
SpecCat: SILDG03

LenGrp	age 3	4	5	6	7	8	9	10	11	12	13	14	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
28-29	13028	26056	-	-	-	-	-	-	-	-	-	-	-	39084	6253.4	160.00
29-30	39084	26056	-	-	-	-	-	-	-	-	-	-	-	65140	11438.5	175.60
30-31	-	52112	39084	-	-	-	-	-	-	-	-	-	-	91195	18616.9	204.14
31-32	52112	26056	13028	-	-	-	-	-	-	-	-	-	-	91195	20623.2	226.14
32-33	-	-	65140	26056	169363	-	-	-	-	-	-	-	-	260558	69973.0	268.55
33-34	-	-	39084	91195	521117	78168	-	26056	39084	26056	-	-	-	820759	240130.7	292.57
34-35	-	-	-	91195	977094	-	104223	651396	39084	390838	-	182391	-	2436222	775083.2	318.15
35-36	-	-	-	78168	325698	104223	325698	1016178	260558	1198569	26056	221475	-	3556623	1206555.0	339.24
36-37	-	-	-	-	26056	-	13028	573229	91195	1237653	78168	169363	26056	2214747	784098.5	354.04
37-38	-	-	-	-	-	-	-	156335	-	455977	13028	143307	-	768647	286783.7	373.10
38-39	-	-	-	-	-	-	-	-	-	13028	-	13028	39084	65140	26720.3	410.20
39-40	-	-	-	-	-	-	-	-	-	-	-	13028	-	13028	5758.3	442.00
TSN(1000)	104223	130279	156335	286614	2019328	182391	442949	2423194	429921	3322120	117251	742592	65140	10422338	-	-
TSB(1000 kg)	21170.4	24401.3	39214.0	87990.6	623216.7	57127.4	149234.9	826478.4	141522.3	1156332.3	43200.6	256741.3	25404.4	-	3452034.7	-
Mean length (cm)	30.13	29.65	31.96	34.09	34.03	34.36	35.03	35.31	35.15	35.70	36.22	35.74	37.40	-	-	-
Mean weight (g)	203.13	187.30	250.83	307.00	308.63	313.21	336.91	341.07	329.18	348.07	368.44	345.74	390.00	-	-	331.21

Variable: Abundance
EstLayer: 1
Stratum: 4
SpecCat: SILDG03

LenGrp	age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	5342	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5342	154.9	29.00
21-22	5342	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5342	299.2	56.00
22-23	-	11753	-	-	-	-	-	-	-	-	-	-	-	-	-	11753	767.9	65.33
23-24	-	18164	-	-	-	-	-	-	-	-	-	-	-	-	-	18164	1424.1	78.40
24-25	-	3740	11219	-	-	-	-	-	-	-	-	-	-	-	-	14959	1323.8	88.50
25-26	-	19233	15386	3847	-	-	-	-	-	-	-	-	-	-	-	38465	3838.8	99.80
26-27	-	15153	18941	7576	-	-	-	-	-	-	-	-	-	-	-	41671	4996.7	119.91
27-28	-	7576	7576	26518	-	-	-	-	-	-	-	-	-	-	-	41671	5602.8	134.45
28-29	-	-	14195	85173	-	-	-	-	-	-	-	-	-	-	-	99368	15241.2	153.38
29-30	-	-	17321	64952	-	-	-	-	-	-	-	-	-	-	-	82273	14272.2	173.47
30-31	-	-	-	46355	3863	-	-	-	-	-	-	-	-	-	-	50218	10024.4	199.62
31-32	-	-	-	17970	7188	14376	-	-	-	-	-	-	-	-	-	39534	9146.6	231.36
32-33	-	-	-	21980	7327	14653	7327	-	-	-	-	-	-	-	-	51287	12682.5	247.29
33-34	-	-	-	3335	36684	53359	-	6670	-	-	10005	-	-	-	-	110053	32005.5	290.82
34-35	-	-	-	12906	12906	61305	-	3227	32266	80665	106477	16133	-	-	-	325885	101698.9	312.07
35-36	-	-	-	-	16232	9739	25971	87651	211011	48695	223997	12985	42202	-	-	678483	223753.3	329.78
36-37	-	-	-	-	-	9708	-	-	51775	42067	220045	6472	122966	-	-	453034	159286.8	351.60
37-38	-	-	-	-	-	-	9895	-	-	23088	82459	6597	16492	13193	-	151724	55755.2	367.48
38-39	-	-	-	-	-	-	-	-	-	-	-	-	3740	-	11219	14959	5833.9	390.00
39-40	-	-	-	-	-	-	-	-	-	-	-	6411	-	-	3205	9616	4199.1	436.67
TSN(1000)	10685	75619	84639	290612	84200	163140	43192	97547	295053	194516	642983	48598	185400	13193	14424	2243802	-	-
TSB(1000 kg)	454.1	7353.7	10665.8	53085.9	24026.4	48175.1	13738.9	32149.7	98141.8	64390.2	217850.2	16799.5	64599.3	4931.0	5946.1	-	662307.7	-
Mean length (cm)	19.75	24.65	26.80	29.41	33.38	33.69	35.10	35.03	35.34	35.31	35.62	35.80	36.08	37.13	38.35	-	-	-
Mean weight (g)	42.50	97.25	126.02	182.67	285.35	295.30	318.09	329.58	332.62	331.03	338.81	345.68	348.43	373.75	412.22	-	-	295.17

Variable: Abundance
EstLayer: 1
Stratum: 5
SpecCat: SILDG03

LenGrp	age 3	4	5	6	7	8	9	10	11	12	13	14	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	593	-	-	-	-	-	-	-	-	-	-	-	-	593	29.0	49.00
22-23	296	-	-	-	-	-	-	-	-	-	-	-	-	296	19.6	66.00
23-24	889	-	-	-	-	-	-	-	-	-	-	-	-	889	70.8	79.67
24-25	593	296	-	-	-	-	-	-	-	-	-	-	-	889	76.5	86.00
25-26	1186	1482	-	-	-	-	-	-	-	-	-	-	-	2668	262.6	98.44
26-27	1482	2668	-	-	-	-	-	-	-	-	-	-	-	4150	460.3	110.93
27-28	-	2668	3853	-	-	-	-	-	-	-	-	-	-	6521	862.0	132.18
28-29	-	2371	8003	-	-	-	-	-	-	-	-	-	-	10375	1558.6	150.23
29-30	-	1186	16303	296	-	-	-	-	-	-	-	-	-	17785	3021.7	169.90
30-31	-	-	5039	593	-	-	-	-	-	-	-	-	-	5632	1063.3	188.79
31-32	-	-	889	889	2075	-	-	-	-	-	-	-	-	3853	814.9	211.46
32-33	-	-	-	296	1186	-	-	-	-	-	-	-	-	1482	351.0	236.80
33-34	-	-	-	593	889	-	-	-	-	2371	-	-	-	3853	1160.2	301.08
34-35	-	-	-	-	889	-	-	889	1186	5632	889	-	-	9486	3022.0	318.59
35-36	-	-	-	-	296	593	296	3557	1482	3261	-	2371	-	11857	4031.4	340.00
36-37	-	-	-	-	-	-	-	2668	-	3557	-	593	-	6818	2430.1	356.43
37-38	-	-	-	-	-	-	-	-	-	593	-	-	889	1482	573.3	386.80
38-39	-	-	-	-	-	-	-	-	-	296	-	-	-	296	102.9	347.00
TSN(1000)	5039	10671	34089	2668	5336	593	296	7114	2668	15710	889	2964	889	88927	-	-
TSB(1000 kg)	455.9	1376.6	5596.2	590.2	1377.5	208.7	90.7	2444.3	869.7	5262.4	286.6	1001.9	349.5	-	19910.1	-
Mean length (cm)	24.29	27.04	28.95	31.22	32.47	35.25	35.00	35.44	34.72	34.97	34.50	35.35	37.33	-	-	-
Mean weight (g)	90.47	129.00	164.17	221.22	258.17	352.00	306.00	343.58	326.00	334.96	322.33	338.00	393.00	-	-	223.89

Variable: Abundance
EstLayer: 1
Stratum: 6
SpecCat: SILDG03

LenGrp	age 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Number (1E3)	Biomass (1E3kg)	Mean W (g)
28-29	-	1006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1006	182.0	181.00
29-30	-	1796	-	257	-	-	-	-	-	-	-	-	-	-	-	-	2053	377.0	183.62
30-31	226	1353	2255	451	226	-	-	-	-	-	-	-	-	-	-	-	4510	962.7	213.45
31-32	230	689	2526	919	689	-	-	-	-	459	-	-	-	-	-	-	5511	1299.5	235.79
32-33	-	652	1739	3043	652	652	-	-	-	-	-	652	-	-	-	-	7389	1882.3	254.74
33-34	-	-	2578	3173	5553	-	198	-	-	595	-	-	-	-	-	-	12098	3350.9	276.98
34-35	-	-	1655	2069	6827	3310	1034	2896	2276	2482	-	-	-	-	-	414	22962	6978.4	303.91
35-36	-	-	-	613	11245	1636	5929	4294	6543	5520	818	1022	204	409	-	-	38234	12471.5	326.19
36-37	-	-	-	-	1819	682	5002	5684	6366	13869	7048	5002	455	455	227	-	46609	16208.0	347.75
37-38	-	-	-	443	221	-	1992	5089	3319	5311	6638	2655	1328	443	1106	-	28545	10275.6	359.98
38-39	-	-	-	-	-	-	-	185	185	741	1482	185	741	1112	556	-	5189	2053.2	395.71
39-40	-	-	-	-	-	-	-	-	-	-	-	-	-	249	-	-	249	97.5	391.00
41-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	186	-	186	81.7	440.00
TSN(1000)	455	5496	10753	10967	27231	6280	14155	18148	18689	28978	15987	9517	2728	2667	2075	414	174540	-	-
TSB(1000 kg)	100.5	1114.7	2695.6	2996.4	8258.5	1897.0	4714.3	6088.8	6432.4	10032.4	5726.8	3300.8	1027.7	973.2	734.8	126.4	-	56220.3	-
Mean length (cm)	30.50	29.89	32.14	33.09	34.43	34.57	35.76	35.90	35.76	35.90	36.73	36.06	37.23	37.36	37.61	34.25	-	-	-
Mean weight (g)	220.89	202.83	250.69	273.23	303.27	302.10	333.04	335.50	344.19	346.21	358.22	346.83	376.71	364.84	354.06	305.50	-	-	322.10

Variable: Abundance
EstLayer: 7
Stratum: 14
SpecCat: SILDG03

LenGrp	age 3	4	5	6	7	8	9	10	11	12	14	Number (1E3)	Biomass (1E3kg)	Mean W (g)
22-23	877	-	-	-	-	-	-	-	-	-	-	877	64.9	74.00
25-26	877	1754	-	-	-	-	-	-	-	-	-	2631	275.3	104.67
26-27	877	-	-	-	-	-	-	-	-	-	-	877	104.3	119.00
27-28	877	-	-	-	-	-	-	-	-	-	-	877	101.7	116.00
29-30	-	-	877	-	-	-	-	-	-	-	-	877	170.1	194.00
30-31	-	-	1754	877	-	-	-	-	-	-	-	2631	509.5	193.67
31-32	-	-	2631	-	-	-	-	-	-	-	-	2631	627.8	238.67
32-33	-	-	1754	-	1754	-	-	-	-	-	-	3507	950.5	271.00
33-34	-	-	877	-	5261	-	-	877	-	877	-	7892	2329.8	295.22
34-35	-	-	-	877	7892	-	877	7015	2631	2631	-	21921	6907.8	315.12
35-36	-	-	-	-	1754	877	3507	7015	1754	8769	1754	25429	8548.4	336.17
36-37	-	-	-	-	-	-	-	877	877	6138	3507	11399	4123.0	361.69
37-38	-	-	-	-	-	-	877	877	1754	1754	877	6138	2232.5	363.71
TSN(1000)	3507	1754	7892	1754	16660	877	5261	16660	7015	20168	6138	87685	-	-
TSB(1000 kg)	363.0	183.3	1900.1	444.6	5077.8	311.3	1821.2	5488.2	2367.5	6839.4	2149.2	-	26945.6	-
Mean length (cm)	25.00	25.25	31.22	32.25	33.89	35.50	35.33	34.82	35.50	35.46	35.93	-	-	-
Mean weight (g)	103.50	104.50	240.78	253.50	304.79	355.00	346.17	329.42	337.50	339.13	350.14	-	-	307.30

Variable: Abundance
EstLayer: 1
Stratum: 8
SpecCat: SILDG03

LenGrp	age 3	4	5	6	7	8	9	10	11	12	13	14	17	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	1681	-	-	-	-	-	-	-	-	-	-	-	-	1681	87.4	52.00
24-25	1681	1681	-	-	-	-	-	-	-	-	-	-	-	3362	299.2	89.00
25-26	8405	-	-	-	-	-	-	-	-	-	-	-	-	8405	896.0	106.60
26-27	11767	-	-	-	-	-	-	-	-	-	-	-	-	11767	1408.7	119.71
27-28	-	5043	3362	-	-	-	-	-	-	-	-	-	-	8405	1223.8	145.60
28-29	-	5043	1681	-	-	-	-	-	-	-	-	-	-	6724	1096.0	163.00
29-30	-	5043	3362	-	-	-	-	-	-	-	-	-	-	8405	1551.6	184.60
30-31	-	-	5043	-	-	-	-	-	-	-	-	-	-	5043	1028.8	204.00
31-32	-	-	11767	-	-	-	-	-	-	-	-	-	-	11767	2839.3	241.29
32-33	-	-	1681	11767	5043	-	-	-	-	-	-	-	-	18491	5001.1	270.45
33-34	-	-	3362	3362	21854	-	-	-	-	5043	-	-	-	33621	9637.4	286.65
34-35	-	-	1681	-	16810	-	-	8405	11767	21854	3362	-	-	63880	20259.9	317.16
35-36	-	-	-	-	1681	8405	6724	3362	11767	50431	-	8405	-	90776	30791.6	339.20
36-37	-	-	-	-	-	-	-	11767	-	15129	8405	11767	1681	48750	17324.8	355.38
37-38	-	-	-	-	-	-	-	1681	-	1681	-	10086	1681	15129	5567.6	368.00
TSN(1000)	23535	16810	31940	15129	45388	8405	6724	25216	23535	94138	11767	30259	3362	336208	-	-
TSB(1000 kg)	2535.0	2630.8	7089.0	4079.9	13740.8	2682.9	2267.7	8632.2	7813.5	31395.1	4021.1	10852.8	1272.5	-	99013.4	-
Mean length (cm)	25.29	27.80	30.68	32.50	33.70	35.30	35.13	35.47	34.71	35.07	35.57	36.17	36.75	-	-	-
Mean weight (g)	107.71	156.50	221.95	269.67	302.74	319.20	337.25	342.33	332.00	333.50	341.71	358.67	378.50	-	-	294.50

Variable: Abundance
EstLayer: 1
Stratum: 9
SpecCat: SILDG03

LenGrp	age 3	4	5	6	7	8	9	10	11	12	13	14	17	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	366	-	-	-	-	-	-	-	-	-	-	-	-	366	19.0	52.00
24-25	366	366	-	-	-	-	-	-	-	-	-	-	-	731	65.1	89.00
25-26	1829	-	-	-	-	-	-	-	-	-	-	-	-	1829	194.9	106.60
26-27	2560	-	-	-	-	-	-	-	-	-	-	-	-	2560	306.5	119.71
27-28	-	1097	731	-	-	-	-	-	-	-	-	-	-	1829	266.3	145.60
28-29	-	1097	366	-	-	-	-	-	-	-	-	-	-	1463	238.5	163.00
29-30	-	1097	731	-	-	-	-	-	-	-	-	-	-	1829	337.6	184.60
30-31	-	-	1097	-	-	-	-	-	-	-	-	-	-	1097	223.8	204.00
31-32	-	-	2560	-	-	-	-	-	-	-	-	-	-	2560	617.7	241.29
32-33	-	-	366	1829	1829	-	-	-	-	-	-	-	-	4023	1088.1	270.45
33-34	-	-	731	731	5120	-	-	-	-	731	-	-	-	7315	2096.8	286.65
34-35	-	-	731	-	3292	-	-	2194	2560	4389	731	-	-	13898	4407.9	317.16
35-36	-	-	-	-	1097	366	2194	1829	2194	11338	-	731	-	19750	6699.2	339.20
36-37	-	-	-	-	-	-	-	2194	-	3292	1829	1829	1463	10606	3769.3	355.38
37-38	-	-	-	-	-	-	-	366	-	366	-	2194	366	3292	1211.3	368.00
TSN(1000)	5120	3657	7315	2560	11338	366	2194	6583	4755	20116	2560	4755	1829	73147	-	-
TSB(1000 kg)	551.5	572.4	1655.3	688.0	3407.9	114.1	752.3	2220.8	1615.8	6714.6	872.6	1708.4	668.2	-	21541.9	-
Mean length (cm)	25.29	27.80	30.90	32.50	33.69	35.50	35.25	35.25	34.69	35.13	35.50	36.42	36.30	-	-	-
Mean weight (g)	107.71	156.50	226.30	268.71	300.58	312.00	342.83	337.33	339.85	333.80	340.86	359.31	365.40	-	-	294.50

Variable: Abundance
EstLayer: 1
Stratum: 10
SpecCat: SILDG03

LenGrp	age 2	3	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
11-12	-	-	0	0	0.0	8.00
14-15	-	-	0	0	0.0	27.00
15-16	0	-	-	0	0.0	20.50
16-17	1	-	-	1	0.0	26.60
17-18	3	-	-	3	0.1	30.21
18-19	1	-	-	1	0.1	35.62
19-20	1	0	-	1	0.0	40.36
20-21	-	0	-	0	0.0	48.00
TSN(1000)	7	0	0	7	-	-
TSB(1000 kg)	0.2	0.0	0.0	-	0.2	-
Mean length (cm)	17.27	19.50	13.00	-	-	-
Mean weight (g)	31.15	41.50	17.50	-	-	31.08

Variable: Abundance
EstLayer: 1
Stratum: 11
SpecCat: SILDG03

LenGrp	age 2	3	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
11-12	-	-	65	65	0.5	8.00
14-15	-	-	65	65	1.8	27.00
15-16	390	-	-	390	8.0	20.50
16-17	1301	-	-	1301	34.6	26.60
17-18	2537	-	-	2537	76.6	30.21
18-19	1366	-	-	1366	48.7	35.62
19-20	651	65	-	716	28.9	40.36
20-21	-	65	-	65	3.1	48.00
TSN(1000)	6246	130	130	6506	-	-
TSB(1000 kg)	194.5	5.4	2.3	-	202.2	-
Mean length (cm)	17.27	19.50	13.00	-	-	-
Mean weight (g)	31.15	41.50	17.50	-	-	31.08