# Cruise report on northeast Atlantic mackerel (*Scomber scombrus*) abundance and distribution in the North Sea and west of the British Isles from 1st to 20th of October 2012

by

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**Abstract**

This report summarizes the findings of the Northeast Atlantic (NEA) mackerel research cruise from 1st to 20th of October 2012. Two chartered fishing vessels, M/V “Brennholm” and M/V “Christina E” covered areas in the northern part of the North Sea and west of the British Isles with the overall aim to estimate spatial distribution and abundance of mackerel by means of echo sounder and pelagic trawling. In addition, herring distribution and abundance were also estimated by means of acoustics and pelagic trawl sampling. Systematic CTD casts were conducted by both vessels during the survey period, as well as collection of sea surface temperatures (SST) from weekly satellite information. The SST during the survey period was close to the long-term average for the survey area. Temperature at 10 m depth ranged from 8.5 to 13.5°C, with coldest water in the north, while temperature at 50 and 100 m depth showed cold water stretching from the south in the areas surrounding the Norwegian trench.

The highest mackerel concentrations were found south-east of Shetland and in the northernmost areas of the North Sea. Vertical and horizontal distribution, behavior and abundance of mackerel were to a large extent different compared to what we expected and compared to previous established knowledge from both the fishing fleet and scientific surveys in similar areas and periods. In contrast to a general deep distribution in dense schools observed previously at this time of the year, mackerel were also found swimming close to the surface in small and loose aggregations. Total abundance of NEA mackerel within the covered area was estimated to 1.144 million tons. Total abundance of herring was estimated acoustically to be 2.934 million tons. The estimated mackerel abundance was significantly lower than expected, probably due to low availability to echosounder and sonar detection as well as considerable concentrations of mackerel distributed outside the covered area during the survey period. Most of the pelagic trawl samples with the new Multpelt 832 sampling trawl were taken in surface waters. Trawl samples west of 2°W were dominated with 0-group mackerel and had a wide distribution.

## Background

The mackerel survey covering northern part of the North Sea, west of the British Isles and in Norwegian waters south of 62°N, was initiated based on a request from the Royal Ministry of Fisheries and Coastal Affairs in Norway in winter 2012. The Institute of Marine Research in Norway was requested to map and quantify the abundance and distribution of mackerel in Norwegian and relevant waters during the 4th quarter (October-December) 2012. The Institute of Marine Research wrote a scientific application to the Ministry of Fisheries and Coastal Affairs, including a research quota in order to fund the mackerel cruise and be able to charter modern and well-equipped fishing vessels for the relevant scientific purposes. The application from the Institute of Marine Research was later approved by the Ministry of Fisheries and Coastal Affairs. The survey plan included two chartered fishing vessels operating for 20 days each from 1st to 20th of October 2012. The overall aim was to cover a major part of the NEA mackerel population both in Norwegian waters and EU waters. The geographical survey coverage for the two chartered combined purse seiners and stern trawlers M/V “Brennholm” and M/V “Christina E.” was planned and decided upon based on previous year’s autumn mackerel surveys up until 2006 as well as recent year’s mackerel fishing from the commercial fleet during the autumn season.

Major aims were to estimate abundance, distribution and patchiness of northeast Atlantic mackerel by means of acoustic multifrequency echosounder recordings, multibeam sonars and pelagic trawling with the new international Multpelt 832 sampling trawl. We collected also hydrographical CTD data systematically along the survey track.

## Data collection

*Biological data collection*

During the mackerel autumn survey a new pelagic trawl, Multpelt 832, was used by both participating vessels; “Brennholm” and “Christina E” during 1-20 October 2012. This trawl is at present a product of international cooperation of participating institutes from Norway, Iceland and Faroe Islands in designing and construction of a standardized sampling trawl for trawl survey in the future for all participants. The trawl has been designed as a future scientific and quantitative pelagic sampling trawl for NEA mackerel, but is also constructed and already used on scientific ecosystem and fisheries surveys related to other pelagic fish species such as herring, blue whiting and capelin (see Nøttestad et al. 2012). The trawl sampling was done opportunistically according to the design, i.e. when mackerel recordings were done with the echo sounder (Fig. 1). However, due to few echo sounder recordings several ‘blind hauls’ were carried out.

*Acoustic data collection*

Both “Brennholm” and “Christina E” were equipped with Simrad scientific echo sounders. “Brennholm” had operating frequencies including 18, 38, 120, 200 and 364 kHz, and “Christina E” 18, 38, 70, 120 and 200 kHz. The echo sounders on both vessels were calibrated for all frequencies prior to the survey using standard sphere method (Foote et al. 1987).

Multibeam sonar data was collected from “Brennholm” and “Christina E”. Onboard “Brennholm”, the sonar Simrad SH90 (centre frequency 114 kHz), was synchronized with the EK60 echo sounder to avoid interference, the latter being the master. Digital raw data was obtained from a scientific output continuously during the whole survey, using an Ethernet connection to a dedicated PC and ad hoc recording software.

“Christina E” was equipped with the Furuno FSV-30 (frequency 80 kHz) and FSV-84 (frequency 21-27 kHz) sonars. An ad-hoc system was created to synchronize both sonars with the EK60 echo sounder (master), with satisfactory results only with the FSV-84 sonar, being necessary to turn off the FSV-30 sonar. Also, a system was installed using a dedicated PC to store the raw data from the FSV-84, during the first part of the survey. The FSV-84 sonar was calibrated, prior the survey, using the reference sphere method, obtaining the calibration parameters for one beam and applying resulting gain to the rest of the acoustic beam (Yasushi Nishimori, com. pers.)

Raw data from each manufacturer has a different format, and two post-processing systems will be used to analyze the sonar data. For the Simrad sonar’s the Processing system for omni-directional fisheries sonar (PROFOS) will be used, which is a module of the Large Scale Survey System (LSSS) (Korneliussen et al. 2006). Furuno has developed non-commercial software for replaying and processing raw data from their fisheries sonars.

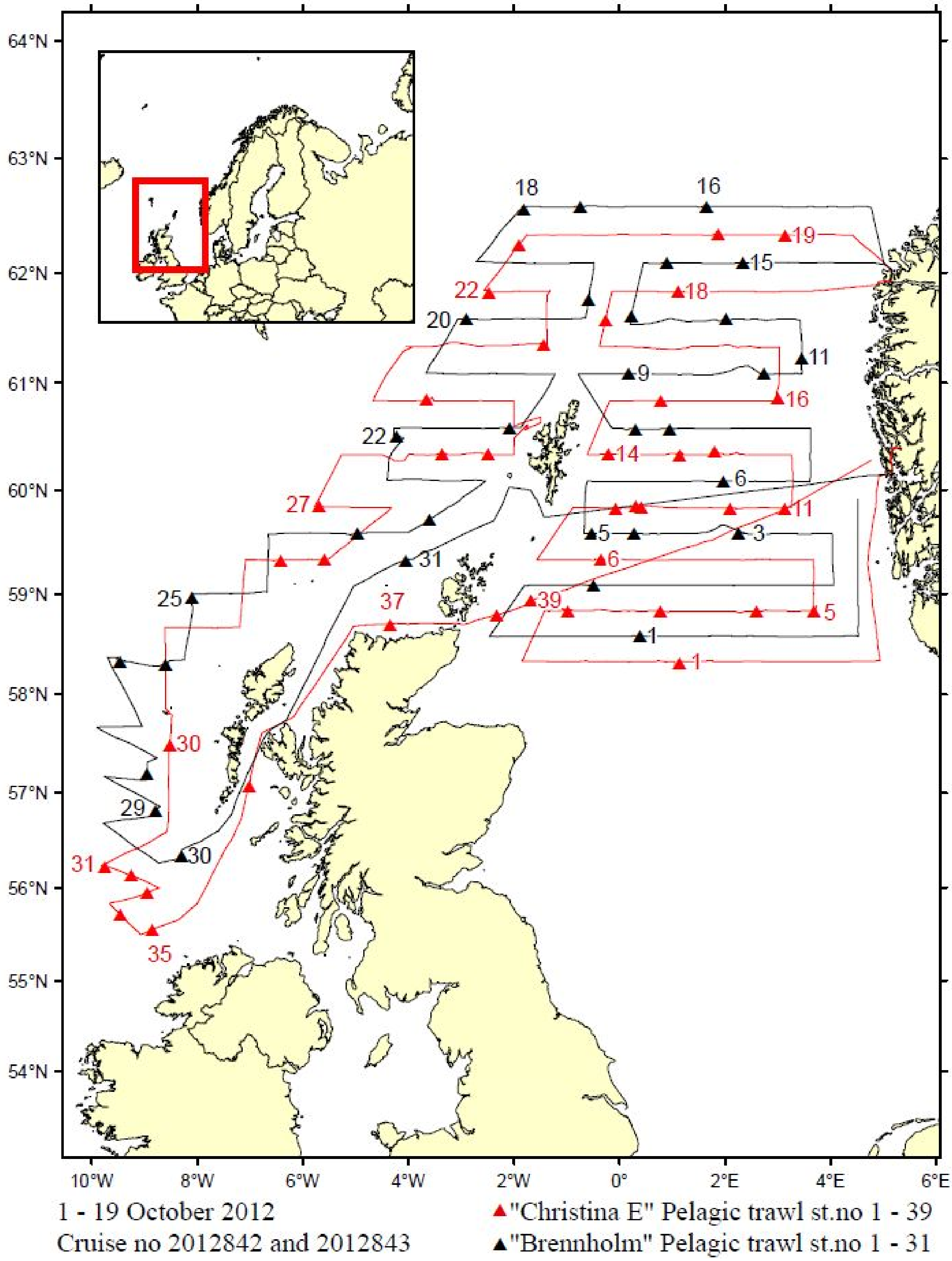


**Figure 1.** Survey track and trawl stations for "Christina E" and "Brennholm" during 1-20 October 2012.

*Hydrographical data collection*

CTD-casts were obtained at predefined positions along the transect grid. Both vessels used a SAIV SD200W sampling down to a maximum of 500 m, with water for calibration obtained with a water sample bottle at the largest depth.

*Biomass calculation*

To estimate the total abundance of fish, the unit area acoustic derivated abundance for each statistical square was multiplied by the number of square nautical miles in each statistical rectangle and then summed for all the statistical rectangles for the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical square then summing all squares within defined subareas and the total area. The BEAM software (Totland and Godø, 2001) was used to compute estimates of total biomass and numbers of individuals by age and length in the whole survey area.

## Results

*Hydrography*

The sea surface temperature during the survey period was close to the long-term average for the survey area (Fig. 2). Temperature at 10 m depth ranged from 8.5 to 13.5°C, with coldest water in the north (Fig. 3) while temperature at 50 and 100 m (Figs. 4 and 5) showed cold water stretching from the south in the areas surrounding the Norwegian trench.

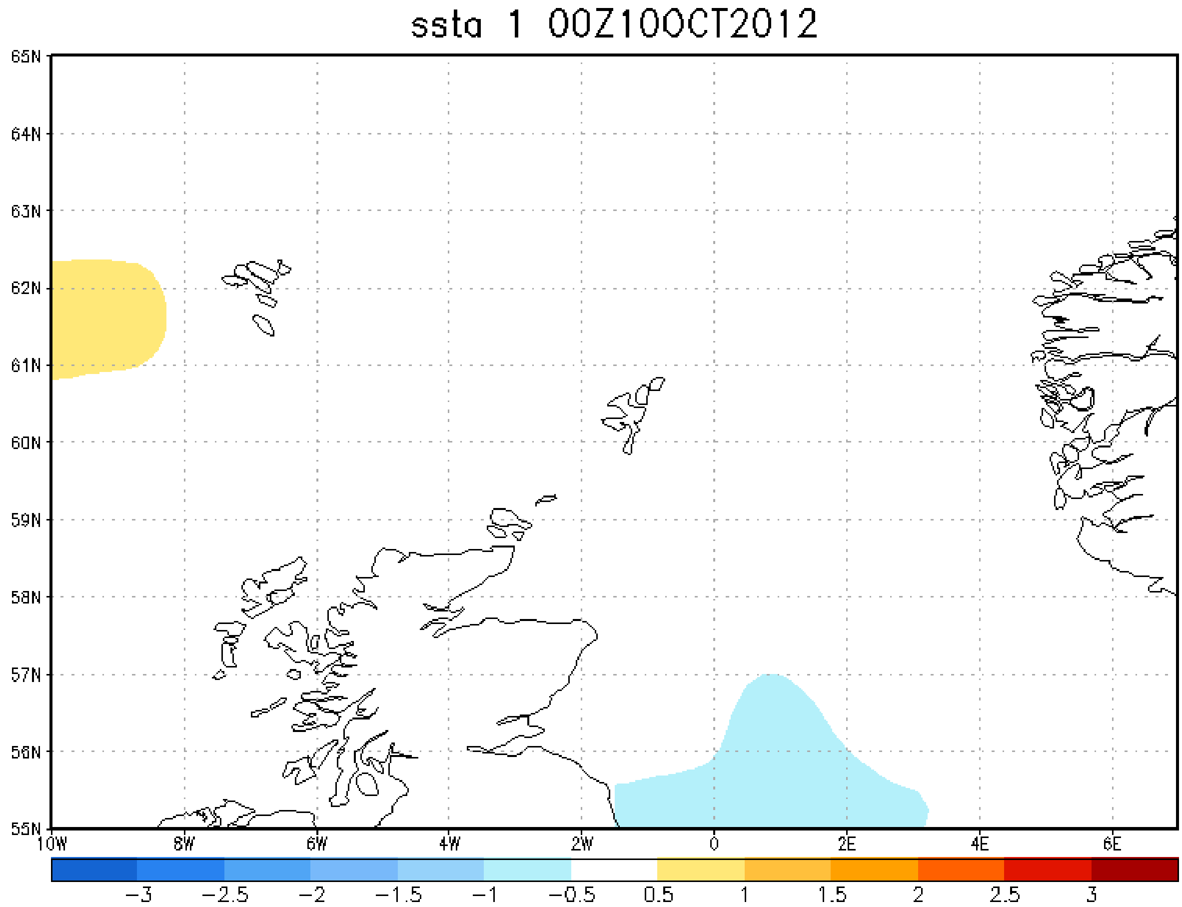


**Figure 2.** Sea surface temperature (SST) anomalies standardized for mid October 2012.

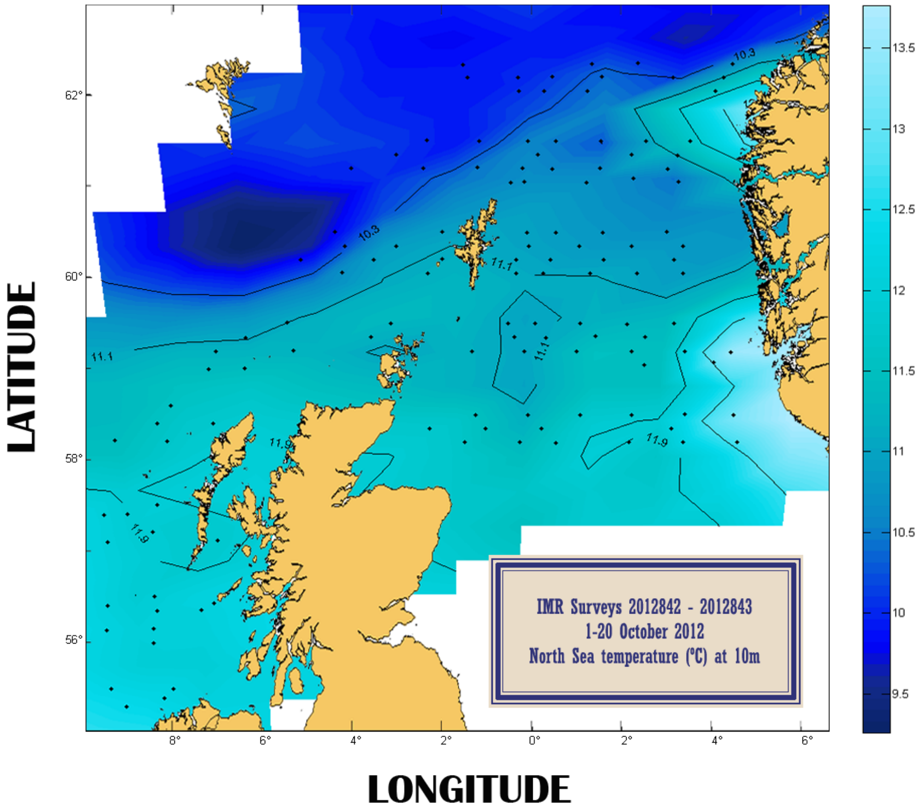


**Figure 3.** Temperature at 10 m depth. Black dots mark the position of CTD stations.

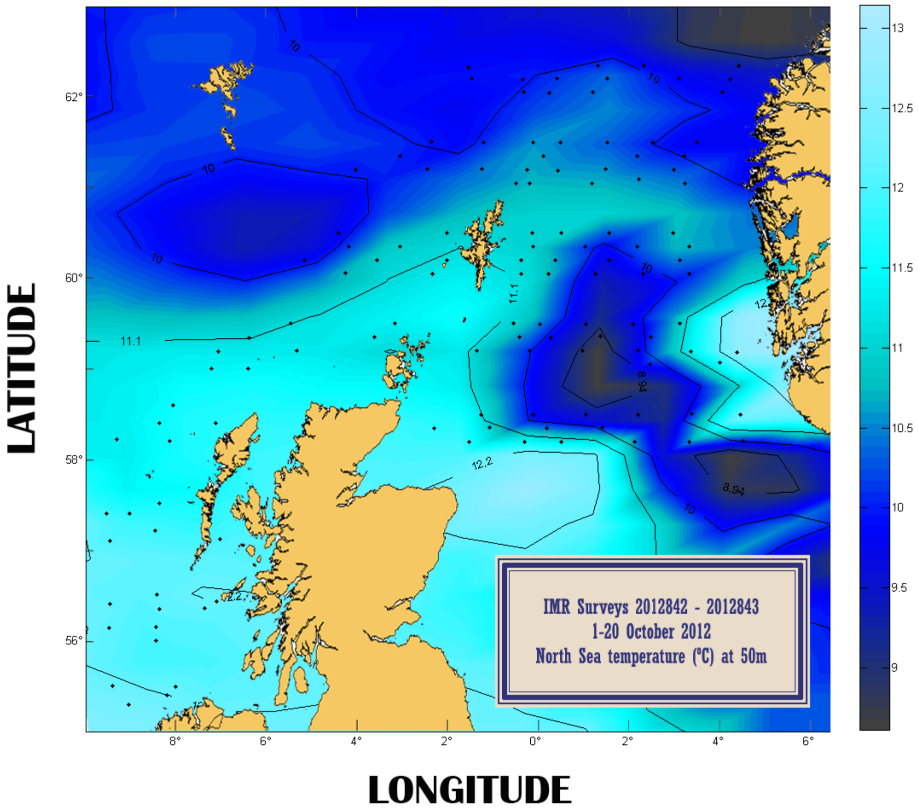


**Figure 4.** Temperature at 50 m depth. Black dots mark the position of CTD stations.

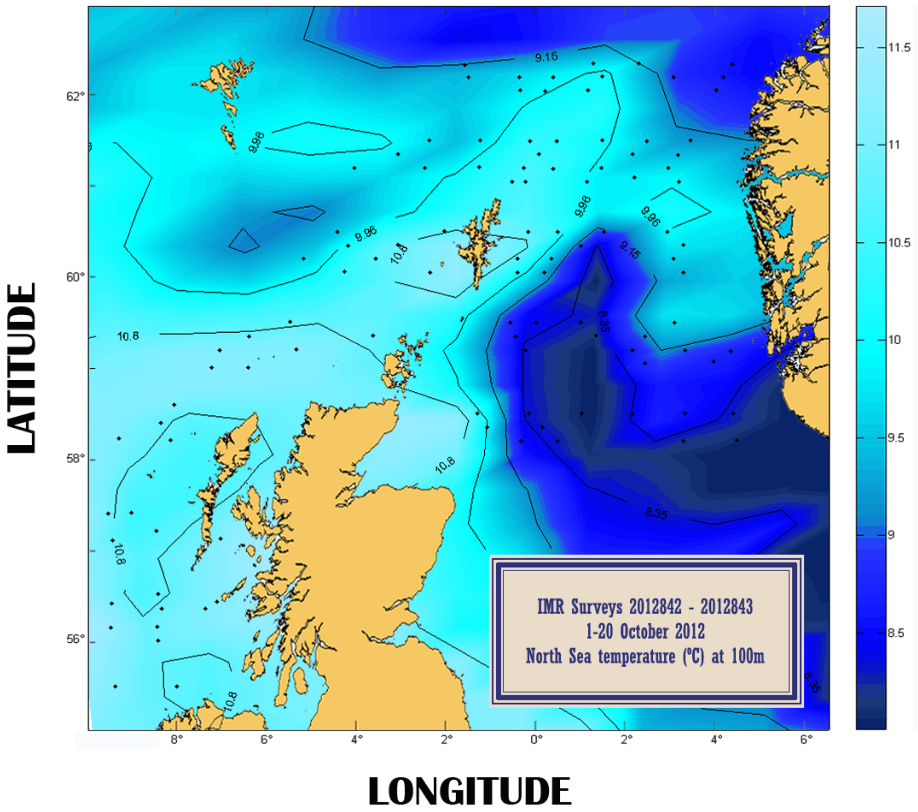


**Figure 5.** Temperature at 100 m depth. Black dots mark the position of CTD stations.

*Abundance and distribution of mackerel and herring based on acoustics*

Total mackerel biomass was estimated to 1.145 million tons and herring biomass to 2.934 million tons (Table 1).

**Table 1.** Estimated mackerel and herring abundance shown in numbers and biomass. TSN is Total Stock Number in million individuals and TSB Total Stock Biomass in thousand tons. Calculations are from BEAM (see text for details).

| | Age/yearclass | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mackerel | TSN ($10^6$) | 2269 | 1235 | 1524 | 269 | 358 | 288 | 328 | 216 | 124 | 66 | 34 | 32 | 13 | 1 | 0 | 0 | 8 | 6766 |
| | TSB ($10^6$ kg) | 60.3 | 156.4 | 290.4 | 73.6 | 110.8 | 101.6 | 130.5 | 91.8 | 52.4 | 30.1 | 16.6 | 17.6 | 7.5 | 1 | 0 | 0 | 4.6 | 1144.7 |
| Herring | TSN ($10^6$) | 0 | 0 | 329 | 1460 | 537 | 2748 | 3584 | 537 | 3337 | 268 | 804 | 1074 | | | | | | 14679 |
| | TSB ($10^6$ kg) | 0 | 0 | 38.2 | 274 | 103.7 | 470.3 | 864.9 | 103.7 | 655.4 | 51.8 | 164.8 | 207.3 | | | | | | 2934 |

The distribution of mackerel based on acoustic recordings from both survey vessels is shown in Figures 6, 8 and 10. The highest concentrations were recorded during the first part, in particular in the area to the south-east of Shetland, where also the fleet had gathered. During the second part, there were very few acoustic recordings of mackerel.

Herring were also recorded in the same area as mackerel south-east of Shetland (Figures 7, 9 and 11), but in even higher abundance in the northern part of the survey area during the first part. Also herring recordings were fewer during the second part of the survey. Note that there were consistent differences between the two vessels in herring recordings: “Brennholm” has in general fewer but stronger recordings than “Christina E”. This is partly due to different horizontal resolutions applied, but partly also different approaches to the scrutiny of the acoustic data on the two vessels. A fully standardized procedure for the allocation of backscatter to species was not completely agreed prior to the survey. The parts with inconsistency in mackerel allocation between the two vessels were re-scrutinized with a harmonized procedure, but this has not yet been prioritized for the acoustic recordings of herring.

There were very few schools of mackerel detected with the multibeam sonars, and a further analysis was subsequently not undertaken.

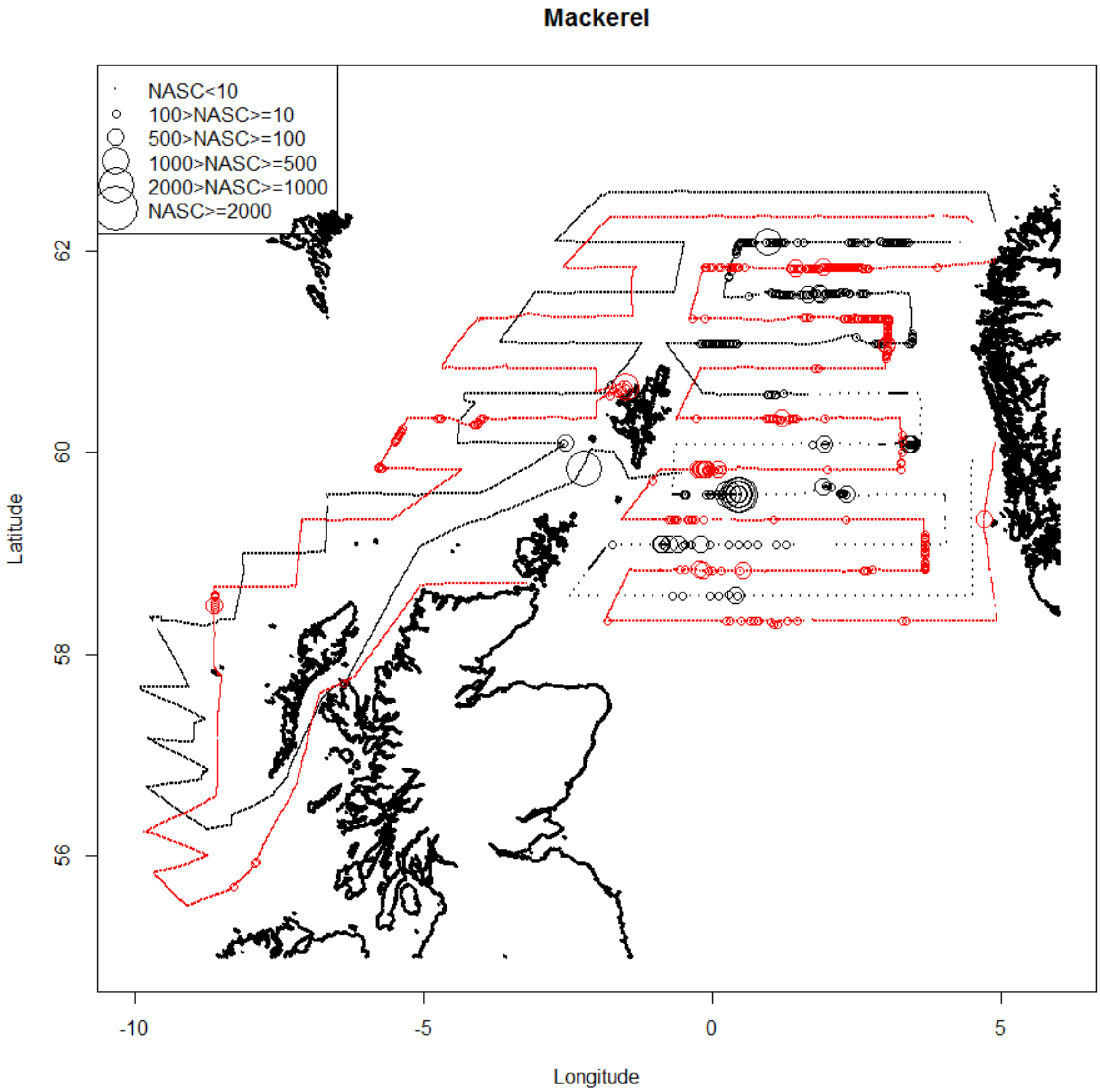


**Figure 6.** Distribution of nautical area scattering coefficient (NASC; $m^2/nmi^2$) values allocated to mackerel along the survey transects. Red denotes data from "Christina E" and black from "Brennholm". The horizontal resolution is generally 1 nmi, with the exception of the first week of data from 'Brennholm', where it is 5 nmi. Note that the mackerel recorded by "Christina E" along the north-western coast of Shetland were not part of the pre-designed cruise track and have not been included in the biomass calculations.

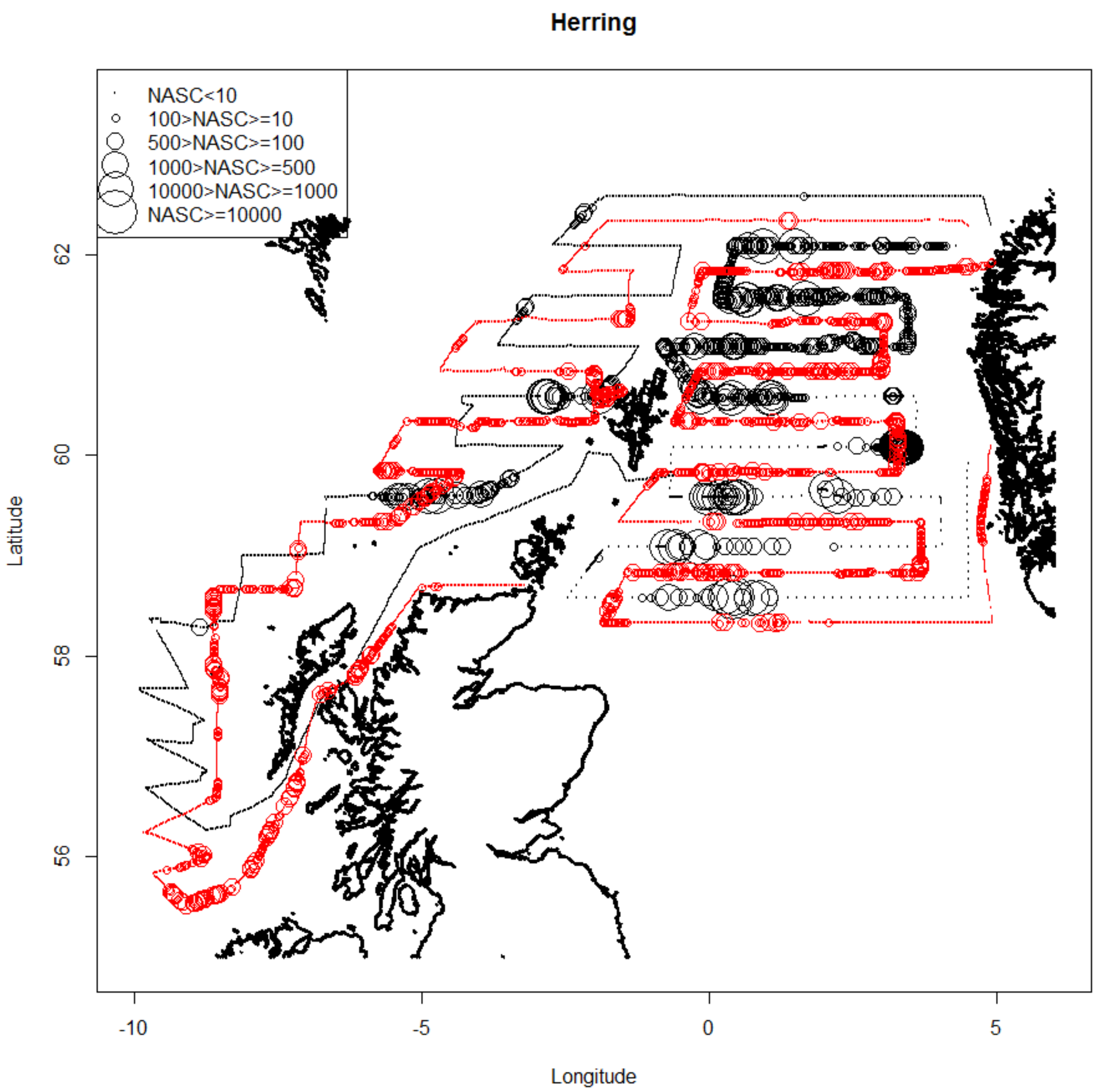


**Figure 7.** Distribution of nautical area scattering coefficient (NASC; $m^2/nmi^2$) values allocated to herring along the survey transect. Red denotes data from "Christina E" and black from "Brennholm". The horizontal resolution was predominantly 1 nmi, with the exception of the first week of data from "Brennholm", where it was 5 nmi.

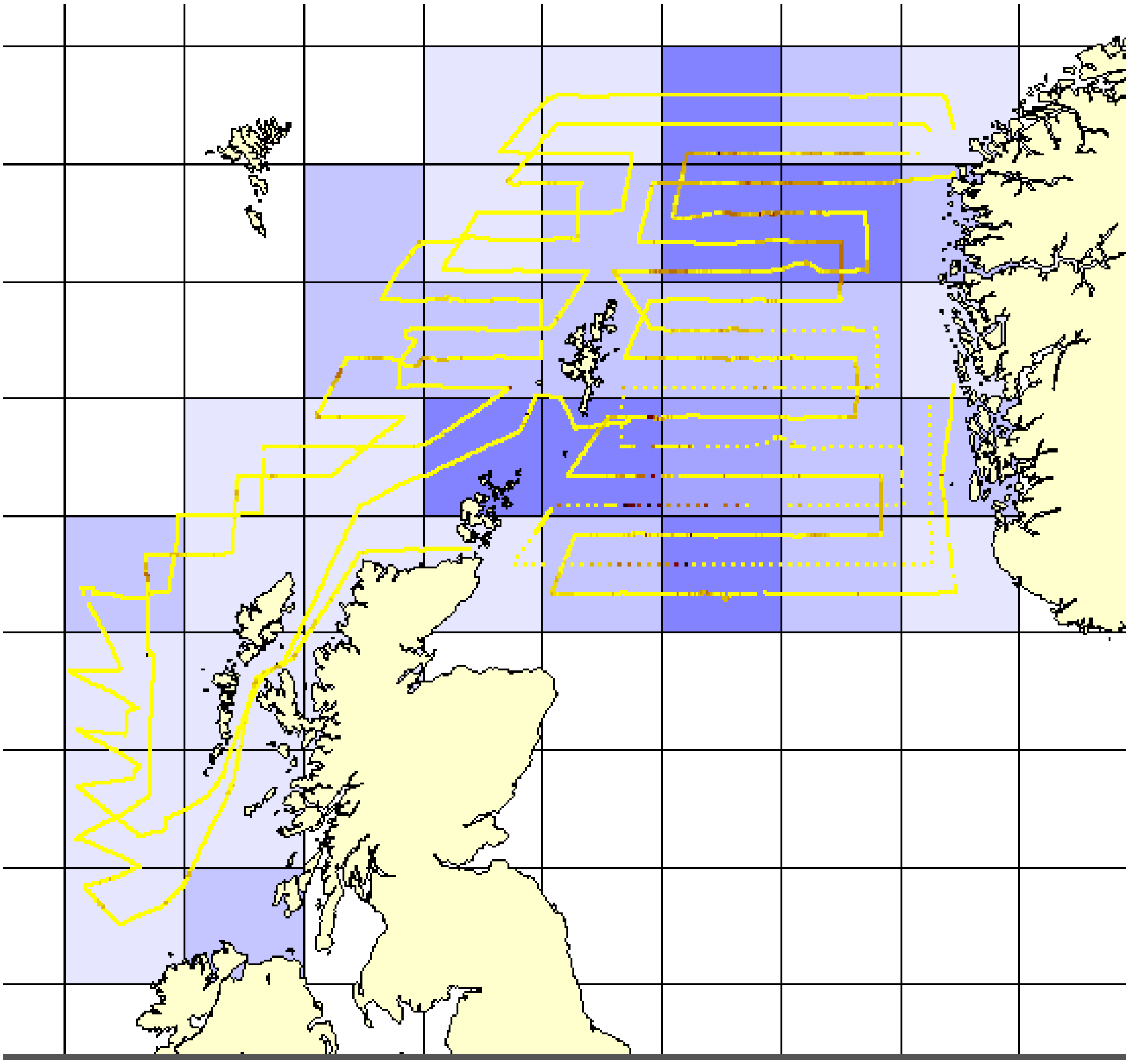

**Figure 8.** Mackerel mean NASC ($m^2/nmi^2$) values allocated to a pre-defined grid and used for the BEAM biomass estimation. The colour scale covers mean NASC 0-200 ($m^2/nmi^2$).

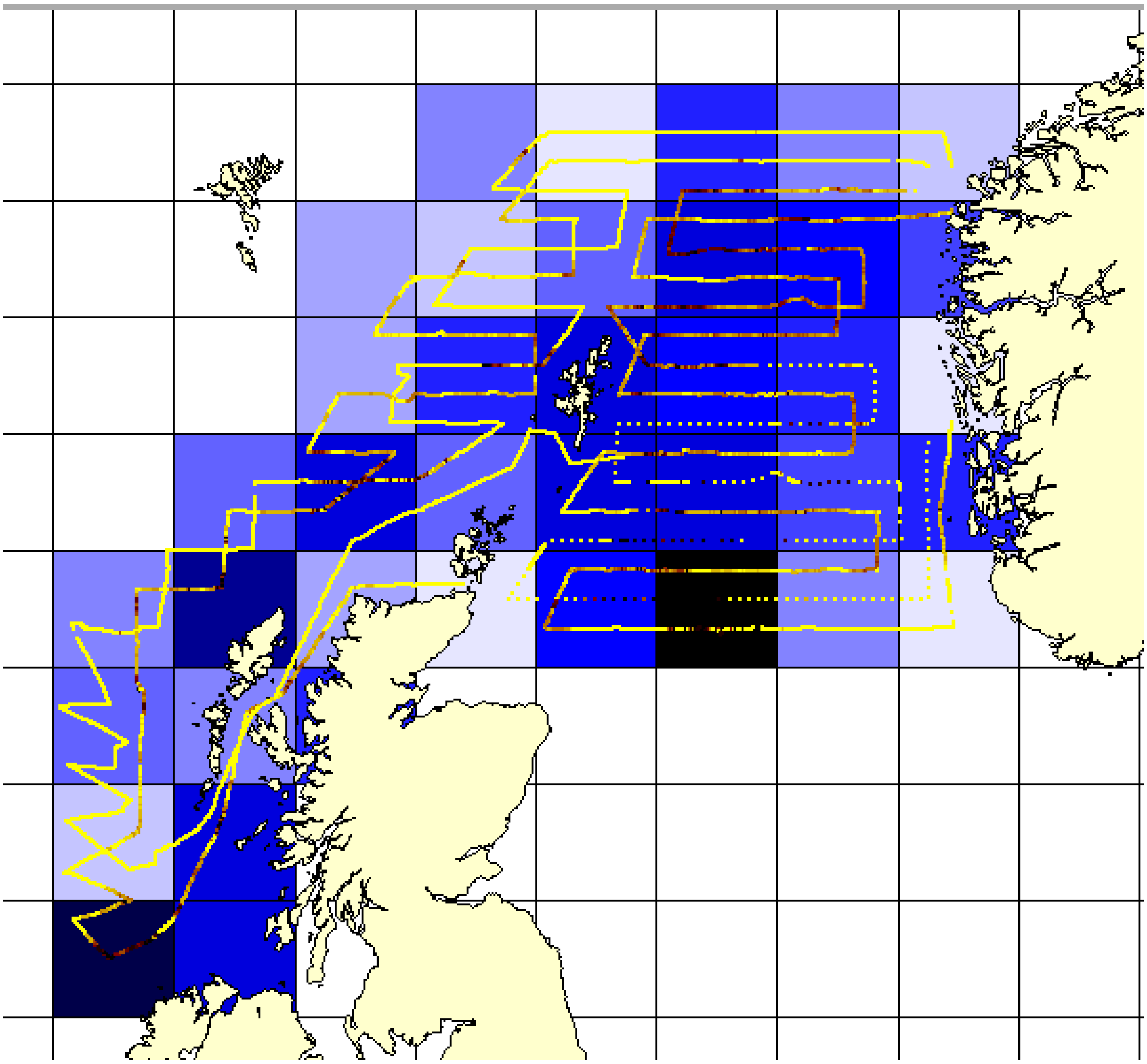

**Figure 9.** Herring mean NASC ($m^2/nmi^2$) values allocated to a pre-defined grid and used for the BEAM biomass estimation. The colour scale covers mean NASC 0-1000 ($m^2/nmi^2$)

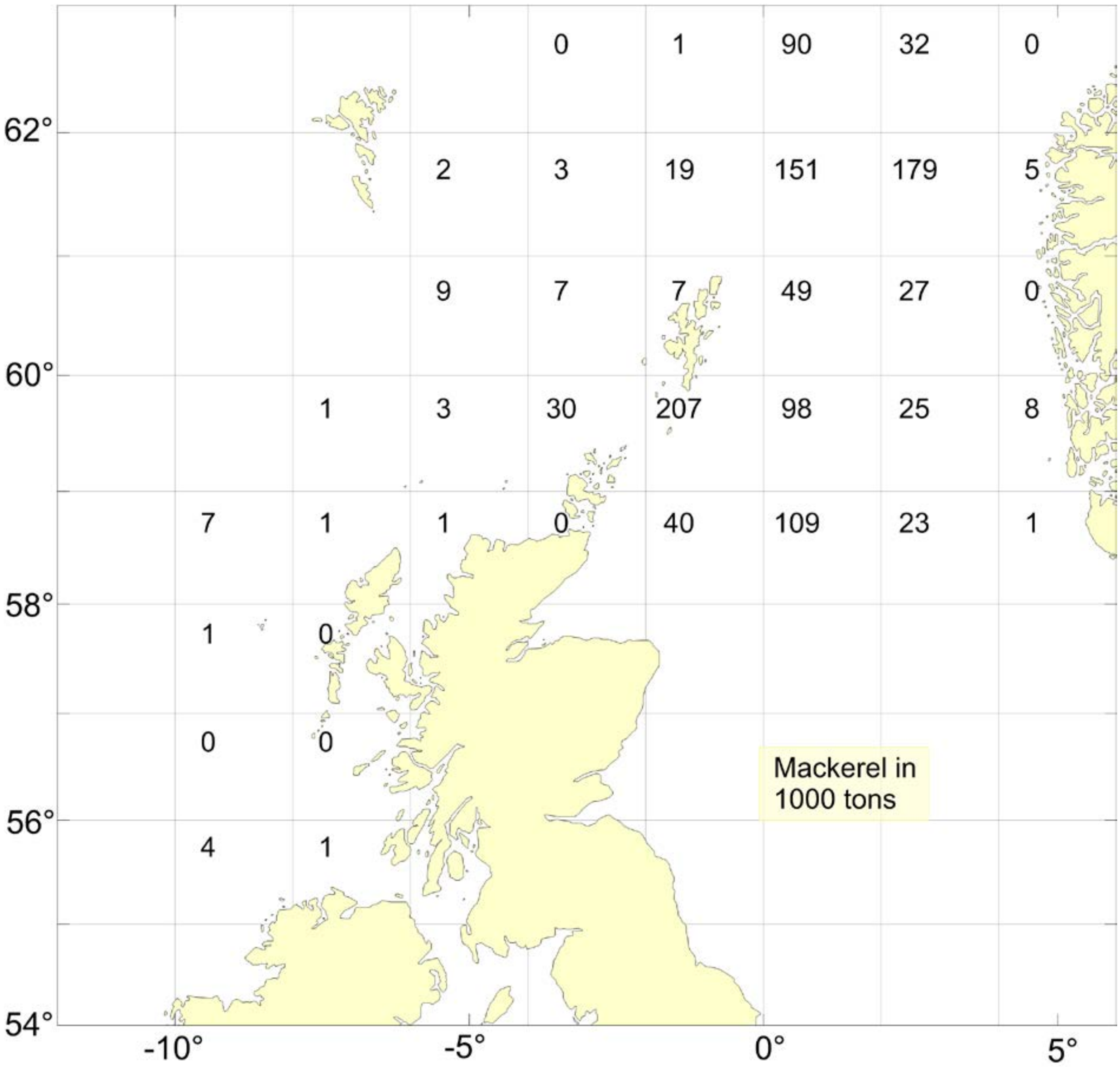


**Figure 10.** Mackerel biomass allocated to a pre-defined grid using BEAM software

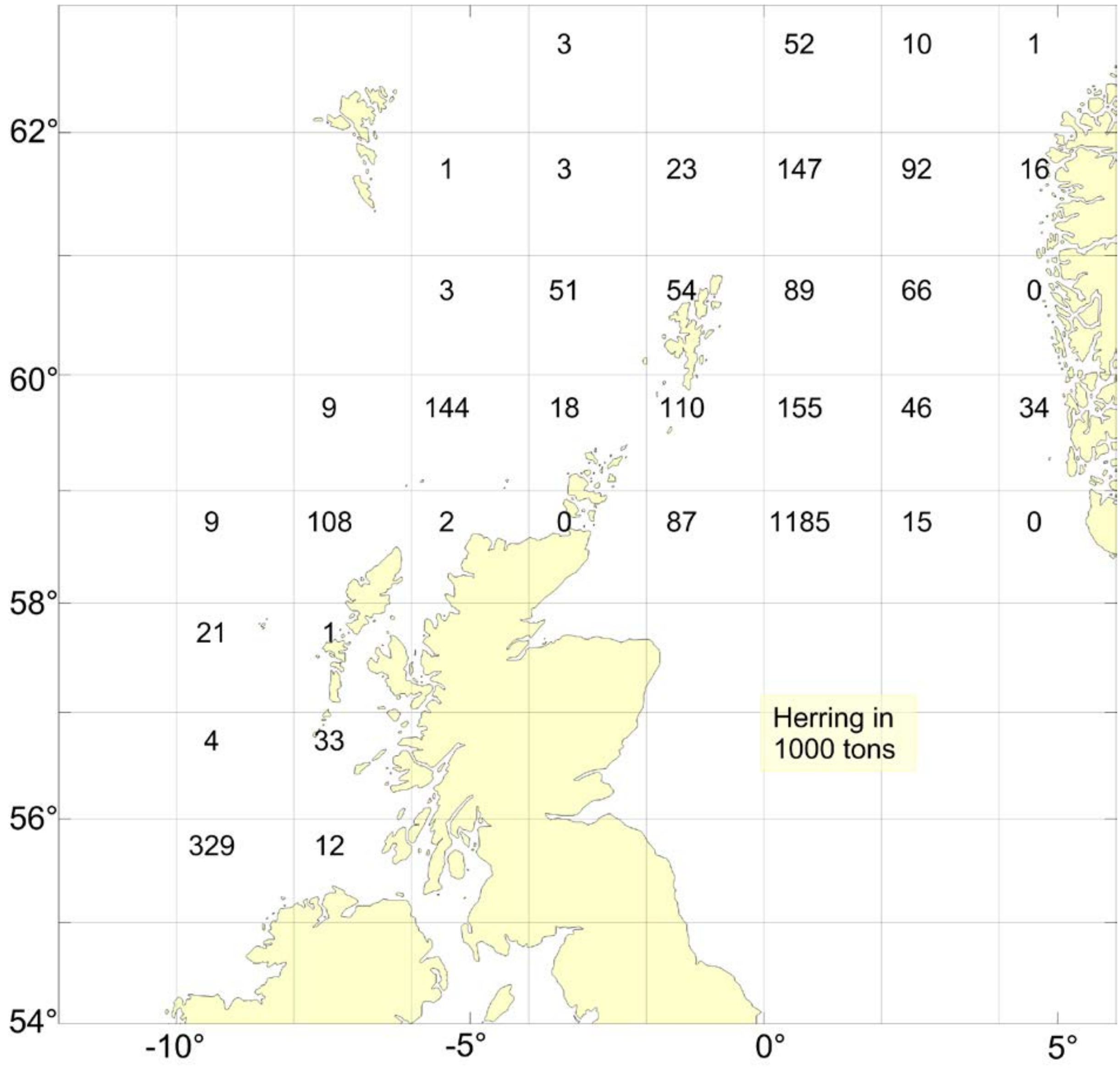


**Figure 11.** Herring biomass allocated to a pre-defined grid using BEAM software

*Biological data*

A summary of the total catches allocated to species or species groups for both vessels is shown in tables 2 and 3. Most of the pelagic trawl samples with the Multpelt 832 sampling trawl were taken in surface waters. Notably, there were several high catches of mackerel after dark, in particular during part 1, which did not coincide in time and space with acoustic recordings of mackerel. This suggests that the survey situation is similar to the summer feeding period when mackerel are practically unavailable to echo sounder registration due to shallow distribution and vessel avoidance. Unlike the summer situation when mackerel schools are usually visible on the sonar, there were in the present survey in some cases only very small-sized, scatters attributed to mackerel visible on the sonar screen.

During the second part of the survey, in particular in the area west of 2°W, the mackerel samples were dominated by 0-group mackerel as found from pelagic trawling with “Christina E” (Tables 2, 3, 4 and figure 12). There were several large catches of around 1000 kg of small mackerel after approximately 30 minutes. 0-group mackerel were found in the samples from 60°N to the southernmost survey point suggesting a widespread distribution.

There were also a few big catches of herring and horse mackerel in the survey area. The first was most common in the samples during part 1, the second during part 2. There was also one big catch of blue whiting, but the expected deeper distribution depth of blue whiting was not normally targeted with trawl during the present survey.

During the present study, the trawl catches were not used for biomass estimation except as input for mackerel and herring length distributions for converting acoustic backscatter to biomass. However, the biological trawl data were used as guidelines for species composition in relation to the scrutiny of the acoustic data. In that respect the difference between the vessels in catch rate is worth noting. The vessels used the same trawl, but given that they surveyed the same areas, the differences may be due to different hauling speed (generally lower speed for “Brennholm”) different position of the trawl split, and different operational experience on board.

**Table 2.** Catch table from 'Christina E'. Plus indicates a catch <1kg. Red colour: most of the catch consists of 0-group fish. 'MACK' is mackerel, 'HORSE' is horse mackerel, 'HERR' is herring, 'BW' is blue whiting, 'POUT' is Norwegian pout and 'MESO' is mesopelagic fish. 'OTHER' is boarfish. Average duration of a trawl haul was around 30 minutes. Note that station 39 was carried out on the transit between the formal end-point of the survey (Pentland) and the harbour in Bergen.

| | | | POSITION | | FISHINGDEPTH (m) | | | SPECIES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PT NR | DATE | TIME (LOCAL) | LATITUDE | LONGITUDE | MAX | MIN | TOTAL CATCH (kg) | MACK | HORSE | HERR | BW | POUT | MESO | OTHER |
| PART 1 | | | | | | | | | | | | | | |
| 1 | 03.10.2012 | 1518 | N 5819,1 | E 0108,6 | 110 | 80 | 2049 | 116 | 0 | 1933 | 0 | 0 | 0 | 0 |
| 2 | 04.10.2012 | 936 | N 5850,0 | W 0058,7 | 75 | 60 | 137 | 108 | 0 | 29 | 0 | 0 | 0 | 0 |
| 3 | 04.10.2012 | 1643 | N 5849,5 | E 0046,0 | 100 | 77 | 122 | 114 | 0 | 1 | 0 | 0 | 0 | 7 |
| 4 | 04.10.2012 | 2319 | N 5849,7 | E 0235,7 | 35 | 20 | 365 | 211 | 0 | 0 | 0 | 118 | 0 | 36 |
| 5 | 05.10.2012 | 334 | N 5849,8 | E 0340,9 | 90 | 50 | 528 | 25 | 8 | + | 492 | 0 | 0 | 3 |
| 6 | 05.10.2012 | 2120 | N 5920,0 | W 0021,1 | 20 | | 3006 | 3000 | 0 | 6 | 0 | 0 | 0 | + |
| 7 | 06.10.2012 | 842 | N 5949,0 | W 0004,6 | 55 | 20 | 2001 | 875 | 0 | 1126 | 0 | 0 | 0 | 0 |
| 8 | 06.10.2012 | 1129 | N 5949,8 | E 0024,8 | 78 | 70 | 145 | 0 | 0 | 145 | 0 | 0 | 0 | 0 |
| 9 | 06.10.2012 | 1257 | N 5950,5 | E 0018,2 | 0 | | 145 | 135 | 0 | 9 | 0 | 0 | 0 | 1 |
| 10 | 06.10.2012 | 1911 | N 5945,7 | E 0205,9 | 2 | 0 | 3000 | 3000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 06.10.2012 | 2328 | N 5949,7 | E 0307,8 | 4 | 0 | 399 | 106 | 199 | 19 | 0 | 2 | 0 | 73 |
| 12 | 07.10.2012 | 1607 | N 6021,7 | E 0148,1 | 3 | 0 | 57 | 55 | 0 | 2 | 0 | 0 | 0 | 0 |
| 13 | 07.10.2012 | 2058 | N 6019,5 | E 0108,1 | 40 | 30 | 1499 | 1350 | 0 | 8 | + | 2 | 0 | 139 |
| 14 | 08.10.2012 | 201 | N 6020,2 | W 0012,4 | 45 | 30 | 70 | 14 | + | + | 0 | 14 | 0 | 42 |
| 15 | 08.10.2012 | 1030 | N 6050,1 | E 0046,8 | 4 | 0 | 15 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 08.10.2012 | 1826 | N 6051,4 | E 0300,2 | 5 | 0 | 1500 | 1500 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 09.10.2012 | 1754 | N 6134,4 | W 0015,7 | 5 | 0 | 24 | 7 | 0 | 17 | 0 | 0 | 0 | 0 |
| 18 | 09.10.2012 | 2359 | N 6149,7 | E 0106,2 | 10 | 4 | 5000 | 5000 | 0 | 0 | 0 | 0 | 0 | 0 |
| PART 2 | | | | | | | | | | | | | | |
| 19 | 11.10.2012 | 128 | N 6220,2 | E 0307,9 | 8 | 4 | 500 | 432 | 64 | 0 | 4 | + | + | 0 |
| 20 | 11.10.2012 | 610 | N 6220,3 | E 0152,0 | 10 | 0 | 36 | 7 | 15 | + | 7 | 0 | 5 | 2 |
| 21 | 11.10.2012 | 1829 | N 6214,9 | E 0154,4 | 16 | 12 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 11.10.2012 | 2323 | N 6149,3 | W 0228,4 | 10 | | 7 | 3 | 0 | 0 | 0 | 0 | 4 | 0 |
| 23 | 12.10.2012 | 739 | N 6121,1 | W 0125,8 | 14 | 4 | 60 | 60 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 13.10.2012 | 151 | N 6050,8 | W 0339,3 | 17 | 1 | 450 | 450 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 13.10.2012 | 1647 | N 6020,1 | W 0229,7 | 5 | 0 | 500 | 500 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 13.10.2012 | 2028 | N 6020,2 | W 0321,3 | 128 | 70 | 509 | 395 | 82 | 12 | 9 | 0 | 0 | 11 |
| 27 | 14.10.2012 | 858 | N 5950,5 | W 0541,7 | 30 | 4 | 2 | + | 0 | 0 | 0 | 0 | + | 2 |
| 28 | 14.10.2012 | 1928 | N 5920,1 | W 0535,7 | 85 | 75 | 600 | 103 | 0 | 497 | 0 | 0 | 0 | 0 |
| 29 | 14.10.2012 | 2254 | N 5919,6 | W 0625,2 | 48 | 3 | 1 | + | 0 | 0 | + | 0 | + | 0 |
| 30 | 15.10.2012 | 2304 | N 5729,7 | W 0831,3 | 38 | 1 | 5 | 5 | + | 0 | 0 | 0 | + | + |
| 31 | 16.10.2012 | 1103 | N 5614,0 | W 0945,6 | 4 | | 0 | 0 | + | 0 | 0 | 0 | 0 | 0 |
| 32 | 16.10.2012 | 1332 | N 5607,8 | W 0915,4 | 155 | 115 | 0 | 0 | 0 | 0 | 0 | 0 | + | 0 |
| 33 | 16.10.2012 | 1751 | N 5557,0 | W 0857,2 | 105 | 98 | 505 | 4 | 1 | 0 | 0 | 0 | 0 | 500 |
| 34 | 16.10.2012 | 2245 | N 5542,6 | W 0927,3 | 5 | 0 | 61 | + | + | 0 | 0 | 0 | 56 | 5 |
| 35 | 17.10.2012 | 212 | N 5533,1 | W 0851,8 | 12 | 0 | 1000 | 1000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 17.10.2012 | 1636 | N 5704,2 | W 0700,9 | 110 | 0 | 1002 | 46 | 934 | 0 | 0 | + | 0 | 22 |
| 37 | 18.10.2012 | 835 | N 5842,0 | W 0420,7 | 3 | 0 | 450 | 450 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 18.10.2012 | 1445 | N 5847,5 | W 0220,1 | 6 | 0 | 3 | 3 | 0 | + | 0 | 0 | 0 | + |
| 39 | 18.10.2012 | 1821 | N 5856,4 | W 0140,9 | 72 | 50 | 1000 | 982 | 0 | 18 | 0 | 0 | 0 | 0 |

**Table 3.** Catch table from 'Brennholm'. Plus indicates a catch <1kg. Red colour: most of the catch consists of 0-group fish. 'MACK' is mackerel, 'HORSE' is horse mackerel, 'HERR' is herring, 'BW' is blue whiting, 'POUT' is Norwegian pout and 'MESO' is mesopelagic fish. Average duration of a trawl haul was around 30 minutes.

| | | | POSITION | | FISHINGDEPTH (m) | | | SPECIES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PT NR | DATE | TIME (LOCAL) | LATITUDE | LONGITUDE | MAX | MIN | TOTAL CATCH (kg) | MACK | HORSE | HERR | BW | POUT | MESO | OTHER |
| PART 1 | | | | | | | | | | | | | | |
| 1 | 03.10.2012 | 1353 | N 5834,9 | E 0023,1 | 80 | 30 | 280 | 28 | 0 | 245 | 0 | + | 0 | 7 |
| 2 | 04.10.2012 | 822 | N 5904,9 | W 0030,1 | 80 | 40 | 331 | 26 | 0 | 300 | 0 | 0 | 0 | 5 |
| 3 | 05.10.2012 | 906 | N 5935,4 | E 0215,2 | 30 | 15 | 807 | 800 | 0 | 7 | 0 | 0 | 0 | 0 |
| 4 | 05.10.2012 | 1708 | N 5934,9 | E 0016,2 | 15 | 10 | 800 | 540 | 0 | 260 | 0 | 0 | 0 | 0 |
| 5 | 05.10.2012 | 2046 | N 5935,0 | W 0031,6 | 30 | 15 | 900 | 900 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 06.10.2012 | 848 | N 6005,0 | E 0157,9 | 40 | 15 | 3 | 3 | 0 | + | 0 | 0 | 0 | 0 |
| 7 | 07.10.2012 | 842 | N 6034,7 | E 0056,9 | 80 | 50 | 507 | 375 | 3 | 125 | 0 | 0 | 0 | 4 |
| 8 | 07.10.2012 | 1455 | N 6034,5 | E 0017,8 | 80 | 50 | 129 | 120 | 0 | 7 | 0 | 0 | 0 | 2 |
| 9 | 08.10.2012 | 0027 | N 6105,0 | E 0010,4 | 50 | | 26 | 1 | 0 | 0 | 0 | 3 | 0 | 22 |
| 10 | 08.10.2012 | 903 | N 6105,0 | E 0244,2 | 180 | 30 | 406 | 400 | 2 | + | 0 | 0 | + | 4 |
| 11 | 08.10.2012 | 1312 | N 6114,1 | E 0326,7 | 30 | 15 | 208 | 200 | 8 | 0 | 0 | 0 | 0 | 0 |
| 12 | 08.10.2012 | 2049 | N 6134,9 | E 0200,6 | 25 | 5 | 254 | 178 | 18 | 0 | 53 | 0 | 1 | 4 |
| 13 | 09.10.2012 | 1257 | N 6136,6 | E 0013,3 | 30 | 15 | 250 | 230 | 0 | 20 | 0 | 0 | 0 | 0 |
| 14 | 09.10.2012 | 1808 | N 6205,0 | E 0053,5 | 80 | 15 | 24 | 20 | 0 | 0 | 0 | 0 | 0 | 4 |
| 15 | 09.10.2012 | 2329 | N 6205,0 | E 0219,8 | 100 | 10 | 54 | 13 | 7 | 0 | 20 | 0 | 10 | 4 |
| PART 2 | | | | | | | | | | | | | | |
| 16 | 11.10.2012 | 552 | N 6234,8 | E 0138,5 | 29 | 27 | 126 | 116 | 2 | 0 | 8 | 0 | + | 0 |
| 17 | 11.10.2012 | 1340 | N 6235,0 | E 0044,4 | 310 | 270 | 80 | 0 | 0 | 0 | 80 | 0 | 0 | 0 |
| 18 | 11.10.2012 | 1730 | N 6233,9 | W 0148,7 | 114 | 105 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 11.10.2012 | 832 | N 6145,9 | W 0035,3 | 17 | 9 | 32 | 25 | 0 | 1 | 0 | 0 | 0 | 6 |
| 20 | 12.10.2012 | 1712 | N 6134,9 | W 0254,2 | 23 | 15 | 60 | 60 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 13.10.2012 | 1044 | N 6035,0 | W 0205,3 | 15 | 2 | 32 | 30 | 0 | 0 | 0 | 0 | 0 | 2 |
| 22 | 13.10.2012 | 1934 | N 6030,4 | W 0413,6 | 50 | 4 | + | + | 0 | 0 | 0 | 0 | + | 0 |
| 23 | 13.10.2012 | 1107 | N 5943,0 | W 0336,2 | 20 | 4 | 3 | 3 | 0 | + | 0 | 0 | 0 | 0 |
| 24 | 14.10.2012 | 1605 | N 5935,1 | W 0458,1 | 80 | 70 | 34 | 32 | 0 | 2 | 0 | 0 | 0 | + |
| 25 | 14.10.2012 | 705 | N 5857,5 | W 0806,3 | 20 | 11 | + | 0 | 0 | 0 | 0 | 0 | 0 | + |
| 26 | 14.10.2012 | 1311 | N 5818,4 | W 0836,1 | 80 | 15 | + | + | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 15.10.2012 | 1809 | N 5820,1 | W 0927,8 | 36 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 16.10.2012 | 1116 | N 5711,5 | W 0857,5 | 60 | 0 | 2 | 0 | + | 0 | 0 | 0 | 0 | 2 |
| 29 | 16.10.2012 | 2024 | N 5649,0 | W 0848,0 | 60 | 50 | 2 | 0 | 0 | 0 | 0 | + | 0 | 2 |
| 30 | 16.10.2012 | 617 | N 5620,6 | W 0818,5 | 70 | 20 | 8 | 3 | 0 | + | 0 | + | + | 5 |
| 31 | 16.10.2012 | 615 | N 5919,4 | W 0403,2 | 65 | 6 | 24 | 4 | + | 0 | 0 | + | 0 | 20 |

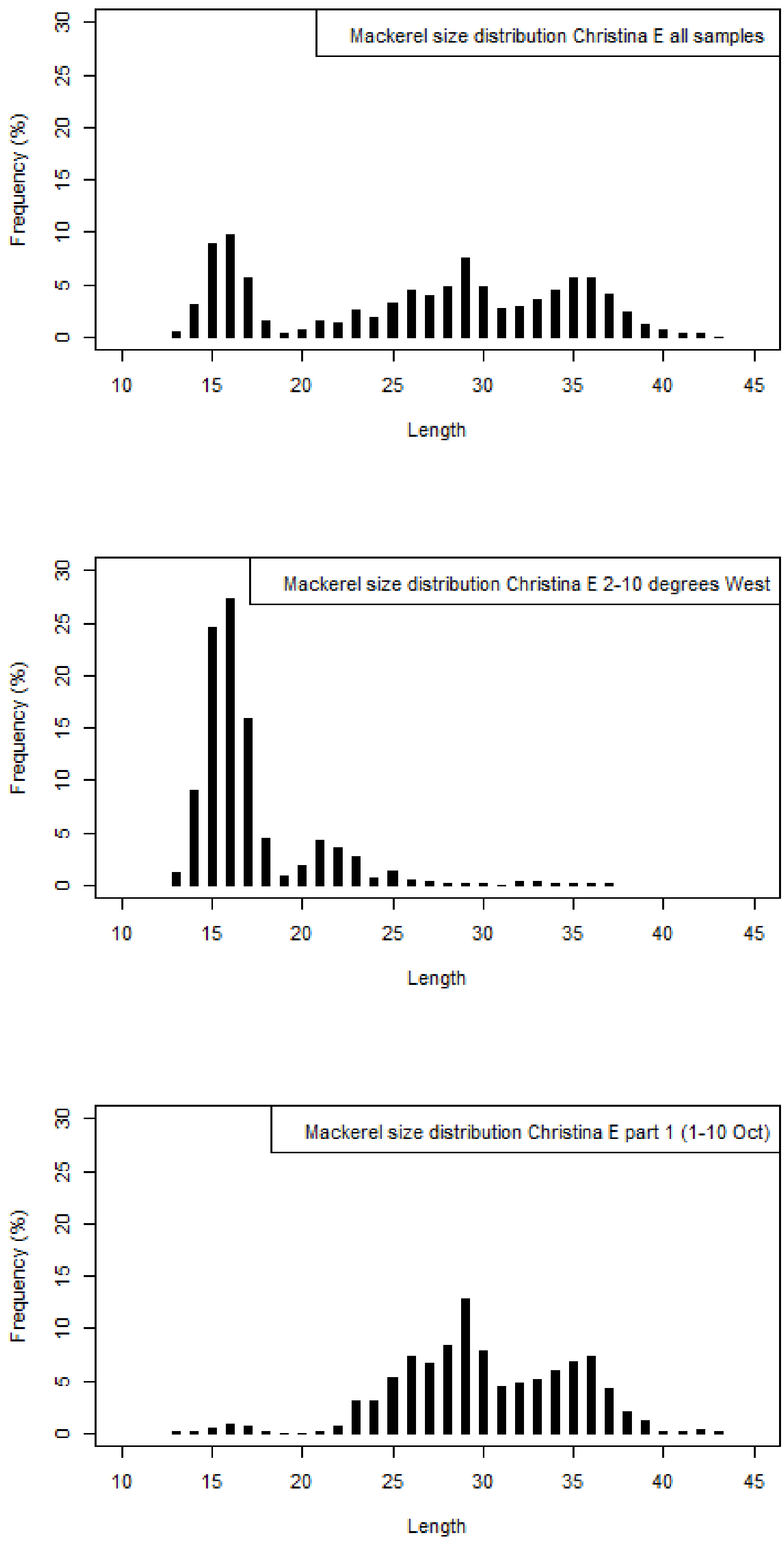


**Figure 12.** Length distribution of mackerel based on trawl samples from “Christina E”. Upper panel shows the distribution based on all sampled fish, mid-panel the distribution in the western part of the survey area (west of 2°W) and lower panel shows the distribution for the first part of the survey.

**Table 4.** Length at age matrix for all mackerel samples from "Christina E".

| Lengde (cm)/Alder | | | | | Samfengt | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ | Sum | Ubs | Sum | % |
| 13.0 | 1 | | | | | | | | | | | | | | | | 1 | 13 | 14 | 0.5 |
| 14.0 | 4 | | | | | | | | | | | | | | | | 4 | 88 | 92 | 3.0 |
| 15.0 | 12 | | | | | | | | | | | | | | | | 12 | 262 | 274 | 8.9 |
| 16.0 | 12 | | | | | | | | | | | | | | | | 12 | 291 | 303 | 9.8 |
| 17.0 | 15 | | | | | | | | | | | | | | | | 15 | 158 | 173 | 5.6 |
| 18.0 | 5 | | | | | | | | | | | | | | | | 5 | 45 | 50 | 1.6 |
| 19.0 | 3 | | | | | | | | | | | | | | | | 3 | 6 | 9 | 0.3 |
| 20.0 | 9 | | | | | | | | | | | | | | | | 9 | 9 | 18 | 0.6 |
| 21.0 | 14 | 11 | | | | | | | | | | | | | | | 25 | 21 | 46 | 1.5 |
| 22.0 | 8 | 16 | 1 | | | | | | | | | | | | | | 25 | 19 | 44 | 1.4 |
| 23.0 | | 29 | | | | | | | | | | | | | | | 29 | 47 | 76 | 2.5 |
| 24.0 | | 18 | 1 | | | | | | | | | | | | | | 19 | 39 | 58 | 1.9 |
| 25.0 | | 44 | | | | | | | | | | | | | | | 44 | 59 | 103 | 3.3 |
| 26.0 | | 48 | 2 | | | | | | | | | | | | | | 50 | 89 | 139 | 4.5 |
| 27.0 | | 21 | 17 | | | | | | | | | | | | | | 38 | 81 | 119 | 3.9 |
| 28.0 | | 8 | 24 | | | | | | | | | | | | | | 32 | 112 | 144 | 4.7 |
| 29.0 | | 2 | 66 | 1 | | | | | | | | | | | | | 69 | 163 | 232 | 7.5 |
| 30.0 | | 1 | 49 | 3 | 1 | | | | | | | | | | | | 54 | 95 | 149 | 4.8 |
| 31.0 | | | 14 | 9 | 5 | | | | | | | | | | | | 28 | 56 | 84 | 2.7 |
| 32.0 | | | 3 | 15 | 13 | 5 | 1 | | | | | | | | | | 37 | 49 | 86 | 2.8 |
| 33.0 | | 1 | | 8 | 21 | 8 | 1 | 1 | 2 | | | | | | | | 42 | 69 | 111 | 3.6 |
| 34.0 | | | | 2 | 14 | 10 | 7 | 5 | | 2 | 1 | | | | | | 41 | 96 | 137 | 4.4 |
| 35.0 | | | | 1 | 5 | 13 | 19 | 5 | 2 | 1 | | | | | | | 46 | 129 | 175 | 5.7 |
| 36.0 | | | | | 2 | 12 | 21 | 14 | 10 | 2 | 2 | | | | | | 63 | 113 | 176 | 5.7 |
| 37.0 | | | | | 1 | 2 | 13 | 17 | 5 | 2 | 1 | 1 | | | | | 42 | 82 | 124 | 4.0 |
| 38.0 | | | | | | 1 | 5 | 13 | 7 | 3 | 1 | 2 | | | | | 32 | 39 | 71 | 2.3 |
| 39.0 | | | | | | 1 | 3 | 3 | 2 | 3 | 2 | 1 | 1 | | | | 16 | 20 | 36 | 1.2 |
| 40.0 | | | | | | | | | 3 | 2 | 3 | 1 | 1 | 1 | | | 11 | 8 | 19 | 0.6 |
| 41.0 | | | | | | | | | | 1 | 1 | 2 | 1 | | | 1 | 6 | 6 | 12 | 0.4 |
| 42.0 | | | | | | | | 1 | 2 | | 2 | 1 | | | | | 6 | 7 | 13 | 0.4 |
| 43.0 | | | | | | | | | 1 | | | | | | | | 1 | | 1 | 0.0 |
| Sum | 83 | 199 | 177 | 39 | 62 | 52 | 70 | 59 | 34 | 16 | 13 | 8 | 3 | 1 | 0 | 1 | 817 | 2271 | 3088 | 100.1 |
| % | 10.2 | 24.4 | 21.7 | 4.8 | 7.6 | 6.4 | 8.6 | 7.2 | 4.2 | 2.0 | 1.6 | 1.0 | 0.4 | 0.1 | 0.0 | 0.1 | 100.3 | | | |
| L | 18.5 | 25.3 | 29.6 | 32.4 | 33.6 | 35.2 | 36.4 | 37.2 | 37.9 | 38.1 | 39.3 | 40.0 | 40.5 | 40.5 | 0.0 | 41.5 | 30.2 | 25.6 | 26.8 | |
| S(L) | 2.6 | 2.0 | 1.3 | 1.2 | 1.3 | 1.6 | 1.4 | 1.5 | 2.3 | 2.1 | 2.5 | 1.8 | 1.0 | 0.0 | 0.0 | 0.0 | 6.2 | 8.2 | 8.0 | |

## Summary and concluding remarks

The main purpose of the survey was to estimate the abundance and zonal distribution of the mackerel stock in the 4th quarter of the year. The survey was designed based on previous knowledge about the migration and spatial distribution pattern of mackerel obtained from recent fishery data and similar mackerel surveys conducted up to 2006. However, the coordinated survey with the two chartered fishing vessels recorded significantly less mackerel than expected within the covered area. There are possible sources of bias related to both the survey design and the methods used in the survey, making it possible that the abundance of mackerel within the surveyed area was underestimated. However, this is likely not the complete explanation of the low estimated abundance of mackerel in the survey area. Hence, the main goal of the survey was not achieved, but the survey results nevertheless provide various important information and new knowledge. One main result is that the migration patterns for mackerel from the feeding to the overwintering/spawning areas have changed considerably in recent years. It shows the importance of having regular surveys to monitor the species, given the rapid changes in geographic distribution and timing of mackerel migration and possibly also changes in stock abundance and spawning areas. Another result is that the methods applied during this survey may not be optimal for observing mackerel during the autumn. Mackerel was frequently taken in trawl hauls close to the surface even though nothing could be properly detected with the acoustic instruments.

We cannot give a clear reason for the low acoustic recordings of mackerel in the surveyed area. The following are thus possible explanations taken into account observations from fishermen and the observations done during recent surveys;

- The mackerel could be located in aggregations south or west of the survey area. We consider this less likely given that large quantities of mackerel stock have been found far north and west in the Nordic Seas during spring and summer in recent years. The findings of mature mackerel ready to spawn, as well as juvenile mackerel in the Norwegian Sea during the spring indicate that both the juvenile and adult part of population has a general movement northwards from the traditional major spawning grounds. It is therefore less likely that the mackerel stock has migrated further south than in previous years during this period of the year.
- The mackerel could be located in dense aggregations north of the survey area. We also find this little likely given that there is an extensive fishery for herring in the western and northern Norwegian Sea during this period and they did not report large aggregations of mackerel. Early in the mackerel fishery season, the catches were mainly taken further north than normal (at the border between the Norwegian Sea and the North Sea), but later on, the landings were taken as normal further southwest around Shetland.
- The mackerel has changed its behaviour and vertical distribution to a large extent during the recent years compared to a decade ago. During the present survey, mackerel were caught in most of the trawl hauls taken in areas without acoustic registrations on the echo sounder. There have been unofficial observations of mackerel mixed in the herring fishery as far north as 73°N. There was an ongoing Faroese fishery for mackerel at the end of October 2012, which is later than reported in previous years. It is therefore likely that a large part of the mackerel stock is located in loose aggregations, probably high in the water column over large areas, making it practically impossible to observe and record with echosounders, due to the acoustic deadzone loose aggregations of mackerel close to the surface. This loose aggregation behaviour could be related to the reduced feeding opportunities in recent years, where low prey concentrations of zooplankton throughout the active summer period may force the fish to elongate their feeding season. This hypothesis can be tested using pelagic trawling at fixed positions to get an estimate of the abundance of fish which have not aggregated in larger and denser schools in late autumn. Also, this could be complemented with dedicated zooplankton sampling, which could be used together with systematic stomach content analysis.

Presently, there are not quota agreements between the coastal states participating in the mackerel fishery and the total landings have been higher than recommended by ICES since 2010. It is therefore of vital importance to improve our understanding about the stock status and dynamics of the mackerel. There is a pertinent need to expand the scientific collaboration of standardized pelagic trawling and the use of Multpelt 832 trawl equipment to relevant EU countries involved in science and fishing on NEA mackerel, which we expect will be agreed upon and implemented by early 2013.

There was a clear distinction of the size/age distribution in the survey area, roughly around 2 °W. The westernmost area going south to Irish waters was dominated by 0-group mackerel with a length of 13-22 cm. In the easternmost area including the area covered in the North Sea, there were several year classes with length in the range of 23-39 cm. The catches of 0-group mackerel do not provide any information about the strength of this year class, given that the total geographic distribution range was probably not covered. However, it is an indication of a general northwards movement of juvenile mackerel compared to previous years.

The spatial difference in the size/age distribution was clear, with very little mixing between 0-group and older mackerel. Further, juvenile mackerel was generally not found together with the older mature mackerel, although there were several catches from pelagic trawling with a combination of juvenile and mature mackerel.

Traditionally, mackerel is aggregated in larger schools and are not feeding in October. From the mackerel samples taken during the survey, stomachs samples were taken but the data are not analyzed yet. However, based on observations during the survey most of the mackerel had not been feeding. However, there were several individuals with prey in their stomachs, and some stomachs were completely full. These findings may indicate that the mackerel has elongated their feeding period. This could be an indication of poorer feeding conditions during the major feeding period in summer, forcing the mackerel to feed for a longer period to gain the necessary energy reserves before the overwintering period. This has implications for the spatial distribution and degree of patchiness. Feeding mackerel will spread out in loose aggregations and be located close to the surface, making them harder to detect on acoustic instruments. Furthermore, this less aggregated mackerel behaviour has also had consequences for the fishing fleet and created challenges for the purse seiners in some areas and periods during the autumn.

## Acknowledgements

We greatly appreciate and thank skippers and crew members onboard M/V “Brennholm” and M/V “Christina E” for outstanding collaboration and practical assistance on the joint mackerel survey in the northern North Sea, along the Norwegian coast and west of the British Isles from 1st to 20th of October 2012.

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