Cruise report: Acoustic assessment of the Iceland-East Greenland-Jan Mayen capelin stock in Autumn 2023

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1 Objective

The main objective of the survey was acoustic assessment of the capelin stock in the Iceland, East Greenland and Jan Mayen area, measuring mature and immature stock components at age 1 and older. The survey was conducted by the r/v Arni Fridriksson on behalf of MFRI and r/v Tarajoq on behalf of GINR.

2 Methods

2.1 Survey area and conditions

The survey area was on and along the shelf edge off East Greenland from about 64°30´N towards about 75°15´ N, also covering the Denmark Strait and the slope off northwest Iceland. The Iceland Sea, Kolbeinsey ridge and Greenland basin were only briefly scouted due to time constraints and for same reason hydrographic measurements and zooplankton sampling were limited compared to previous years.

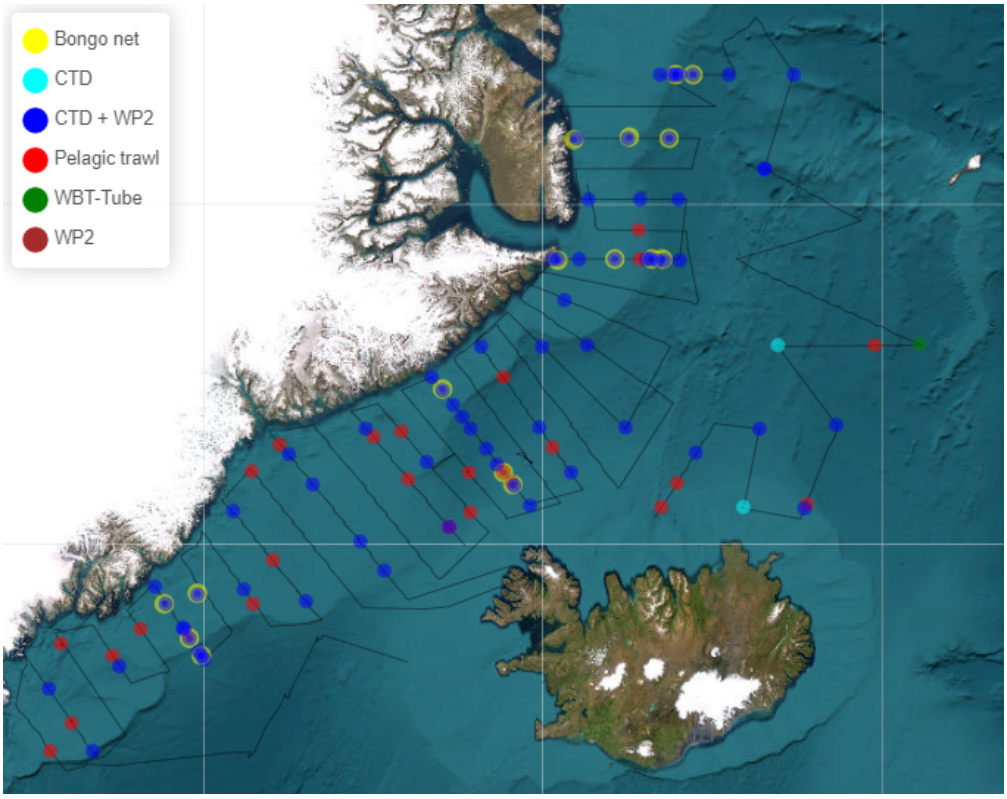


Figure 1: Survey tracks and sampling stations of the participating vessels. Type of sampling gear at each location shown by color.

Tarajoq departed from Hafnafjordur harbour just after midnight 23 August, initially operating pelagic trawl stations for a mackerel project and then heading to the first capelin assessment transect at the southwest extent of the survey area. From there Tarajoq followed paralell transects covering the East-Greenland continental shelf from Umivik towards Denmark Strait. Due to bad weather, Tarajoq went into Isafjordur harbor on 1 September and with an exchange of personnel planned on September 4th it was decided to use the time to calibrate the transducers. Tarajoq departed for the second half of the survey on September 4.

Arni departed from Hafnarfjordur the 5 September and headed to Denmark Strait where both vessels operated along transects covering Denmark Strait and shelf areas outside Scoresby Sund. On the first transect Arni deployed 5 drift boys for the NORSE project. The 8 September, both vessels had to halt operation for about 16 - 18 hours in Denmark Strait outside Kogurgrunn, due to bad weather. On 13 September Arni deployed wave glider at between Scoresby Sund and Jan Mayen for the international NORSE project. Then the 12 September Tarajoq had to leave the project to assist stranded cruise ship, Ocean explorer, in Alpe fjord. Hence, Arni finished all transects from Scoresby towards Kong Oscar Fjord while only CTD and net samples on the eastern half of Transect D (outside Kong Oscar Fjord) could be sampled due to time constrain and drift ice distribution. Planned transects and sampling scheme north of Kong Oscar Fjord could not be covered due to drift ice. Hence, the ice edge was followed with adapted zik-zak transects north to 32°33 N and then

sailing along coarse zik-zak transects southwards over the East Greenland-Jan Mayen ridge and Iceland basin. At 71°N and 15°09W Arni stopped and made trial to do open water calibration of WBT-Tube echosounder but without success due to lack of tilt control of the instrument transducers. While covering the Iceland basin Arni could not always extend transects as planned to the west due to bad weather and the 18 September the vessel had to head to shelter in Axarfjordur bay and wait until 20 September for calmer weather. Then, coarse transects were sailed from shelf areas north of NE-Iceland and into the Icelandic basin heading towards Kolbeinsey-ridge. 18 nmi south of Kolbeynsey island the last transect was finished and headed towards Hafnarfjordur. While bypassing Vestfirðir peninsula Arni stopped outside Talknafjordur fjord for potential assistance of rv Bjarni Saemundsson that had stranded close to the coast inside the fjord, then Arni escorted Bjarni to harbour in Hafnarfjordur where both vessels arrived in the morning of 23 September.

In general, in areas south of Scoresby, drift ice did not limit the coverage of the survey vessels although icebergs and a lack of benthic mapping occasionally limited extension of transects towards the Greenlandic coast. On the other hand, drift ice hindered the coverage of areas north of Kong Oscar Fjord.

2.2 Acoustic sampling

Acoustic data was sampled with Simrad EK80 echosounders at five frequencies. The data were scrutinized by a scientist onboard the vessel using LSSS (version 2.15.0) software where capelin backscatter at 38 kHz was defined and its Nautical Area Scattering Coefficient (NASC) in SA units (m^2/nmi^2) calculated at 0.1 nmi integration intervals. Then, average NASC within squares of 30 minutes latitude and 60 minutes longitude was calculated. Abundance in numbers was estimated using a length dependent target strength relationship (TS; in dB re $1m^2$)

$$TS = 19.1 * log(L) - 74.5$$

Total length of the capelin was measured to nearest mm. For each length interval within the length distribution of capelin in the samples the following parameters were calculated: backscattering proportion, number and weight.

$$\sigma_L = 4 * \pi * 10^{TS_L/10}$$

$$C_L = \frac{\frac{Cs_L * \sigma_L}{\sum_L (C_L * \sigma_L)} * NASC * A}{\sigma_L}$$

$$W_L = C_L * \overline{Ws_L}$$

Where L is measured length, σ is backscattering cross-section, C is total number, Cs is number in sample, A is surface area and Ws is average weight in sample. Further, for ongoing project studying capelin backscatter (target strength), the backscatter was measured at chosen locations by a TS-probe(WBT-Tube) that was lowered to depths in the proximity of capelin schools.

2.3 Biological sampling:

2.3.1 Pelagic trawl:

Total length and weight of up to 100 individual capelin fish was measured for a subsample from the catch at each of 36 pelagic trawl stations. Also, sex and maturity were estimated visually and the gonads from maturing capelin were weighted. Age was estimated from otoliths. Stomachs of 10 capelin were preserved on each station. Also 50 individual capelin were sampled on every second station for genetic analysis and further on every station 100 individuals in two size categories (above and below 14 cm) were sampled for fat content analysis.

2.3.2 WP2 zooplankton net:

Zooplankton was sampled by WP2 nets at depths down to 50 and 200 m at same location as CTD measurements if weather permitted.

2.3.3 Bongo nets:

Further Bongo samples were sampled diagonally down to 200 m at chosen transects.

2.3.4 Environmental measurements

Environmental parameters where measured at predefined locations by lowering a conductivity, temperature and depth meters (CTD) down to 500 m or down to bottom if shallower. This was done along defined transects with dense sampling at locations of interest often near shelf edges. More spread CTDs were also sampled in other regions to get general overall coverage. Further, a continuous surface measurements were registered along the track of r/v Arni Fridriksson.

2.3.5 WBT Tube acoustic back scattering measurements

Submersible echousounders (Simrad: WBT Tube) were brought for measuring back-scatter properties of capelin at depth, allowing for higher resolution measurements of individual targets. This equipment needs calm weather while capelin registrations are observed. This was not accomplished during this survey. A trial was made to calibrate the echosounders in the open ocean during good weather conditions but without success, addressing need for further development of the platform.

3 Results and conclusions

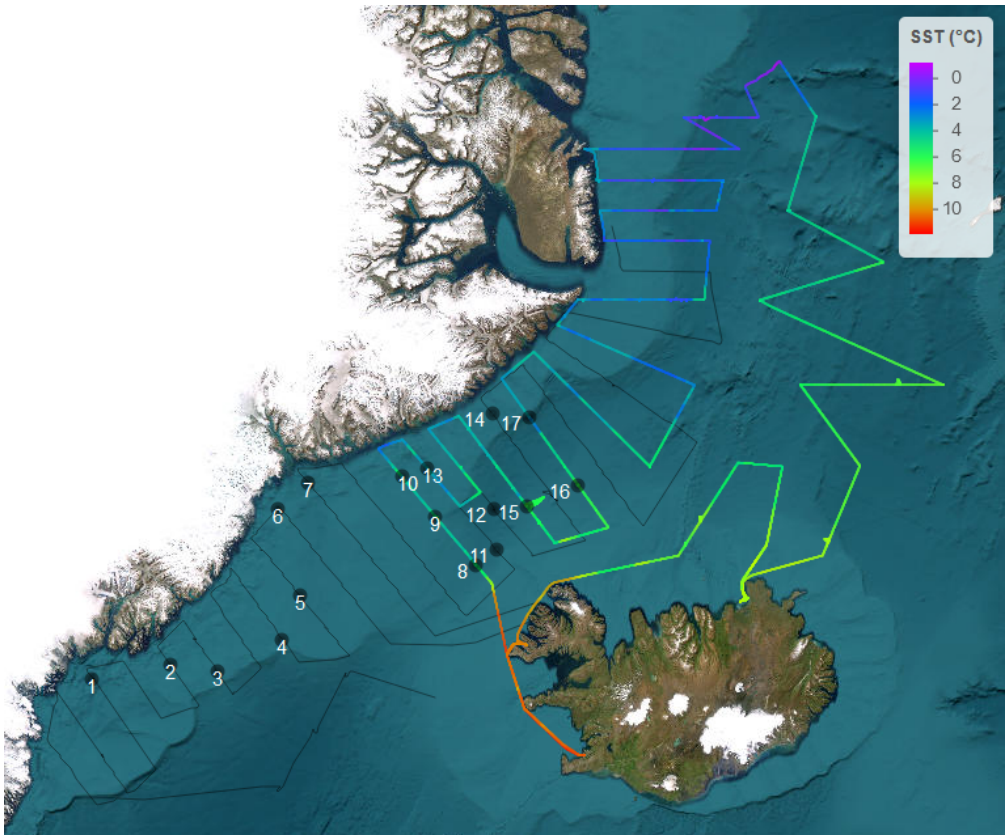


Figure 2: Tracks of the participating vessels. Route of rs Arni Friðriksson with sea surface temperature (SST) color scale as measured onboard and route of rs Tarajoq in the research area shown as black line. Pelagic trawl stations that caught capelin one year and older are shown as black circles labelled in chronological order

3.1 Distribution of capelin

Maturing capelin was mainly observed along the East Greenlandic continental shelf and shelf edges in Denmark Strait. In western Denmark Strait maturing capelin was mixed with immature capelin, but mainly maturing capelin was found further west. No important quantities of mature capelin were found east of Denmark Strait and that is a drastic change from observations during preceding years when mature capelin was found on or along the East Greenland continental shelf south, east and north of Scoresby. Further, no capelin was found by West Jan Mayen ridge or Kolbeinsey ridge. In general there were no signs of any important quantities of capelin east of Kolbeinsey ridge nor along Icelandic shelf edges. Juveniles (0-group) of various species, including capelin (although not quantified) were observed along the continental shelf north of Iceland. Immature capelin was found along the Greenlandic shelf, dominating in southwestern part of the survey area

and western Denmark Strait. Overall, the distribution of maturing capelin was not reaching as far east in the autumn as in preceding years. Figures 1 and 2 show the cruise tracks, distribution and relative density of the capelin during the survey.

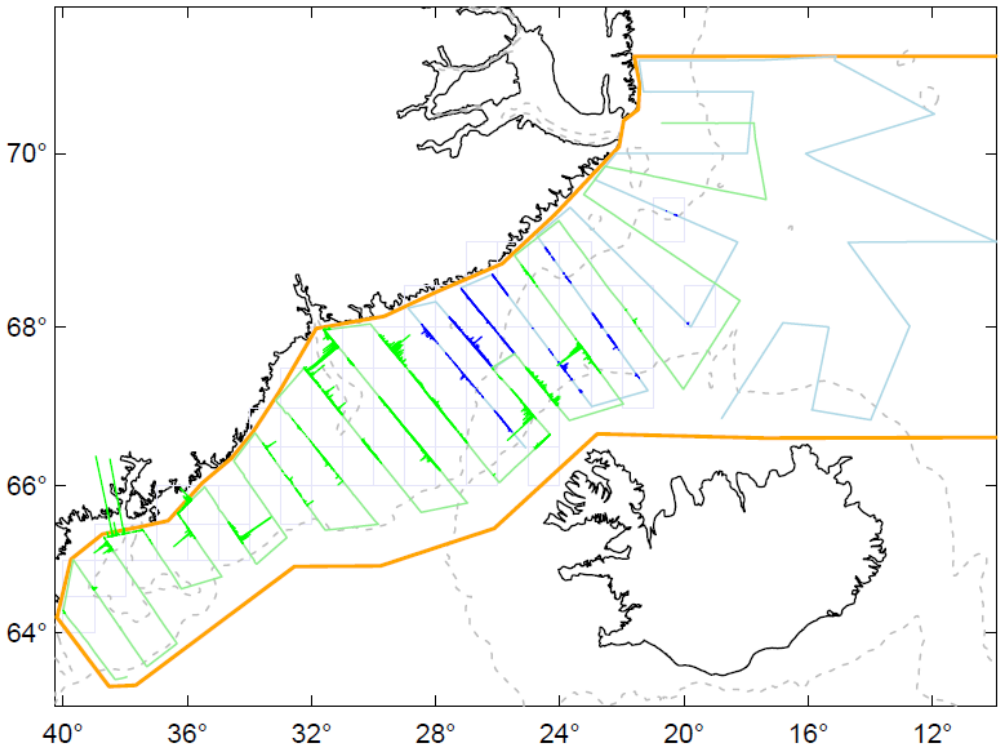


Figure 3: Capelin distribution as relative density of acoustic backscatter during the survey. Bars perpendicular to survey tracks show capelin acoustic backscatter as NASC per 0.1 nmi. Tarajoq track light green, NASC dark green, Árni Friðriksson track cyan, NASC blue.

3.2 Biomass and age composition of capelin

Age and length disaggregated biomass is shown in tables 1-6. The total number of capelin amounted to 64 billions whereof the 1-group was about 50.7 billions. The total estimate of 2 group capelin was about 8.3 billions. The total biomass estimate was 697 000 tonnes of which about 286 000 tonnes were 2 years and older. About 9.4 % in numbers of the 1-group was estimated to be maturing to spawn, about 79.8 % of the 2 year old and 97.4 % of the 3 year old capelin appeared to be maturing. This gives about 325 000 tonnes of maturing 1 - 4 year old capelin. Tables 1-6 give the age disaggregate biomass, numbers and weights of the capelin stock components.

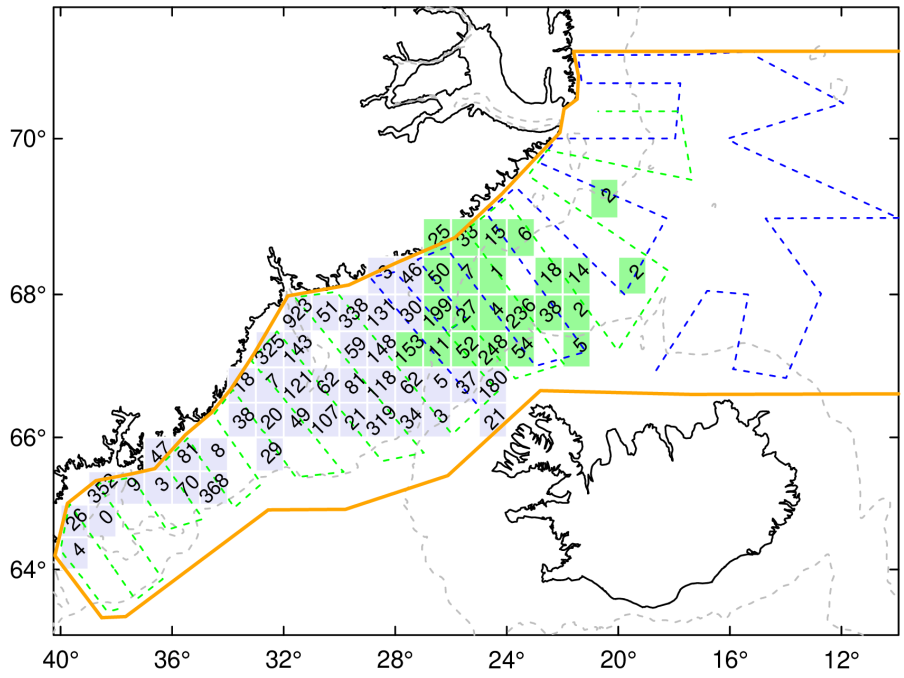


Figure 4: Capelin distribution as relative density of acoustic backscatter during the survey.

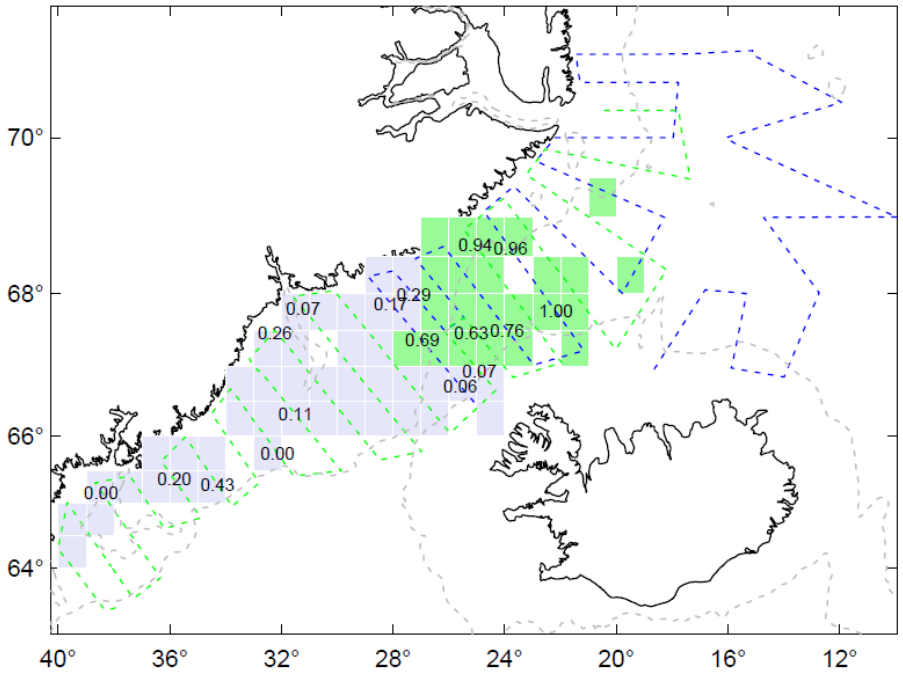


Figure 5: Proportion of mature capelin at each trawl station.

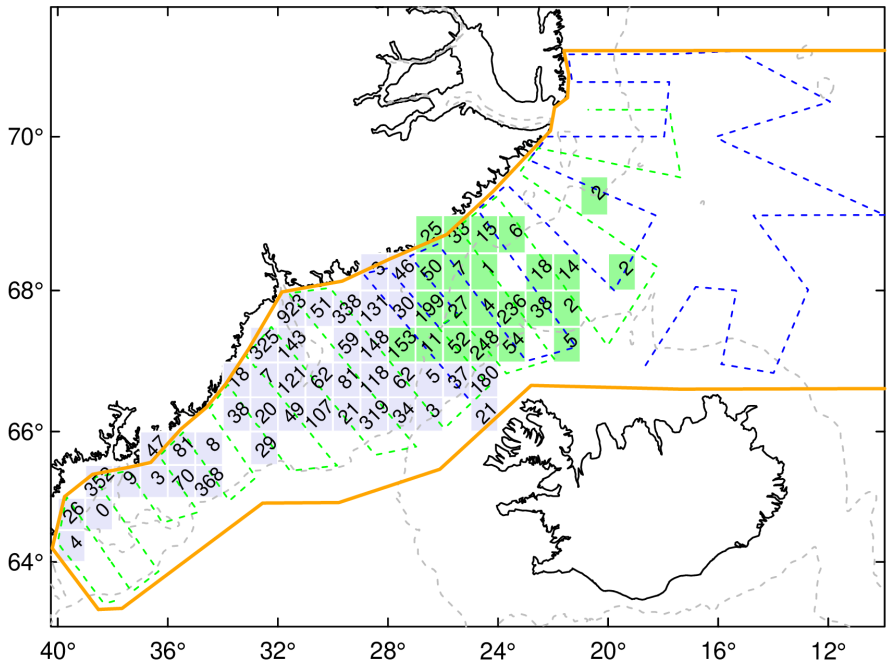


Figure 6: Average NASC within each rectangle.

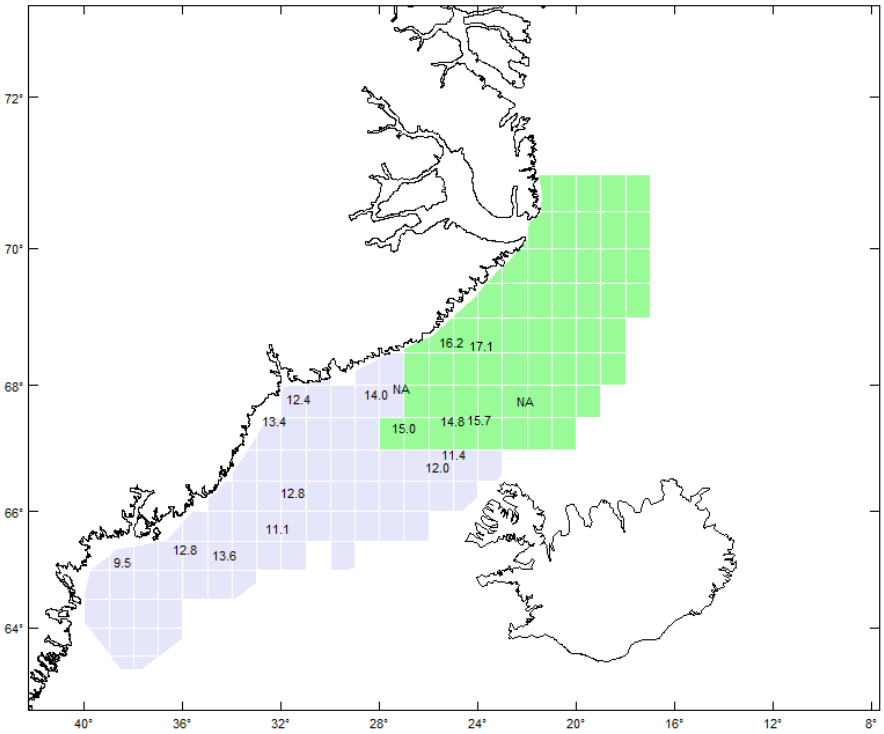


Figure 7: Mean length(cm) of capelin at each trawl station.

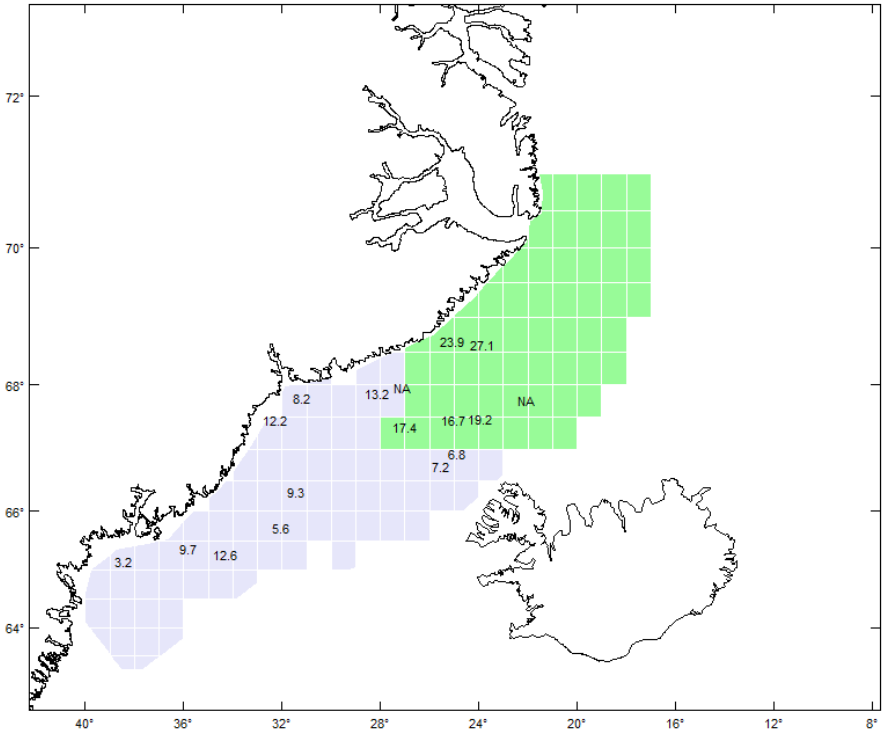


Figure 8: Mean weight(g) of capelin at each trawl station.

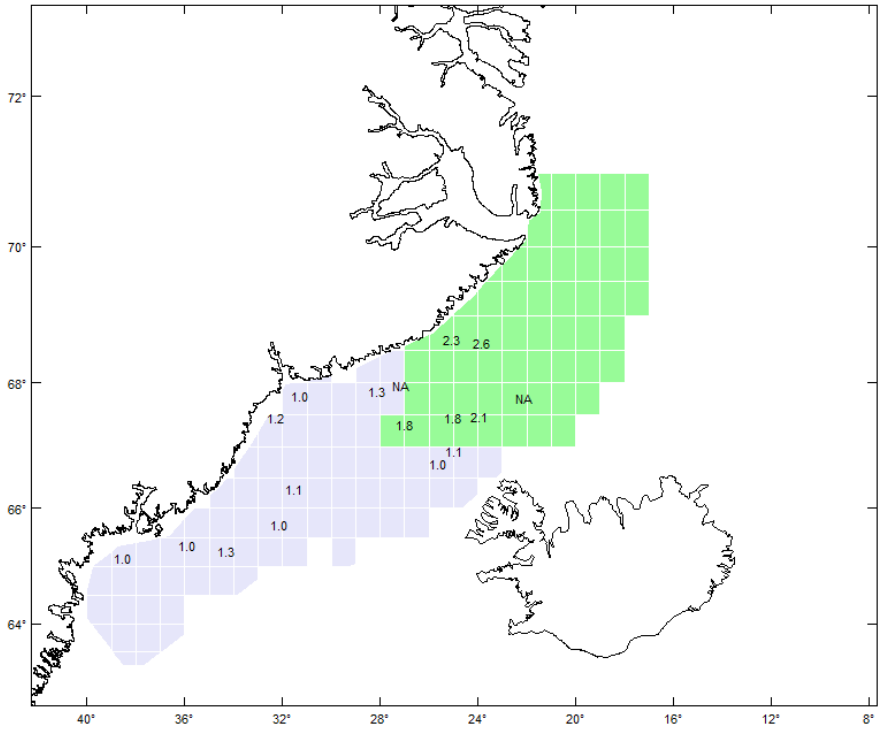


Figure 9: Mean age (years) of capelin at each trawl station.

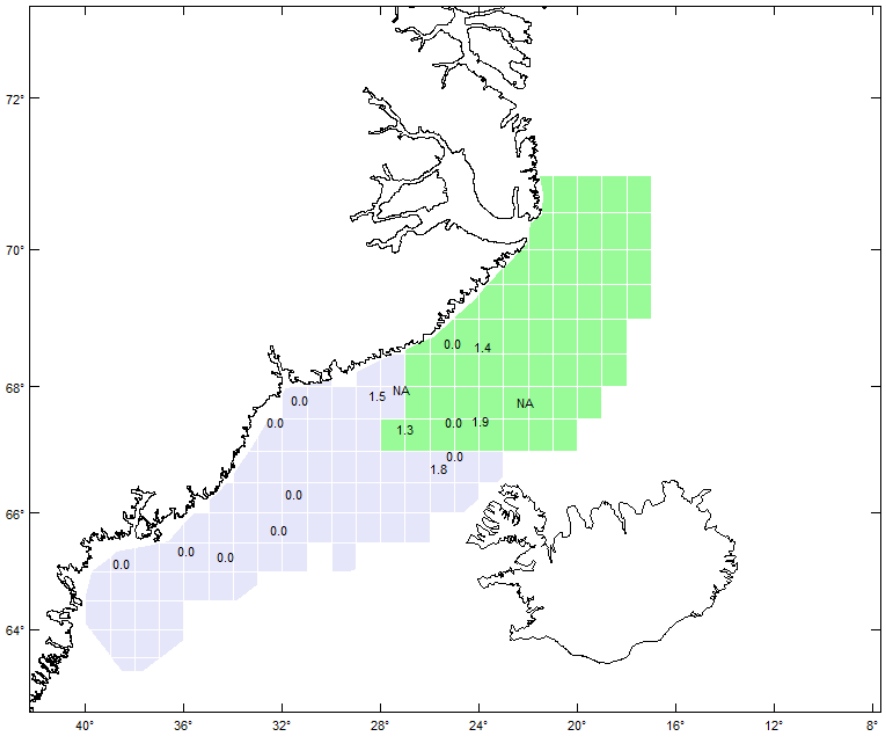


Figure 10: Gonadosomatic index of maturing female capelin at each trawl station.

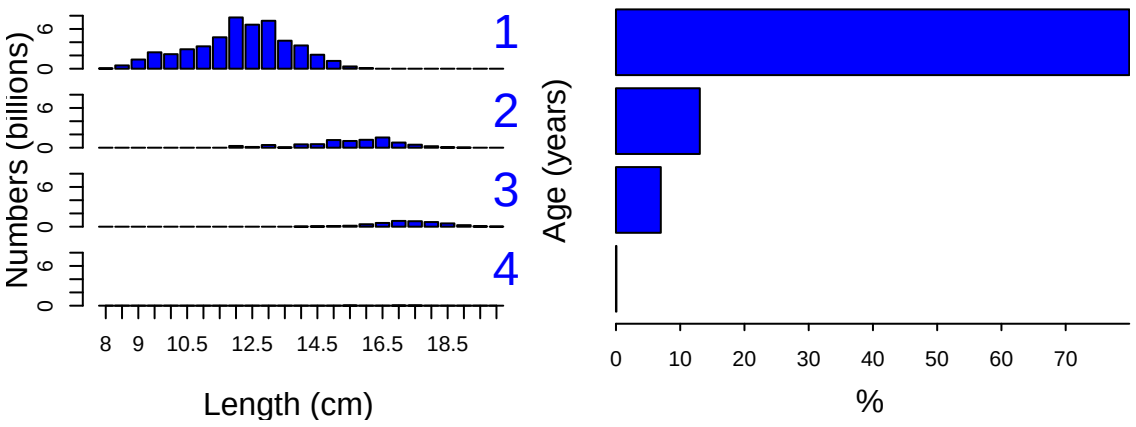
3.3 Total stock

Table 1: Estimated stock size of Iceland-Greenland-Jan Mayen capelin total stock in numbers (millions) by age (years) and length (cm), and biomass (thous. tonnes) from the acoustic surveys in 23. August – 23. September 2023. Mean weight is in grams

length	a1	a2	a3	a4	num.sampled	numbers	biomass	weight.mean
8.0	49.50	0.00	0.00	0.00	1	49.50	99.00	2.00
8.5	495.02	0.00	0.00	0.00	10	495.02	1113.81	2.25
9.0	1386.07	0.00	0.00	0.00	28	1386.07	3678.03	2.65
9.5	2475.12	0.00	0.00	0.00	50	2475.12	7681.80	3.10
10.0	2193.22	0.00	0.00	0.00	45	2193.22	8284.43	3.78
10.5	2935.75	0.00	0.00	0.00	60	2935.75	13260.14	4.52
11.0	3377.09	0.00	0.00	0.00	71	3377.09	17819.28	5.28
11.5	4743.87	0.00	0.00	0.00	100	4743.87	28962.31	6.11
12.0	7740.04	262.62	0.00	0.00	170	8002.66	57995.97	7.25
12.5	6646.80	114.11	0.00	0.00	147	6760.91	56538.99	8.36
13.0	7236.65	406.94	0.00	0.00	169	7643.59	72775.15	9.52
13.5	4227.92	45.32	0.00	0.00	103	4273.23	47097.23	11.02
14.0	3511.41	501.76	15.11	0.00	105	4028.27	50622.01	12.57
14.5	2111.87	531.97	49.50	0.00	69	2693.34	39212.92	14.56
15.0	1175.50	1157.13	94.82	0.00	81	2427.45	38739.22	15.96
15.5	342.33	1012.81	144.32	15.11	57	1514.57	28419.73	18.76
16.0	99.00	1189.89	370.91	0.00	78	1659.80	35401.82	21.33
16.5	0.00	1540.59	564.73	0.00	87	2105.33	48913.94	23.23
17.0	0.00	776.21	869.40	15.11	94	1660.72	42718.59	25.72
17.5	0.00	450.62	824.08	15.11	74	1289.81	37742.28	29.26
18.0	0.00	219.85	699.05	0.00	54	918.90	28303.02	30.80
18.5	0.00	64.61	495.94	0.00	28	560.55	19275.17	34.39
19.0	0.00	15.11	230.77	0.00	14	245.88	9002.22	36.61
19.5	0.00	0.00	60.42	0.00	4	60.42	2309.98	38.23
20.0	0.00	0.00	15.11	0.00	1	15.11	666.47	44.12

Table 2: Age (years) aggregated total stock summary. T = Total, S = Stock, N = Numbers(billions), W = Weight(grams), L = Length(Cm), p = %

parameter	a1	a2	a3	a4	All
TSN	50.75	8.29	4.43	0.05	63.52
TSB	410.24	162.62	122.65	1.11	696.63
MeanW	8.08	19.62	27.66	24.58	10.97
MeanL	12.15	15.59	17.29	16.67	12.96
TSNp	79.90	13.05	6.98	0.07	100.00



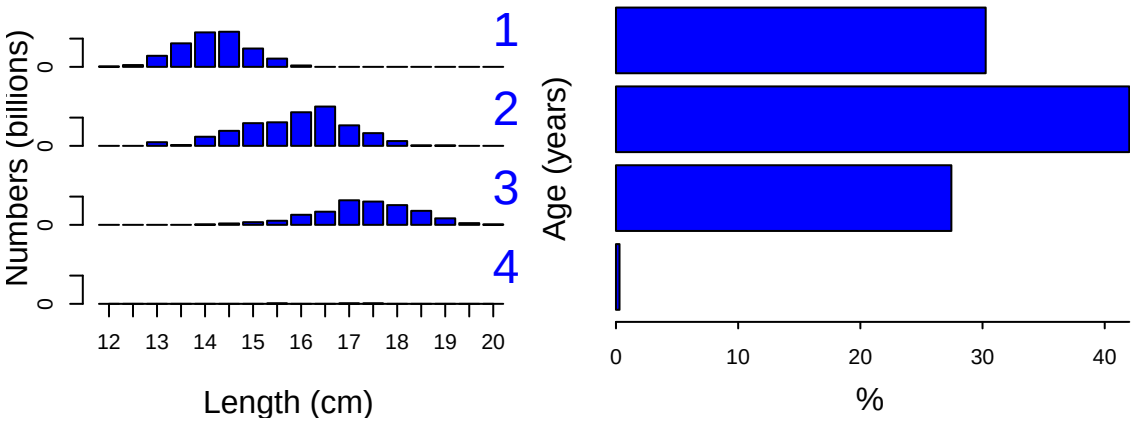
3.4 Spawning stock

Table 3: Estimated stock size of the Iceland-Greenland-Jan Mayen capelin spawning stock component in numbers (millions) by age (years) and length (cm), and biomass (thous. tonnes) from the acoustic surveys in 23. August – 23. September 2023. Mean weight is in grams

length	a1	a2	a3	a4	num.sampled	numbers	biomass	weight.mean
12.0	15.11	0.00	0.00	0.00	5	15.11	120.54	7.98
12.5	64.61	0.00	0.00	0.00	26	64.61	573.34	8.87
13.0	391.83	129.22	0.00	0.00	164	521.05	5284.13	10.14
13.5	833.17	30.21	0.00	0.00	103	863.38	10077.14	11.67
14.0	1220.82	323.04	15.11	0.00	105	1558.97	20041.36	12.86
14.5	1244.30	531.97	49.50	0.00	69	1825.77	27101.18	14.84
15.0	650.27	803.88	94.82	0.00	81	1548.96	25054.50	16.18
15.5	292.83	834.09	144.32	15.11	57	1286.35	24465.17	19.02
16.0	49.50	1189.89	355.80	0.00	78	1595.20	33914.50	21.26
16.5	0.00	1392.09	465.73	0.00	87	1857.81	43232.04	23.27
17.0	0.00	726.71	869.40	15.11	94	1611.22	41255.30	25.61
17.5	0.00	450.62	824.08	15.11	74	1289.81	37742.28	29.26
18.0	0.00	170.35	699.05	0.00	53	869.40	26600.13	30.60
18.5	0.00	15.11	495.94	0.00	27	511.05	17443.58	34.13
19.0	0.00	15.11	230.77	0.00	14	245.88	9002.22	36.61
19.5	0.00	0.00	60.42	0.00	4	60.42	2309.98	38.23
20.0	0.00	0.00	15.11	0.00	1	15.11	666.47	44.12

Table 4: Age (years) aggregated spawning stock comonent summary. T = Total, S = Stock, N = Numbers(billions), W = Weight(grams), L = Length(Cm), p = %

parameter	a1	a2	a3	a4	All
SSN	4.76	6.61	4.32	0.05	15.74
SSB	65.70	138.34	119.73	1.12	324.88
MeanW	13.79	20.92	27.71	24.63	20.64
MeanL	14.18	15.91	17.31	16.67	15.77
SSNp	30.26	42.01	27.45	0.29	100.00



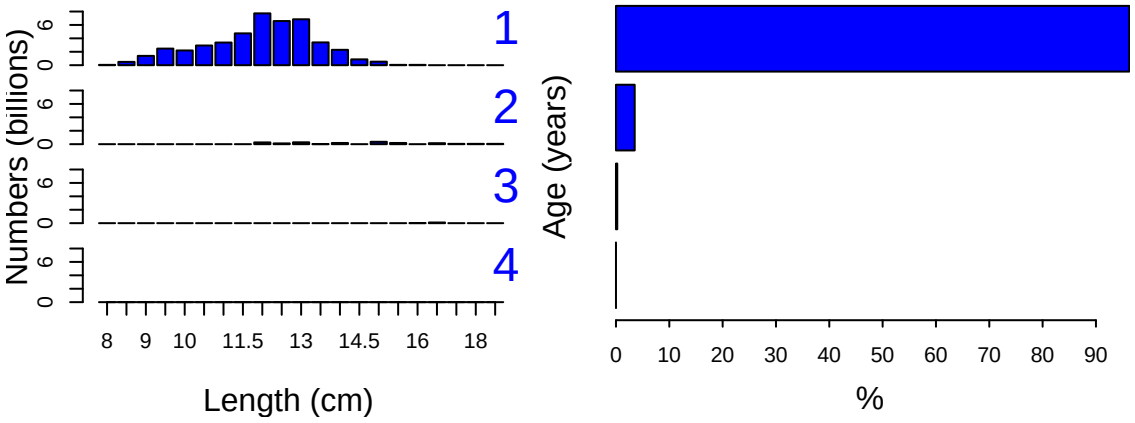
3.5 Immature stock

Table 5: Estimated stock size of the Iceland-Greenland-Jan Mayen capelin immature stock component in numbers (millions) by age (years) and length (cm), and biomass (thous. tonnes) from the acoustic surveys in 23. August – 23. September 2023. Mean weight is in grams

length	a1	a2	a3	a4	num.sampled	numbers	biomass	weight.mean
8.0	49.50	0.00	0.00	0	1	49.50	99.00	2.00
8.5	495.02	0.00	0.00	0	10	495.02	1113.81	2.25
9.0	1386.07	0.00	0.00	0	28	1386.07	3678.03	2.65
9.5	2475.12	0.00	0.00	0	50	2475.12	7681.80	3.10
10.0	2193.22	0.00	0.00	0	45	2193.22	8284.43	3.78
10.5	2935.75	0.00	0.00	0	60	2935.75	13260.14	4.52
11.0	3377.09	0.00	0.00	0	71	3377.09	17819.28	5.28
11.5	4743.87	0.00	0.00	0	100	4743.87	28962.31	6.11
12.0	7724.94	262.62	0.00	0	170	7987.56	57875.43	7.25
12.5	6582.20	114.11	0.00	0	146	6696.31	55965.65	8.36
13.0	6844.81	277.72	0.00	0	169	7122.54	67491.02	9.48
13.5	3394.75	15.11	0.00	0	102	3409.85	37020.09	10.86
14.0	2290.59	178.72	0.00	0	105	2469.30	30580.65	12.38
14.5	867.57	0.00	0.00	0	67	867.57	12111.73	13.96
15.0	525.24	353.25	0.00	0	70	878.49	13684.71	15.58
15.5	49.50	178.72	0.00	0	30	228.22	3954.56	17.33
16.0	49.50	0.00	15.11	0	15	64.61	1487.33	23.02
16.5	0.00	148.51	99.00	0	20	247.51	5681.90	22.96
17.0	0.00	49.50	0.00	0	2	49.50	1463.29	29.56
18.0	0.00	49.50	0.00	0	1	49.50	1702.89	34.40
18.5	0.00	49.50	0.00	0	1	49.50	1831.59	37.00

Table 6: Age (years) aggregated immature stock component summary. T = Total, S = Stock, N = Numbers(billions), W = Weight(grams), L = Length(Cm), p = %

parameter	a1	a2	a3	a4	All
ISN	45.98	1.68	0.11	0	47.78
ISB	344.26	24.87	2.62	0	371.75
MeanW	7.49	14.83	22.96	0	7.78
MeanL	11.94	14.35	16.43	0	12.03
ISNp	96.25	3.51	0.24	0	100.00



3.6 Survey bootstrap uncertainty estimation

Uncertainty of estimates of stock parameters was estimated using bootstrap according to ICES (2015). Table 3.7 gives the bootstrap mean, CV and standard quantiles of selected stock parameters.

Table 7: Mean, coefficient of variation (CV) and quantiles of stock assessment. EA: echo abundance (NASC*Area, millions), N: number of individuals (billions), B: biomass (thous. tonnes), SS: mature, Imm: immature.

Parameter	mean	CV	5%	25%	50%	75%	95%
EA	3.88	0.20	2.72	3.34	3.82	4.36	5.21
N	63.70	0.21	43.46	54.04	62.57	72.17	87.77
B	694.65	0.19	490.28	599.21	686.12	780.15	929.10
SSN	15.65	0.23	10.20	13.12	15.40	17.90	21.90
SSB	322.58	0.23	207.50	269.58	317.84	370.64	453.59
ImmN	48.06	0.25	30.58	39.42	46.93	55.38	69.51
ImmN1	46.33	0.25	29.28	37.89	45.16	53.48	67.39
ImmN2	1.62	0.45	0.66	1.09	1.50	2.01	2.99
ImmB	372.08	0.23	243.70	310.09	365.36	425.83	524.51

3.7 Predation model results

After the survey and upon completion survey estimation of stock parameters and their uncertainty 100 thous. bootstrap replicates were used as starting values for predation model runs. Results from the autumn 2033 predation runs are given in Table 8 and shown in Figures 11–13.

Table 8: Quantiles and mean of SSB at time of spawning (15. March) and total predator consumption in thous. tonnes based on the predation model

Parameter	mean	5%	25%	50%	75%	95%
SSB	210.19	113.33	162.11	203.34	250.67	330.94
Predation	114.81	72.98	94.67	112.25	132.40	165.10

The model (ICES 2023a, ICES 2023b) is designed to cover predation on the main spawning migration of capelin. A schematic description of the model is in Figure 11.

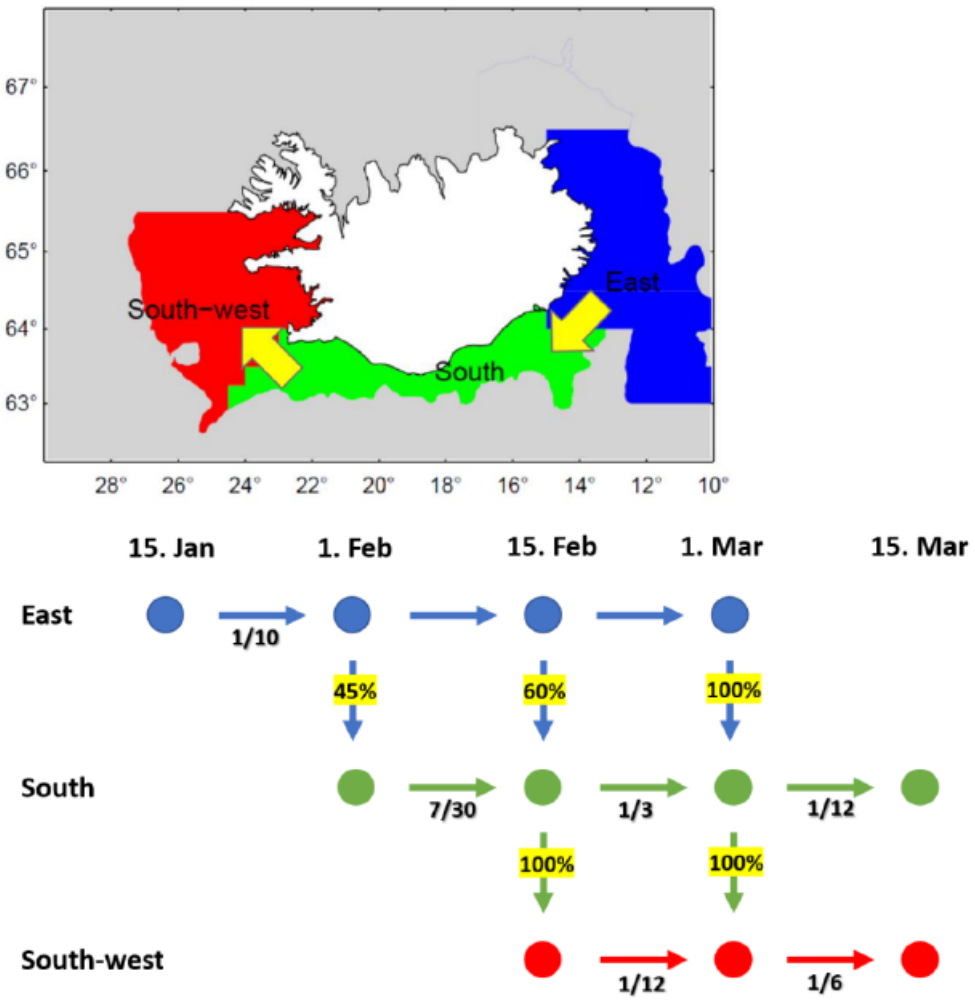


Figure 11: Top: The 3 regions used in the simulations of predation on the eastern capelin migration with yellow arrows showing migration route. Bottom: Schematic showing proportional distribution of migrations and catches in the predation model as discretized over 2 week intervals. Catches are shown as fractions below horizontal arrows and clockwise migrations are given as percentages over vertical arrows.

The predation model (ICES 2023a, ICES 2023b) applies to the stock component that migrates the clockwise route around Iceland. In most years, majority of the stock has migrated that route and nearly all the catches have been taken from that component. All the capelin stock is assumed to be in the east on 15th of January, and on 15th of March, it is assumed that all the capelin stock spawns in the south and southwest, a higher proportion in the southwest. The predators (cod, haddock and saithe) are assumed to be stationary during the period of capelin migration and their spatial distribution is obtained from the demersal survey in March from 1985 to previous year. The total abundance of each predator is predictions for the current year based on assessment in previous year.

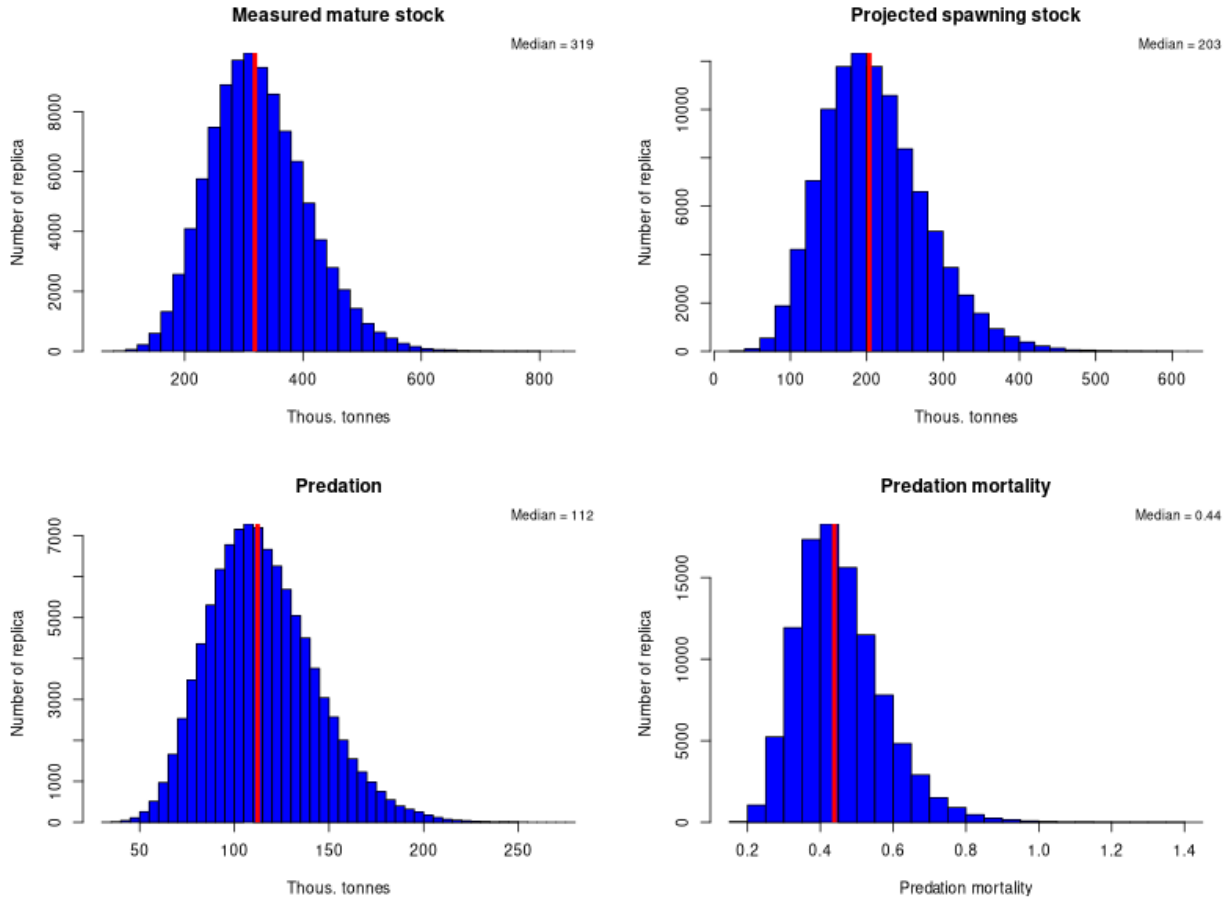


Figure 12: Summary of results from the 2023 autumn acoustic survey and predation model Biomass survey estimates of mature capelin (top-left), the projected spawning stock biomass left for spawning based on the predation model (top-right), predicted predation 15 January – 15 March (bottom-left) and the applied predation mortality (bottom-right)

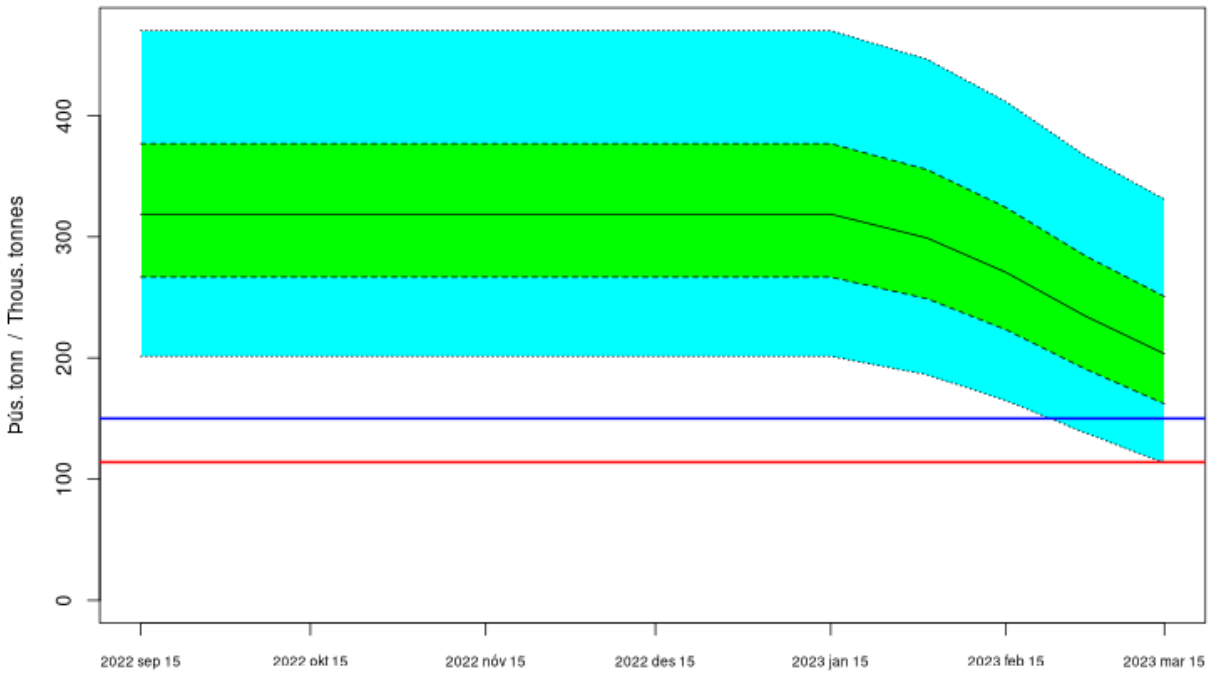


Figure 13: Predicted development of the SSB with no catch based on the predation model. Blue line indicates Blim = 150 000 tonnes from previous HCR (ICES 2015) while red line shows current Blim = 114 000 tonnes from current HCR (ICES 2023a, ICES 2023b).

3.8 Environmental measurements

Temperature and salinity profiles down to maximum of 500 m or down to bottom if shallower than 500 m for three chosen transects are shown on Figures 14 - 20.

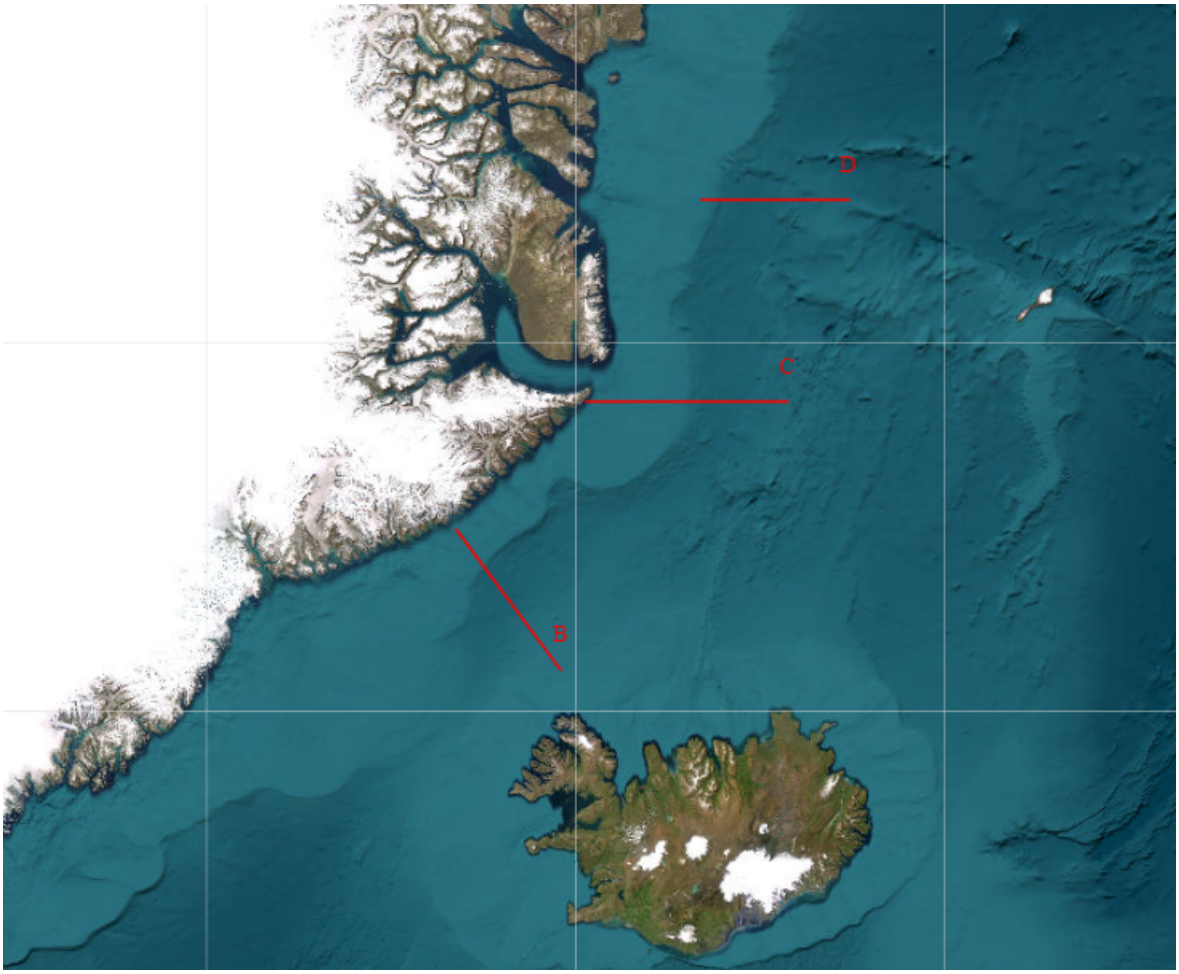


Figure 14: Overview of three CTD profile transects.

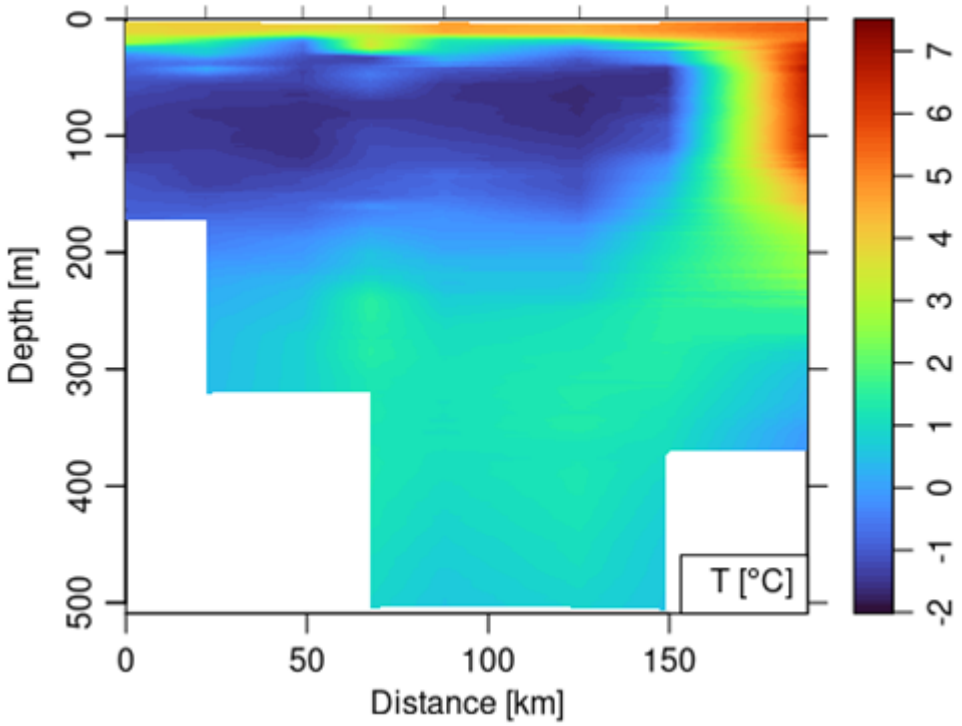


Figure 15: Temperature profile down to 500 m along transect B crossing Denmark Strait.

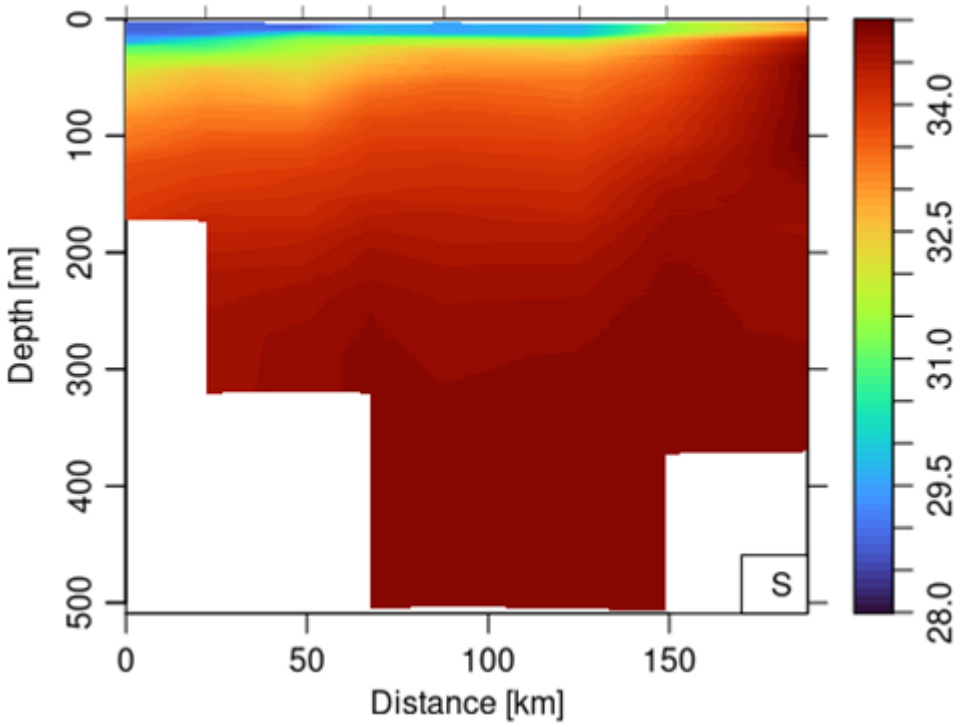


Figure 16: Salinity profile down to 500 m along transect B crossing Denmark Strait.

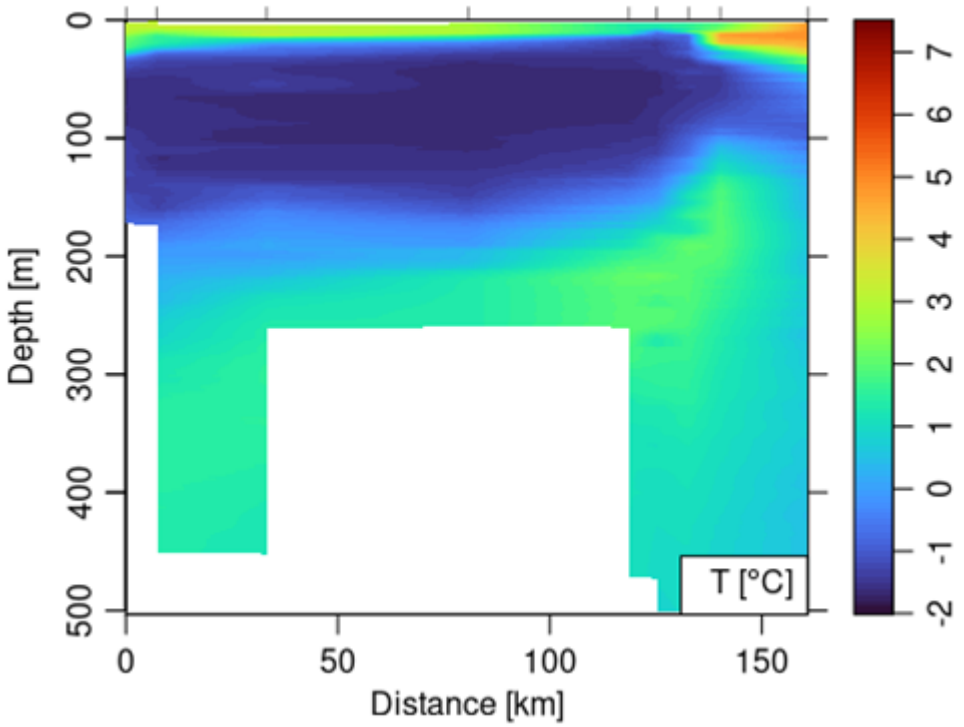


Figure 17: Temperature profile down to 500 m along transect C along 70°N near Scoresby Sund.

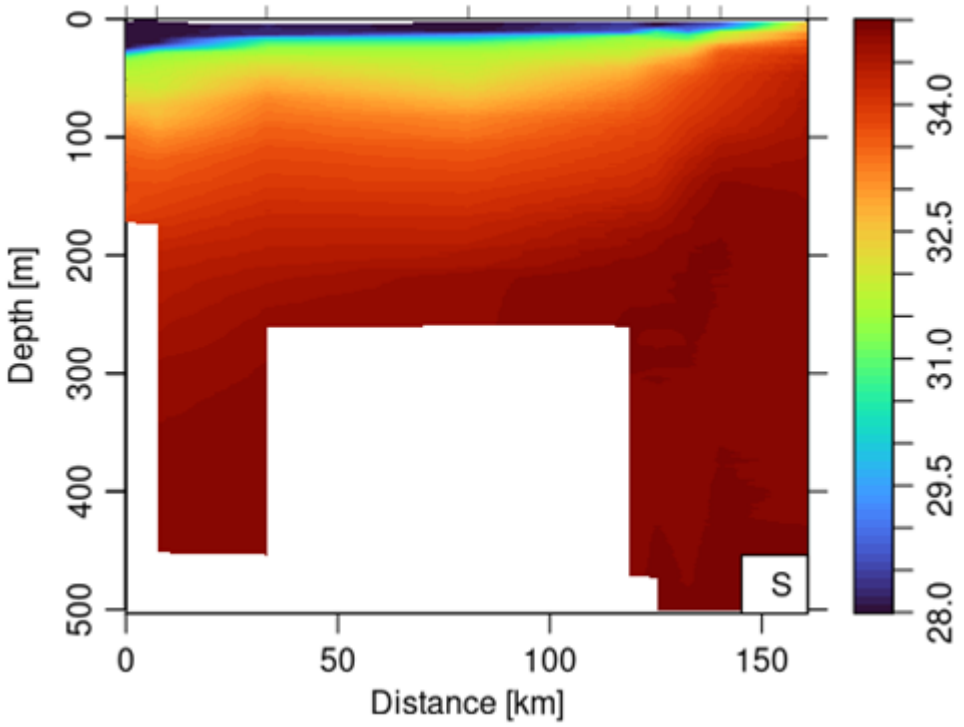


Figure 18: Salinity profile down to 500 m along transect C along 70°N near Scoresby Sund.

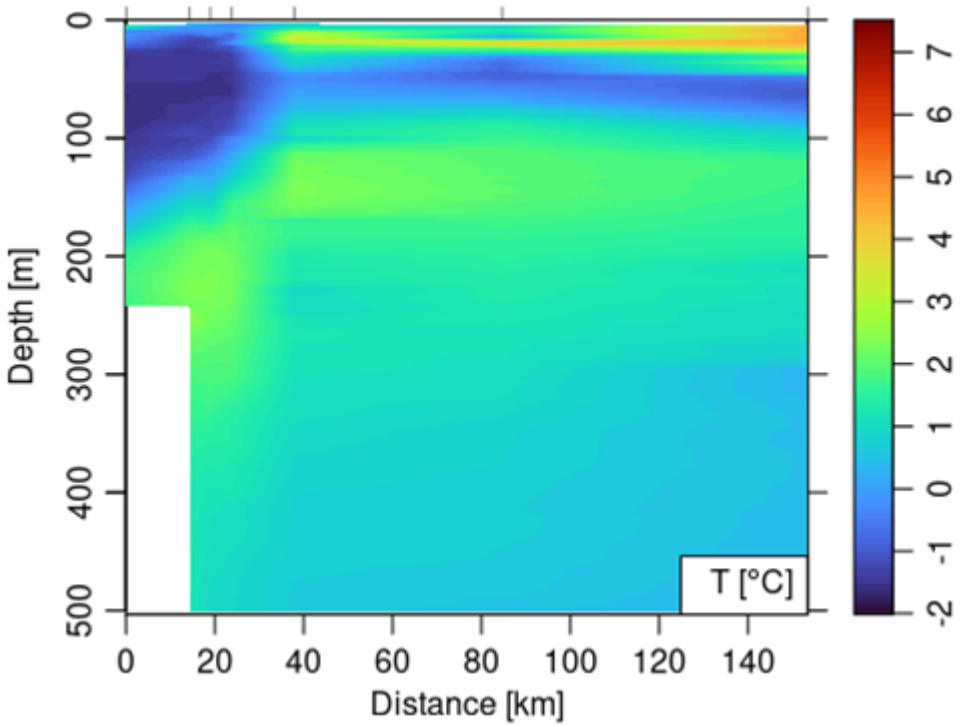


Figure 19: Temperature profile down to 500 m along transect D along 72°N near Kong Oscar Fjord. Only eastern part of the transect could be measured due to drift ice and time constraints.

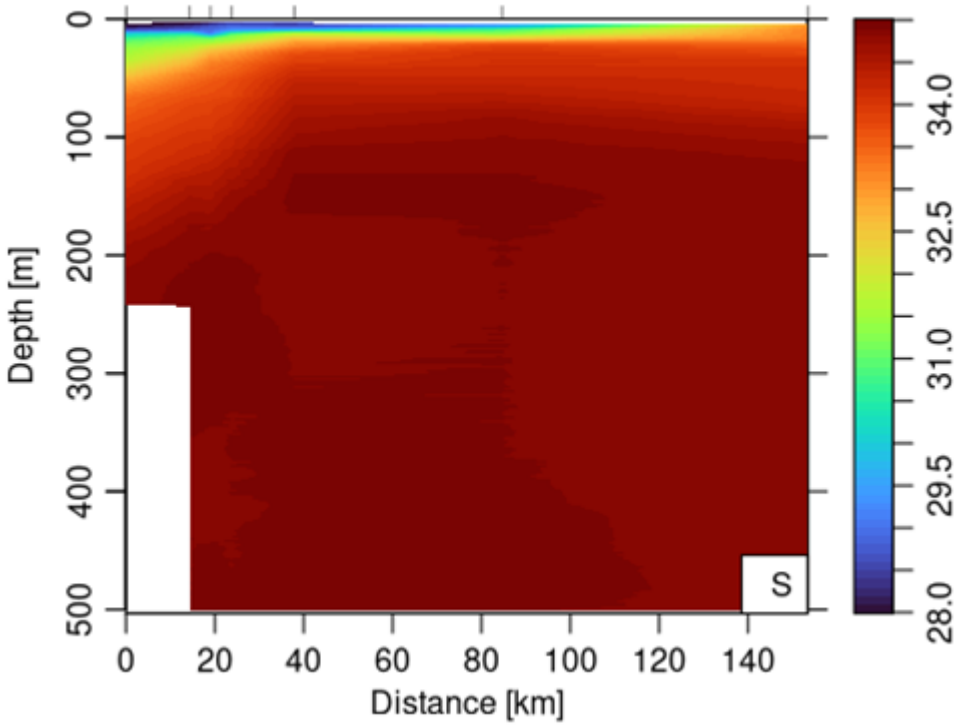


Figure 20: Salinity profile down to 500 m along transect D along 72°N near Kong Oscar Fjord. Only eastern part of the transect could be measured due to drift ice and time constraints.

4 References

ICES. 2023a. Benchmark workshop on capelin (WKCAPELIN). ICES Scientific Reports. 5:62. 282 pp. https://ices-library.figshare.com/articles/report/Benchmark_workshop_on_capelin_WKCAPELIN_/23260388

ICES. 2023b. Stock annex: Capelin (Mallotus villosus) in subareas 5 and 14 and Division 2.a west of 5°W (Iceland and Faroes grounds, East Greenland, Jan Mayen area). ICES Stock Annexes. Report. https://doi.org/10.17895/ices.pub.23600094