TESTING OF TRAWL-ACOUSTIC STOCK ESTIMATION OF SPAWNING CAPELIN 2022

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Summary (English):

This report describes the fourth in a series of trawl-acoustic monitoring surveys of the spawning stock of capelin during the migration to the coast. The survey is a response to a proposal from the industry to evaluate the possibility of using winter monitoring of maturing capelin as an input to the capelin assessment and advice. The timing and geographic coverage of the survey are such that the results would be relevant to use for advice given that the output is reliable. Pre-defined areas off the Troms and Finnmark coast were covered using two vessels, Vendla surveying the eastern part and Eros the western part. A stratified random transect design was originally adopted with two complementary zig-zag grids, the first going in a west-east and the second in an east-west direction over the same strata. However, the high capelin abundances north of Varangerhalvøya lead to changes in the design, and a new stratum with increased effort covering the area with high abundance. The biomass estimate we present is based on the second coverage, but evaluation of the mobility of the fish can be done by comparing the coverages. Echo sounders with frequencies from 18-333 kHz were run together with sonars, and target trawls were carried out on significant pelagic aggregations. Capelin abundance was estimated using 38 kHz data. The median biomass of maturing capelin in the coverage area based on 500 bootstrap runs was estimated at 426 618 tons, with a CV of 42%. The 5% lower and 95% upper confidence limits were 167 555 and 757 229 tons, respectively. The confidence bands overlap with the prediction from the autumn 2021, but the wide confidence interval shows that the survey result is uncertain. The high uncertainty despite the good survey coverage is likely due to the very patchy distribution. Capelin aggregations recorded north of Varanger in the eastern coverage area totally dominated in the estimate. Capelin concentrations were also observed in the west, in areas associated with Fugløybanken and Malangsgrunnen, but the capelin abundance in these areas seemed to decrease over the survey period. Capelin at age 3 dominated in the samples and were estimated to constitute more than 6 times the biomass of the other age groups combined. The 3-year-olds had an average length of 15.5 cm and weight 16.3 g. Maturation had progressed further in the western than the eastern area similar as last year, and quite a high proportion of the females sampled towards the end of the survey in the western area were spent. We undertook 7 stations with a submersible probe measuring acoustic target strength of capelin. Preliminary results indicate that the target strength and acoustic frequency response of capelin this year were more in accordance with expectations for capelin than last year. A thorough evaluation of this survey series and its usefulness as input to the capelin advice will be prepared for the capelin benchmark in June this year.

Summary (Norwegian):

Denne rapporten oppsummerer den fjerde i serien av trål-akustiske tokt som tester ut overvåkning av bestanden av modnende lodde under gytevandringa. Toktet er svar på et innspill fra næringa om å evaluere muligheten for å bruke resultat fra overvåkning av gytelodde inn mot bestandsrådgivninga. Tidspunktet for toktet og dekningsområdet er valgt slik at det ville vært relevant å bruke til rådgivning gitt at resultatet fra toktet var pålitelig. Et forhåndsbestemt område langs kysten av Troms og Finnmark ble dekket med de to fartøyene Vendla og Eros. Vendla dekket det østlige området og Eros det vestlige. Områdene ble dekket to ganger, og høye konsentrasjoner av lodde nord for Varangerhalvøya gjorde at dette området fikk høyere dekningsgrad ved andre dekning. Mengde-estimatet vi presenterer her er basert på den andre dekninga. Median biomasse av lodde ble beregnet til 426 618 tonn, med en usikkerhet beregnet til 42% (Variasjonskoeffisient). 5% og 95% konfidensgrensene ble beregnet til henholdsvis 167 555 og 757 229 tonn. Konfidensintervallet overlapper med prediksjonen fra høst-toktet i 2021, men det vide konfidensintervallet viser at toktresultatet er usikkert. Den høye usikkerheten til tross for den gode dekninga er sannsynligvis hovedsakelig et resultat av at lodda står svært flekkvis fordelt. Loddeforekomstene nord av Varanger-halvøya dominerte totalt i mengde. Men loddekonsentrasjoner ble også observert i vest, særlig i områdene rundt Fugløybanken og Malangsgrunnen. Men loddeforekomstene her så ut til å minke gjennom toktperioden og modningen hadde også kommet lenger i det vestlige enn det østlige området slik det også var i 2021. En ganske høy andel av hunn-lodda var utgytt mot slutten av toktet i det vestlige området. 3 år gammel lodde dominerte gyteinnsiget. Disse hadde en snittlengde på 15.5 cm og en snittvekt på 16.3 gram. Vi gjennomførte 7 stasjoner hvor vi foretok akustiske målstyrkemålinger på lodde med en nedsenkbar TS-probe. Foreløpige resultat indikerer at målstyrke og frekvensrespons hos lodda i år var mer i tråd med forventningene enn det vi observerte i fjor. I juni vil det være et

metoderevisjonsmøte for lodde i ICES-regi, og det blir da en grundig evaluering av dette toktet sammen med de foregående tre gytetoktene i tidsserien. Det vil da også bli evaluert hvorvidt og eventuelt hvordan det kan brukes i bestandsrådgivninga.

Content

1 - Introduction

In 2018, there was a proposal from the industry forwarded through FUR (‘Faglig Utvalg for Ressursforskning’; Joint science/industry association for resource investigations), that funding from the Fisheries Resource Tax (FFA) should be spent on a winter monitoring of the Barents Sea capelin spawning migration to evaluate whether such monitoring could be used to improve capelin assessment and quota advice.

The main spawning of the Barents Sea capelin takes place in the period from late February to early April mainly along the coast of northern Norway between Tromsø and Varangerfjord, but also along the Russian coast. If there is opening for a fishery, it takes place on maturing capelin off the spawning areas starting from late January. In the present assessment of the Barents Sea capelin stock, there is only one annual input to assess the biomass, and that is the estimate from the joint Russian/Norwegian Barents Sea monitoring in the autumn (ICES 2020). The quota advice is based on a forward projection of mature capelin biomass from the autumn survey the previous year to 1 April the present year, including associated uncertainty (Gjøsæter et al. 2002). Previous attempts have shown that winter monitoring of the capelin spawning migration is challenging (Ref: https://www.hi.no/resources/images/3_arig_rapport_gyteinnsig_lodde.pdf), both because the spawning region has a wide geographical extension and because the timing of the migration and hence availability to acoustic detection, is variable. Nevertheless, a reliable winter survey could potentially reduce uncertainty in the assessment of biomass of mature capelin and improve the advice. IMR therefore approved the proposal from the industry and took on to conduct a series of three winter monitoring surveys which were carried out from 2019 to 2021. Since the capelin fishery was closed in all these three years, the series was prolonged to include 2022 when the fishery again was open. The results from this fourth survey in the series is described in the current report.

2 - Objectives

The main objective of this effort is to conduct a series of surveys with a timing and a design such that it could potentially could have been used in an advice process. The surveys will form the main basis for an evaluation of the usefulness of such a monitoring in capelin assessment and advice. In addition, the survey will serve as a platform for selected methodological studies relevant for the capelin surveying during spawning including acoustic target strength measurements. These are presented in part B of this survey report.

3 - Part A. Monitoring of the capelin stock spawning migration

3.1 – Methodology

3.1.1 - Vessels

The fishing vessels FV *Vendla* and FV *Eros* were selected to carry out the acoustic survey, which started and ended in Tromsø, on 27 February and 13 March, respectively.

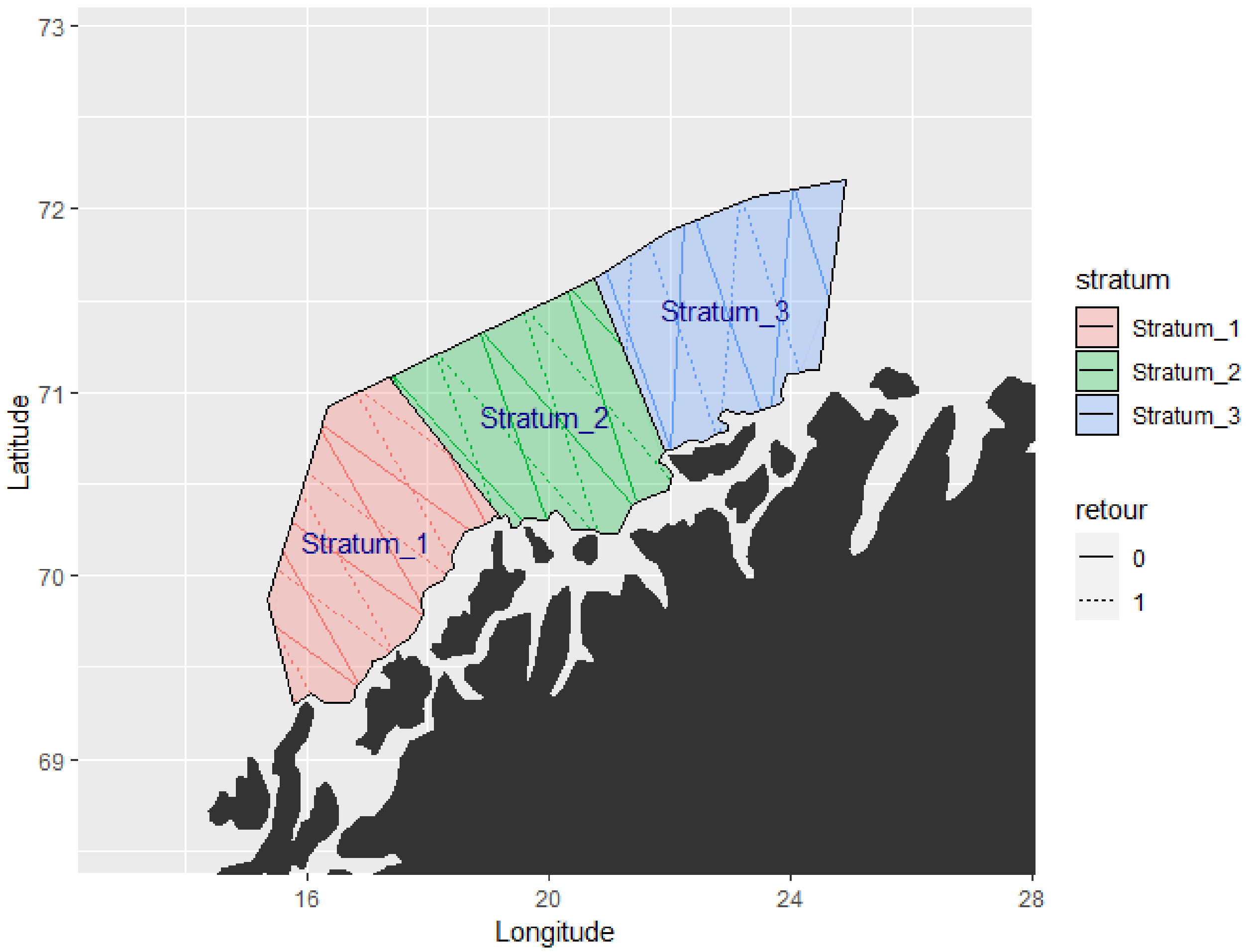
3.1.2 - Survey design

We adopted a stratified random transect survey design with the allocation of effort reflecting the expected abundance of capelin within a given stratum. The strata and distribution of effort are shown in Fig. 1 and were similar to the original strata system from 2019 which was based on a compilation of historical distribution data, and was followed up in 2020 and 2021 (see survey reports for details, available at https://www.hi.no/resources/Toktrapport-loddetokt-mars-2019.pdf , https://www.hi.no/hi/publikasjoner/toktrapporter/2020/testing-of-trawl-acoustic-stock-estimation-of-spawning-capelin-2020-nr.-2-2020 and Survey-report-capelin-spawning-survey-2021_final-1.pdf (hi.no) for the years 2019-2021). It is important to underline that the survey area we have defined is a core area for the capelin spawning migration, and the survey period is adequate in the case an advice would have been provided, but this is not a complete coverage of the Barents Sea capelin spawning stock.

Like in 2019-2021, we implemented a zig-zag transect design, which has the advantage of allowing more time spent on transects and less on transit compared to a design with parallel transects. Like in 2020 and 2021, we originally adopted a design including a complementary return zig-zag going in the opposite direction (Harbitz 2019). We can then get an abundance estimate by combining the two complementary directions, but an advantage with the two-direction design is that population mobility can be examined by comparing the two directions (Harbitz 2019). With two vessels available we could use this design in a western area comprising strata 1, 2 and 3 for Eros and an eastern area comprising strata 4, 5 and 6 for Vendla. During the first coverage, it became clear from sonar and echo sounder observations that an area north of Varangerhalvøya had higher capelin concentrations than other areas, and it was decided to spend more effort in this area during the second coverage. The second coverage is shown in the lower panel in Fig. 1, and the biomass estimate we present is based on this coverage.

No scouting vessel was used like in 2019 and 2020. But updated information on recent capelin distribution was available prior to the survey, including information from fish plants reporting the presence of capelin in cod stomachs, data from the ground fish survey with RV Johan Hjort in the Barents Sea (the 'winter survey'), and acoustic and trawl data from the NSS herring spawning survey which finished off Tromsø on February 27. Based on information from the herring spawning survey and the fish plants, we allocated more effort into stratum 1 where capelin was observed and extended the stratum towards north-west. We also extended the strata 4-6 northwards to include locations where Russian vessels were reported to fish capelin.

Strata boundaries were drawn using the software Stox (Johnsen et al. 2019), and allocation of effort within the strata was done using the "survey planner" function in the R package Rstox (https://github.com/arnejohannesholmin/sonR). The method used for generating the zig-zag transect plan was "Rectangular enclosure zigzag sampler" (Harbitz 2019). The starting point of the transects was random in all strata.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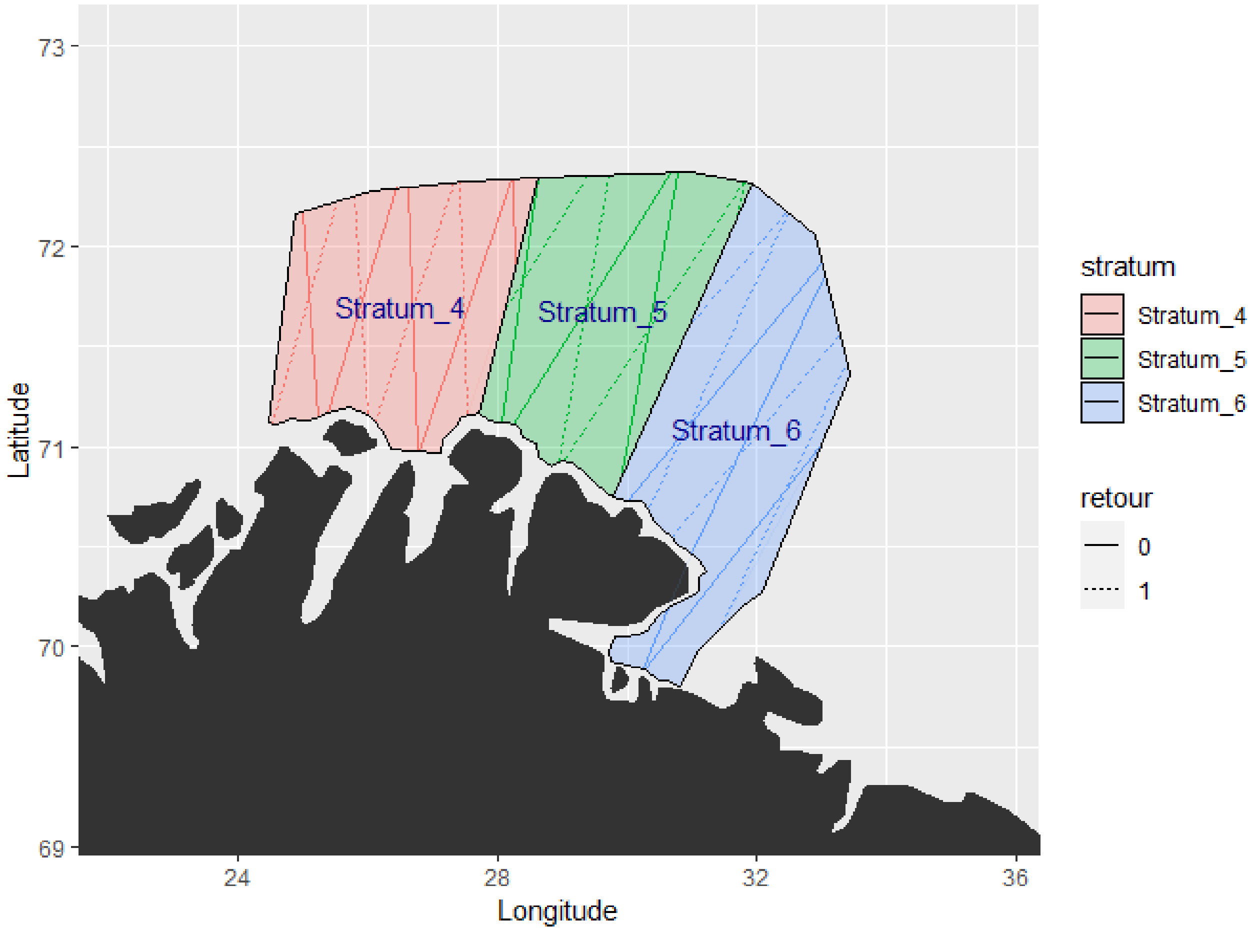
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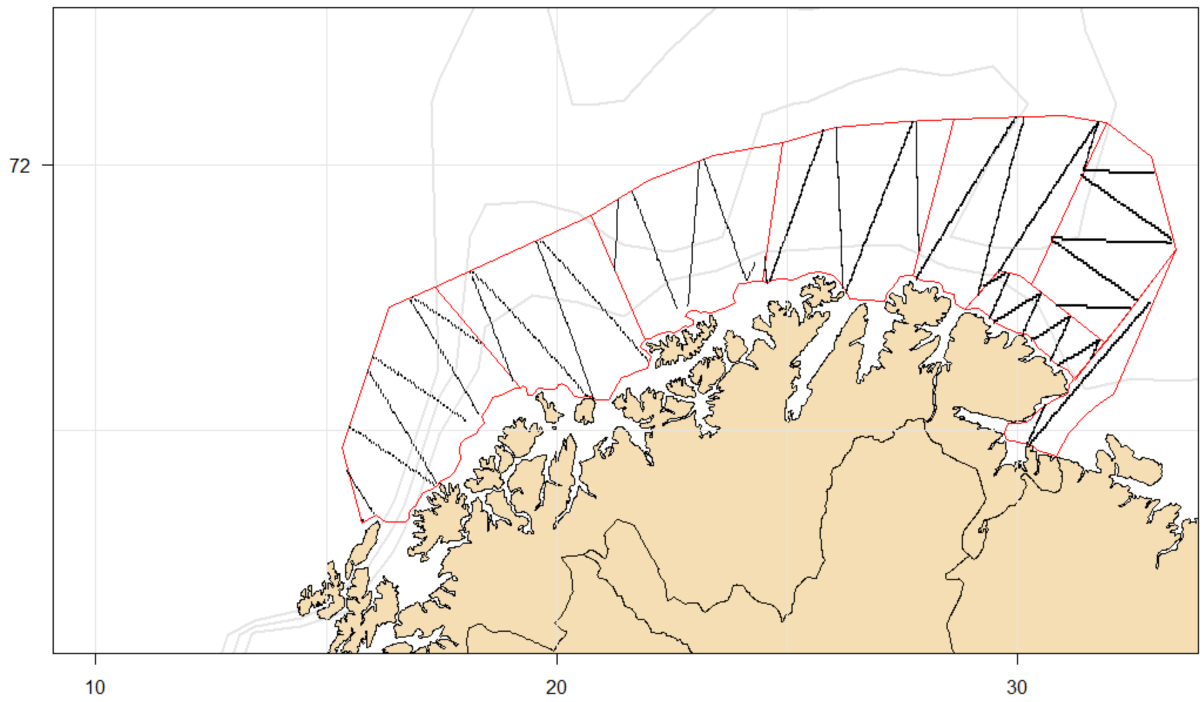


Fig. 1. Upper two panels) Survey coverage originally planned for Vendla (east) and Eros (west) with 6 strata, zig-zag transects and coverage in each stratum reflecting the expectancy of finding capelin. The fully drawn lines represent transects for the west to east coverage and the dashed lines for the east to west coverage. The east to west coverage was modified to what is shown in the lower panel. Lower panel) Survey coverage during the east-west coverage when effort was adjusted based on the capelin observations made during the west-east coverage (see text).

3.1.3 - Acoustic data collection and processing

3.1.3.1 - Echo sounder

Acoustic data from calibrated Simrad EK80 echo sounders were collected at frequencies of 18, 38, 70, 120, 200 and 333 kHz on board both *Eros* and *Vendla*. Transducers were mounted in a drop keel 3 m below the vessel hull. Data were collected up to 500 m range and with a ping interval of about 1 second. Raw acoustic data were scrutinized daily using the LSSS software at 38 kHz to the categories ‘Capelin’, ‘Herring’, ‘Bottom fish’, ‘Plankton’ and ‘Other’. The scrutinized data were stored at a resolution of 0.1 nmi horizontal and 5 m vertical and exported in units of Nautical Area Scattering Coefficient (NASC; m^2nmi^{-2}). This output was used for the biomass estimation (see section below).

3.1.3.2 - Sonar

Low frequency omni directional fisheries sonar (14-24 kHz) are used by fishermen for long distance search of commercial fish aggregations. During surveying, the large sampling volume of the sonar can provide valuable information on the spatial distribution of fish schools. In particular this can be important if the schools have a patchy distribution and are low in abundance. The sonar can also provide valuable information about potential vessel avoidance or schools distributed shallowly in the echo sounder blind-zone.

Also, when schools are tracked at low vessel speed or for a long period, the direction and speed of the schools can be estimated, information that is particularly important for the capelin during the spawning migration towards the coast.

Sonar data from Simrad ST90 at a frequency of 20 kHz was collected continuously with horizontal beams up to 1500 m range with a tilt of -3 to –6 deg when surveying on both vessels. Outside the survey transects, the tilt and range were adjusted to ensure a better sampling of the schools either for detailed inspection or during trawling.

The ST90 sonars of Vendla and Eros were not calibrated prior the start of the survey due to time constraints. Calibration results from the 2021 survey will be used to calibrate the data collected in the current survey. Time series of sonar calibration show consistent results, which allow us to have reasonable confidence in the application of calibration results obtained in 2021.

As in previous years, the methodology for the sonar data collection was the following: when a school was observed along the cruise line in the sonar and echo sounder, a trawl was performed to verify that it was capelin and for biological sampling. In some occasions, when schools were observed with the sonar outside of the track line, the vessel abandoned the transect once the school have been left to port or starboard side, and a detailed inspection with sonar and echo sounder was made. After the trawl for identification was completed, the survey was resumed in the point the transect line was left.

3.1.4 - Biological sampling

Multpelt trawls were applied on both vessels. A split in the codend was made to protect the trawl and avoid large catches.

Only target trawl hauls were carried out, i.e. on significant pelagic aggregations that were thought to be capelin. From every trawl haul, a maximum of 100 randomly selected capelin were sampled. Weight and length were measured for all, while age, sex and gonad stage was sampled for 50. In addition, roe weight was measured per specimen for the 50 individuals, but the scale was not precise enough to allow for quality measurements at such a fine scale so the weight of roe for all females among the 50 at each individual station was summed up and recorded. By dividing this roe weight with total weight of the females, roe percentage could be calculated. In addition, we this year quantified swimbladder fullness of the fish as part of the investigations of capelin target strength. The swimbladders were categorised as 1 – Emptied of air, 2 - Half-filled with air or 3 – Filled with air. We also deep-froze 25 capelin from each sample in rubbing alcohol as quickly as possible after capture to store for later examination of swimbladders using scanning and dissection.

In addition, length and weight of 100 herring were sampled, and age from 25 of these. Length and total weight were recorded in case there was other catch.

3.1.5 - Collection of CTD data

Conductivity Temperature Depth (CTD)-data were collected using an RBR concerto[3] sonde. CTD-casts were spread over the survey area (See Fig. 2).

3.1.6 - Video stations to ground-truth potential occurrence of capelin roe and spawning substrate

In order to investigate whether there was roe/dead capelin on the bottom indicating spawning, a photo rig was applied on each vessel. A Gopro 4 camera was mounted in a waterproof housing and mounted on a metal rig together with an underwater led flashlight. The rig was lowered down each time the vessel was at the innermost point of a transect. Thereby we got video footage of potential spawning products and spawning substrate at a set of random locations with adequate spawning depths.

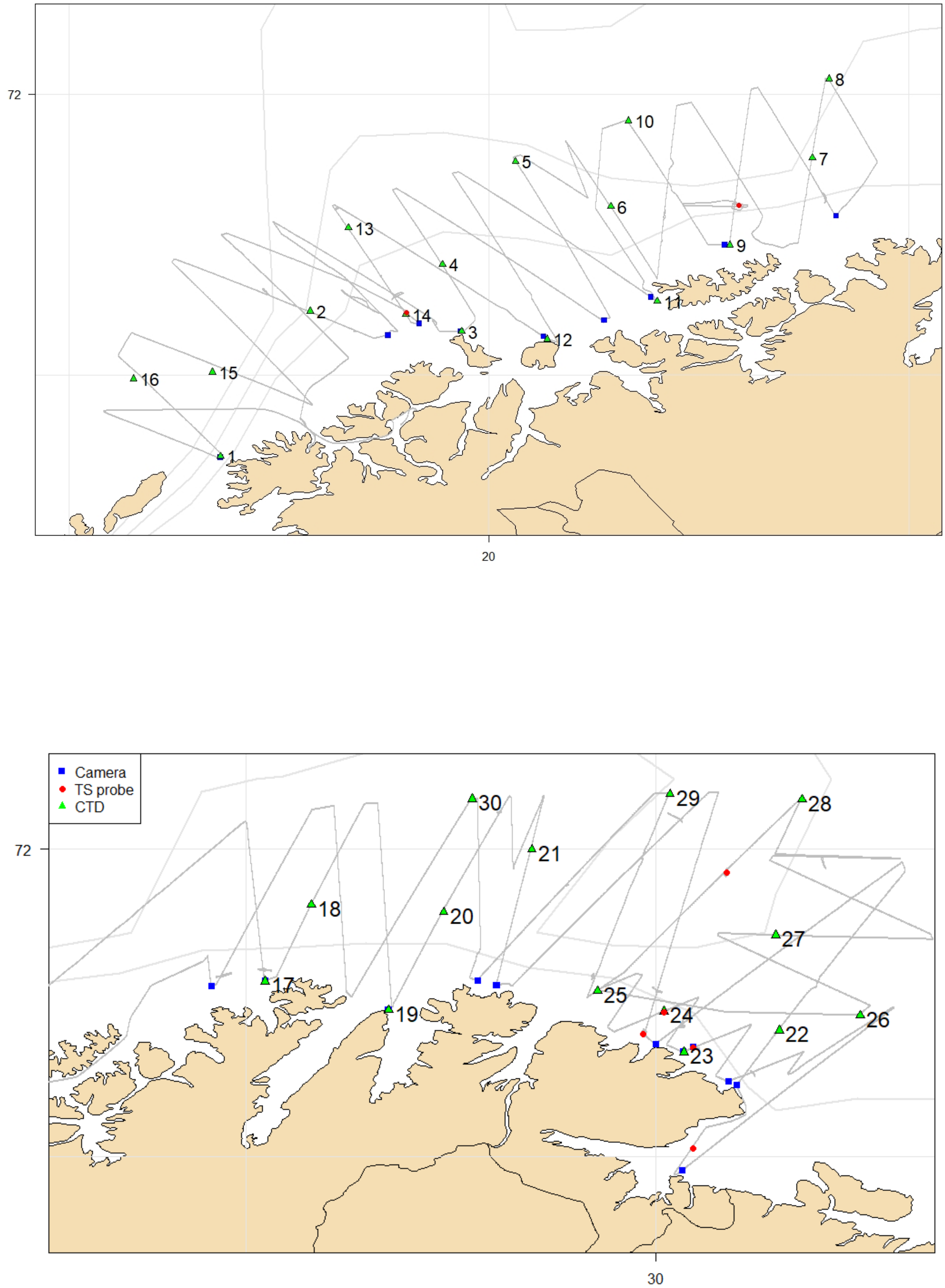


Fig. 2. Overview of cruise track and stations of Eros in the western coverage area (upper panel) and Vendla in the eastern coverage area (lower panel). The CTD-stations are marked with station numbers which are referred back to in Fig. 10.

3.1.7 - Biomass estimation

The Stox 3.3.3 application (Johnsen et al. 2019) was used to calculate a standard transect-based trawl acoustic estimate. Some main steps of the protocol can be mentioned: All acoustic recordings outside the transect lines (due to for instance trawling) were excluded from the estimation. Only transects from the second coverage and the two easternmost transects of the first coverage were used for the estimation. All the assigned biological stations were given equal weight when generating the total length distribution used in the estimation. The following target strength – length relationship was applied for the density (numbers/nmi^2) calculation (Dommasnes & Røttingen 1985):

$$TS = 19.1 \log L - 74$$

Abundance of fish in numbers and biomass were estimated by stratum and age based on 500 bootstrapping iterations of biotic stations and acoustic transects. The results are reported in Tabs 1 to 3.

3.2 - Results

3.2.1 - Capelin biomass estimate

An overview of all transects and stations included in the biomass estimation is shown in Fig. 3. The median biomass of capelin within the coverage area was estimated to 426 618 tons (Tab. 1) based on 500 bootstrap replicates, with a relative sampling error or Coefficient of Variation (CV) of 42% (Tab. 1). This CV is based on bootstrapping with replacement of transects as well as bootstrapping of biological stations used in the assignment. A 5% lower and 95% upper confidence limit were calculated from the replicates, and the lower and upper limits were 167 555 and 757 229 tons, respectively. Estimates of biomass by age with associated CV are provided in Tab. 2. Fish of age 3 was dominant. Mean length and weight by age are given in Tab. 3. The confidence interval of the estimate is overlapping with the confidence interval of the prediction from the 2021 autumn survey (Fig. 4). However, the sampling error is large, in particular given the high sampling effort. The biomass estimate is completely driven by the biomass in the small stratum 7 and CV in this stratum was 0.54 (Tab. 1). The results indicate a very patchy distribution of the capelin which can also be seen in Fig. 4.

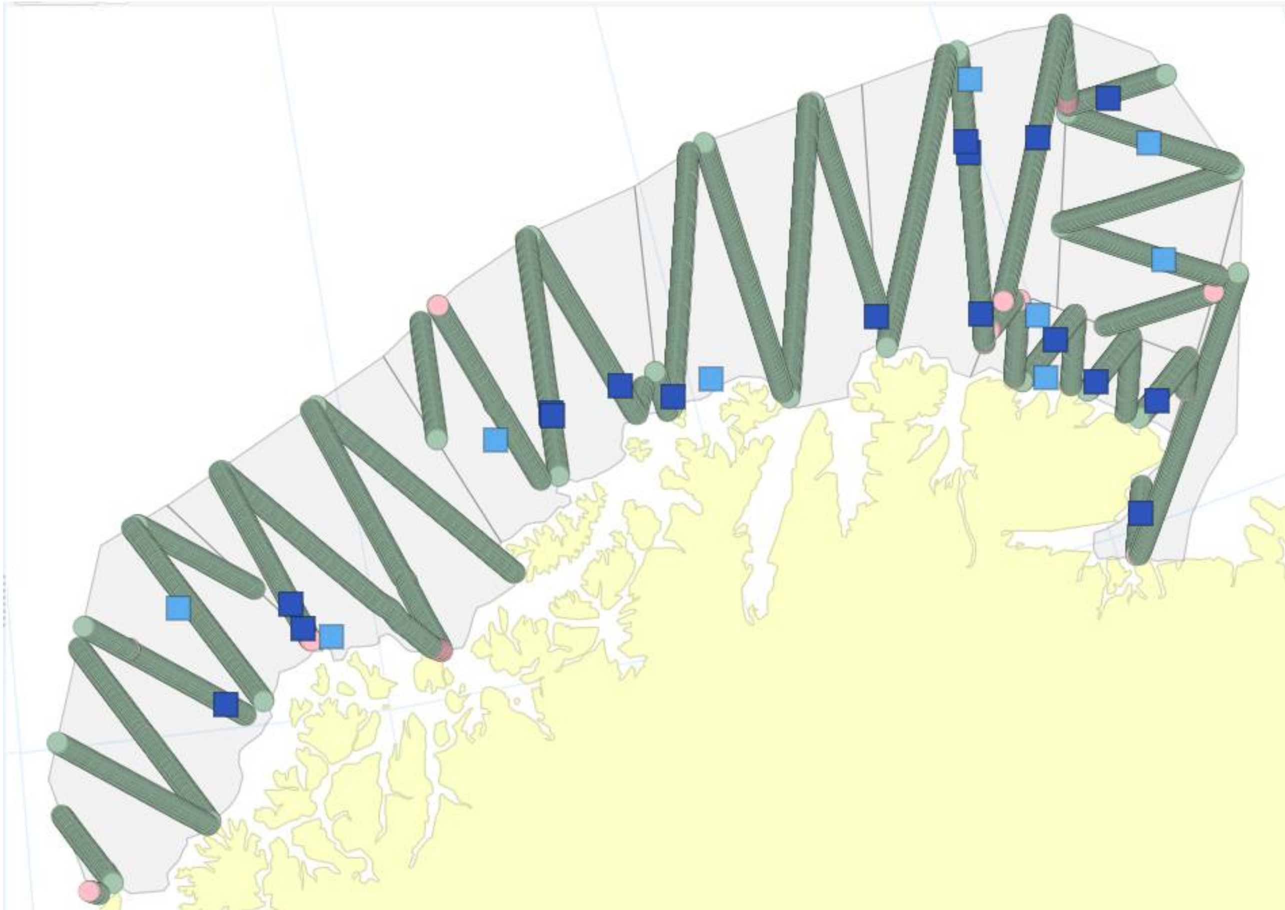


Fig. 3. Overview of transects (green: included in the biomass estimation, pink: not included in the biomass estimation). Blue squares mark trawl stations, with dark blue denoting those stations included in the estimation (only stations from east-west coverage included). The gray shaded areas mark the strata (counting 1-8 from west to east).

Table 1. Biomass estimation (BM, tons) output in tons by stratum during the spawning survey 27 February-13 March 2022, based on 500 bootstrap replicates.

Stratum	5th percentile	Median	95th percentile	Mean	CV
1	2373	34456	95723	35657	0.87
2	800	14443	30678	14762	0.75
3	3713	27202	53684	27731	0.52
4	1360	3684	7190	3904	0.44
5	4957	13825	25523	14133	0.45
6	2581	4301	6330	4359	0.26
7	60468	323644	638834	335276	0.54
8	461	4169	7877	4109	0.63
Survey	**167555**	**426618**	**757229**	**439932**	**0.42**

Table 2. Biomass (tons) of capelin at age during the spawning survey 27 February-13 March 2022, based on 500 bootstrap replicates.

Age	5th percentile	Median	95th percentile	Mean	CV
3	145649	365795	647743	376530	0.41
4	15887	48864	96445	51888	0.48
5	2320	9361	26574	11076	0.69

Table 3. Estimated length and weight of individual capelin at age during the spawning survey 27 February-13 March 2022, based on 500 bootstrap replicates.

Age	Mean weight (g)	CV weight	Mean length (cm)	CV length
3	16.34	0.03	15.5	0.008
4	19.74	0.03	16.4	0.007
5	22.05	0.09	16.8	0.024

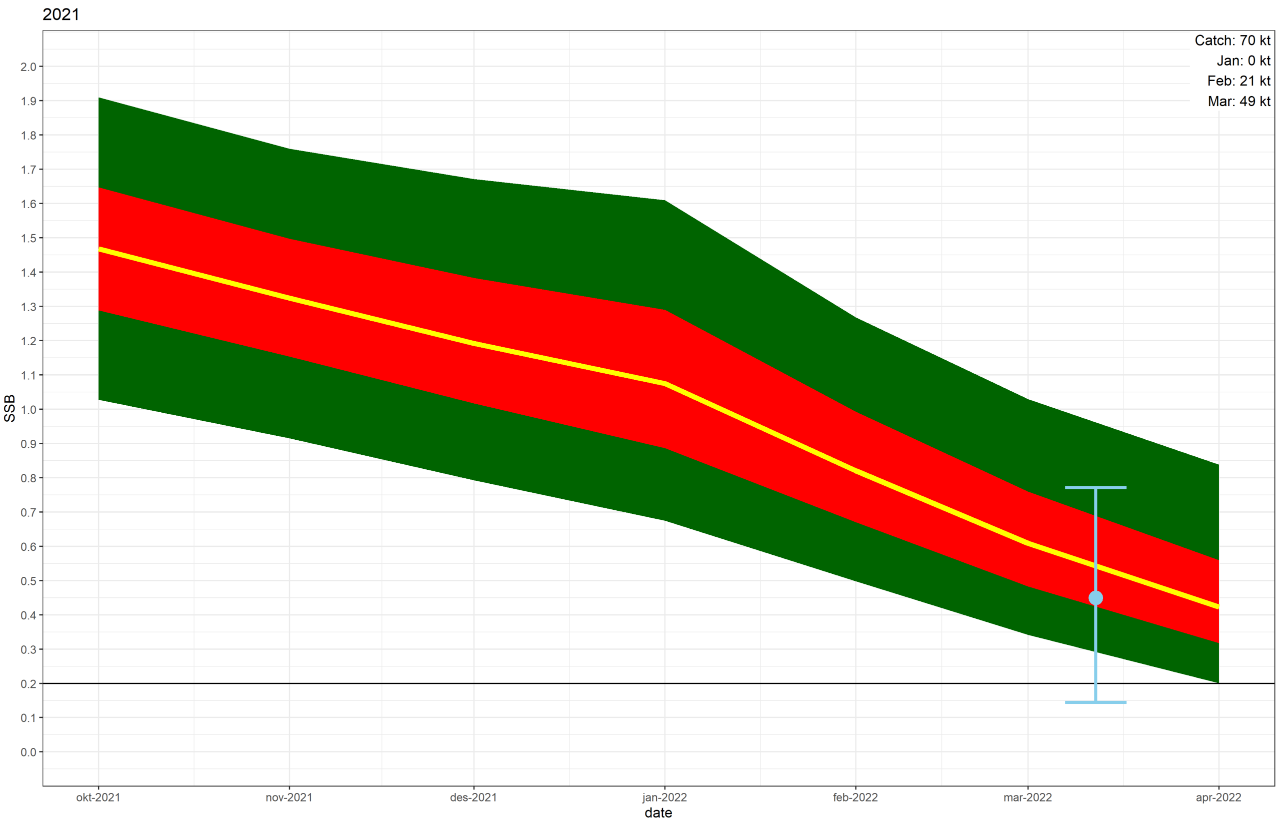
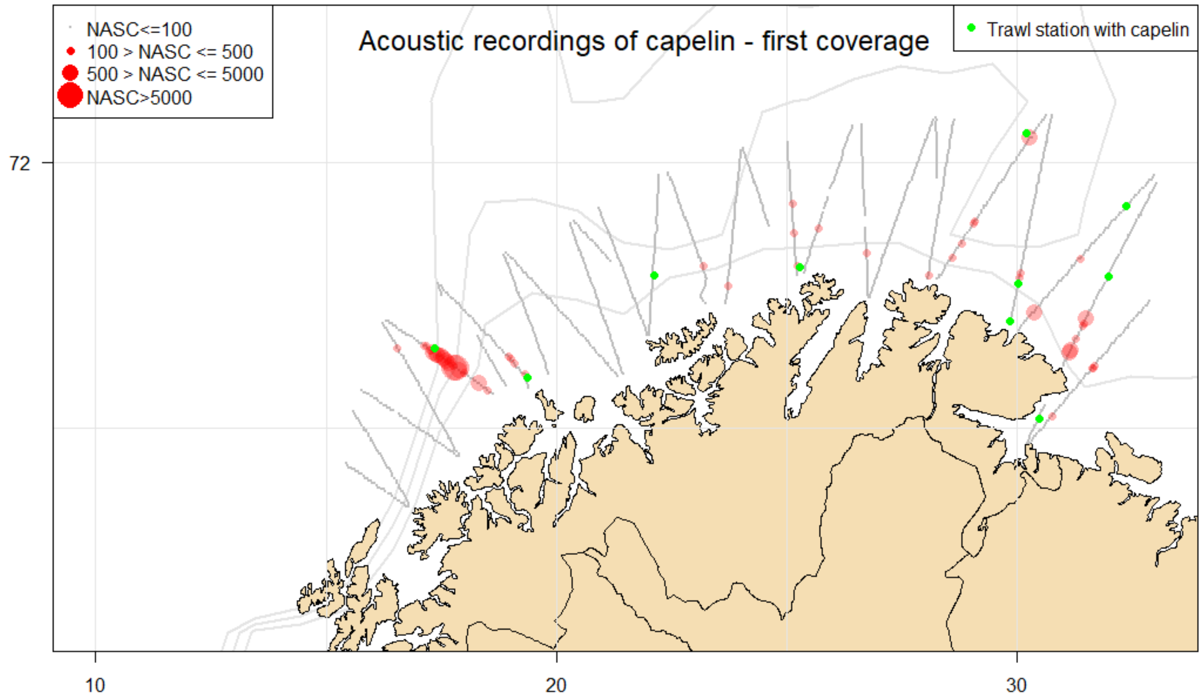


Fig. 4. Biomass estimate from the present capelin spawning survey shown in blue (dot indicating median with whiskers indicating 5 and 95% CI), compared to the model prediction based on the capelin autumn survey in 2021.

3.2.2 - Acoustic recordings

3.2.2.1 - Echo sounder

The distributions of acoustic backscatter from both coverages of both vessels are shown in Fig. 5. Echo sounder recordings from the coastal shelf area north of Varangerhalvøya dominated the echo sounder recordings. There were lower capelin recordings in the western coverage area.



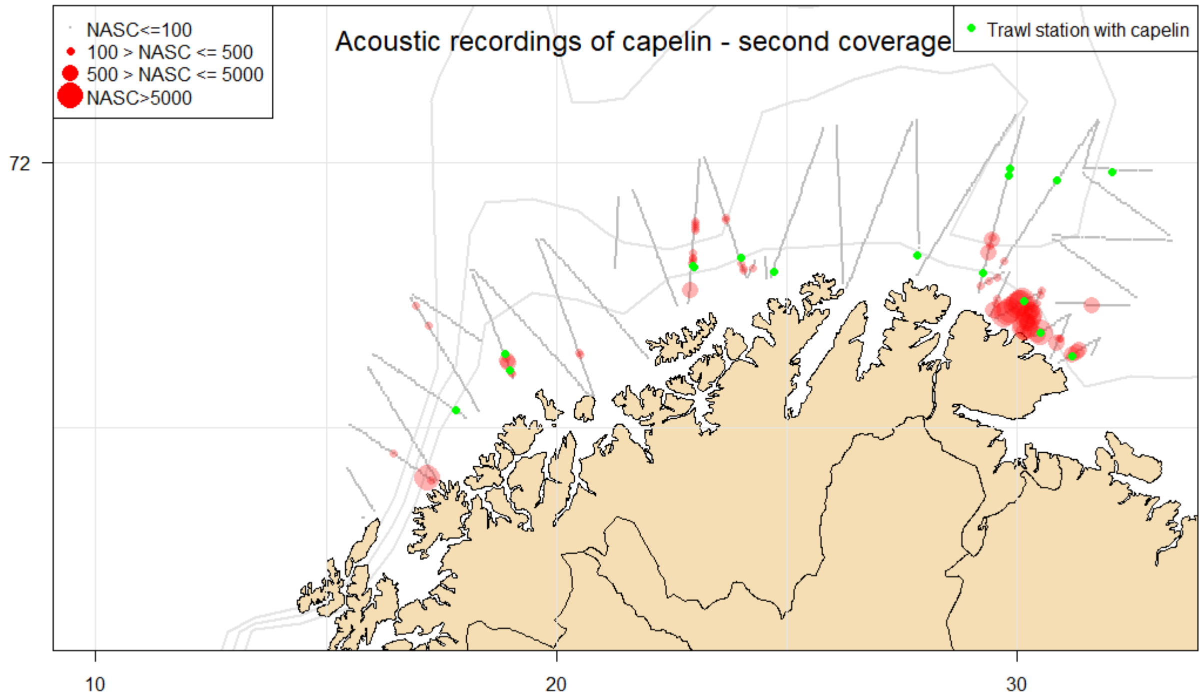
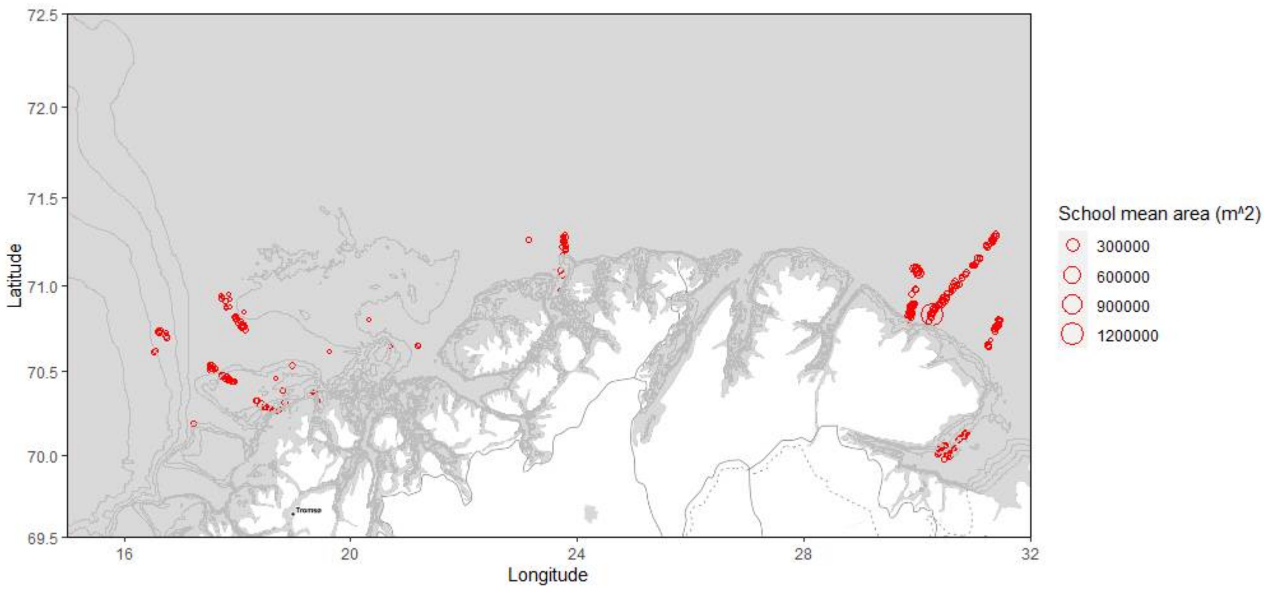


Fig. 5. Distribution of NASC (m^2nmi^{-2}) allocated to capelin from the first coverage going in the eastward direction (upper panel) and the second coverage going in the westward direction (lower panel). The size of the circles corresponds to NASC-value per 1 nautical mile.

3.2.2.2 - Sonar recordings

An overview of the schools recorded by the sonar are shown in Fig. 6. Most of the schools were observed in the coastal shelf area north of Varangerhalvøya, in the same area that most of the echosounder registrations were made. The conditions for sonar observations were in general better in the eastern region than in the western region where strong winds and storms resulted in poor conditions. The capelin were observed in different types of aggregations from small schools to large layers (Fig. 7). All schools were observed during daytime from close to the surface and down to 250 m depth. The largest layers were observed at nighttime and extended over thousands of meters from the surface down to 120 m depth and covered areas between 1 and 2 million m^2. In some areas (several nautical miles along the transect), many small and medium sized schools were observed in the sonar. A good example of this was in the Varangerfjord (Fig. 7a).

When the fish has a very patchy distribution like is typically the case for capelin during the spawning season, the large sampling volume of the sonar compared to the echo sounder is very valuable. The sonar recordings revealed a high number of schools close to the shelf off Varanger, and also some really large schools. A few of them were also detected with the echo sounder (see upper panel in Fig. 5), but statistically a very low proportion compared to what is detected on the sonar operating with 1500 m range. The decision to have a higher survey effort in this area on the return coverage was mostly based on the sonar recordings.



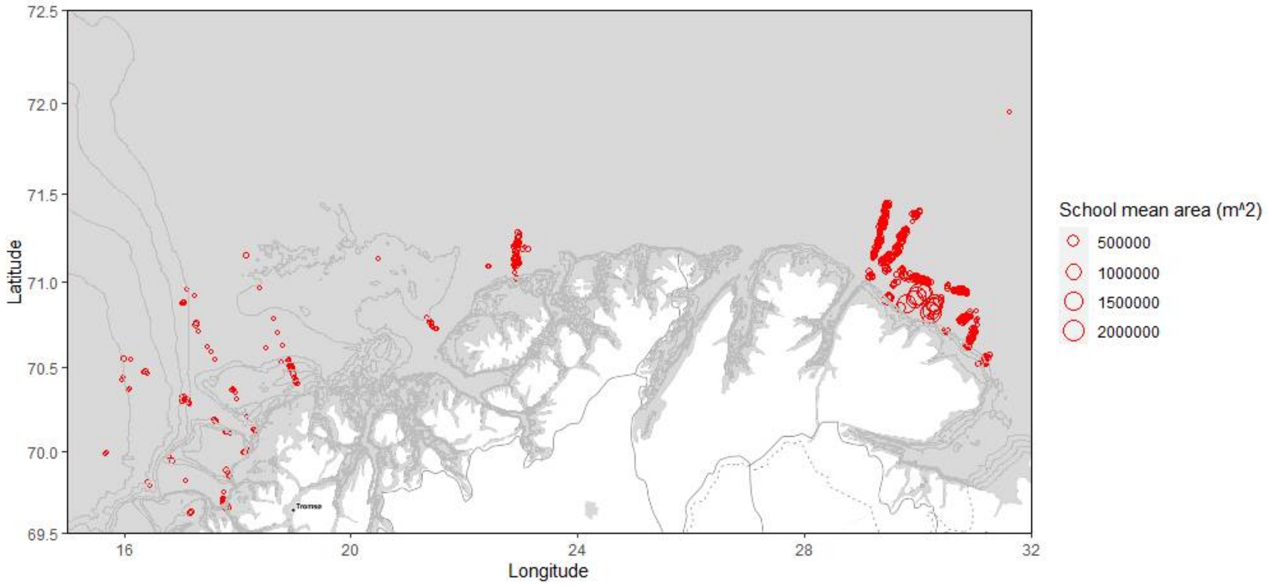


Fig. 6. Capelin aggregations (schools and layers) observed with sonar from Eros and Vendla during the first west-east (upper panel) and the second east-west (lower panel) coverage. Aggregations with mean area above 5 000 m^2 are shown.

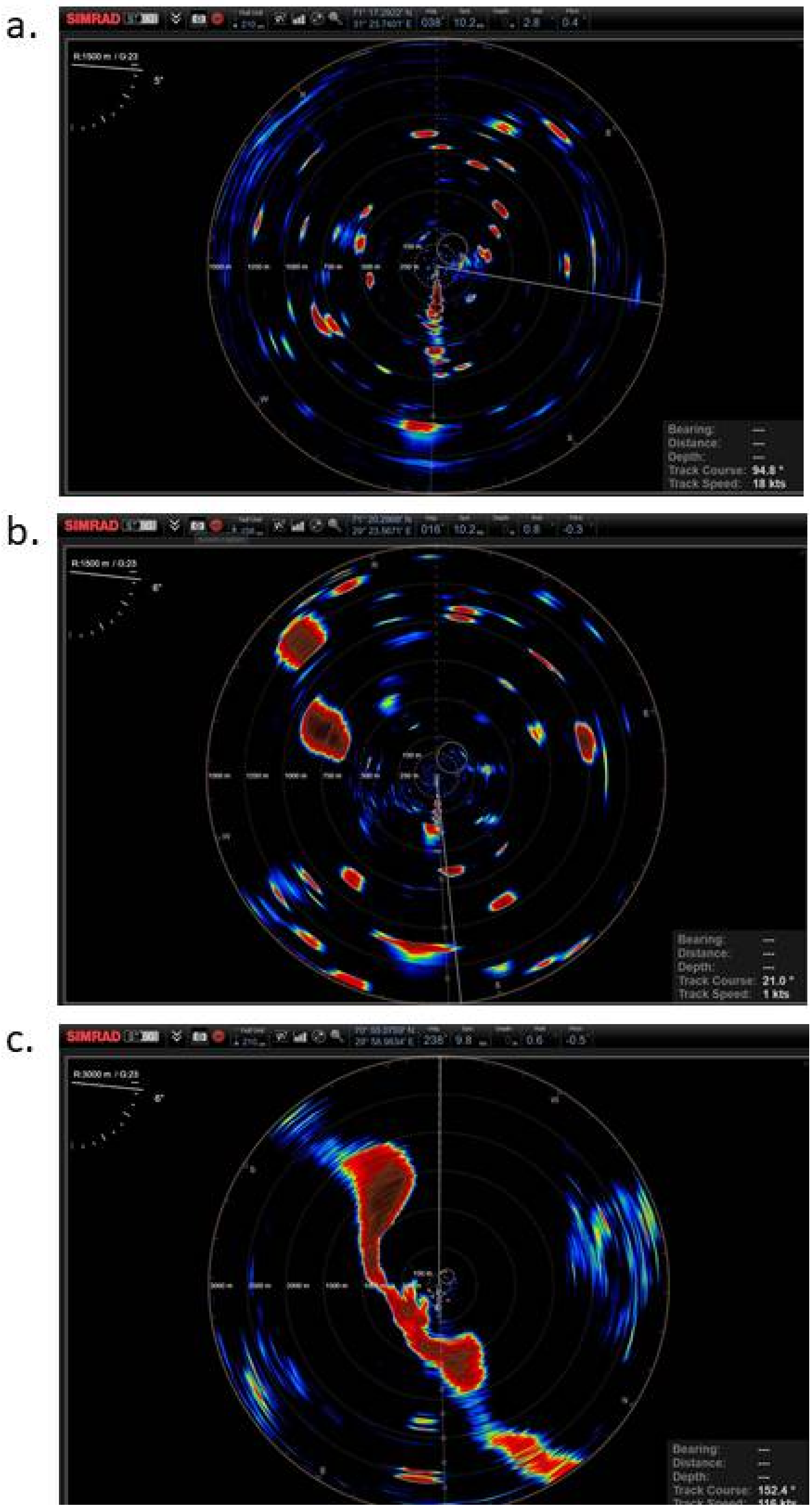


Fig. 7. Examples of capelin distributions observed with the sonar. Small to medium sized schools (a), medium to large sized schools (b) and large layers (c). The sonar range in panel a and b is 1500 m and in panel c 3000 m.

3.2.3 - Biology of the capelin

The mean length of capelin based on all biological samples was 15.5 cm (Fig. 8). This mean value is including samples taken on dispersed layers north of the core distribution area (i.e. stations 37152, 37155, 37161, 37162, 37164 and

37165; see figs. A1_1 and A1_2). When excluding these stations mean length was 16.0 cm and similar between western (16.1) and eastern (15.9) coverage areas. The length distribution supports the assumption in the stock prediction that capelin >14 cm are migrating to the coast to spawn. Mean weight was 16.4 g with a lower average weight in the east, but this difference between east and west was small when excluding the samples taken in the north listed above (18.0 g in the west and 18.5 in the east). Length distributions by station are presented in Appendix 1.

Most of the capelin was in maturity stage 5, which is mature. In the eastern overage area in the samples taken in the dispersed layers to the north, many capelin were found to be in stage 3 and even immatures were sampled. In the samples taken towards the end of the survey in the western coverage area, a high proportion of the capelin were in stage 7 (spent).

The roe percentage was calculated to get additional information on the maturation and spawning progress. It is calculated as the sum weight of roe in the individual samples divided by the total weight of females in the same sample. The results are presented in Fig. 9. Roe percentage varied between close to 0 and 25, with most samples showing a roe percentage around 16. It is important to note that the samples are from different areas and maturation had typically progressed far less in the dispersed layers in the north, than closer to the coast. Overall, the samples indicated that maturation had progressed further in the western coverage area than in the east.

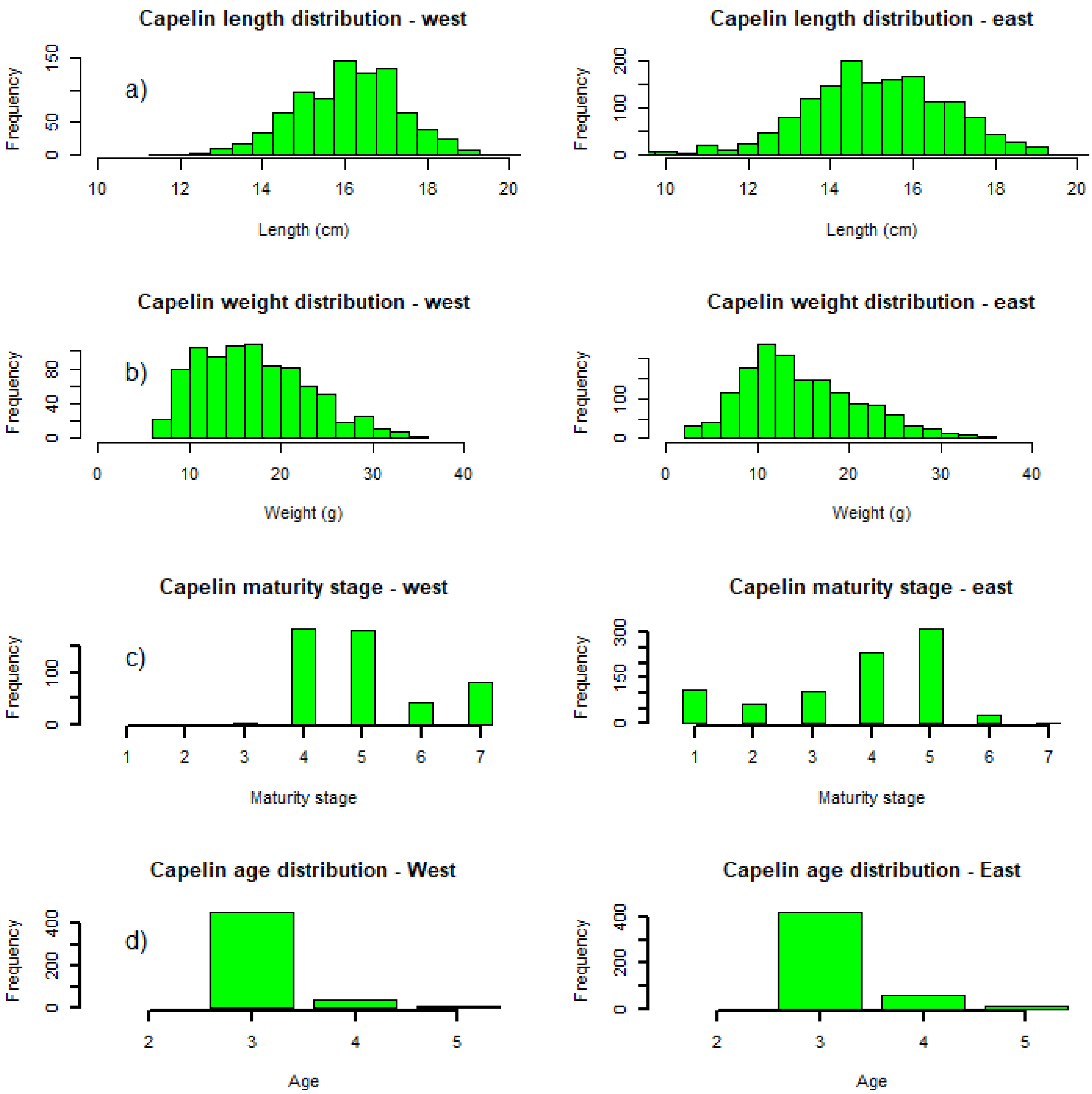


Fig. 8. Capelin a) length distribution b) weight distribution, c) spawning state and d) age distribution in the western (left column of panels) and eastern (right column of panels) coverage areas.

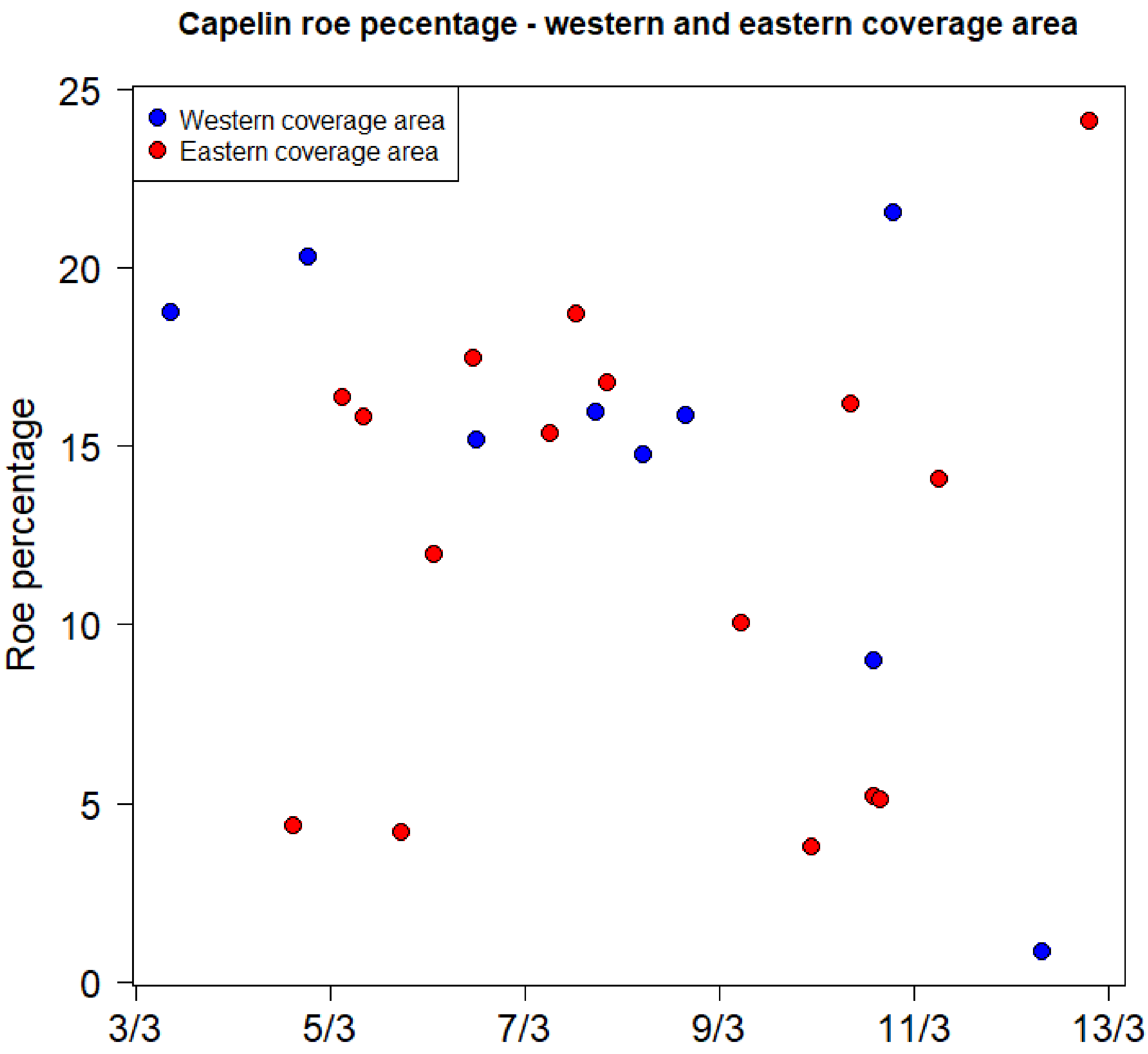


Fig. 9. Capelin roe percentage (Weight of roe in all sampled females divided by the total weight of those females) per station as a function of time. Blue : Stations from Eros in the western coverage area, and red : stations from Vendla in the eastern coverage area.

Some Norwegian spring spawning herring were present in the south-western part of the survey area. The herring were not sampled with trawl. A map showing herring distribution is found in Appendix 2.

3.2.4 - Environmental data

The temperature and salinity profiles for all stations in the study area at different depths are shown in Figs. 10a and b. The water masses close to the coast were similar in the eastern and western coverage areas with temperatures around 3.5-4°C throughout the water column and salinity between 34 and 34.5. The off-shelf temperatures in the south-west were 6-7°C compared to 2.5-4.5°C in the eastern coverage area, while estimated salinity were similar (around 35).

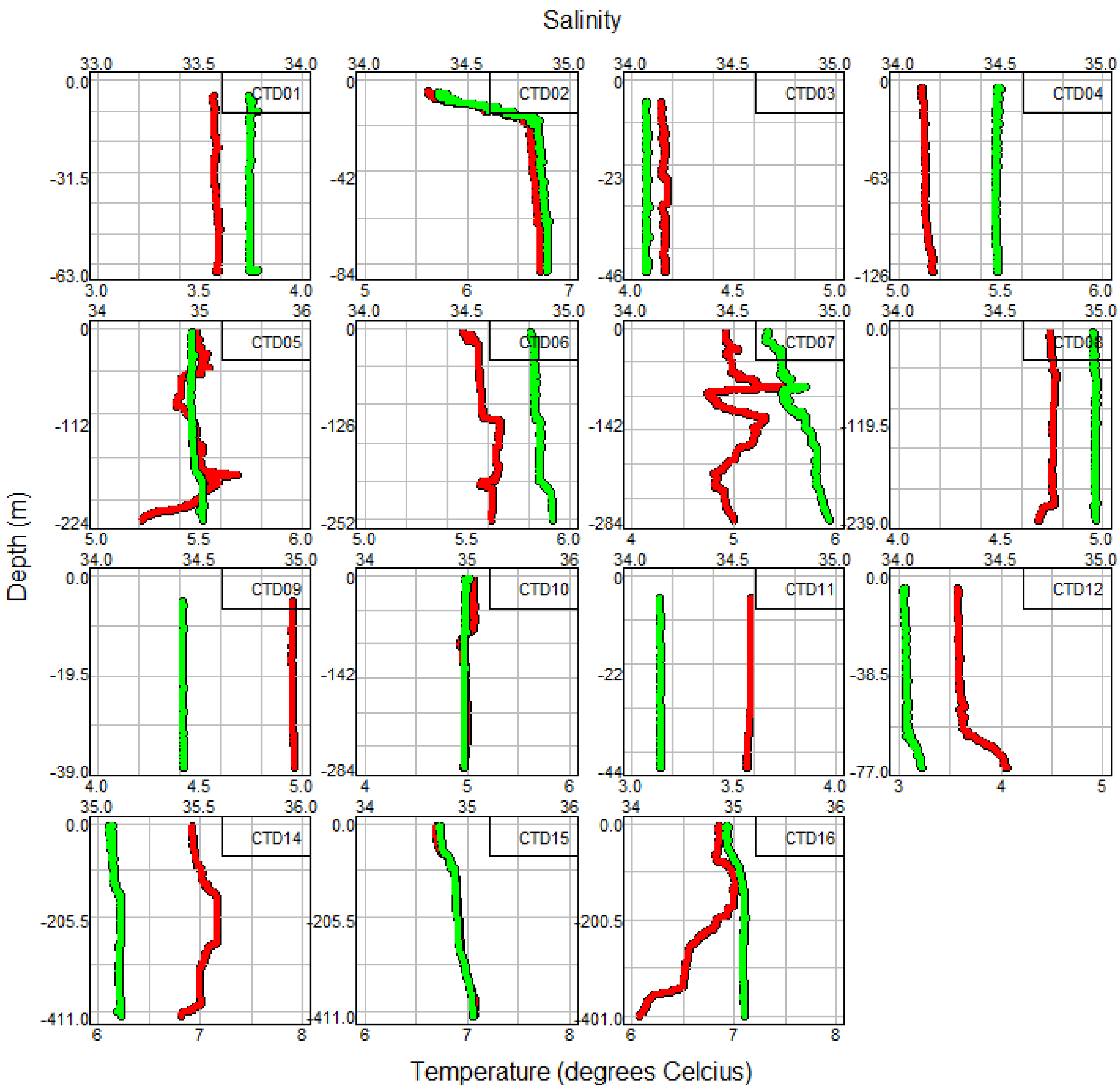


Fig. 10a) Temperature (red) and salinity (green) profiles for the western coverage area. The stations referred to are shown in the upper panel of Fig. 2.

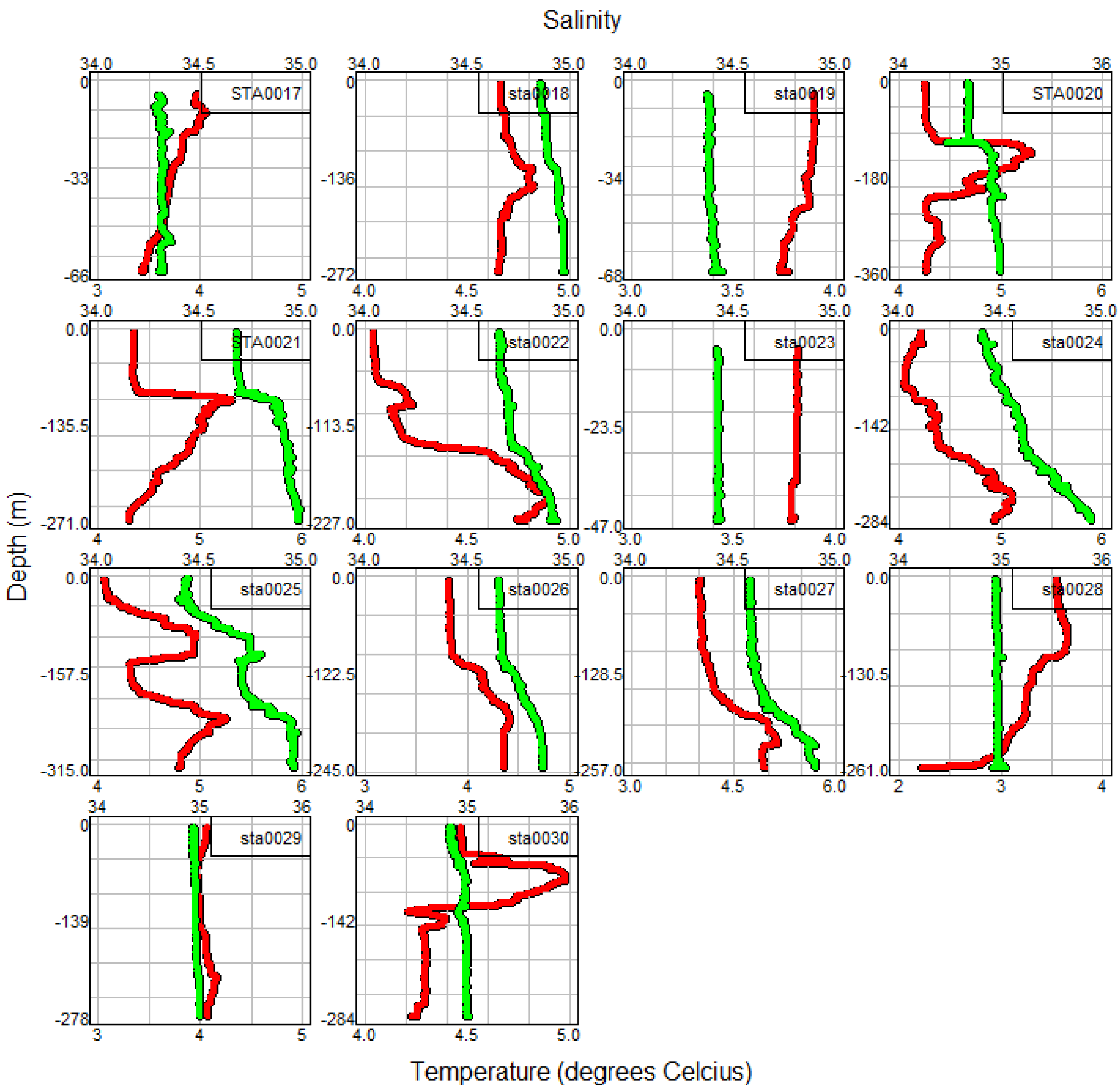


Fig. 10b) Temperature (red) and salinity (green) profiles for the eastern coverage area. The stations referred to are shown in the lower panel of Fig. 2.

3.2.5 - Spawning products and spawning substrate

Several of the video station recordings revealed bottom made up of stones and gravel which are preferred bottom substrate for capelin, however, no capelin roe or spawning capelin was observed in any of the stations.

4 - Part B. Methodological investigations

4.1 - Acoustic target strength investigations

4.1.1 - TS measurements – Background

Fish target strength (TS) is a key parameter for abundance and biomass estimation of fish stocks when using the acoustic echo integration method. The target strength represents the acoustic backscattered energy from a single fish and is used to convert the echo energy measured with an echo sounder into number of fish. The conversion is normally done through a target strength-length relationship which for Barents Sea capelin is defined as TS= 19.1 log(L)-74 at 38 kHz. This relationship is derived from ex-situ measurements of maximum TS of capelin and other species (Dalen et al., 1976) and theoretical corrections to convert it into a mean TS relation (Dommasnes and Røttingen, 1985). *In situ* target strength measurements that reflect the acoustic backscattering of free-swimming capelin are needed, in particular when there are new survey situations like the spawning survey represents.

Measurements of single fish are required for deriving reliable estimates of TS. That is a challenge in schooling species like capelin, especially during normal acoustic surveying. However, deployment of an echo sounder close to the fish targets and the use of broadband echo sounders will increase the chances of obtaining measurements of single individuals. In the 2021 capelin spawning survey we used submersible independent transducers for the TS measurements, and in 2022 survey Target Strength probes (TS probe) were made available both for *Eros* and *Vendla* .

4.1.2 - Data collection

Following from the experience gained in 2020 and 2021, a dedicated TS probe was used to carry out TS measurements of capelin. In order to detect single fish close to or inside a capelin school it is required to have: high ping rate, a narrow beam and broadband transmission mode. The TS probes used on board *Vendla* and *Eros* were equipped with 4 Simrad wideband transceivers (WBT) operating at frequencies of 38, 70, 120 and 200 kHz. All transducers are depth rated and have full broadband transmission on all frequencies except for the ES38D, which has a limited broadband (34 to 42 kHz). The settings used for calibration and data collection are shown in Tabs 4a and 4b. The echosounder systems are mounted in a rigid frame that can be lowered to the desired depth and controlled and monitored in real time via fiber optic to the vessel (Fig. 11). The frame was submerged as close as possible to the capelin school which had been detected with the vessel echo sounder. To avoid acoustic interference with the TS probe echo sounders, the vessel echo sounders were stopped during deployment of the probe. Once the probe reached the desired depth, the vessel was slowly maneuvered aiming to stay on top and at the borders of the school during the measurements, by using the sonar during brief periods.

Fig. 11 . Retrieval of the TS probe onboard Eros after data collection for single fish target strength measurements.

Table 4a) Setting used for calibration and collection of acoustic Target Strength (TS) data with the TS-probe on board Vendla.

Channel	Pulse shape	Bandwidth, kHz	Taper	Pulse duration, ms	Power, W
38-CW	CW	-	-	0.256	200
38-CW	CW	-	-	1.024	200
38-FM	FM-Up	34-42	Fast	2.048	200

Table 4b) Settings used for calibration and collection of acoustic Target Strength (TS) data with the TS-probe on board Eros.

Channel	Pulse shape	Bandwidth, kHz	Taper	Pulse duration, ms	Power, W
38-CW	CW	-	-	1.024	200
38-CW	CW	-	-	0.256	200
70-FM	FM-Up	55-85	Fast	2.048	75
120-FM	FM-Up	95-165	Fast	2.048	80
200-FM	FM-Up	170-260	Fast	2.048	105

The TS probe onboard Vendla malfunctioned when several frequencies were run simultaneously or when the tilt and roll system was run, so only the 38 kHz transducer was calibrated.

During deployment, data were collected with single band (CW) and broadband (FM). A pelagic trawl was carried out for biological sampling of the capelin either before or after the deployment.

After the deployment data were examined in the EK80 software, and detailed analysis of single targets will be done at a later stage.

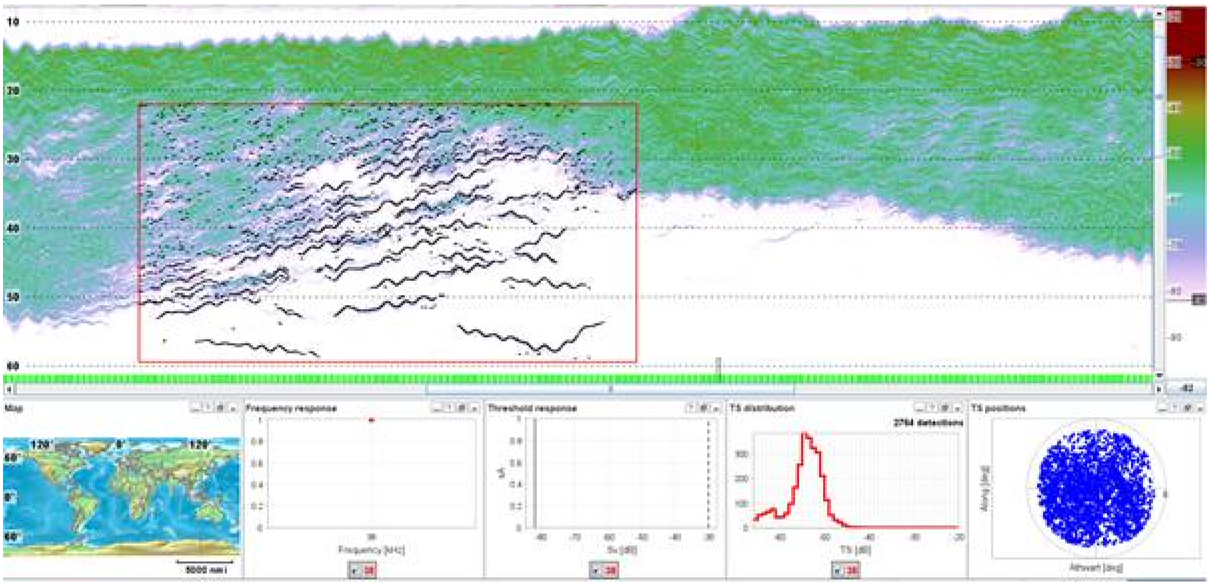
4.1.3 - Results

Five TS probe deployments were done on Vendla and two on Eros (Fig. 2). Single target measurements were possible when the fish was dispersed enough to be isolated as single individuals (Fig. 12). When fish was found in densely packed schools, it was difficult to resolve single fish even with the probe very close to the school. In Fig. 12 single fish detections are shown as black dots and it is possible to identify continuous lines of dots representing tracks of single fish.

Preliminary results indicate target strength values in the level expected when using the standard TS length relation (TS=19.1 log(L)-74), which corresponds to a TS of -51 dB assuming a fish mean length of 16 cm. These results agree with a general impression that the frequency response of most of the capelin aggregations (in particular the large ones in the eastern region) showed an expected decrease in echo strength from lower to higher frequencies, typical of a fish with a filled swimbladder.

A more detailed analysis of the TS probe deployments will be done following procedures used in previous years, filtering the data by range from the transducer and cut-off angle to ensure normal target distribution inside the acoustic beam. In addition, tracking algorithms will be used to identify single fish and calculate corresponding track target strength. This method reduces the chances of obtaining target strength from multiple targets.

The use of the TS-probe was logistically more challenging than the use of a single frequency submersible transducer that was used last year. However, the use of the TS-probe provided the flexibility to lower the transducer to any depth close to the fish and provided the option to run multifrequency transducers with broadband capabilities.



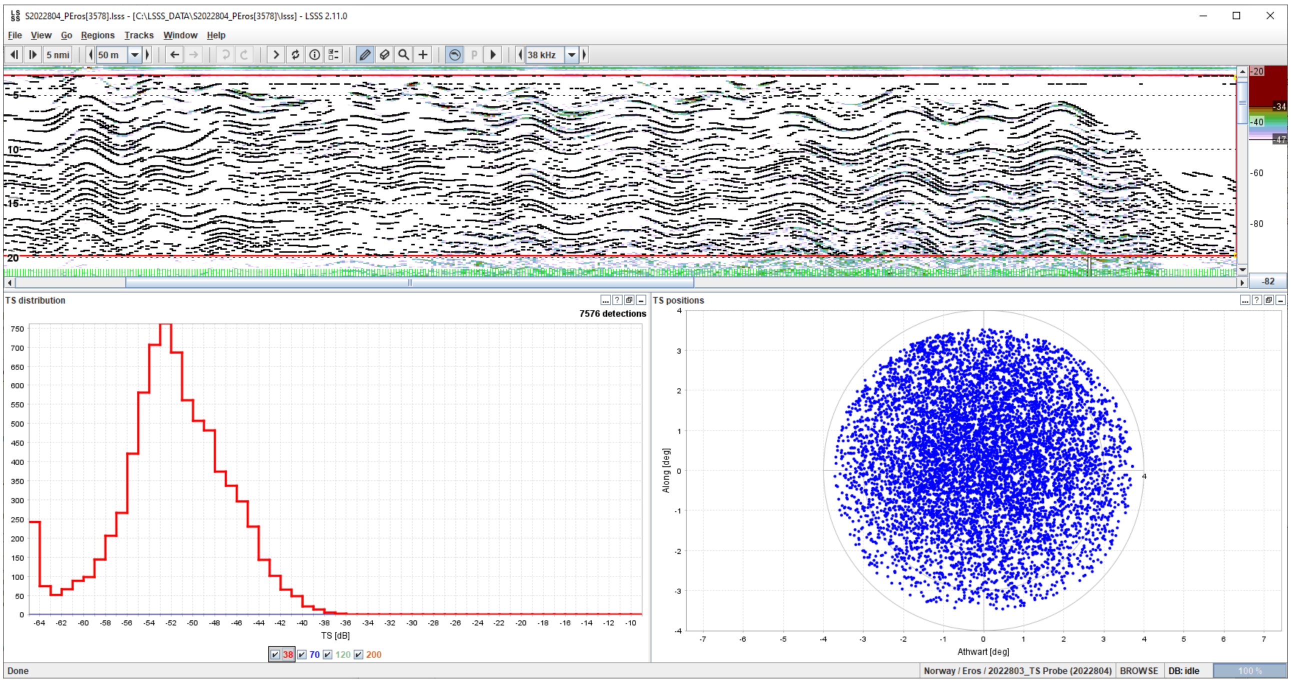


Fig. 12 . Echograms showing TS probe measurements at 38 kHz in CW transmission mode from Vendla (upper panel) and Eros (lower panel). Single individual fish were detected below a denser layer in the data from Vendla , and from a very disperse layer in Eros data. The histogram shows the target strength of the single targets and the polar plot their position inside the beam.

4.2 - Use of acoustic doppler current profiler (ADCP)

4.2.1 - Introduction

The dynamics of predominant currents in the survey area is relevant to understand the spawning migration when capelin approaches the coast from the oceanic region of the Barents Sea. Models showing the prevailing currents are available (http://havstraum.no/), but space and time scales are too coarse to be well-suited for understanding the spawning migration. We therefore collected ADCP data simultaneous to the echo sounder data. The Simrad EC150-3C ADCP was available onboard Eros for a second year. The data from this instrument can potentially provide information on swimming direction of fish schools im three dimensions in addition to detailed information about prevailing currents. In 2020 the ADCP was installed, but time synchronization and adequate motion reference unit (MRU) data were missing. In 2021, a time server from Meinberg was installed to synchronize the MRU with GPS data but without success since the Meinberg server did not work as it was supposed to. In 2022, a Simrad engineer came on board Eros before the survey and found that MRU on board Eros cannot be synchronized, since the MRU sends out data without time datagram. The Meinberg time server worked as expected.

4.2.2 - Data collection

At the start of the NSS herring survey (14 days prior to the capelin survey), the ADCP was set up to collect data per layer thickness of 2m, in CW mode, and at 1 ping/s. Due to limited survey time, the ADCP was calibrated during the capelin survey while Eros was forced to rest in a fjord due to a storm (see Fig. 13). The calibration was performed during the night of 9 th March 2022. Thereafter the calibration data were processed both on board Eros and post processed by Simrad. It was confirmed by Simrad that the calibration was not as expected due to few data pings, which was caused by geographical limitations at the calibration site.

In general, the ADCP worked as expected with few alarms and warnings, and it was confirmed by the Eros captain that the surface current direction shown in the ADCP seemed correct. However, several points should be addressed, and they are listed below:

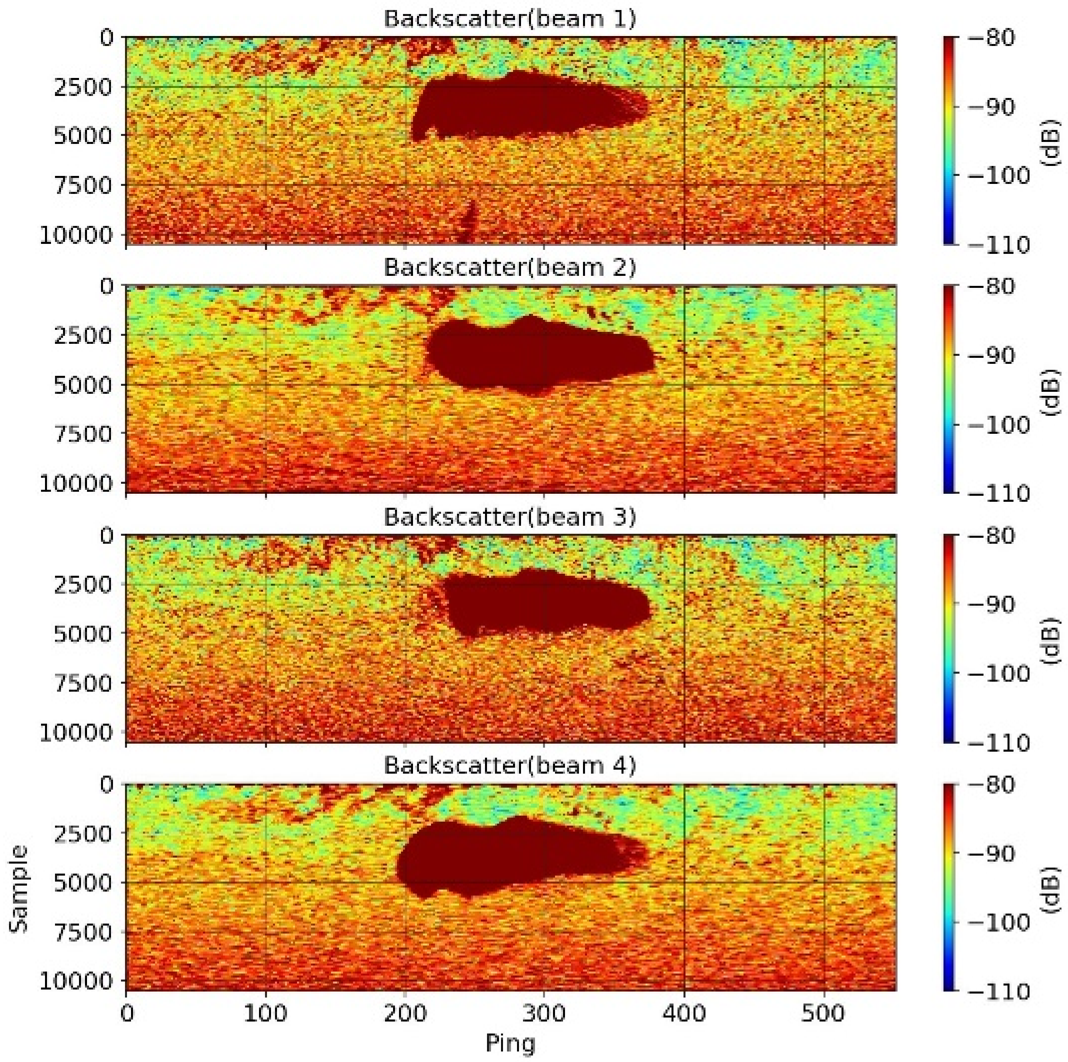
1. The ADCP ping rate cannot be kept at 1 ping/s, although the bottom detection was turned off. It was observed that 1 ping/s could be applicable when the water depth (ping depth) was about 150m. Otherwise the ping rate increased to 1.5 ping/s or even more.
2. The ADCP does not use heave from MRU for vertical speed calculations, and this has been confirmed by Simrad. Discussions with Simrad are still going on in order to understand the causes behind this.
3. ADCP bottom speed measurement values should be close to the Speed Over Ground given by the GPS. This did not seem to be the case, but a more detailed data analysis is needed to confirm this impression.

Fig. 13. The calibration site is shown by the red rectangle.

4.2.3 - Results

During the survey, after the daily routine scrutiny of the EK80 data, ADCP measurements were discussed. The first example is shown in Fig. 14, and the raw data were post-processed with a 100 ping averaging. Note that the calculations were done by EK80. As shown by the beam coverage in the upper four panels of Fig. 14, this fish school is spread enough to let ADCP have full coverage, less heave, and therefore it ensures that the ADCP calculates speed and direction correctly. In the three lower panels of Fig. 14, the directional speeds were calculated by the Simrad EK80 software, and the color contrast shows the capelin school movement. It is shown that:

1. this school is not large, and there are only 170 pings in the time domain. The few pings result in much uncertainty given the 100 ping average, and it is seen that before and after this school, the speed calculations have high uncertainties. The valid calculations only comprise around 70 pings between those areas with high uncertainties.
2. this school does not move much vertically, and the geo north speed is almost as the ambient water speed.
3. this school moves west, as indicated by the color contrast.



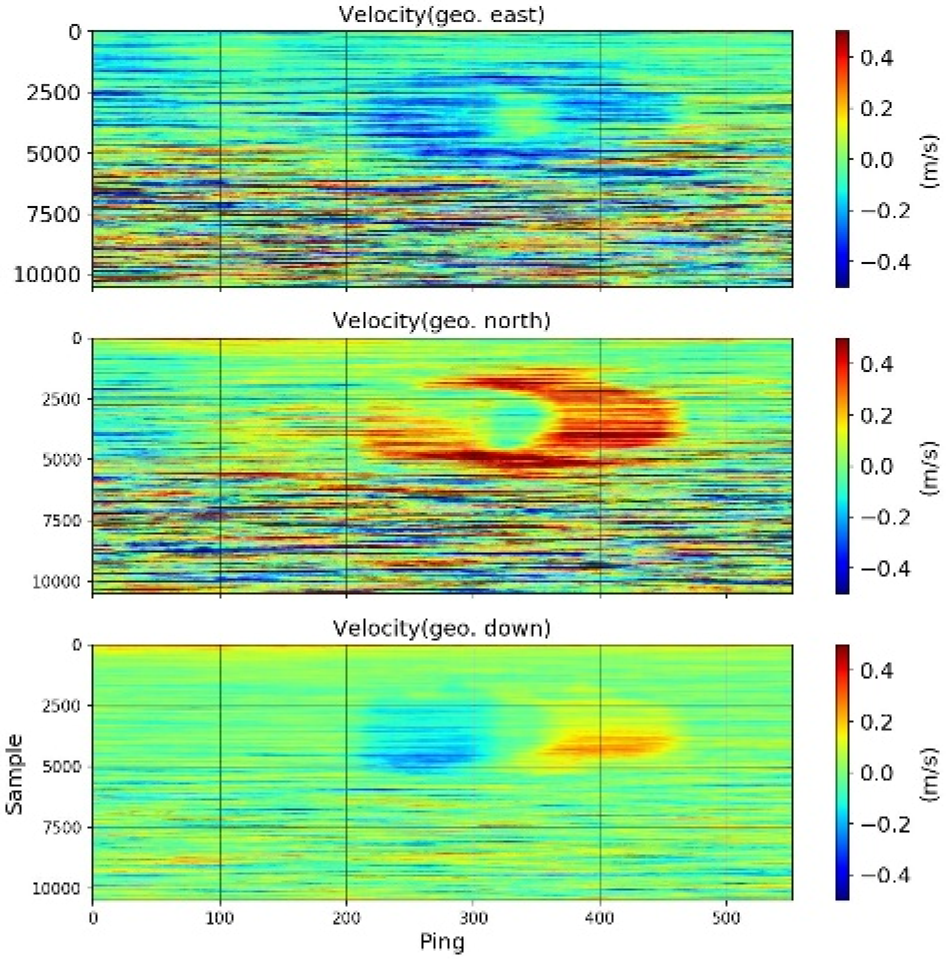


Fig. 14. The ADCP measurement of a capelin school from UTC 07.29.29 to UTC 07.44.59 of the 7th March 2022. Upper four panels) backscattering from the 4 beams. Lower three panels) the directional velocity calculated by the ADCP.

It is advised to visualize the quantified speed by manual selecting the valid pings between the areas of high uncertainty. Fig. 15 shows how the valid data are selected for capelin speed statistics. The selection is performed manually, with selections based on color contrast in each direction. The selection is to ensure that only valid fish speed values are taken into discussions.

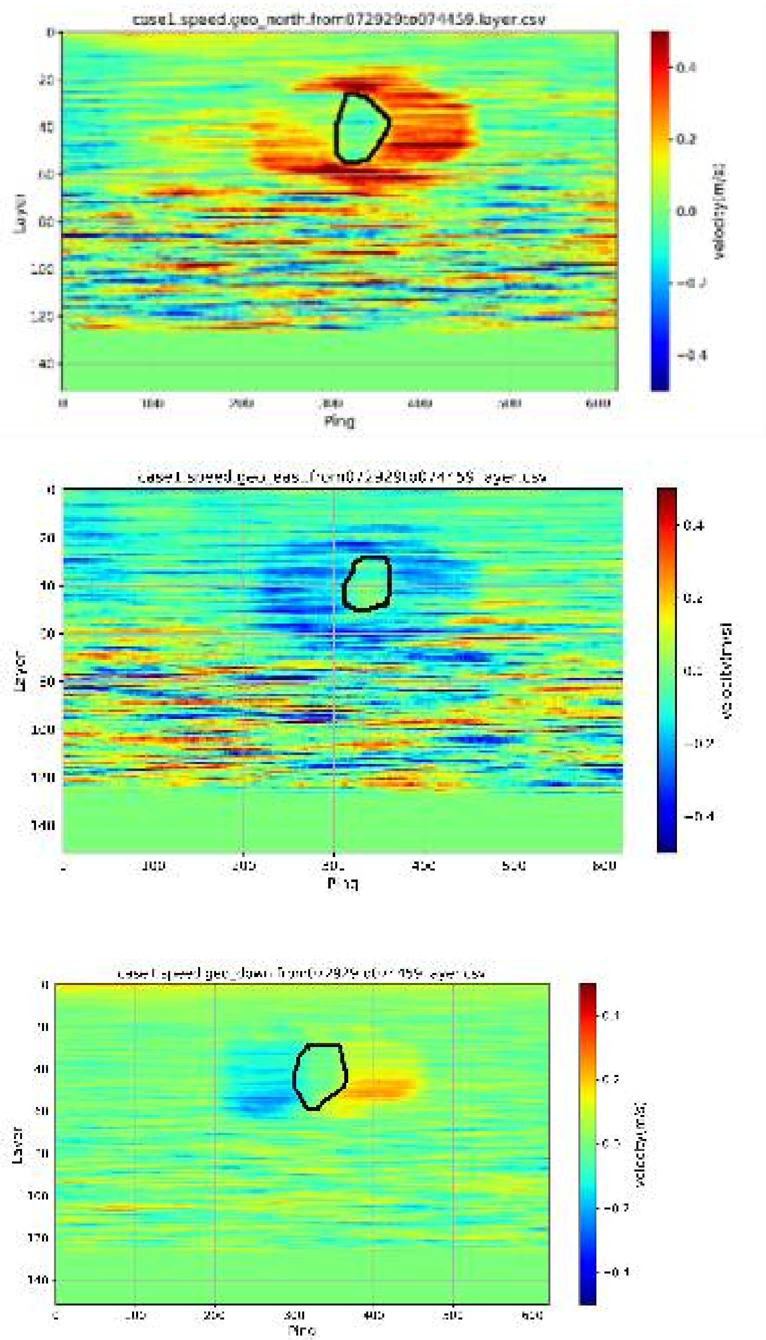


Fig. 15. Data selection over the valid pings in north-south (upper panel), east-west (middle panel) and up-down (lower panel) directions.

Fig. 16 shows a box plot of fish speed and water speed around this school. Note that due to the uncertainties before the selected data, only fish velocities are valid here. The fish moves northwards, and the median values show that the west speed is about 0.05 m/s, while movement is 0 m/s for both the north and down directions.

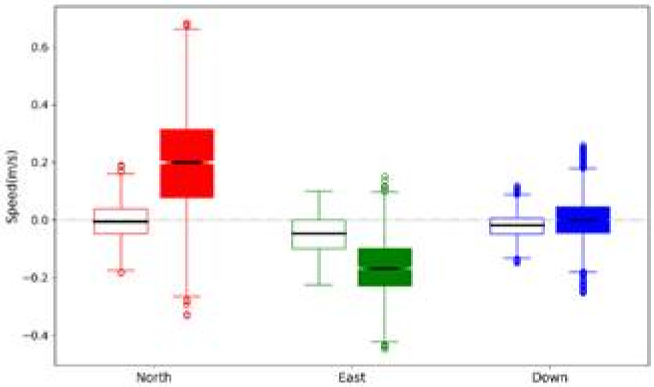
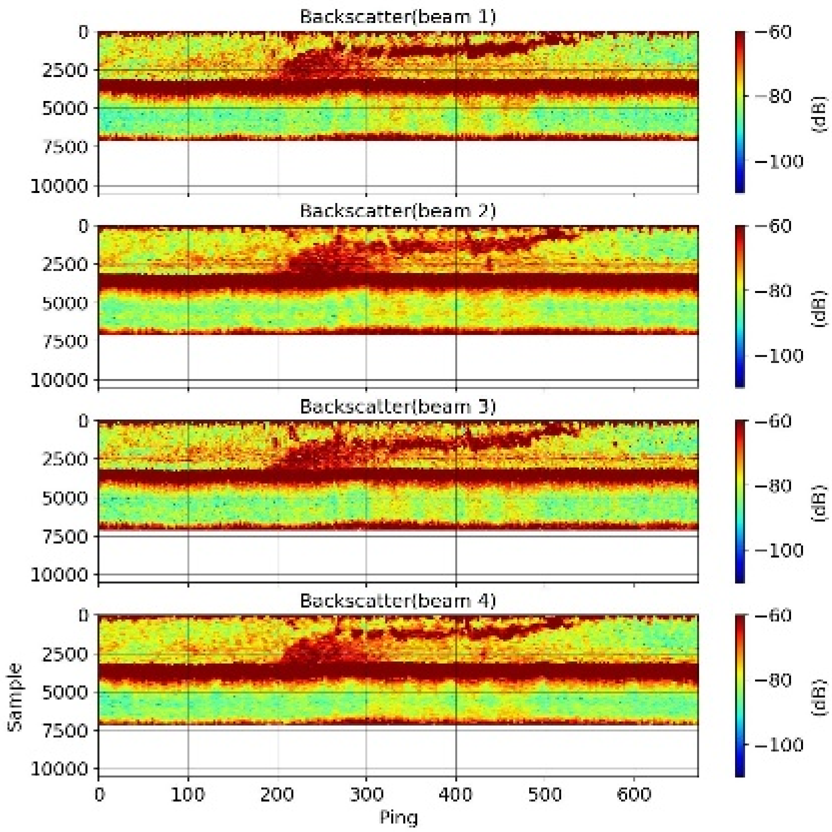


Fig. 16 . Box plot of fish speed versus the water speed around the fish school. The colour filled boxes show the water speed.

The same analysis method as above was applied to another capelin school, which was much larger. Good ADCP beam coverage shown in the upper four panels of Fig. 17 ensured that the ADCP could accurately calculate the speed of this fish school. It is shown in the three lower panels of Fig. 17 this school is moving towards the west and south, and is diving down. This school movement is clear enough for analysis. Fig. 18 shows a box plot of fish speed versus water. The fish swims in the direction of the current but faster than the current, and median speeds are about 0.5 m/s in all directions. Note that the water also has a downward movement, which is probably due to the heave as no heave compensation was used.



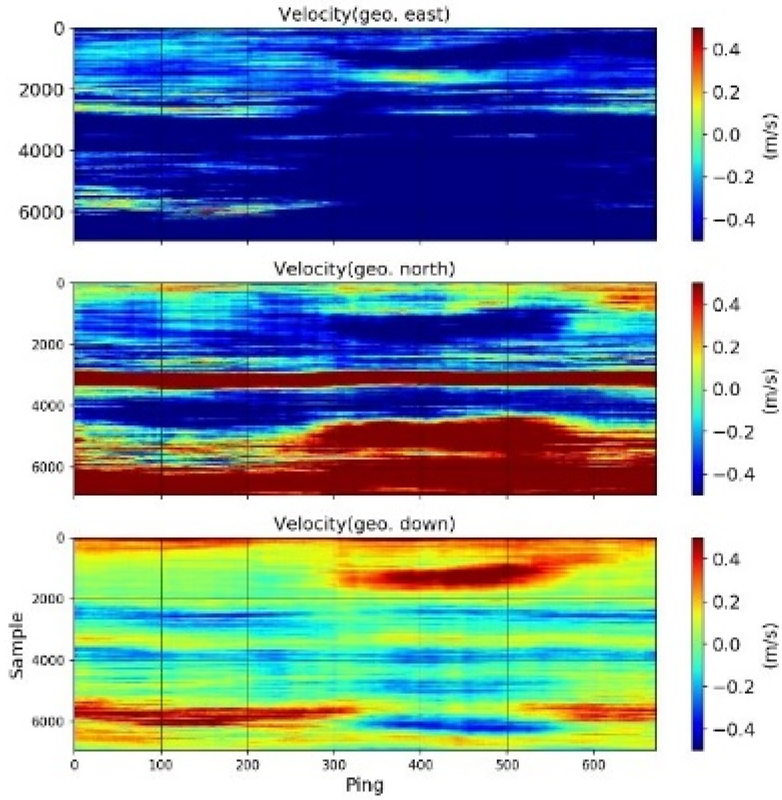


Fig. 17. The ADCP measurement of a capelin school from UTC 00.37.05 to UTC 01.02.18 of the 2nd March 2022. a) backscattering from the four beams and b) directional velocity calculated by the ADCP.

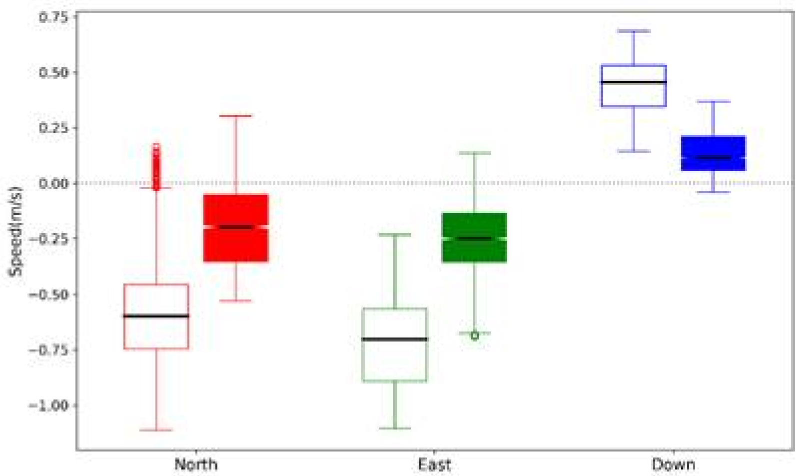


Fig. 18 . Box plot of fish speed versus water speed around the fish school. The colour filled boxes show the water speed.

Summary of the ADCP data collection:

1. The ADCP mostly seemed to work as expected, but detailed analysis of the data for verification should be carried

out.

2. ADCP measurements depend on the school size, and it is challenging to quantify features of small schools.
3. ADCP measurements, e.g. the school speed, can be verified by sonar data scrutiny.
4. ADCP data processing demands heavy computing, and therefore requires much time also after the survey.

4.3 - Concluding remarks about the survey

- The total biomass was estimated at 426 618 tons, with a sampling variance expressed as Coefficient of Variation (CV) of 42%. The high CV despite the good coverage likely reflects a patchy distribution with a few transects with very high densities.
- The dominating amounts of capelin were in the east, and most capelin were recorded north of Varangerhalvøya. There were also concentrations of capelin in the western coverage area, mostly in association with Fugløybanken and Malangsgrunnen. The abundance of capelin in the west seemed to decrease over the survey period, and a fair amount of the capelin here were spent and close to the shore during the second coverage.
- This is the fourth year of conducting this survey and like for the previous years the survey results overlap with the range of the confidence band of the stock forecast based on the autumn survey. This consistency in the survey results indicates that the survey can be a reliable addition to the assessment and advice of capelin.
- Multi-frequency recordings and TS measurements showed that most of the capelin had a frequency response and TS in accordance with the expectation, but some showed a frequency response similar to what was commonly observed last year indicating empty swimbladder.
- The experience gained during the present survey, together with the surveys in 2019-2021 forms the basis for a proper evaluation of the usefulness of a capelin winter monitoring as input to the stock assessment and advice.

4.4 - Acknowledgments

The skipper and crew on board FV *Vendla* and FV *Eros* are thanked for their excellent assistance and engagement during the whole survey .

5 - Appendix

5.1 - Appendix 1. Capelin length distribution by station

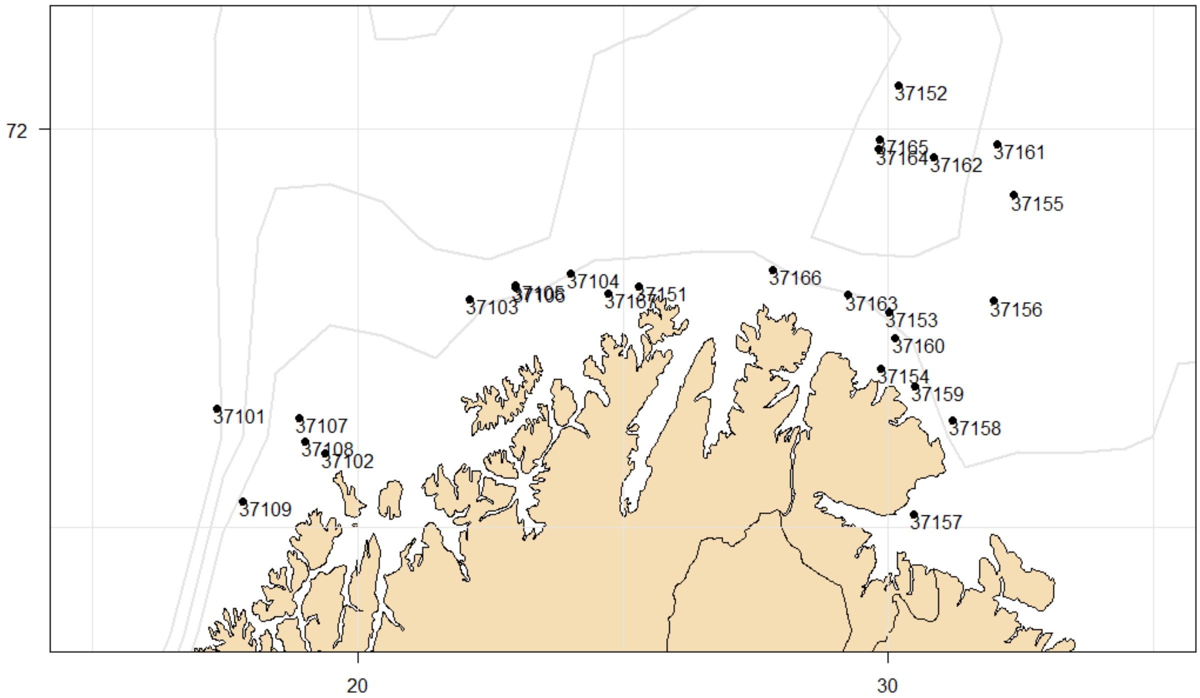


Fig. A1_1. Pelagic trawl stations with associated serial numbers.

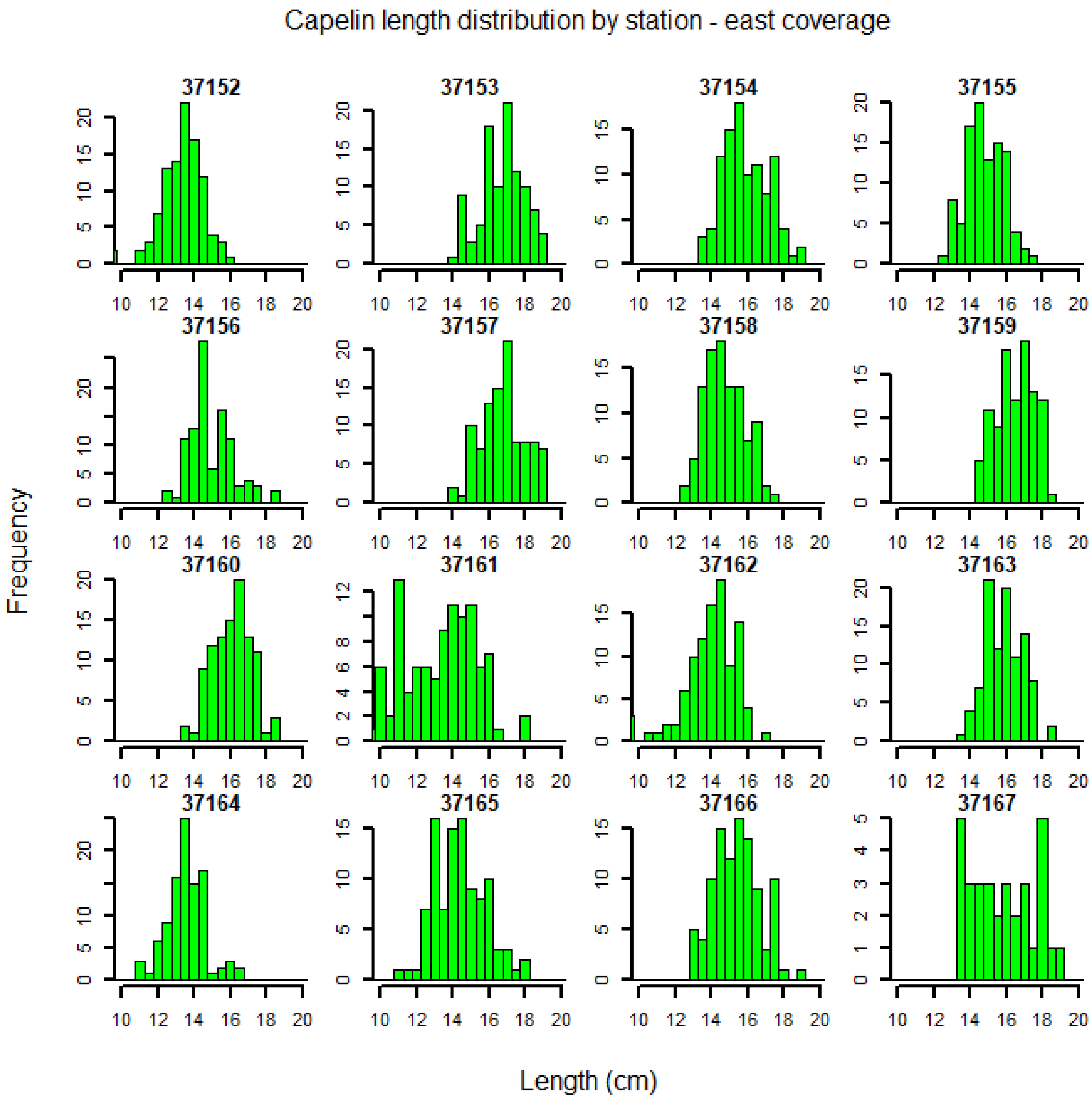


Fig. A1_2a) Capelin length distribution by station for the east coverage; station serial number is given at the top of each panel (see Fig. A1_1 for geographical position of the stations).

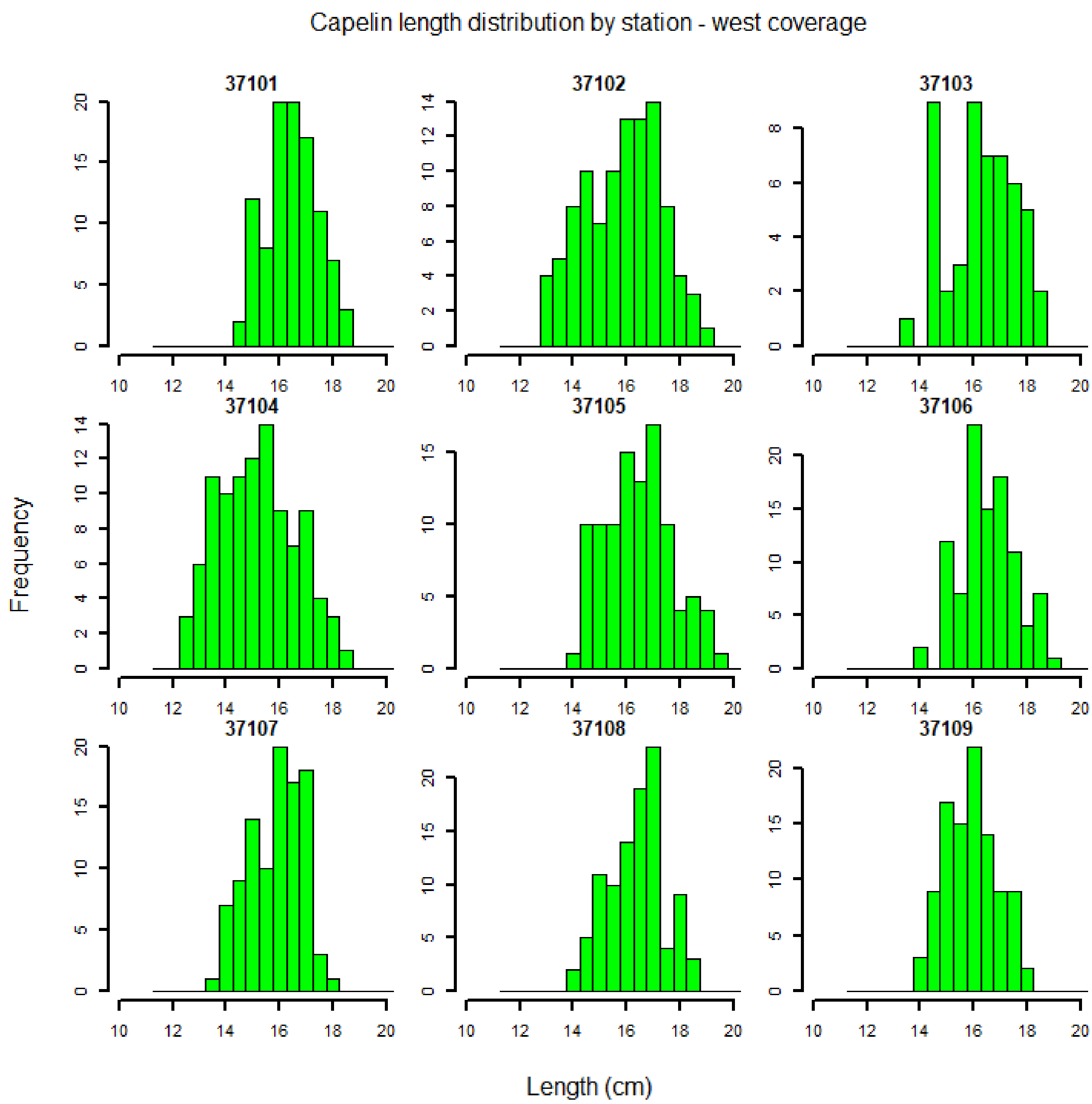


Fig. A1_2b) Capelin length distribution by station for the west survey coverage; station number is given at the top of each panel (see Fig. A1_1 for geographical position of the stations).

5.2 - Appendix 2. Herring distribution based on acoustic data

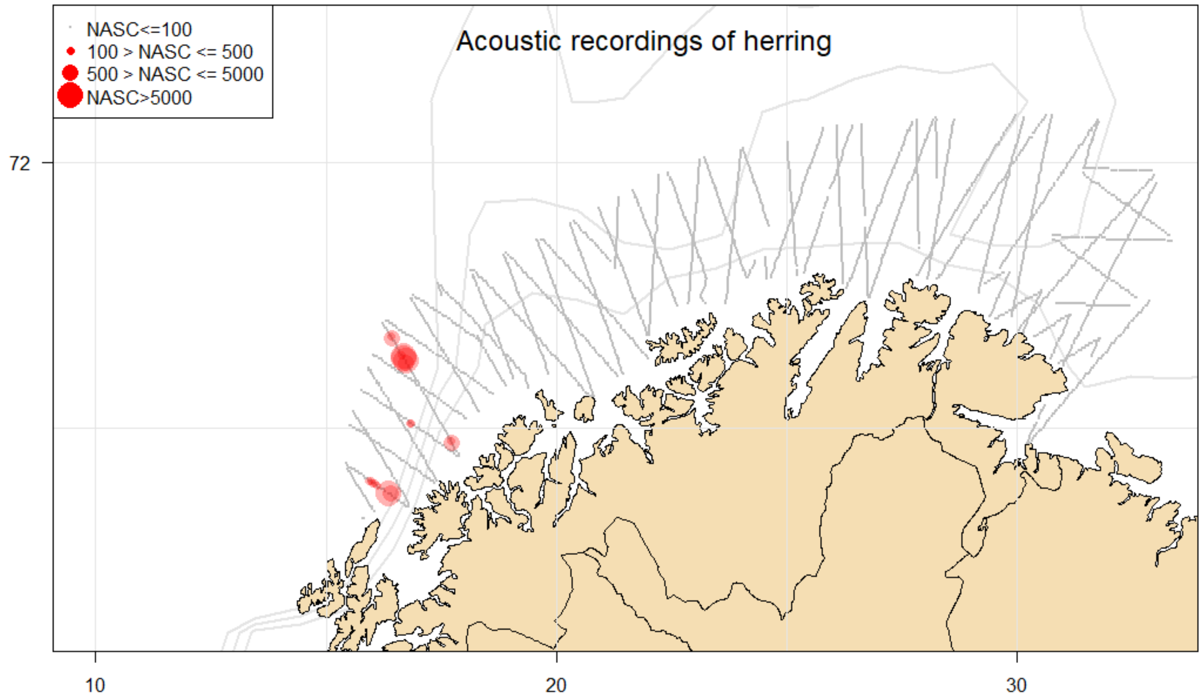


Fig. A2_1. Distribution of NASC (m^2nmi^{-2}) allocated to herring. The size of the circle corresponds to NASC-value per 1 nautical mile

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5.3 - References

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