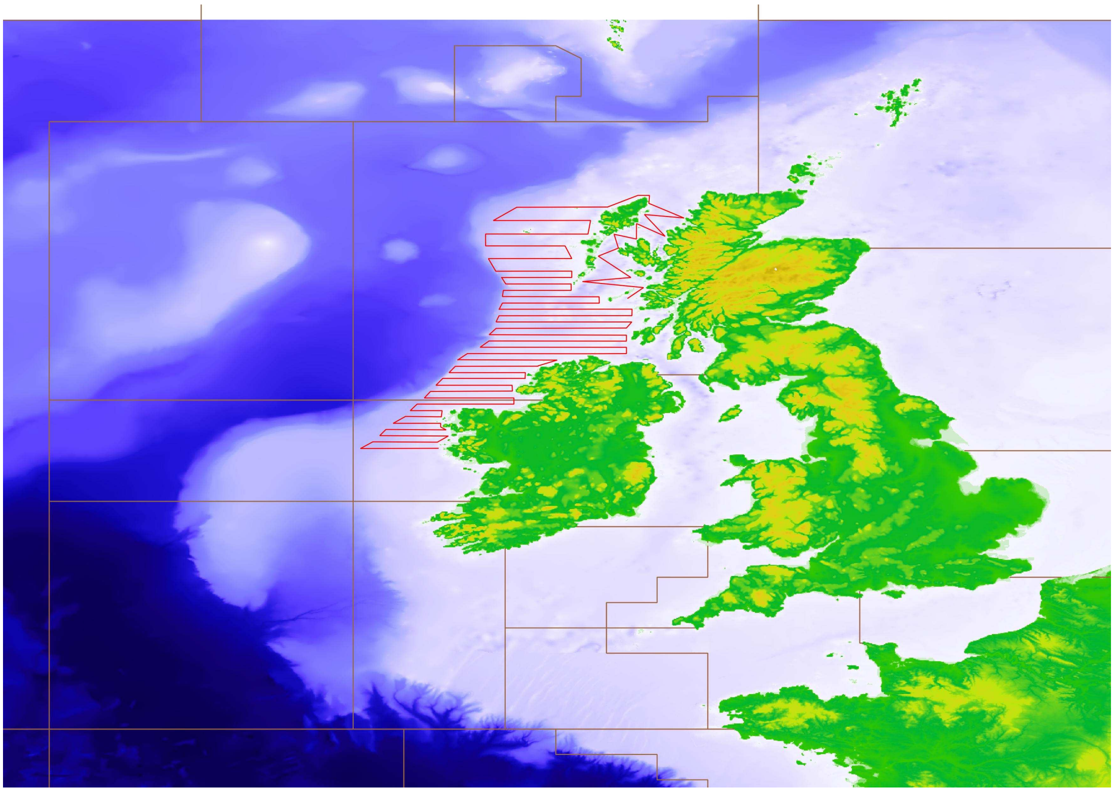
FEAS Survey Series: 2012/04

Northwest Herring Acoustic Survey Report

21 June – 11 July, 2012



RV Celtic Explorer

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Fisheries Ecosystems Advisory Services

Marine Institute

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1 Introduction

The northwest and west coast (ICES Divisions VIaS & VIIb, c) herring acoustic survey programme was first established in 1994. Prior to acoustic estimation, a larval survey programme was conducted from 1981-1986. In the early 1990s, the ICES herring working group (HAWG) identified the need for a dedicated herring acoustic survey in this area (Anon, 1994). From 1994 to 1996 surveys were carried out on this stock during the summer feeding phase. In 1997 a two-survey spawning survey was established covering both autumn and winter components. In 2004, this was modified to a single spawning stock survey which was carried out early in quarter 1 and continued until 2007. In 2008, it was decided that this survey should be incorporated into the larger coordinated Malin shelf survey on recommendation from SGHERWAY and WGHAWG.

The summer 2012 survey represents the fifth in the new time series (est. in 2008). The Irish component was carried out to cover, 1) the regions around western Ireland 2) the regions west of Scotland that are usually covered by Marine Scotland and 3) northern sector of the Irish Sea survey (AFBI). The survey was coordinated through the ICES Working Group of International Pelagic Surveys (WGIPS). Combined survey data on herring distribution, abundance and age are used to provide a measure of the relative abundance of herring within the Malin shelf stock complex. Survey data on stock numbers at age are submitted to the ICES Herring Assessment Working Group (HAWG) and used in the annual stock assessment process.

The northwest and west coast (ICES Divisions VIaS & VIIb) herring stock is composed of two spawning components, autumn and winter spawners. Spawning covers a large geographical area and extends over a 4-month period from late September through to late March (Molloy *et al*, 2000). Traditionally, fishing effort has been concentrated on spawning and pre-spawning aggregations. The autumn spawning component, which mostly occurs within VIIb and VIaS, feeds along the shelf break area to the west of the spawning grounds. The winter spawning component is found further north in VIaS. In VIaS, summer distribution extends from close inshore to the shelf break. Components of the winter spawning fish are known to undertake northward feeding migration into VIaN before returning in the winter to spawn along the Irish coast.

2 Materials and Methods

2.1 Scientific Personnel

Organization	Name	Capacity
FEAS	Cormac Nolan	Acoustics (SIC)
FEAS	Eugene Mullins	Acoustics
FEAS	Andy Campbell	Acoustics
FEAS	Robert Bunn	Acoustics
FEAS	Mairead Sullivan	Biologist
FEAS	M. Blaszkowski	Biologist
FEAS	Tobias Rapp	Biologist
FEAS	David O'Sullivan	Biologist

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives of the survey are listed below:

- Carry out a pre-determined survey cruise track based on the known summer herring distribution

- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of survey stock
- Determine an age stratified estimate of relative abundance and biomass of herring within the survey area (ICES Divisions VIIb & VIaS-N) using acoustic survey techniques
- Collect physical oceanography data as horizontal and vertical profiles from a deployed sensor array.
- Collect detailed morphometric data on individual herring to contribute to stock discrimination studies for SGHERWAY
- Collect Boarfish (*Capros acer*) samples where possible

2.2.2 Area of operation and survey design

The survey focused on the northwest and west coast of Ireland and the west coast of Scotland (ICES Divisions VIaS & VIaN and VIIb) as shown in Figure 1. The survey track started in the region south of the Hebrides and worked progressively southwards after surveying the Minches region.

A systematic parallel transect design was adopted for the majority of the survey, with a randomised start point. Transects were positioned running perpendicular to the lines of bathymetry where possible. Transects were generally positioned between the 30 m and 250m depth contours. Transect spacing was set at 7.5 nmi in the main body of the survey and at 15 nmi between 57° and 58.5°N. A zigzag design was uti lised in the Minches region.

To keep in line with existing survey methodology acoustic data collection was only undertaken during daylight hours (04:00 and 00:00).

In total, the survey covered 3,286nmi, 2417nmi of which were on transect and suitable for acoustic integration. Survey design and methodology adheres to the methods laid out in the PGHERS acoustic survey manual.

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings were determined before the start of the survey and are based on established settings employed on previous surveys (O'Donnell *et al.,* 2004). Equipment settings are shown in Table 1.

Acoustic data were collected using the Simrad EK60 scientific echosounder. A Simrad ES-38B (38 kHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3 m below the vessels hull or 8.8 m below the sea surface. Data were also collected at operating frequencies of 18, 120 and 200 kHz during the survey. Estimates of herring abundance and biomass were derived exclusively from 38 kHz data.

While surveying on track, the vessel is powered using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations (Anon, 2002). Cruising speed is maintained at a maximum of 10Kts (knots) where possible. During fishing operations, normal 2 engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

The EK60 was calibrated near Tobermory, on the Isle of Mull, on the 22nd of June before the survey start point. A second calibration was performed in Dunmanus Bay at the end of the survey to ensure optimal operation of the echosounder during data logging. The results of the first 38 kHz calibration are presented in Table 1. Prior to the survey, the EK60 was last calibrated in April 2012.

2.3.4 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the EK60 processing PC. The “RAW files” were copied via a continuous Ethernet connection as “EK5” files to the vessels server as a backup in the event of system failure. Further back-up copies were stored on an external HDD and magnetic LTO2 tapes. Myriax Echoview Echolog (Version 4.8) live-viewing software was used to display the echogram during data collection to allow the scientists to monitor target locations and depths of fish shoals in almost real-time. A member of the scientific crew monitored the equipment continually. Time and position were recorded for each transect start/end point within each strata. The log was also used to record “off track events” such as fishing operations and hydrographic stations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Myriax Echoview (vers. 4.8) post-processing software. Partitioning of data into the biological categories was largely subjective and was performed by scientists experienced in analysing echograms.

The “EK5” files were imported into Echoview for post-processing. The echograms were divided into transects. Echo integration was performed on regions which were defined by enclosing selected marks or back-scatter that belonged to one of the four categories outlined below. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

NASC (Nautical Area Scattering Coefficient) values attributable to herring were allocated to one of 4 categories during echogram scrutinization. Categories identified on the basis of trace recognition were:

1. “Definitely herring” echo-traces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echo-traces directly, and on large marks which had the characteristics of “definite” herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in mid-water and in the case of spawning shoals very dense aggregations in close proximity to the seabed).
2. “Probably herring” were attributed to smaller echo-traces that had not been fished but which had the characteristic of “definite” herring traces.
3. “Herring in a mixture” were attributed to NASC values arising from all fish traces in which herring were thought to be contained, owing to the presence of a proportion of herring within the nearest trawl haul or within a haul which had been carried out on similar echo-traces in similar water depths.
4. “Possibly herring” were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

Estimates of total abundance and biomass were calculated following the well-established method of Dalen and Nakken (1983).

The following TS/length relationships used were those recommended by the acoustic survey planning group (Anon, 1994):

Herring	TS =	20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS =	20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS =	20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS =	20logL – 67.5 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS =	20logL – 67.5 dB per individual (L = length in cm)

For boarfish (*Capros aper*) a species specific TS length relationship was applied based on theoretical swimbladder modelling from as yet unpublished data (Fassler *et al.* in review).

Boarfish TS = $20\log_{10}L - 65.98$ dB per individual (L = length in cm)

The same categories were applied to other target pelagic species encountered during the survey. Selection criteria are based primarily upon the species composition of trawl samples as well as target strength (TS) information.

2.3.6 Biological sampling

A single pelagic multipurpose midwater trawl with the dimensions of 54m in length (LOA) and 8m at the wing ends and a fishing circle of 420m was employed during the survey (Figure 13). Mesh size in the wings was 2.2m through to 4cm in the cod-end. The net was fished with a vertical mouth opening of approximately 22m, which was observed using a cable linked “BEL Reeson” netsonde (50 kHz). The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring were weighed as a component of the catch and length and weight measurements were taken for 100 individuals in addition to a 300 fish length frequency sample. Age, length, weight, sex and maturity data were recorded for individual herring within a random 100 fish sample from each trawl haul with a further 100 random length/weight measurements in addition to a 300 fish length frequency sample. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective, though an attempt was made to target all significant fish mark-types throughout the survey grid regardless of subjective eye-ball classifications. No bottom trawl gear was used during this survey.

2.3.7 Oceanographic data collection

Hydrographic stations were carried out during the survey at predetermined locations along the track. Data on temperature, depth and salinity were collected using a Seabird 911 sampler from 1 m subsurface to full depth.

2.4 Analysis methods

2.4.1 Abundance estimates

Total abundance, N_T, is given by $\sum_{m}^{Mark-types} N_{T,m}$, the sum over the total abundance by mark-types.

$$N_{T,m} = \sum_{s}^{strata} N_{m,s}$$

Suppressing the mark-type index, m, the stratum abundance is

$$N_s = area_s \sum_{l}^{transects} \bar{n}_{s,t} l_{s,t} \Big/ \sum_{j} l_{s,j}$$

,where *l* is the transect length and $\bar{n}$ is the transect mean abundance n.mi^{-2} which is given by

$$\sum_{j}^{track\cdot fragments} n_{s,t,j} d_{s,t,j} \Big/ l_{s,t}$$

, where d is the distance of the track fragment and $n_{s,t,j}$ is the mean abundance n.mi^{-2} for the jth track fragment.

Because hauls are assigned with their own stratification that will not necessarily coincide with the acoustic strata, the conversion of NASC into mean density is done at the track fragment level, usually a 1 n.mi segment, but these could be just for the schools themselves. The haul assigned, $h_{m,s,t,j}$, depends strongly on the mark-type (m) and since more than one school can be in a track fragment it needs to be specified. Since age and maturity length-keys are to be applied, the basic estimation is mean density by length bins. The $n_{s,t,j}$ is found by summing over the $n_{s,t,j}$.

$$n_{t,j,i} = \frac{NASC_{t,j}}{\bar{\sigma}_{h_{m,t,j}}} p_{i,h_{m,t,j}}$$

, where i indexes length bins, p_i is the proportion of herring in the i^{th} length bin, and is given by $\sum_{spe}^{species} \sum_{i} p_{spe,i} 10^{(a+b\log 10(L_{spe,i}))/10}$

, where $p_{spe,i}$ applies over all species considered in the haul, $L_{spe,i}$ is the length to use for the i^{th} length bin and the data comes from the haul (of combination of hauls) assigned, $h_{m,t,j}$. For non-mix mark-types, the later simplifies to

$$\sum_{i} p_{herring,i} 10^{(073+20\log 10(L_{herring,i}))/10} .$$

For biomass, a mean weight is also applied to the $n_{t,j,i}$ using the estimated regression relationship, a L_i^b.

For abundance by age and maturity, the abundance by length bin, $n_{t,j,i}$, is averaged over track fragments and then transects to give a strata (and mark-type) mean. The age and maturity keys are applied to the results.

$V_s = area_s^2 s_s^2 W_s$, where $W_s = \sum_{l}^{transects} {l^2}_{s,t} \Big/ (\sum_{j} l_{s,j})^2$ and s^2 is the sample variance.

The variance for the total is the sum of strata variances.
The total biomass can be obtained directly from the track fragment mean biomass by

$B_T = \sum_{k}^{track\cdot fragment} \bar{n}_k w_k$, where w_k is a factor that takes into account the factors for transect

and strata averaging, i.e., $w_k = \frac{1n.mi}{l_{t_k}} \frac{l_{t_k}}{\sum_{t}^{stratum.s_k} l_{s_k,t}} area_{s_k} = \frac{1}{\sum_{t}^{stratum.s_k} l_{s_k,t}} area_{s_k}$

, where the 1 n.mi is the length of the track fragment. This ignores the mark-type since that is already accounted for in the $\bar{n}_k$. The $\bar{n}_k w_k$ is the biomass from a track fragment and they can then be used to map the biomass at a fine spatial scale.

Estimates were made for SSB, total abundance and biomass, abundance by age (ring counts), and abundance by age x length bins. A cv (based on strata standard error divided by the strata mean) is estimated for SSB, total abundance and biomass, and abundance by age.

3 Results

3.1 Herring abundance and distribution

Twenty nine hauls were carried out during the survey of which 18 contained herring (Figure 2, Table 2). 4220 herring lengths were taken, together with 2,855 length/weight measurements and 1,597 individual age readings. 1,151 photographs and over 100 additional otoliths were collected for the SGHERWAY stock identification project.

3.1.2 Herring biomass and abundance

Total herring abundance, biomass and SSB for the whole area surveyed by Celtic Explorer are summarised in the table below.

All herring	Abund. (millions)	Biomass (t)	% Contribution
Def Herring	1,529	223,501	56
Herring in a mix	176	35,071	9
Probably Herring	910	139,225	35
Total	**2,615**	**397,797**	**100**
SSB herring			
Def Herring	969	178,641	55
Herring in a mix	167	33,960	10
Probably Herring	596	113,234	35
Total	**1,732**	**325,835**	**100**

In ICES area VIaN, total herring biomass (TSB) was 329,500 t and total herring abundance (TSN) was 2,073 million individuals. SSB and SSN were 283,300t and 1,492 million individuals, respectively.

TSB was 63,800t in ICES area VIaS, and TSN was 509 million individuals. This area comprised a SSB of 39,300 t and a SSN of 280 million individuals.

ICES area VIIb had the lowest biomass, with a TSB of 4,500 t and a TSN of 33 million individuals. SSB and SSN were 3,200 t and 23 million individuals, respectively, in area VIIb.

A full breakdown of the survey stock structure by strata, age, length, maturity and area is presented in Tables 4-8.

3.1.3 Herring distribution

The majority of herring detected during the survey were in VIaN (Figure 3). Herring were predominantly distributed in a relatively narrow band between the shelf-break and 8° W in southern regions of this sector. However, several large schools were also distributed to the west and north-west of Donegal, unlike during the 2011 survey. The majority of herring detected in VIaN occurred in discrete, small to medium sized schools in close proximity to the seabed (see Appendix 1; e.g. Hauls 1, 4 and 9). Herring also occurred in mixed-species assemblages, forming a light scattered layer along the seabed with juvenile mackerel, horse mackerel and blue whiting (Table 2). These layers often extended for several miles. Very few herring schools were observed in the upper layers of the water column, with the exception of one large surface school that could not be sampled (Appendix 1; Haul 3).

In contrast to the 2011 survey, but similar to 2010, relatively large quantities of herring were observed in close proximity to Donegal. A number of large, dense, mid-water schools were observed in the north of sector VIaS (Appendix 1; Hauls 21 to 24). In general, herring schools were larger but sparser in VIaS.

Similar to the 2011 survey, very few herring were observed in VIIb. Unfortunately, due to the small size of the few marks that were seen, there was a low success rate for hauls in VIIb.

3.1.4 Herring stock structure

Age analysis of biological samples showed herring within the survey area to be composed of age-groups from 1-11 years (winter rings; Tables 4-6). Overall, the stock age profile was dominated by 3-ring (19.3%) and 4-ring (24.4%) herring in terms of biomass (Table 5), and 1-ring (23.3%) and 3-ring (19.9%) in terms of abundance (Table 6). This trend in stock structure was not similar for all the regions surveyed, however. For example, 28% of the abundance in VIaN was 1-ring fish while 68% were 2-ring in VIaS (Table 6). Inspection of the length-frequency data showed that smaller fish (<21cm) were exclusively caught in VIaN (Table 3), although the three hauls containing small fish were widely spread across this region (Figure 2).

Combined maturity analysis indicated that over 18% of the TSB was immature, with this group comprising almost 34% of the TSN. This is in contrast to the 9% biomass and 15% abundance reported in 2011. The majority of herring encountered during the survey were spent fish (55% by biomass, 44% by abundance; Tables 7 and 8). This trend was similar in all regions except for abundance in VIaS, where there was a greater proportion of immature fish than mature fish (Table 8), which corresponds well with the high proportion of 2-ringed fish in this region (Table 6).

3.2 Other pelagics

3.2.1 Boarfish

Boarfish (*Capros aper*) were encountered from 40-250 m and were distributed mainly in area VIaS close to the shelf-break (Figure 5). The majority of boarfish that was detected acoustically occurred in small, discrete mid-water column schools (see Appendix 1; Haul 8 and 14). However, boarfish were often encountered in net hauls that were trawled close to the seabed indicating that there is likely to be an unquantifiable proportion of boarfish pressed to the bottom that cannot be detected acoustically.

Overall, 1,132 individual length measurements and 441 length/weight measurements were recorded from six hauls. Boarfish length ranged from 8.5-18 cm with a corresponding weight range of 14-116 g. Mean length was 14.5 cm and mean weight 66.9 g.

Estimates of boarfish abundance and biomass are not report here because the data were combined with those collected over a much wider area as part of a dedicated boarfish acoustic survey. See O'Donnell et al. (2012) for estimates of boarfish abundance and biomass.

3.2.2 Mackerel

Mackerel were the most commonly observed species on the survey and were found in 83% of hauls. Mackerel were distributed over the entire survey area as both single species schools and mixed species scattering layers. Mackerel were observed mainly in the surface layers or in mid-water and were very difficult to catch during fishing operations.

In total 2,137 individual lengths and 1,458 length/weight measurements were recorded for mackerel from 24 hauls. Length ranged from 17-43 cm with a corresponding weight range of 10-596 g. Mean length was 24.0 cm and mean weight 127.5 g.

3.3 Oceanography

A total of 42 CTD casts were made during the survey (Figure 1). All data were compiled to produce horizontal plots of temperature and salinity at the following depths; 5m, 20m, 40m and 60m subsurface (Figures 6-9).

Our data showed that, similar to 2011, the upper regions of the water column (0- 20 m) around northwest Ireland were considerably warmer than that further north in the VIaN region (c. 14.0 ℃ cf. 12.5 ℃ north of 56°N; Figure 6 and 7). At 40 and 60 m, the water temperature was much cooler throughout most of the survey sector (c. 10.5 ℃), indicating that the water was well-stratified thermally in all regions except for those off Mayo (area VIIb; Figure 9). As with last years survey, water temperatures around Mayo were high throughout the water column (between 5 and 60 m), suggesting a high degree of mixing in this region. Our results showed generally that the water salinity decreased gradually from the shelf-break (c. 35.4 ppt) towards land (c. 33.7 ppt) at all depths surveyed through the survey region (Figures 6-9). Salinity was fairly uniform throughout the water column, varying by approximately 0.1 to 0.5 ppt between the upper layers and 60 m.

In general, the spatial pattern in temperature variation in 2012 was similar to that in 2011, with coastal waters around northwest Ireland being predominantly warmer than those in the northern and shelf-break regions. The main difference was the pool of cold water (< 10℃) at 40-60m west of Barra, between 8° and 9° west.

4 Discussion and conclusions

4.1 Discussion

Overall, the survey can be considered a success with all components of the work program completed as planned. The entire survey grid was completed and two calibrations were performed to ensure optimal functioning of the EK60. Our estimates of abundance and biomass had a relatively high degree of precision, with CVs around 23%, and our acoustic analyses were supported by a relatively high number of net hauls.

In 2011 this survey was extended substantially to cover regions in VIaN that were previously surveyed by Marine Scotland. This is the second year that the entire survey area was covered by the Marine Institute and the results are therefore directly comparable to those of 2011. Estimated TSN for the entire area in 2012 was 2,615 million individuals, with a TSB of 397, 797 t and an SSB of 325, 835 t. This represents an increase in TSN, TSB and SSB of 37%, 27% and 14.5% respectively over 2011 figures.

Areas VIaS and VIIb have been consistently surveyed since 2008 so the biomass estimates from these areas in 2012 can be considered comparable to the previous four years. There has been a substantial increase in TSB from 40, 700 t in 2011 to 68, 300 t in 2012, making the 2012 estimate the second highest in the time series. Care should be taken in interpreting these results as herring are a highly mobile and migratory species and they frequently migrate northward from regions around Ireland during the summer months. It is therefore possible that the fluctuations seen in areas VIaS and VIIb could be due to small variations in the timing of the herring movements, the exact timing of the survey, or a combination of both.

During the 2011 survey, herring were predominantly distributed in area VIaN (between 56 and 57°N) and very few schools were detected in VIaS and VIIb. In 2012 the largest concentration of herring schools was once again between 56 - 57°N and 8-9°W but, unlike 2011 and similar to 2010, a number of large, dense schools were observed in VIaS. It is also interesting to note that the majority of herring schools detected during this survey were situated in regions north of 56°N where there was a pool of water at 40 - 60m that was markedly cooler than all other areas (see Figures 3, 8 and 9). However bio-physical interactions in the region are likely to be complex and it was not possible to substantiate any robust correlations between temperature and herring distribution based on our data.

Relatively few juvenile herring were recorded during the 2011 survey last year, however there has been a large influx of juvenile herring into the population in 2012, with approximately 10% of the herring biomass and 23% of the abundance attributed to 1-ringed fish during this year's survey. This is a good signal of the emerging year class which has yet to recruit to the spawning stock. The survey also successfully tracked the progress of the strong 2008 year class. There was a strong presence of 3- and 4-ring herring that suggests successful recruitment in the area, and indicates that the survey design is fairly robust in terms of tracking cohorts.

The passage of this year's survey past the coast of Donegal and Mayo coincided with a large bloom of the algae *Karenia mikimotoi*, as identified and monitored by the Marine Institute (Figure 11). Coastal waters in the area were dark brown in colour and large numbers of dead demersal fish and invertebrates were reportedly washed up on some local beaches. According to Joe Silke of the Marine Institute, "This recent bloom is similar in impact and duration to one which we experienced in 2005, and is most likely due to a combination of environmental conditions and ocean currents providing optimal conditions on the continental shelf." Despite the algae affecting the respiratory systems of fish and reducing the oxygen concentration of the water (particularly in bottom waters and while the bloom is decaying) the presence of *Karenia* does not seem to have adversely impacted the herring population in the region. Large, dense, mid-water schools of herring were observed to the north, north-west and west of Donegal, in and around the bloom.

4.2 Conclusions

- The northwest herring survey was completed successfully and robust estimates of herring abundance and biomass were calculated that accorded well with previous acoustic surveys in the region.
- The majority of herring were distributed within ICES area VIaN and VIaS and very few herring schools were observed in VIIb.
- It was possible to track herring cohorts from the data and there is evidence of successful recruitment within the northwest herring population; approximately 10% of the biomass and 23% of the abundance was attributed to 1-ringed fish.
- Other species observed regularly on the survey were mackerel and boarfish.
- CTD data indicated that coastal waters around northwest Ireland were warmer than those in the northern and shelf-break regions. The majority of herring seemed to be concentrated near a pool of cold water (< 10°C), 40-60m deep, west of Barra (between 8° and 9°) but in-depth analyses of the correlations between temperature and herring distribution were not performed.
- An algal bloom that coincided with the survey's passage around the north west of Ireland does not seem to have adversely impacted the herring population in the region.

5 Acknowledgements

We would like to express our thanks and gratitude to Anthony Hobin (Captain) and crew of the Celtic Explorer for their good will and professionalism during the survey. Also to the scientists working in the wetlab for their hard work and diligence during the survey.

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Table 1. Survey settings and calibration report (38kHz) for the Simrad ER60 echosounder. Northwest herring survey, June\July 2012.

```
#  Calibration  Version   2.1.0.12
#
#  Date:  22/06/2012
#
#  Comments:
#    Tobermory
#
#  Reference Target:
#    TS                  -33.50 dB       Min. Distance        15.00 m
#    TS Deviation           5.0 dB       Max. Distance        25.00 m
#
#  Transducer:  ES38B  Serial No.   30227
#    Frequency            38000 Hz       Beamtype              Split
#    Gain                 25.89 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     6.98 deg       Along. Beam Angle    7.03 deg
#    Athw. Offset Angle  -0.06 deg       Along. Offset Angle -0.07 deg
#    SaCorrection         -0.66 dB       Depth                8.80  m
#
#  Transceiver:  GPT  38 kHz 009072033933 2-1 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.192   m
#    Power                2000  W        Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing           100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength         80 %
#    Max. Phase Dev.        8.0          Max. Echolength        180 %
#
#  Environment:
#    Absorption Coeff.   9.4 dB/km       Sound Velocity     1499.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 25.92 dB       SaCorrection       = -0.66 dB
#    Athw. Beam Angle   = 7.03 deg       Along. Beam Angle  = 6.94 deg
#    Athw. Offset Angle =-0.03 deg       Along. Offset Angle=-0.04 deg
#
#  Data deviation from beam model:
#    RMS =    0.14 dB
#    Max =    0.33 dB  No. =   166  Athw. =  2.1 deg  Along =  3.2 deg
#    Min =   -0.67 dB  No. =   326  Athw. =  3.3 deg  Along = -4.0 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.09 dB
#    Max =    0.38 dB  No. =   322  Athw. =  3.8 deg  Along = -3.3 deg
#    Min =   -0.54 dB  No. =   298  Athw. = -2.3 deg  Along = -4.4 deg
```

Table 2. Catch composition and position of hauls undertaken by the RV *Celtic Explorer*.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (kg)	Sampled Catch (kg)	Herring %	Mackerel %	Boarfish %	H Mack %	Others %
1	23-Jun-12	56.9157	6.6038	13:11	95	85	400	152	93.5	2.0	0.0	0.0	4.5
2*	23-Jun-12	57.2415	7.013	16:55	135	95	0	0	0.0	0.0	0.0	0.0	0.0
3	23-Jun-12	57.4936	6.7798	20:37	131	25	15	15	0.0	22.3	0.0	0.0	77.7
4	24-Jun-12	58.3108	7.1821	21:38	110	100	500	139	100.0	0.0	0.0	0.0	0.0
5	26-Jun-12	57.5487	8.9	07:51	150	140	143	143	74.0	24.4	0.0	0.0	1.6
6*	26-Jun-12	57.3001	8.0486	15:17	125	90	0	0	0.0	0.0	0.0	0.0	0.0
7	27-Jun-12	57.0487	8.1185	06:08	131	119	350	140	99.6	0.4	0.0	0.0	0.0
8	27-Jun-12	56.7928	8.9532	15:47	123	108	400	129	26.3	4.7	66.9	1.9	0.2
9	27-Jun-12	56.7959	8.1528	19:28	122	117	1,000	127	98.5	1.5	0.0	0.0	0.0
10	28-Jun-12	56.4142	9.0417	21:44	144	114	300	115	0.8	22.4	61.7	2.2	12.9
11	29-Jun-12	56.2886	6.8867	11:14	65	55	2,000	124	0.2	96.5	0.0	0.0	3.4
12	30-Jun-12	56.0416	8.459	07:13	133	128	37	37	38.4	22.4	0.0	0.0	39.2
13	30-Jun-12	56.0428	7.7295	11:34	126	121	33	33	7.8	68.1	0.0	0.0	24.1
14	01-Jul-12	55.9227	9.1423	07:39	170	60	1,500	114	0.0	3.1	88.5	8.3	0.0
15	01-Jul-12	55.7833	9.0917	10:54	133	128	3,500	135	0.4	7.7	1.1	90.9	0.0
16	02-Jul-12	55.6657	7.9917	05:54	81	21	149	149	37.8	58.8	0.0	3.3	0.0
17	02-Jul-12	55.6681	8.5366	09:15	86	71	163	163	98.2	1.3	0.0	0.0	0.6
18	02-Jul-12	55.5465	8.7435	16:36	95	80	2,000	157	88.9	11.1	0.0	0.0	0.0
19	03-Jul-12	55.4149	6.8085	07:26	60	55	5,500	156	98.1	0.5	0.0	0.0	1.4
20	03-Jul-12	55.4173	9.5885	17:51	188	50	2,000	119	0.0	86.4	8.6	5.0	0.0
21	03-Jul-12	55.2983	9.4425	22:56	105	15	1,000	125	0.0	92.3	0.0	7.7	0.0
22	04-Jul-12	55.1602	8.6825	11:10	80	65	1,000	146	97.1	2.9	0.0	0.0	0.0
23	05-Jul-12	54.9228	9.3345	05:46	87	47	2,000	153	82.9	17.1	0.0	0.0	0.0
24	05-Jul-12	54.9083	9.9122	20:17	96	71	4,000	124	100.0	0.0	0.0	0.0	0.0
25*	06-Jul-12	54.1672	10.2767	22:12	70	20	0	0	0.0	0.0	0.0	0.0	0.0
26	07-Jul-12	53.913	10.6318	12:56	141	136	63	63	0.4	4.3	0.0	0.0	95.3
27	07-Jul-12	53.8028	10.6752	21:34	124	104	33	33	39.9	0.4	2.3	0.0	57.5
28	08-Jul-12	53.6717	11.6312	11:26	250	50	500	138	0.0	98.9	0.0	0.7	0.0
29	08-Jul-12	53.5445	11.3973	15:28	177	97	25	25	0.0	79.4	0.9	7.2	12.6

Table 3. Length-frequency of herring hauls used in the analysis. Northwest herring survey, June\July 2012.

Length (cm)	Haul 1	Haul 4	Haul 5	Haul 7	Haul 9	Haul 17	Haul 18	Haul 19	Haul 22	Haul 23	Haul 24
15	-	-	-	-	-	-	-	-	-	-	-
15.5	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-
16.5	-	-	-	-	-	-	-	1	-	-	-
17	5	-	-	-	-	-	-	9	-	-	-
17.5	13	-	-	-	-	-	-	13	-	-	-
18	26	3	-	-	-	-	-	33	-	-	-
18.5	25	8	-	-	-	-	-	15	-	-	-
19	22	14	-	-	-	-	-	17	-	-	-
19.5	5	11	-	-	-	-	-	5	-	-	-
20	4	20	-	-	-	-	-	3	-	-	-
20.5	-	10	-	-	-	-	-	1	-	-	-
21	-	8	-	-	-	-	-	1	1	2	-
21.5	-	2	-	-	-	1	1	1	1	3	-
22	-	1	-	-	-	3	5	1	5	14	-
22.5	-	-	-	-	-	6	8	-	5	12	1
23	-	-	-	-	-	9	11	-	9	17	2
23.5	-	-	-	-	-	17	14	-	14	19	2
24	-	-	-	-	-	16	13	-	11	10	5
24.5	-	1	-	-	1	15	6	-	15	6	3
25	-	2	-	2	1	9	7	1	10	8	5
25.5	-	1	-	2	2	8	10	-	9	1	5
26	-	2	-	1	6	3	7	-	5	1	10
26.5	-	3	-	9	8	5	6	1	6	3	10
27	-	2	6	18	14	4	7	1	4	1	15
27.5	-	6	5	20	22	1	3	-	3	1	12
28	-	3	16	22	15	-	3	-	2	1	11
28.5	-	1	18	10	15	1	1	-	1	-	6
29	-	-	19	9	6	-	-	-	-	-	6
29.5	-	1	16	4	7	-	-	-	-	-	2
30	-	-	14	3	1	-	-	-	-	-	1
30.5	-	1	3	1	2	-	-	-	-	-	-
31	-	-	2	1	-	-	-	-	-	-	-
31.5	-	-	1	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-
32.5	-	-	-	-	-	-	-	-	-	-	-
Division	**VIaN**	**VIaN**	**VIaN**	**VIaN**	**VIaN**	**VIaS**	**VIaS**	**VIaN**	**VIaS**	**VIaS**	**VIaS**

Table 4. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Northwest herring survey, June\July 2012.

Length (cm)	Age 0	(rings) 1	2	3	4	5	6	7	8	9	10	Abund. (mill.s)	Biomass '000's tonnes	Mn Wt (g)
17	0.84	-	-	-	-	-	-	-	-	-	-	0.84	0.04	44.3
17.5	4.66	-	-	-	-	-	-	-	-	-	-	4.66	0.23	48.3
18	25.2	-	-	-	-	-	-	-	-	-	-	25.2	1.33	52.6
18.5	69.55	-	-	-	-	-	-	-	-	-	-	69.55	3.98	57.2
19	113.8	-	-	-	-	-	-	-	-	-	-	113.76	7.05	62
19.5	90.03	-	-	-	-	-	-	-	-	-	-	90.03	6.03	67
20	153.3	4.74	-	-	-	-	-	-	-	-	-	158.07	11.44	72.4
20.5	77.14	3.21	-	-	-	-	-	-	-	-	-	80.35	6.26	78
21	48.05	19.82	-	-	-	-	-	-	-	-	-	67.87	5.69	83.9
21.5	8.01	17.19	-	-	-	-	-	-	-	-	-	25.2	2.27	90
22	13.92	55.68	-	-	-	-	-	-	-	-	-	69.6	6.72	96.5
22.5	3.85	46.33	2.59	-	-	-	-	-	-	-	-	52.77	5.45	103.3
23	-	75.4	2.33	-	-	-	-	-	-	-	-	77.73	8.58	110.4
23.5	-	87.84	8.29	1.36	-	-	-	-	-	-	-	97.49	11.49	117.9
24	-	49.48	15.12	0.85	-	-	-	-	-	-	-	65.44	8.22	125.6
24.5	-	41.77	16.56	3.46	-	-	-	-	-	-	-	61.78	8.26	133.7
25	-	25.83	34.96	9.12	3.07	-	-	-	-	-	-	72.98	10.37	142.2
25.5	-	6.91	25.9	11.22	0.85	-	-	-	-	-	-	44.89	6.78	151
26	-	8.84	36.34	23.55	1.98	-	-	-	-	-	-	70.71	11.32	160.1
26.5	-	6.22	43.67	67.12	4.66	4.66	3.11	-	-	-	-	129.45	21.96	169.6
27	-	-	75.15	86.19	17.16	7.89	11.05	-	-	-	-	197.43	35.44	179.5
27.5	-	2.28	121.4	121.4	23.04	9.1	2.28	4.55	-	-	-	284.12	53.92	189.8
28	-	-	47.99	117.3	31.91	13.44	13.44	16.08	-	-	-	240.18	48.14	200.5
28.5	-	-	14.29	50.58	55.28	28.39	14.29	11.09	11.09	3.2	-	188.22	39.81	211.5
29	-	-	-	22.4	32.74	18.99	17.29	17.29	13.75	3.41	5.11	130.97	29.2	223
29.5	-	-	-	-	5.22	19.03	27.63	20.67	22.41	8.59	5.22	108.76	25.54	234.8
30	-	-	-	1.49	4.41	10.25	19.02	5.84	4.41	5.84	-	51.27	12.67	247.1
30.5	-	-	-	-	-	2.31	4.65	6.96	4.65	6.96	2.31	27.85	7.24	259.8
31	-	-	-	-	-	1.2	2.41	1.2	-	1.2	-	6.02	1.64	273
31.5	-	-	-	-	-	0.17	0.33	0.17	-	0.17	-	0.83	0.24	286.6
33	-	-	-	-	-	-	1.44	-	-	-	-	1.44	0.47	330.1
SSN	0.28	204.7	423.5	510.1	179.5	115.2	116.8	83.77	56.31	29.37	12.64	1732.15	-	-
SSB	0.029	26.39	74.04	95.99	36.69	24.81	26.11	18.76	12.97	7.082	2.966	-	325.835	-
Mn Weight	69.5	115.3	173	187.9	204.2	215.2	223.5	223.8	230.4	241.2	234.6	-	-	-
Mn Length	19.9	23.5	26.9	27.6	28.4	28.9	29.2	29.3	29.6	30	29.7	-	-	-

Table 5. Herring biomass (000's tonnes) at age (winter rings) by strata and ICES division.

Strata	1	2	3	4	5	6	7	8	9	10	11	Total
36D8	0	0	0	0	0	0	0	0	0	0	0	0
36D9	0.1	1.9	1	0.6	0.1	0	0	0	0	0	0	3.8
37D8	0	0	0	0	0	0	0	0	0	0	0	0
37D9	0	0.1	0	0	0	0	0	0	0	0	0	0.2
37E0	0	0.2	0.1	0.1	0	0	0	0	0	0	0	0.5
37E1	0	0	0	0	0	0	0	0	0	0	0	0
38D9	0	0.2	0.1	0	0	0	0	0	0	0	0	0.3
38E0	0.6	8.1	1.9	0.9	0.2	0.1	0.1	0	0	0	0	11.9
38E1	0	0	0	0	0	0	0	0	0	0	0	0
39D9	0	0	0	0	0	0	0	0	0	0	0	0
39E0	0.9	13.3	3.1	1.5	0.3	0.1	0.1	0.1	0	0	0	19.5
39E1	0.5	6.8	1.6	0.8	0.2	0.1	0	0	0	0	0	10
39E2	0	0	0	0	0	0	0	0	0	0	0	0
39E3	0	0.8	0.5	0.3	0.1	0	0	0	0	0	0	1.7
40E0	0	0.2	0.1	0	0	0	0	0	0	0	0	0.3
40E1	0.3	9.8	4.4	2.2	0.3	0.1	0.1	0	0	0	0	17.2
40E2	0	0.8	0.9	1	0.4	0.3	0.4	0.3	0.2	0.2	0.1	4.6
40E3	0	0.1	0.1	0	0	0	0	0	0	0	0	0.2
41E0	0	0	0	0	0	0	0	0	0	0	0	0
41E1	0	0.3	2.6	3.6	1.4	1	1	0.8	0.6	0.3	0.1	11.5
41E2	0	0.4	2.6	3.5	1.3	0.8	0.8	0.6	0.4	0.2	0.1	10.7
41E3	0	0	0	0	0	0	0	0	0	0	0	0
42E0	0	0	0	0	0	0	0	0	0	0	0	0
42E1	0	2.2	28.3	40	14.8	9.3	9.1	6.7	4.4	2.2	1	118
42E2	0	0.2	2.9	4	1.5	1	0.9	0.7	0.5	0.2	0.1	12.1
42E3	0.9	0.2	2	2.8	1.1	0.7	0.7	0.5	0.4	0.2	0.1	9.5
43E0	0	0	0.1	0.1	0	0	0	0	0	0	0	0.3
43E1	0	0.4	6.2	9.1	3.2	1.9	2.1	1.4	0.8	0.4	0.2	25.6
43E2	0	0	0.3	0.4	0.1	0.1	0.1	0.1	0	0	0	1
43E3	0	0	0.6	1.5	1.1	1	1.3	0.8	0.6	0.4	0.1	7.6
44E0	0	0.1	1	1.5	0.5	0.3	0.3	0.2	0.1	0.1	0	4.3
44E1	0	0.1	2.8	5.4	3.8	3.1	3.6	2.5	2.1	1.1	0.5	24.9
44E2	0	0	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0	1
44E3	0	0	0	0.1	0	0	0.1	0	0	0	0	0.3
44E4	0	0	0	0	0	0	0	0	0	0	0	0
45E0	0	0.1	2.7	5.1	3	2.5	3.1	2	1.5	0.9	0.3	21.4
45E2	28.1	4.1	7.7	8.5	2	1.3	1.4	1.1	0.7	0.5	0.2	55.6
45E1	7.6	1.1	2.3	2.8	0.9	0.7	0.7	0.5	0.4	0.2	0.1	17.3
45E3	1.6	0.2	0.4	0.5	0.1	0.1	0.1	0.1	0	0	0	3.2
45E4	1.6	0.2	0.4	0.5	0.1	0.1	0.1	0.1	0	0	0	3.1
Total	**42.3**	**52.1**	**76.9**	**97**	**36.8**	**24.8**	**26.1**	**18.8**	**13**	**7.1**	**3**	**397.8**
%	**10.6**	**13.1**	**19.3**	**24.4**	**9.3**	**6.2**	**6.6**	**4.7**	**3.3**	**1.8**	**0.7**	**100**

VIaN	39.9	10.7	63.7	89.9	35.3	24.1	25.4	18.4	12.8	6.9	2.9	329.5
VIaS	2.3	39.2	12.1	6.4	1.4	0.7	0.7	0.4	0.2	0.2	0.1	63.8
VIIb	0.1	2.2	1.1	0.7	0.1	0	0	0	0	0	0	4.5

Table 6. Herring abundance (millions) at age (winter rings), by strata and ICES division.

Strata	1	2	3	4	5	6	7	8	9	10	11	Total
36D8	0	0	0	0	0	0	0	0	0	0	0	0
36D9	0.65	15.4	6.95	3.61	0.57	0.21	0.17	0.08	0.03	0.02	0.01	27.7
37D8	0	0	0	0	0	0	0	0	0	0	0	0
37D9	0.09	1.04	0.2	0.08	0.02	0.01	0	0	0	0	0	1.44
37E0	0.08	1.98	0.89	0.46	0.07	0.03	0.02	0.01	0	0	0	3.55
37E1	0	0	0	0	0	0	0	0	0	0	0	0
38D9	0.18	2.12	0.4	0.17	0.03	0.01	0.01	0.01	0	0	0	2.92
38E0	6.18	72	13.7	5.6	1.03	0.36	0.29	0.16	0.05	0.01	0.01	99.4
38E1	0	0	0	0	0	0	0	0	0	0	0	0
39D9	0	0	0	0	0	0	0	0	0	0	0	0
39E0	10.1	118	22.5	9.19	1.68	0.59	0.47	0.27	0.08	0.02	0.02	163
39E1	5.17	60.2	11.6	4.81	0.89	0.32	0.26	0.15	0.05	0.01	0.01	83.4
39E2	0	0	0	0	0	0	0	0	0	0	0	0
39E3	0.25	6.41	3.03	1.81	0.29	0.11	0.1	0.04	0.01	0	0	12.1
40E0	0.08	1.57	0.51	0.22	0.03	0.01	0.01	0	0	0	0	2.45
40E1	3.15	81.6	30.4	13.4	1.94	0.67	0.58	0.14	0.08	0.02	0.02	132
40E2	0.2	6.84	5.7	5.35	1.74	1.44	1.71	1.31	0.98	0.71	0.27	26.3
40E3	0.04	0.96	0.45	0.27	0.04	0.02	0.02	0.01	0	0	0	1.81
41E0	0	0	0	0	0	0	0	0	0	0	0	0
41E1	0.01	1.93	14.3	18.8	6.68	4.43	4.39	3.38	2.39	1.33	0.56	58.3
41E2	0.04	2.58	14.4	18.6	6.47	3.93	3.59	2.74	1.88	0.88	0.4	55.4
41E3	0	0	0	0	0	0	0	0	0	0	0	0
42E0	0	0	0	0	0	0	0	0	0	0	0	0
42E1	0	14.5	156	211	72.8	43.7	41.5	30.3	19.4	9.19	4.19	602
42E2	0	1.58	16.1	21.2	7.44	4.51	4.1	3.13	2.15	0.99	0.46	61.6
42E3	15.9	1.16	11.2	14.9	5.32	3.28	3.04	2.3	1.59	0.75	0.34	59.7
43E0	0	0.04	0.46	0.65	0.21	0.12	0.13	0.09	0.05	0.02	0.01	1.76
43E1	0	2.84	33.8	47.7	15.7	9.13	9.24	6.26	3.38	1.69	0.74	131
43E2	0	0.12	1.37	1.94	0.64	0.37	0.38	0.25	0.14	0.07	0.03	5.3
43E3	0	0.02	3.23	7.43	5.23	4.52	5.45	3.64	2.79	1.66	0.61	34.6
44E0	0	0.48	5.7	8.04	2.65	1.54	1.56	1.05	0.57	0.28	0.13	22
44E1	0	0.78	15.2	26.9	17.6	13.9	15.4	11	8.89	4.51	2.1	116
44E2	0	0	0.44	1.01	0.71	0.61	0.74	0.49	0.38	0.23	0.08	4.69
44E3	0	0	0.13	0.29	0.21	0.18	0.21	0.14	0.11	0.07	0.02	1.35
44E4	0	0	0	0	0	0	0	0	0	0	0	0
45E0	0	0.69	14.3	26	14.3	11.3	13.2	8.86	6.47	3.78	1.41	100
45E2	409	40.8	44.3	46.5	10.5	6.37	6.32	5	2.89	1.91	0.75	574
45E1	111	11.1	13	14.8	4.37	3.05	3.3	2.42	1.6	1	0.38	166
45E3	23.5	2.35	2.55	2.68	0.6	0.37	0.36	0.29	0.17	0.11	0.04	33
45E4	22.9	2.29	2.49	2.61	0.59	0.36	0.36	0.28	0.16	0.11	0.04	32.2
Total	**608**	**452**	**445**	**516**	**180**	**115**	**117**	**83.8**	**56.3**	**29.4**	**12.6**	**2615**
%	**23.3**	**17.3**	**17**	**19.7**	**6.9**	**4.41**	**4.47**	**3.21**	**2.15**	**1.12**	**0.48**	**100**
Cv (%)	**57.2**	**33.4**	**19**	**19.1**	**19.4**	**19.8**	**19.7**	**19.9**	**21.1**	**20.1**	**21.6**	**NA**

VIaN	582	90.6	352	473	172	112	113	81.7	55	28.6	12.3	2073
VIaS	25.1	342	84.7	38.7	7.34	3.41	3.32	2.03	1.25	0.78	0.33	510
VIIb	0.82	18.5	8.03	4.16	0.66	0.24	0.2	0.1	0.04	0.03	0.01	32.7

Table 7. Herring biomass (000's tonnes) at maturity by strata and ICES division.

Strata	Immature	Mature	Spent	Total
36D8	0	0	0	0
36D9	0.9	1	1.8	3.8
37D8	0	0	0	0
37D9	0.1	0	0.1	0.2
37E0	0.1	0.1	0.2	0.5
37E1	0	0	0	0
38D9	0.2	0.1	0.1	0.3
38E0	5.5	2.3	4.2	11.9
38E1	0	0	0	0
39D9	0	0	0	0
39E0	9	3.7	6.8	19.5
39E1	4.6	1.9	3.5	10
39E2	0	0	0	0
39E3	0.4	0.5	0.8	1.7
40E0	0.1	0.1	0.1	0.3
40E1	4.8	4.4	7.9	17.2
40E2	0.4	1.4	2.8	4.6
40E3	0.1	0.1	0.1	0.2
41E0	0	0	0	0
41E1	0.1	3.7	7.6	11.5
41E2	0.2	3.5	7.1	10.7
41E3	0	0	0	0
42E0	0	0	0	0
42E1	1	38.2	78.8	118
42E2	0.1	3.9	8	12.1
42E3	1	2.8	5.7	9.5
43E0	0	0.1	0.2	0.3
43E1	0.2	8.2	17.2	25.6
43E2	0	0.3	0.7	1
43E3	0	2.3	5.3	7.6
44E0	0	1.4	2.9	4.3
44E1	0.1	7.5	17.4	24.9
44E2	0	0.3	0.7	1
44E3	0	0.1	0.2	0.3
44E4	0	0	0	0
45E0	0.1	6.6	14.8	21.4
45E2	31.1	8.5	16	55.6
45E1	8.5	3	5.9	17.3
45E3	1.8	0.5	0.9	3.2
45E4	1.7	0.5	0.9	3.1
Total	**72**	**106.9**	**218.9**	**397.8**
%	**18.1**	**26.9**	**55**	**100**

VIaN	46.3	91.9	191.4	329.5
VIaS	24.6	13.9	25.4	63.8
VIIb	1.1	1.1	2.1	4.5

Table 8. Herring abundance (millions) at maturity by strata and ICES division.

Strata	Immature	Mature	Spent	Total
36D8	0	0	0	0
36D9	8.337	6.989	12.418	27.745
37D8	0	0	0	0
37D9	0.749	0.242	0.445	1.437
37E0	1.067	0.895	1.59	3.551
37E1	0	0	0	0
38D9	1.524	0.493	0.905	2.922
38E0	51.831	16.754	30.79	99.374
38E1	0	0	0	0
39D9	0	0	0	0
39E0	85.075	27.5	50.539	163.114
39E1	43.32	14.138	25.982	83.44
39E2	0	0	0	0
39E3	3.796	3.045	5.22	12.061
40E0	0.911	0.55	0.986	2.447
40E1	43.262	31.888	56.807	131.956
40E2	3.288	7.83	15.136	26.253
40E3	0.569	0.456	0.782	1.808
41E0	0	0	0	0
41E1	0.69	19.153	38.41	58.254
41E2	1.14	18.104	36.193	55.436
41E3	0	0	0	0
42E0	0	0	0	0
42E1	5.786	197.096	399.184	602.066
42E2	0.616	20.296	40.701	61.614
42E3	16.396	14.377	28.949	59.723
43E0	0.016	0.573	1.175	1.763
43E1	1.19	42.383	86.965	130.538
43E2	0.048	1.721	3.531	5.3
43E3	0.049	10.505	24.027	34.58
44E0	0.201	7.14	14.651	21.992
44E1	0.467	35.015	80.797	116.279
44E2	0.007	1.423	3.255	4.685
44E3	0.002	0.411	0.94	1.353
44E4	0	0	0	0
45E0	0.37	31.099	68.862	100.331
45E2	442.057	46.095	85.83	573.982
45E1	120.327	15.59	30.322	166.239
45E3	25.423	2.651	4.936	33.01
45E4	24.819	2.588	4.819	32.225
Total	**883.331**	**577**	**1155.146**	**2615.478**
%	**33.773**	**22.061**	**44.166**	**100**

VIaN	643.967	469.721	959.548	2073.239
VIaS	229.211	99.153	181.145	509.506
VIIb	10.153	8.126	14.453	32.733

Table 9. Herring biomass and abundance by survey strata. Northwest herring survey, June\July 2012.

Stratum	No. Transects	No. Schools	Def Schools	Mix Schools	Prob. Schools	% zeros	Def. Bio.	Mix Bio.	Prob. Bio.	Biomass ('000's t)	SSB ('000's t)	Abund (mills.)
36D8	4	0	0	0	0	100	0	0	0	0	0	0
36D9	4	16	0	14	2	25	0	3.6	0.2	3.8	2.8	27.745
37D8	1	0	0	0	0	100	0	0	0	0	0	0
37D9	4	1	0	0	1	75	0	0	0.2	0.2	0.1	1.437
37E0	1	11	0	10	1	0	0	0.5	0	0.5	0.4	3.551
37E1	1	0	0	0	0	100	0	0	0	0	0	0
38D9	4	2	2	0	0	75	0.3	0	0	0.3	0.2	2.922
38E0	4	28	23	0	5	0	11.3	0	0.6	11.9	6.4	99.374
38E1	4	0	0	0	0	100	0	0	0	0	0	0
39D9	1	0	0	0	0	100	0	0	0	0	0	0
39E0	4	9	0	0	9	25	0	0	19.5	19.5	10.5	163.114
39E1	4	7	3	0	4	25	8.6	0	1.4	10	5.4	83.44
39E2	2	0	0	0	0	100	0	0	0	0	0	0
39E3	1	9	7	0	2	0	1.3	0	0.3	1.6	1.2	12.061
40E0	4	2	0	0	2	50	0	0	0.3	0.3	0.2	2.447
40E1	4	41	30	0	11	0	15.9	0	1.4	17.2	12.4	131.956
40E2	4	16	2	12	2	0	0.9	3.4	0.4	4.6	4.2	26.253
40E3	4	3	0	0	3	75	0	0	0.2	0.2	0.2	1.808
41E0	4	0	0	0	0	100	0	0	0	0	0	0
41E1	4	43	0	26	17	0	0	2.9	8.6	11.5	11.4	58.254
41E2	4	28	0	2	26	0	0	0.1	10.6	10.7	10.6	55.436
41E3	3	0	0	0	0	100	0	0	0	0	0	0
42E0	3	0	0	0	0	100	0	0	0	0	0	0
42E1	4	105	73	7	25	0	109.4	1.7	6.9	118	117.1	602.066
42E2	6	18	5	0	13	17	3.4	0	8.6	12.1	12	61.614
42E3	4	27	7	0	20	0	6.3	0	3.2	9.5	8.5	59.723
43E0	2	3	0	0	3	50	0	0	0.3	0.3	0.3	1.763
43E1	2	37	14	0	23	0	13.4	0	12.2	25.6	25.4	130.538
43E2	4	2	2	0	0	75	1	0	0	1	1	5.3
43E3	2	4	0	0	4	50	0	0	7.6	7.6	7.6	34.58
44E0	2	3	0	0	3	50	0	0	4.3	4.3	4.3	21.992
44E1	2	29	0	28	1	0	0	22.9	2	24.9	24.8	116.279
44E2	2	5	0	0	5	50	0	0	1	1	1	4.685
44E3	5	1	0	0	1	80	0	0	0.3	0.3	0.3	1.353
44E4	2	0	0	0	0	100	0	0	0	0	0	0
45E0	1	17	0	0	17	0	0	0	21.4	21.4	21.3	100.331
45E2	2	29	13	0	16	0	51.6	0	4	55.6	24.5	573.982
45E2	2	31	0	0	31	0	0	0	17.3	17.3	8.9	166.239
45E3	3	6	0	0	6	67	0	0	3.2	3.2	1.4	33.01
45E4	2	4	0	0	4	50	0	0	3.1	3.1	1.4	32.225
Total	**120**	**537**	**181**	**99**	**257**	**45**	**223.5**	**35.1**	**139.2**	**397.8**	**325.8**	**2615.478**
Cv (%)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**19.3**	**NA**	**22.8**

Table 10. Historic survey time-series for areas VIaS and VIIb. Abundance (millions), TSB and SSB (tonnes), age in winter rings. Northwest herring survey, June\July 2012.

Winter rings	2008	2009	2010	2011	2012
0	-	-	-	-	-
1	6.1	416.4	16.5	44.6	25.9
2	75.9	81.3	292.8	86.3	360.9
3	64.7	11.4	85.2	146.8	92.8
4	38.4	15.1	63.2	28.9	42.9
5	22.3	7.7	43.2	5.7	8.0
6	26.2	7.1	27.3	4.3	3.7
7	9.1	7.5	19.0	4.8	3.5
8	5.0	0.4	12.5	2.1	2.1
9	3.7	0.9	5.5	1.4	1.3
10+	-	-	-	0.8	1.1
TSN (mil)	251.4	547.7	565.2	325.7	542.2
TSB (t)	44,611	46,460	82,100	40,700	68,300
SSB (t)	43,006	20,906	81,400	28,600	42,600
CV	34.2	32.2	-	-	-

Survey coverage: VIaS & VIIb

Table 11. Historic survey time-series for all areas surveyed. Abundance (millions), TSB and SSB (tonnes), age in winter rings. Note that the 2011 and 2012 survey coverage in VIaN was much greater than that in 2010.

Winter rings	2008^	2009^	2010*	2011*	2012*
0	-	-	-	-	-
1	6.1	416.4	524.8	82.1	608.3
2	75.9	81.3	504.3	202.5	451.5
3	64.7	11.4	133.3	752.0	444.6
4	38.4	15.1	107.4	381.0	516.1
5	22.3	7.7	103.0	110.8	180.3
6	26.2	7.1	83.7	124.0	115.4
7	9.1	7.5	57.6	118.4	116.9
8	5.0	0.4	35.3	70.7	83.8
9	3.7	0.9	17.5	41.6	56.3
10+	-	-	-	25.6	42.0
TSN (mil)	251.4	547.7	1,566.9	1,909	2,615
TSB (t)	44,611	46,460	192,979	313,305	397,797
SSB (t)	43,006	20,906	170,154	284,632	325,835
CV	34.2	32.2	24.7	22.4	22.8

^ Survey coverage: VIaS & VIIb

* Survey coverage: VIaS, VIaN & VIIb

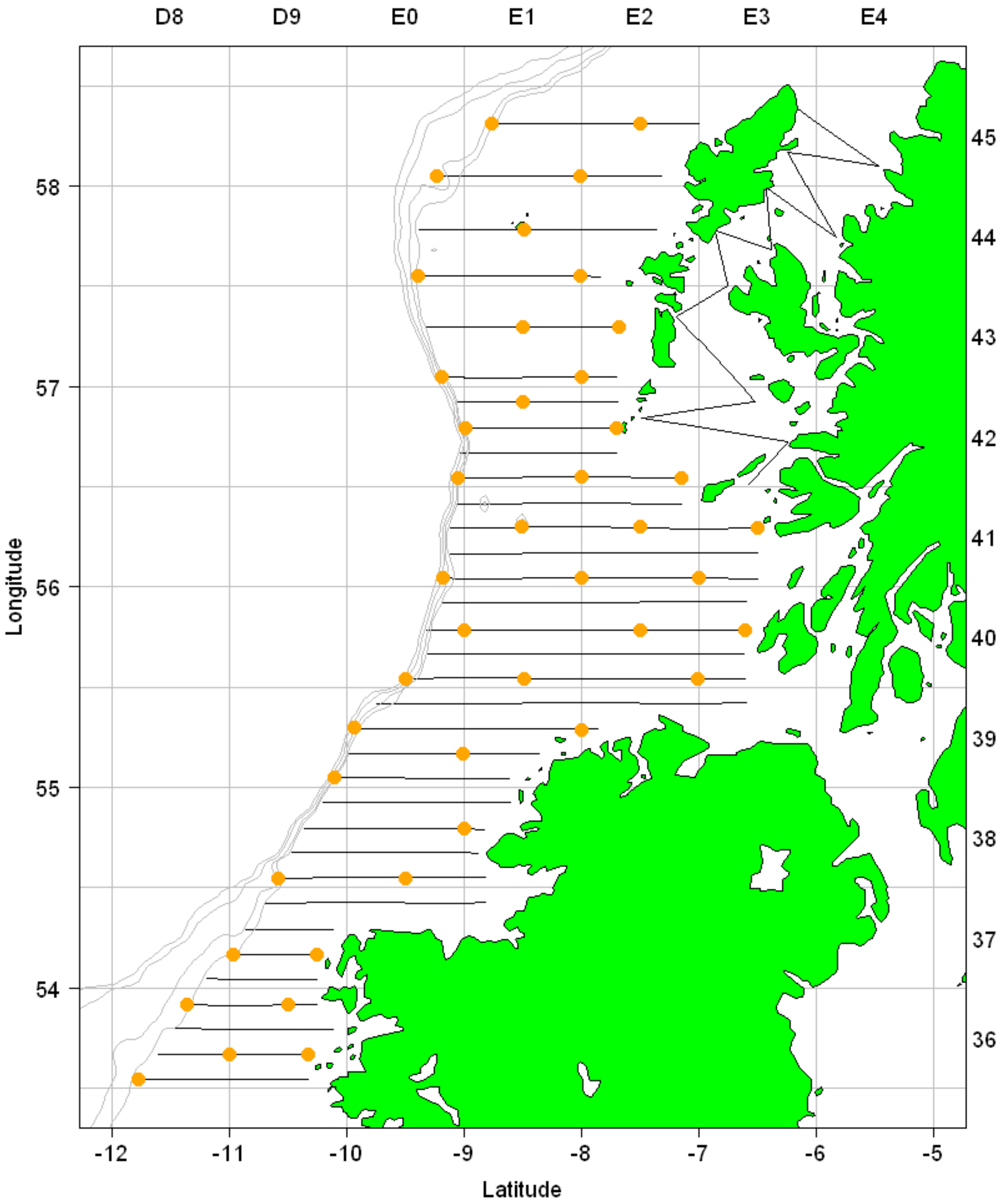


Figure 1. RV Celtic Explorer cruise track during the Northwest herring survey, June\July 2012 (excluding inter-transect segments). Orange circles are hydrographic stations.

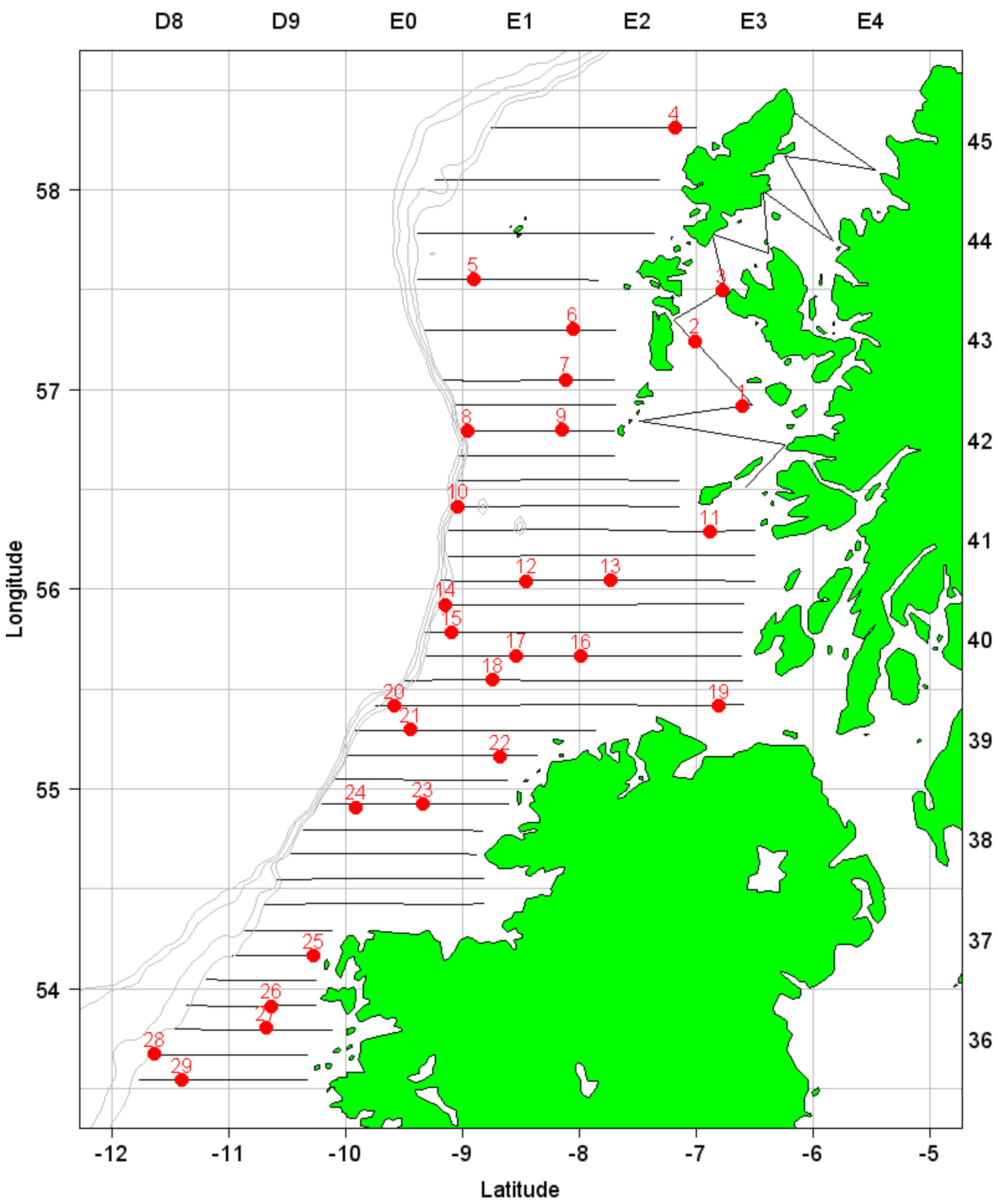


Figure 2. RV Celtic Explorer fishing trawl stations. Northwest herring survey, June\July 2012.

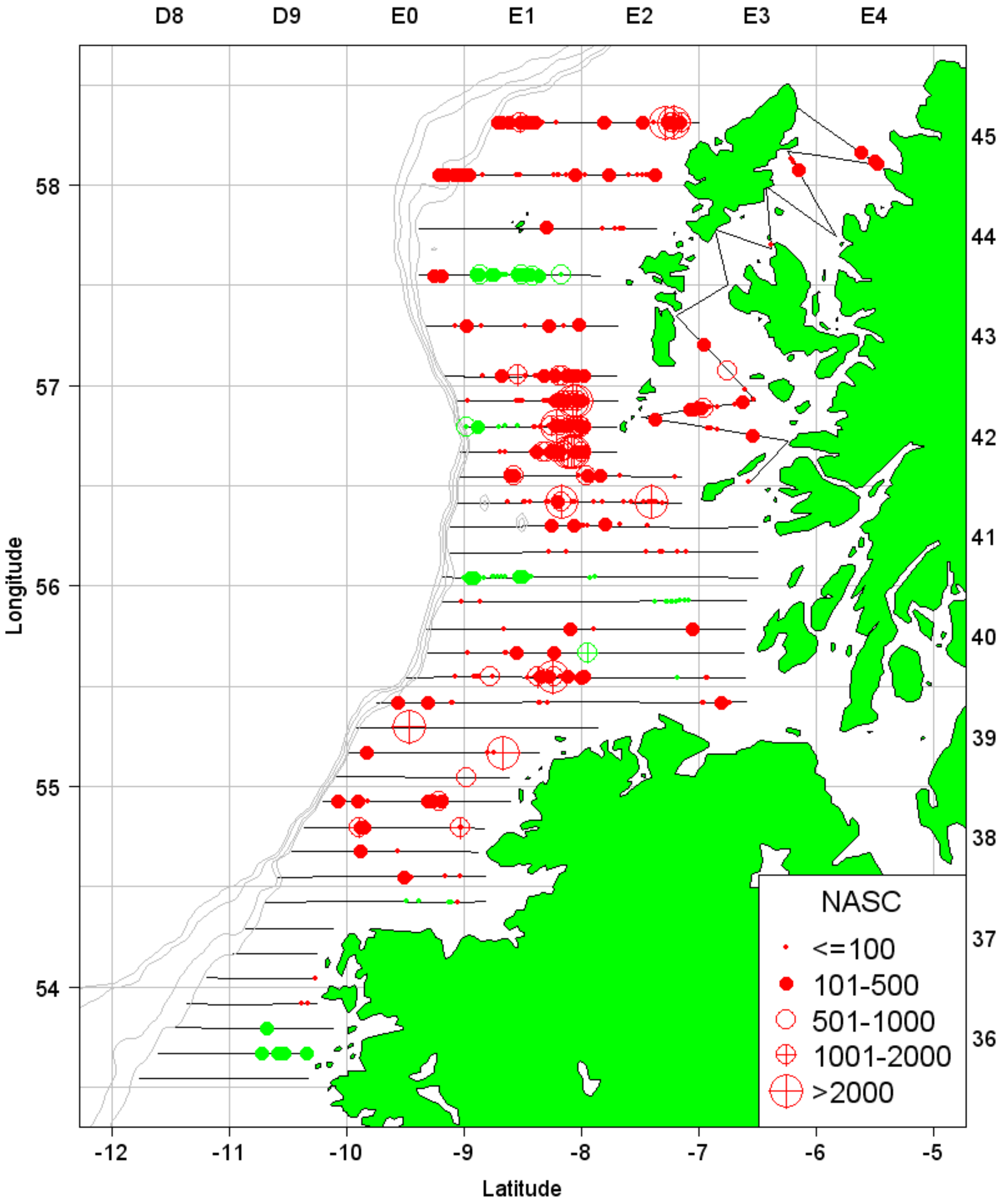


Figure 3. NASC plot of herring distribution during the 2012 survey. Red circles represent single herring schools ("definitely" and "probably" herring categories). Green circles represent herring occurring in mixed schools.

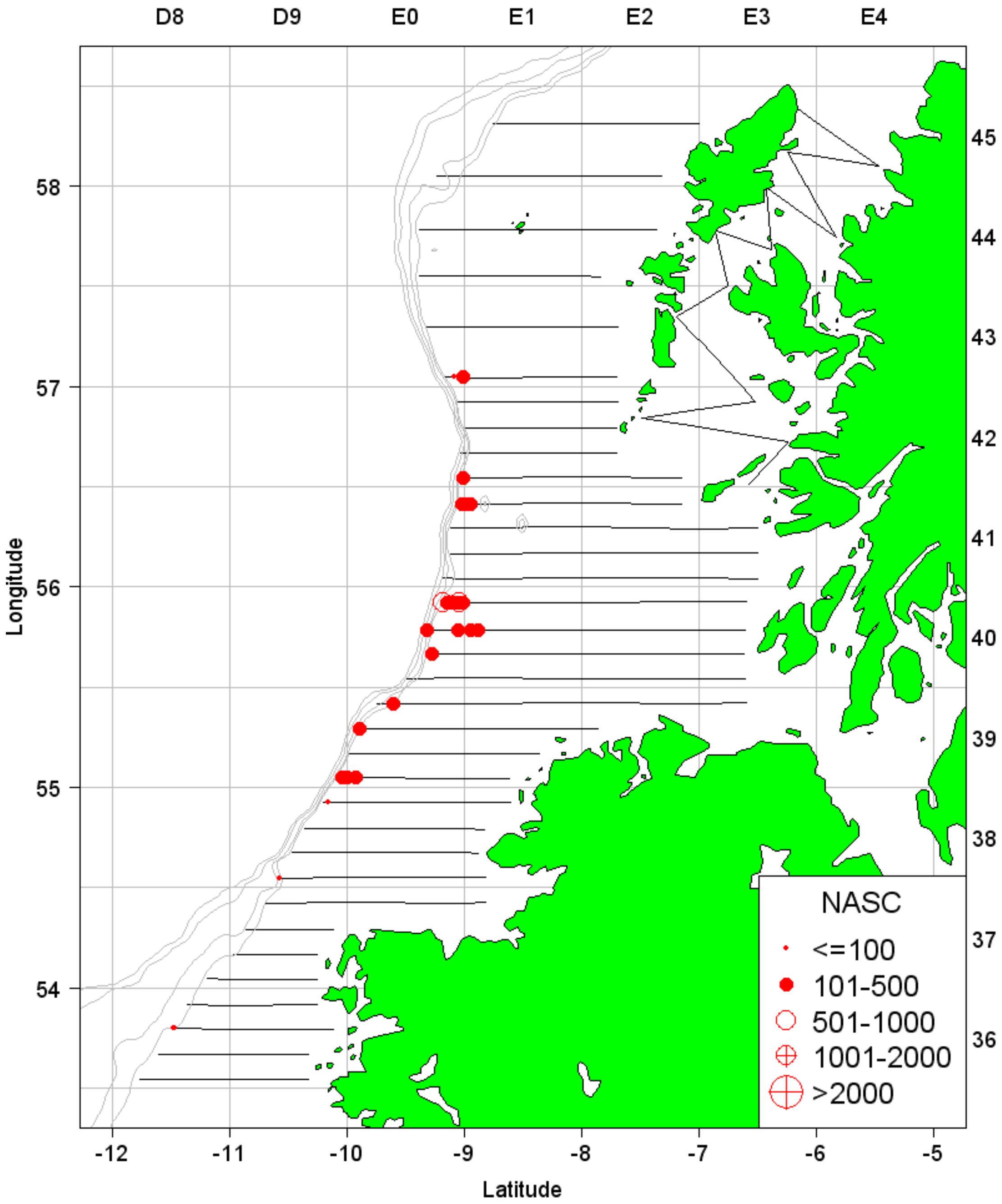


Figure 4. NASC plot of boarfish (*Capros aper*) distribution during the 2012 Northwest herring survey.

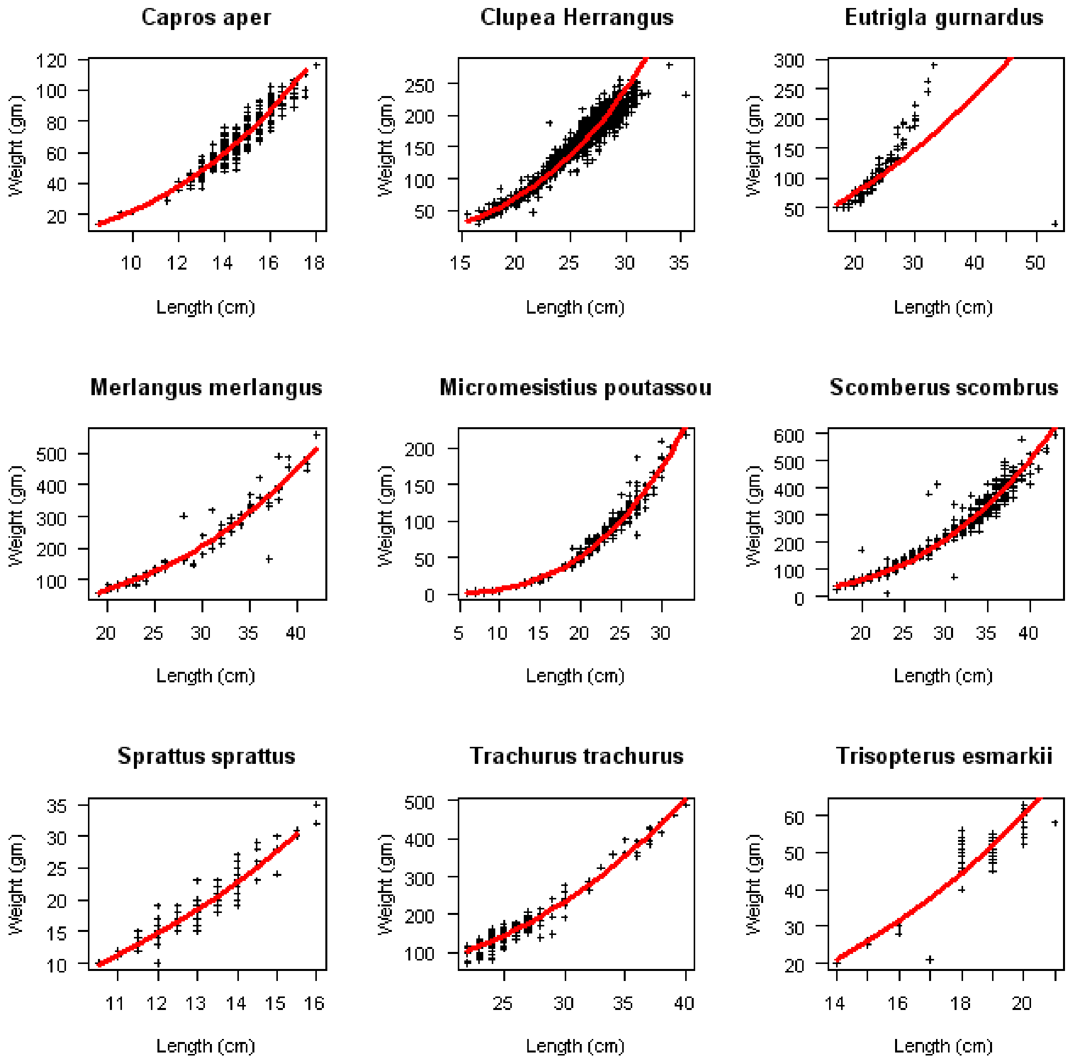


Figure 5. Length-weight plots of major species encountered during the Northwest herring acoustic survey, June\July 2012.

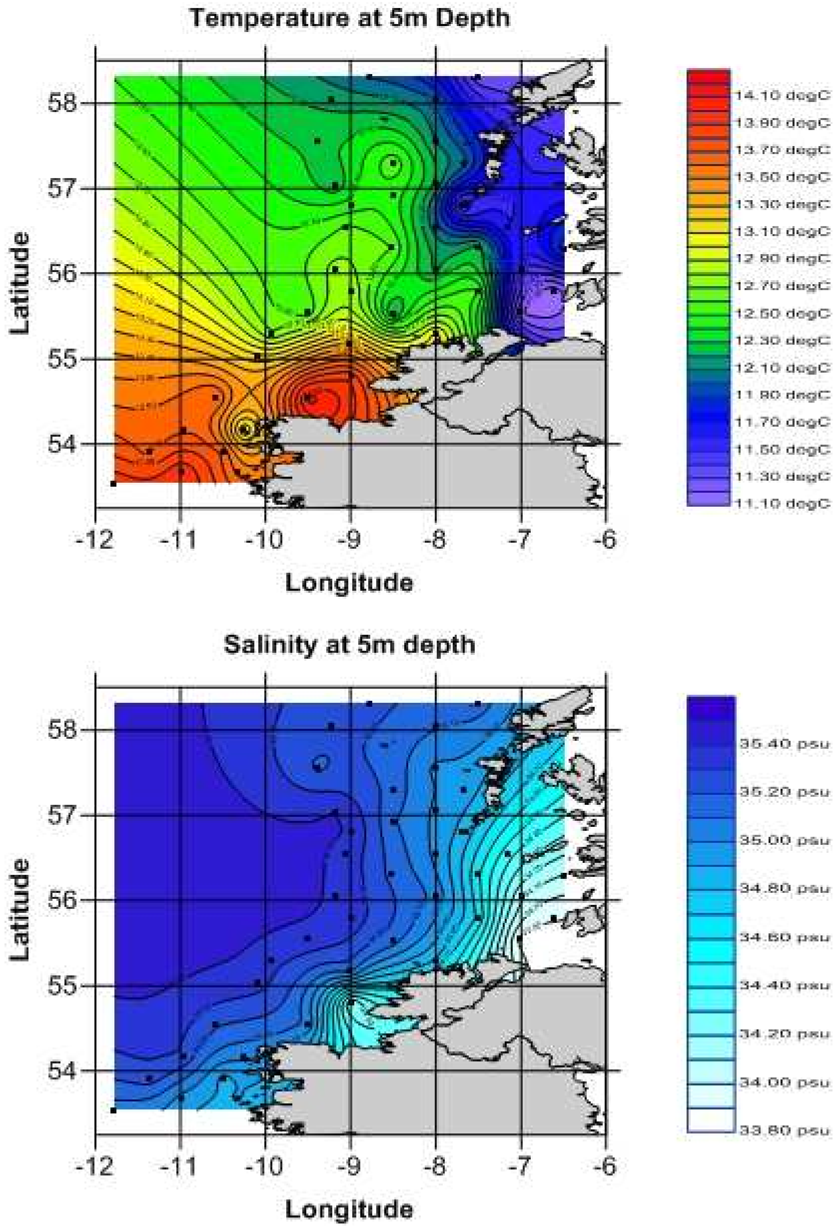


Figure 6. Horizontal temperature (top panel) and salinity (bottom panel) at 5m subsurface as derived from vertical CTD cast data (black squares). Northwest herring survey, June/July 2012.

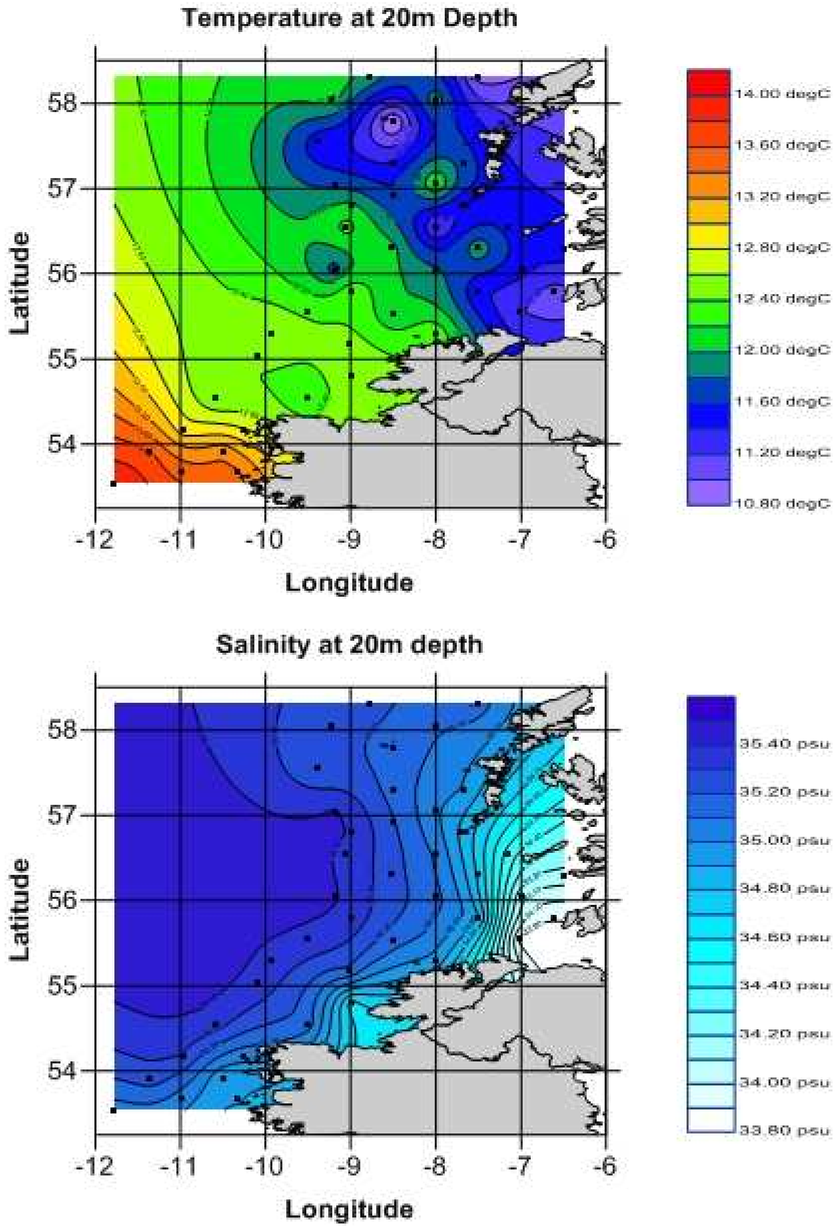


Figure 7. Horizontal temperature (top panel) and salinity (bottom panel) at 20m subsurface as derived from vertical CTD cast data (black squares). Northwest herring survey, June/July 2012.

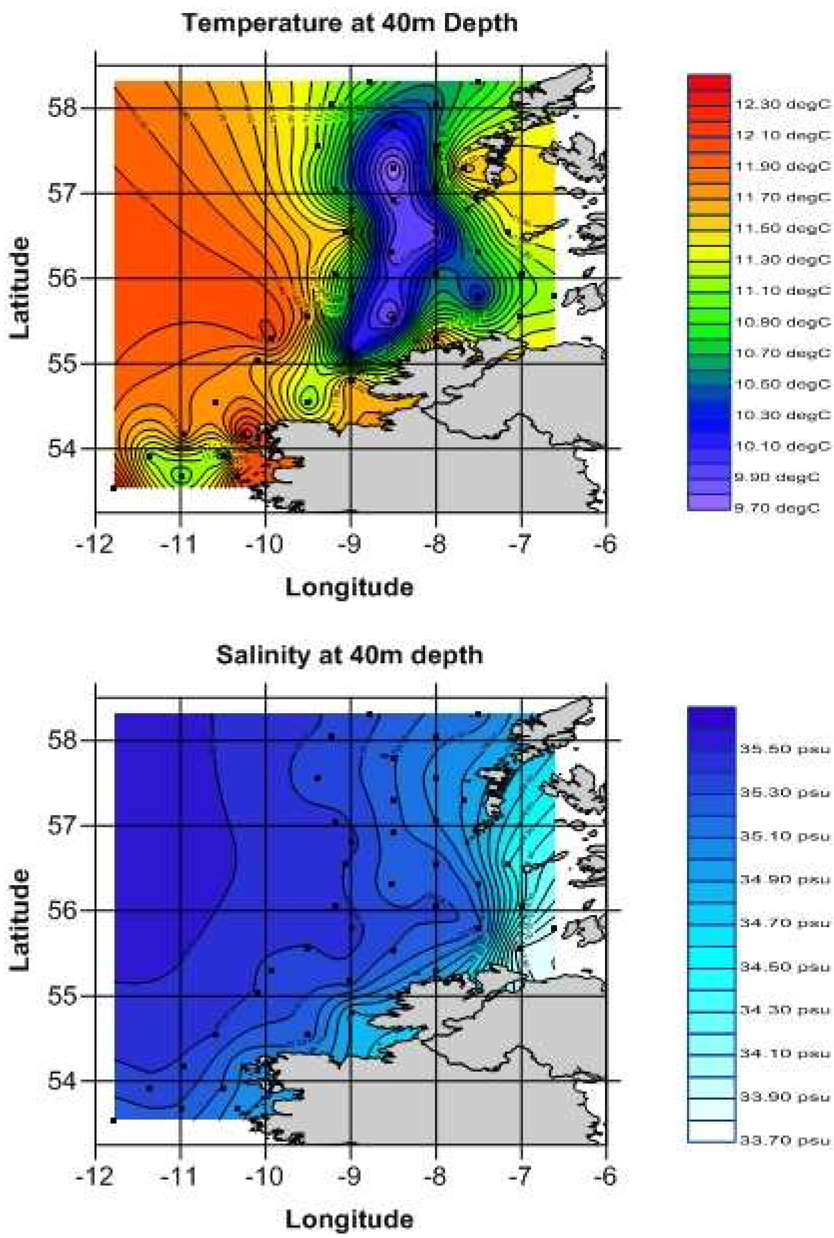


Figure 8. Horizontal temperature (top panel) and salinity (bottom panel) at 40m subsurface as derived from vertical CTD cast data (black squares). Northwest herring survey, June/July 2012.

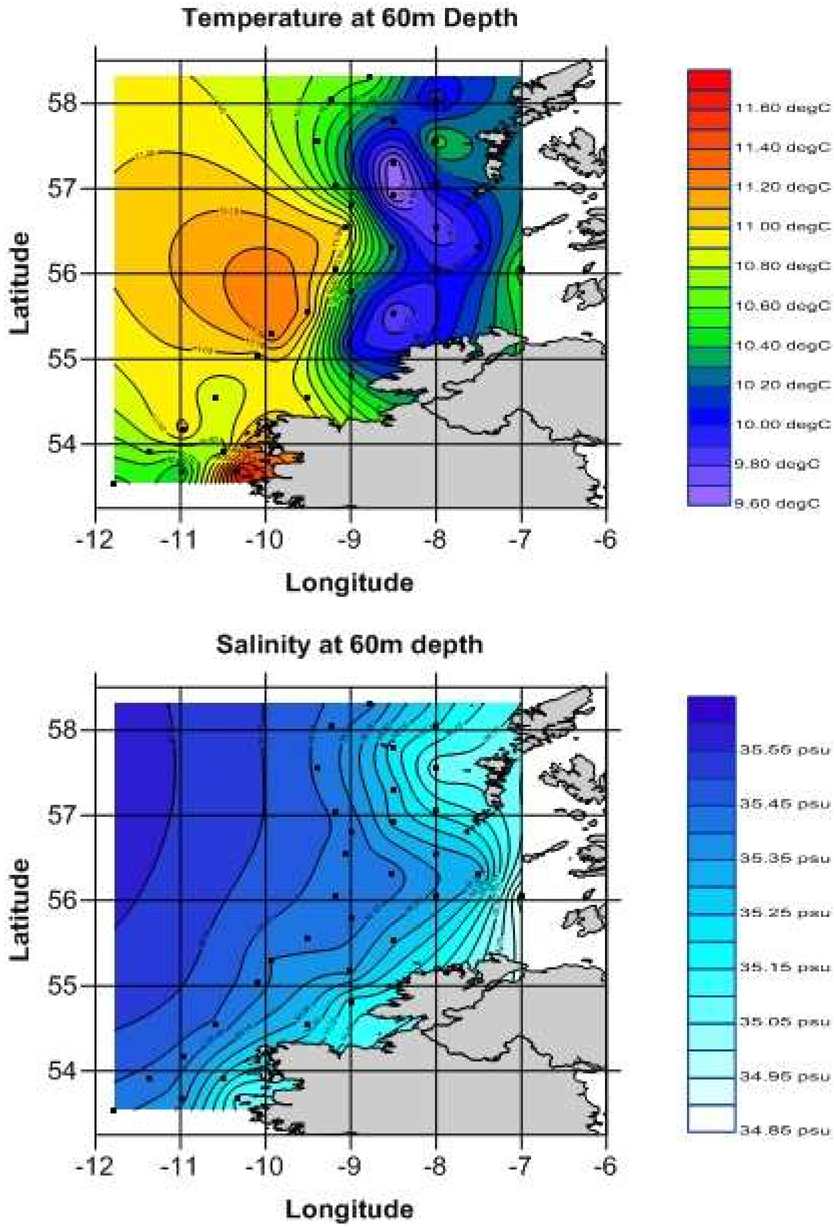


Figure 9. Horizontal temperature (top panel) and salinity (bottom panel) at 60m subsurface as derived from vertical CTD cast data (black squares). Northwest herring survey, June/July 2012.

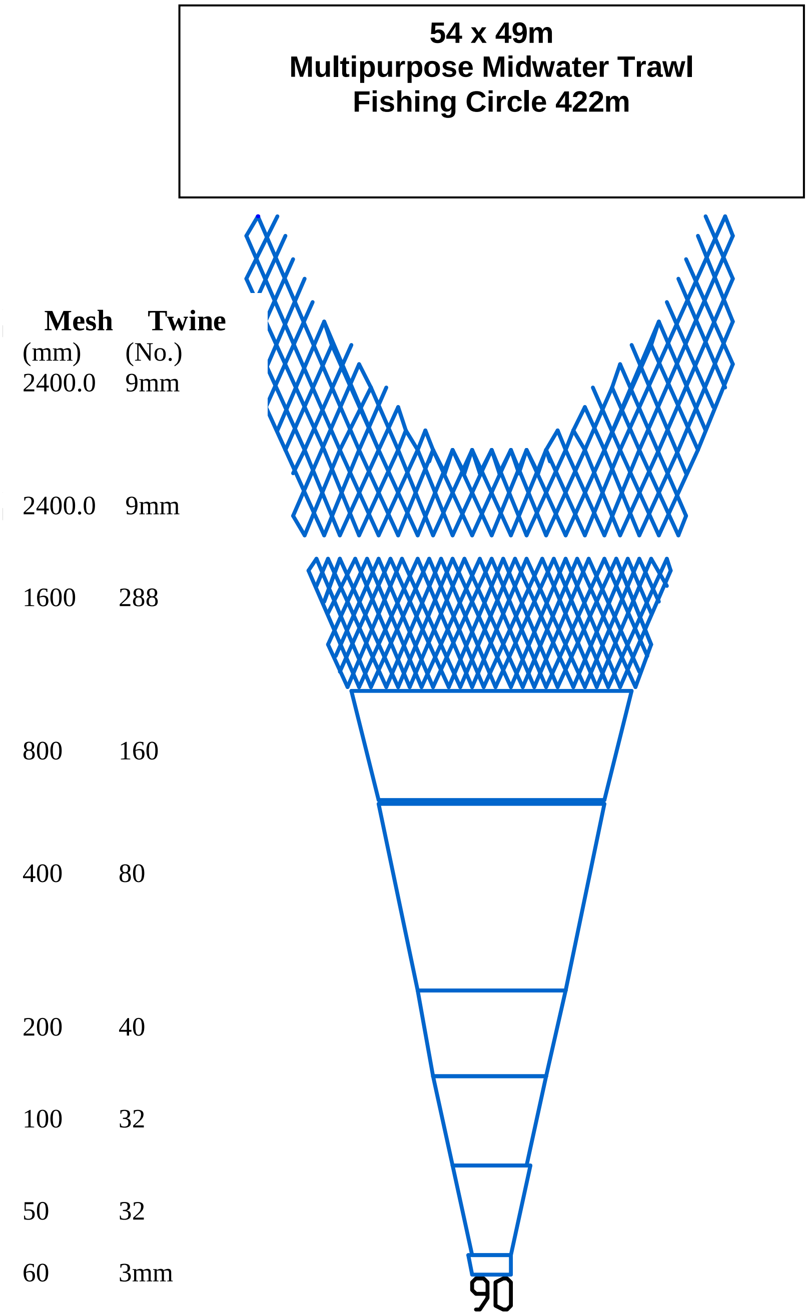


Figure 10. Celtic Explorer multi-purpose midwater trawl employed during the Northwest herring acoustic survey, June\July 2012.

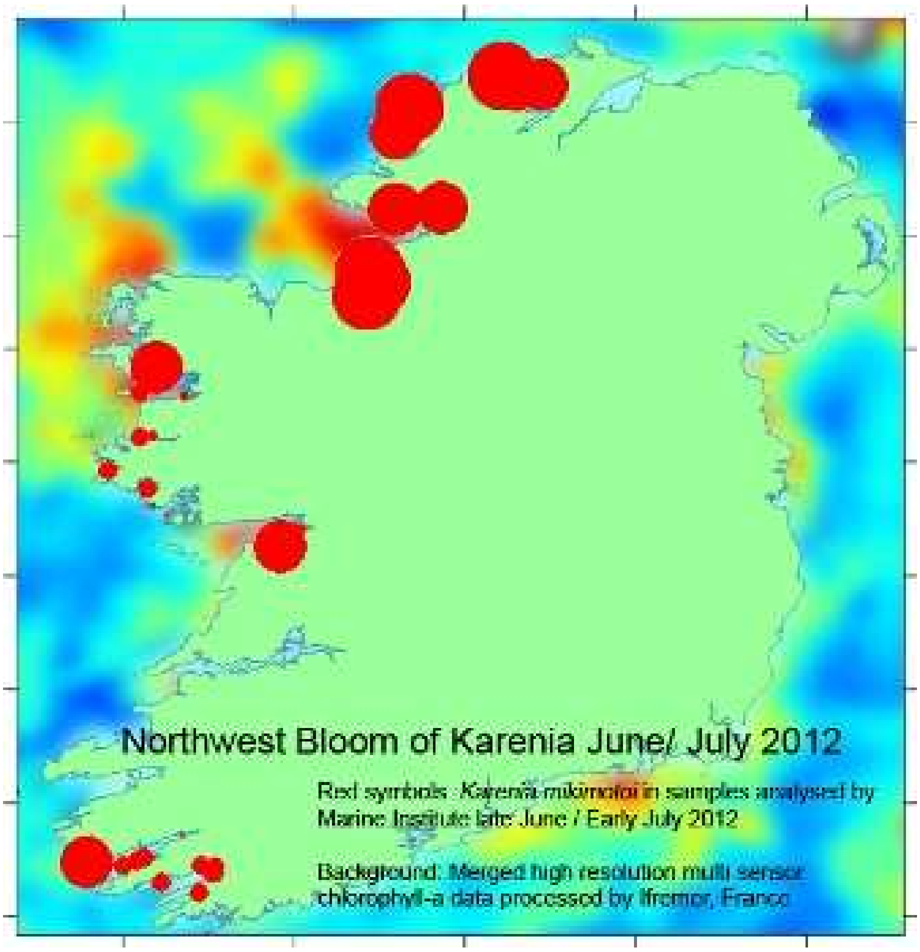
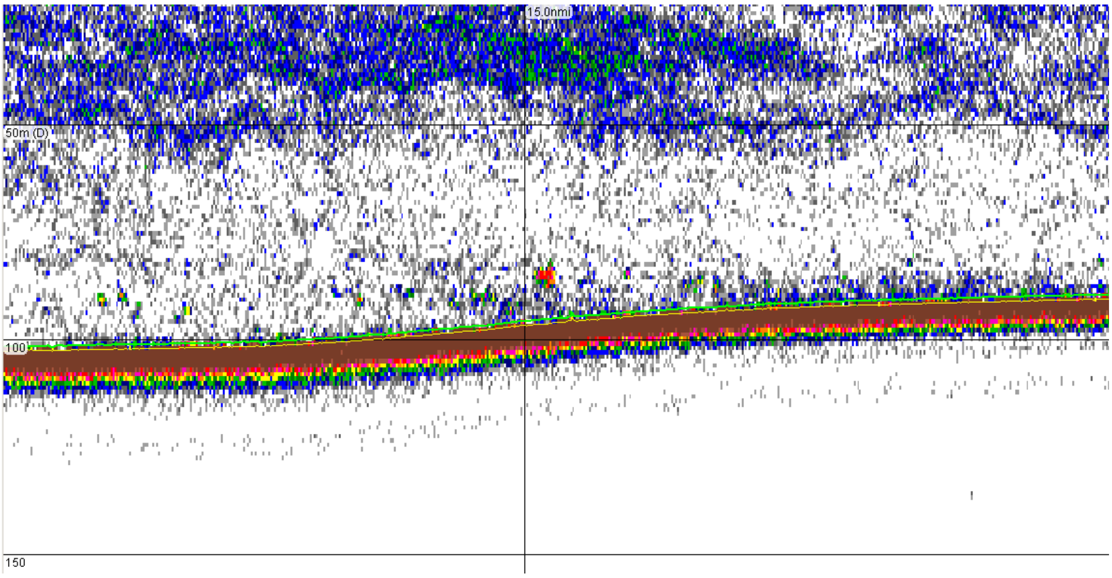
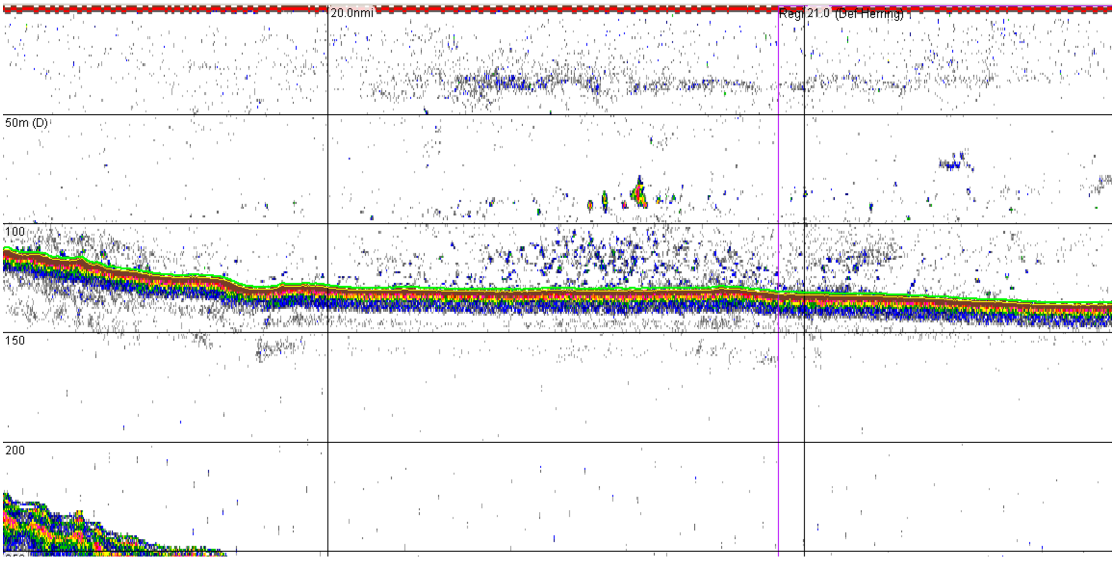


Figure 11. Depiction of the *Karenia mikimotoi* algal bloom that coincided with the 2012 herring survey.

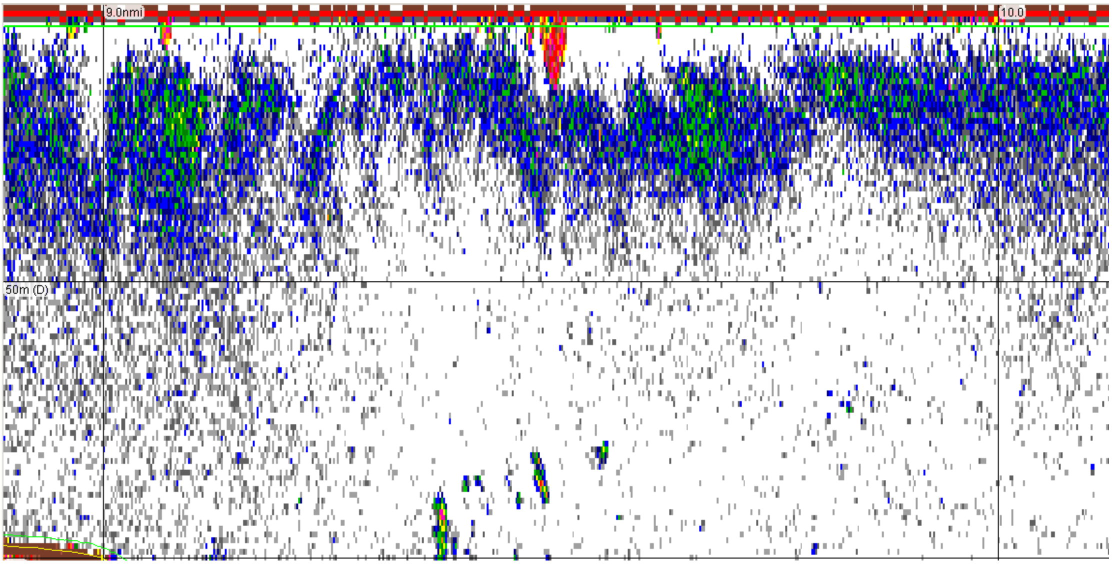
Appendix 1: Echograms prior to fishing



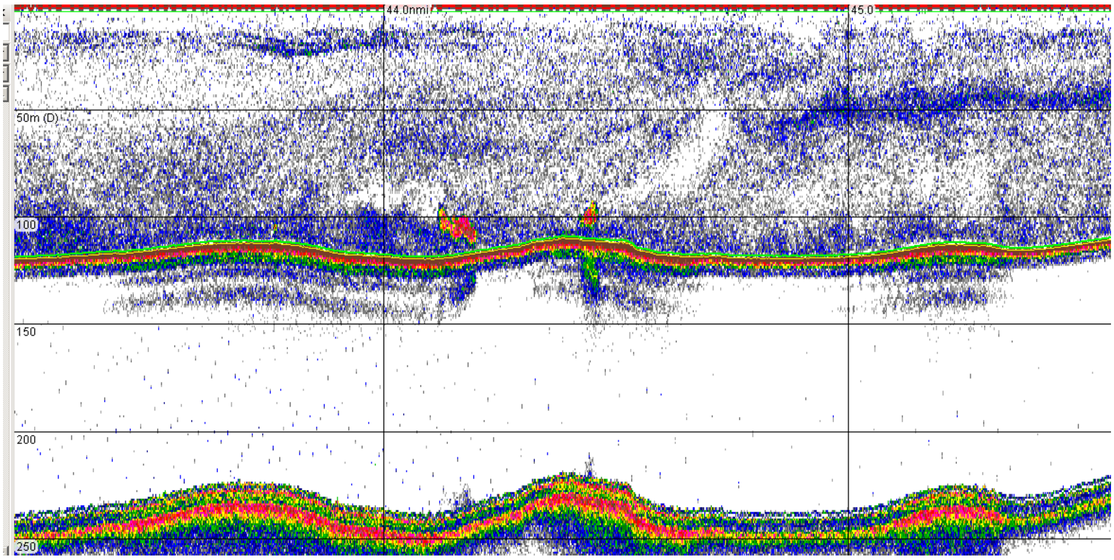
Haul 1. 23/6/12. A mark of juvenile herring sampled in the south of the Minches.



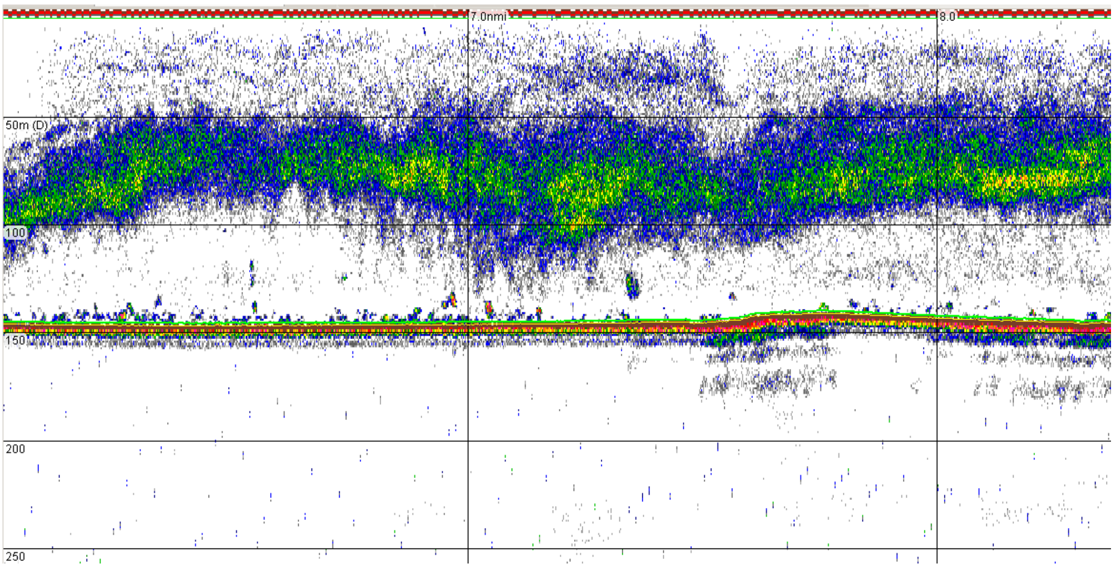
Haul 2. 23/6/12. Mid-water marks in the South Minch. Main targets were missed; void haul.



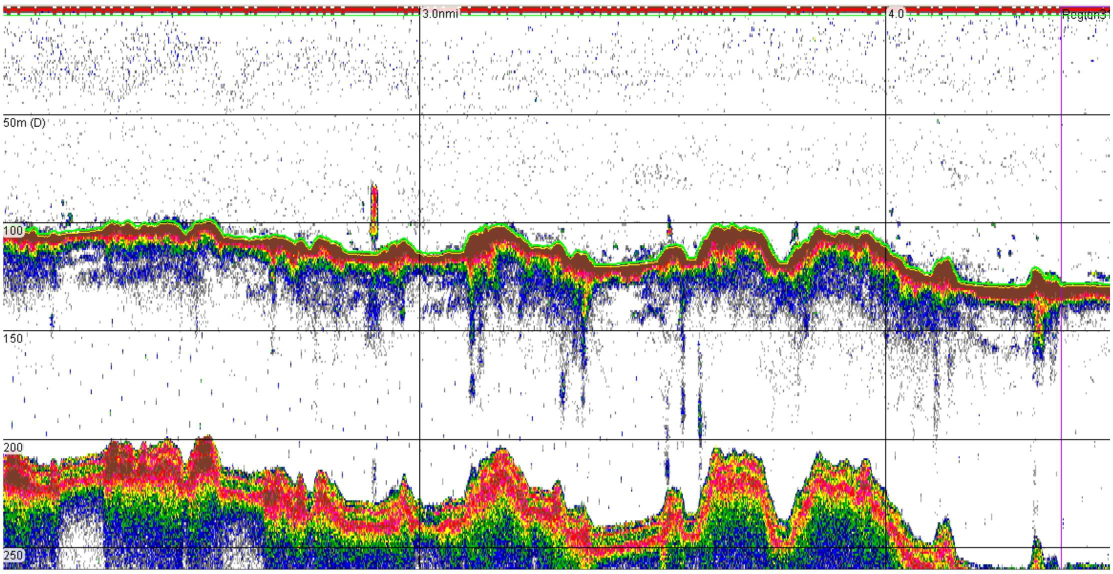
Haul 3. 23/6/12. Surface school west of the Isle of Skye. Main target missed and haul comprised mostly jellies.



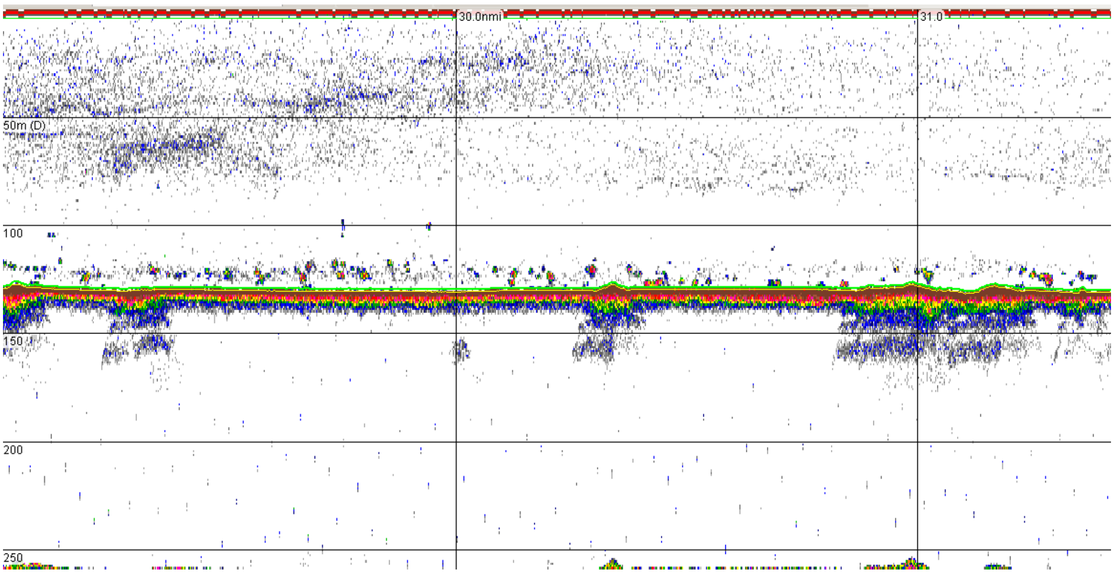
Haul 4. 24/6/12. Two schools of herring close to the seabed west of Lewis.



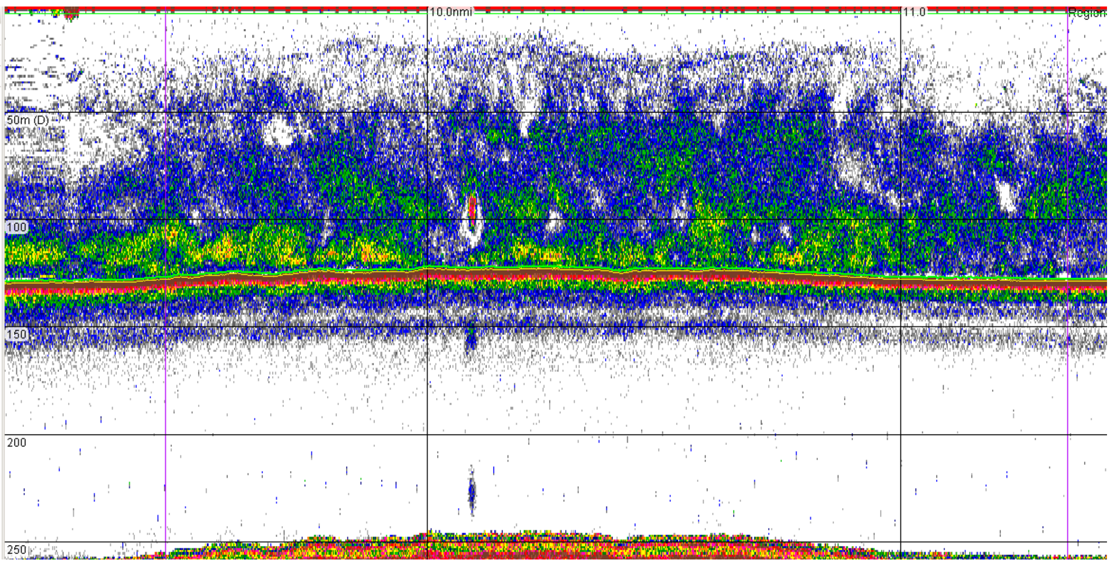
Haul 5. 26/6/12. Light, scattered marks of herring close to the seabed.



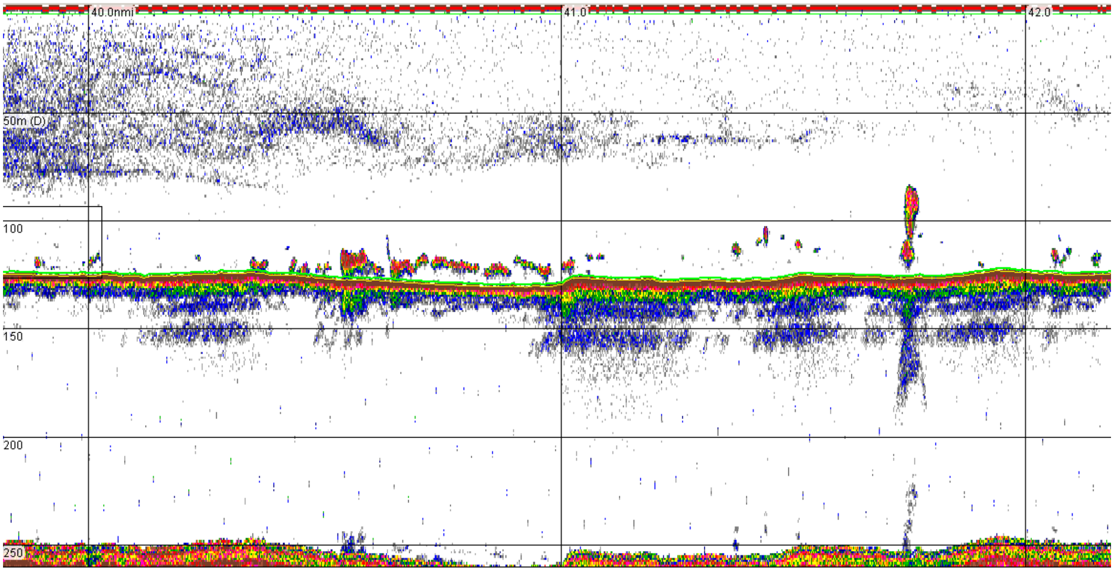
Haul 6. 26/6/12. Tall school of fish (probably herring) seen west of South Uist. Target not seen on headline transducer; invalid haul.



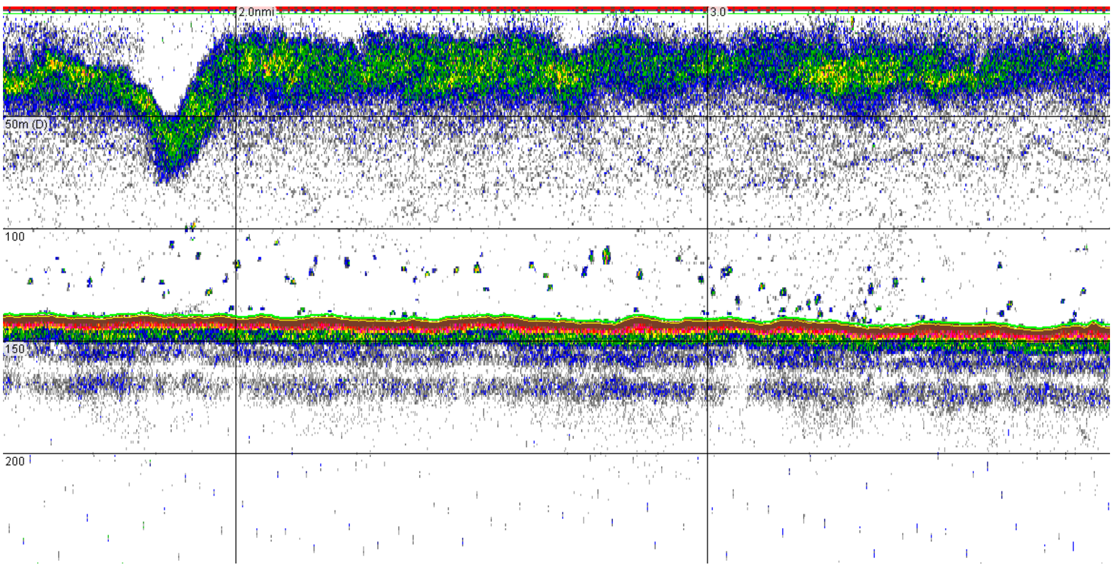
Haul 7. 27/6/12. Scattering of herring schools caught west of Barra.



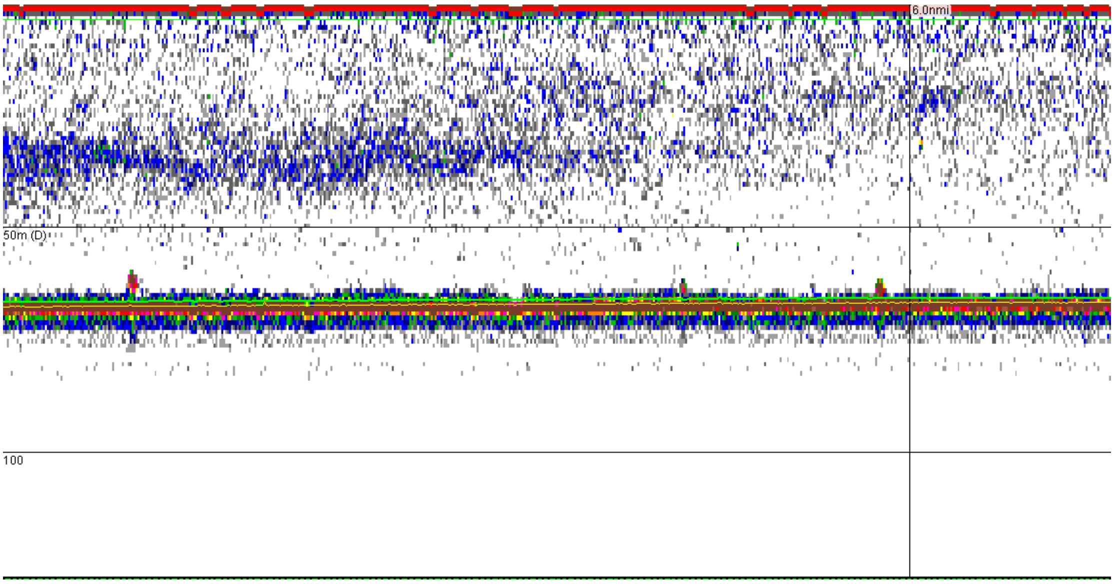
Haul 8. 27/6/12. Mark of boarfish caught near the shelf edge.



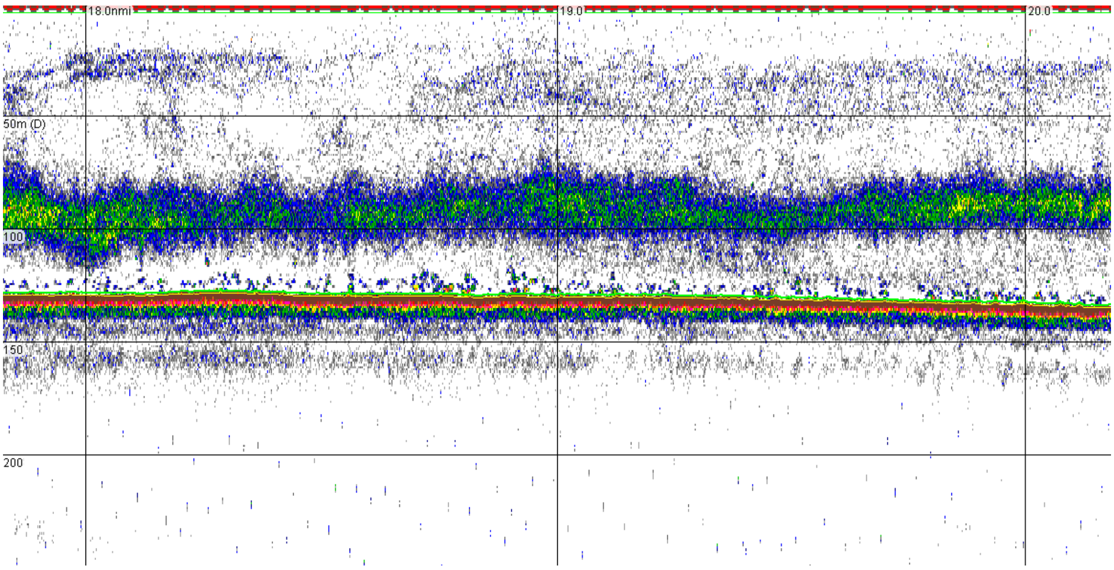
Haul 9. 27/6/12. Herring schools west of Barra Head.



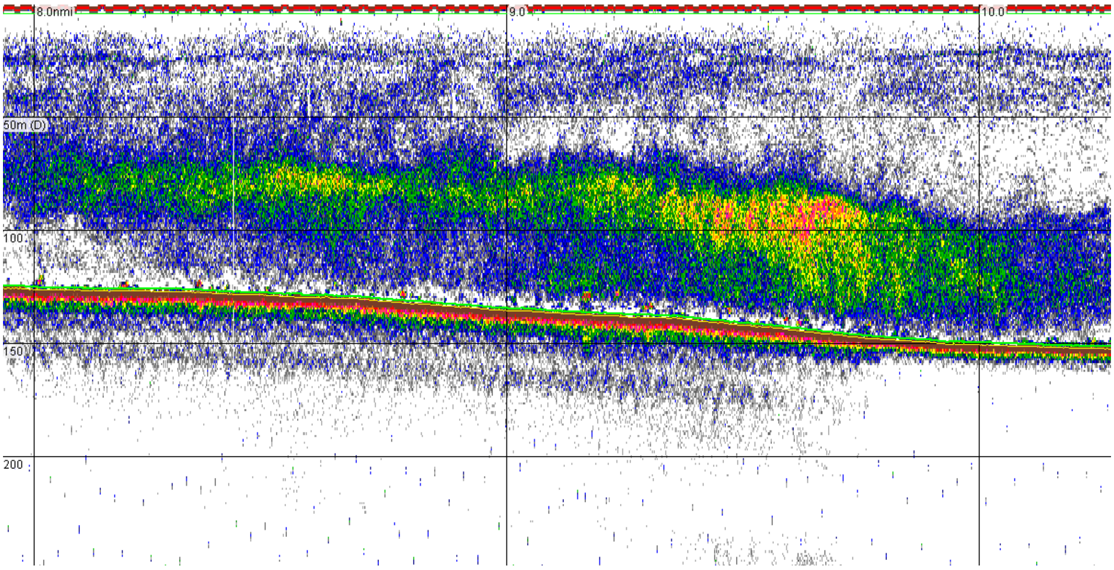
Haul 10. 28/6/12. Scattering of small mixed schools, mainly boarfish, sampled near the shelf edge.



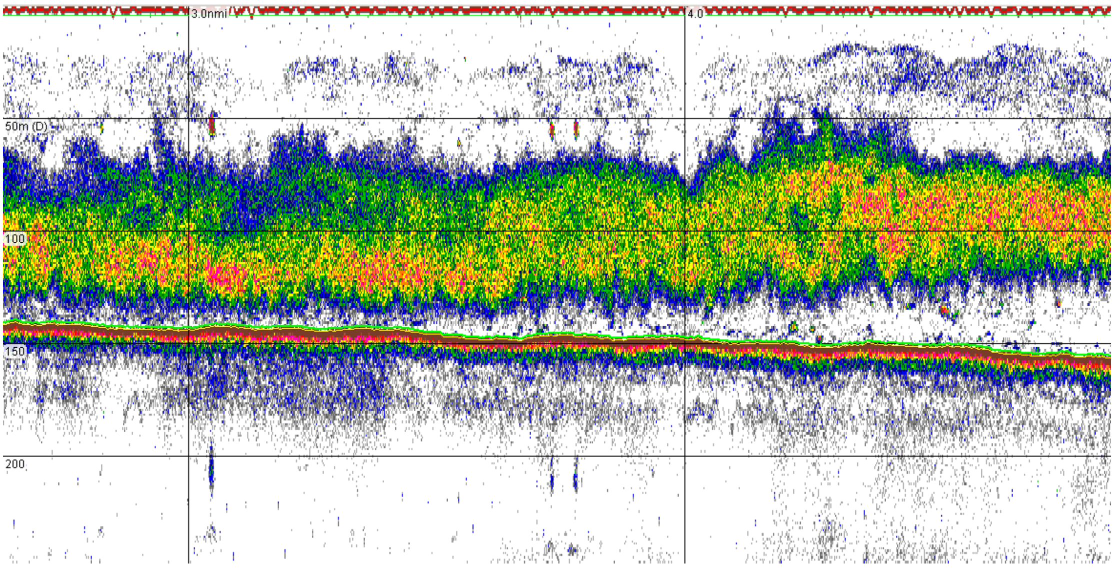
Haul 11. 28/6/12. Three small marks of mackerel sampled south of Tiree.



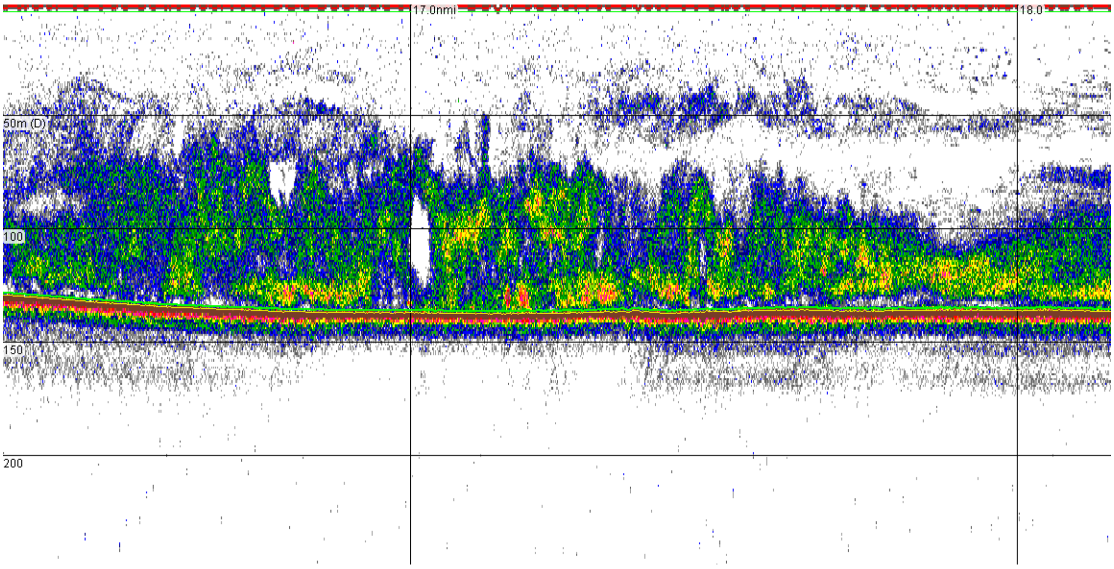
Haul 12. 30/6/12. Very light mixed layer near the seabed. Small sample comprised roughly 40% herring.



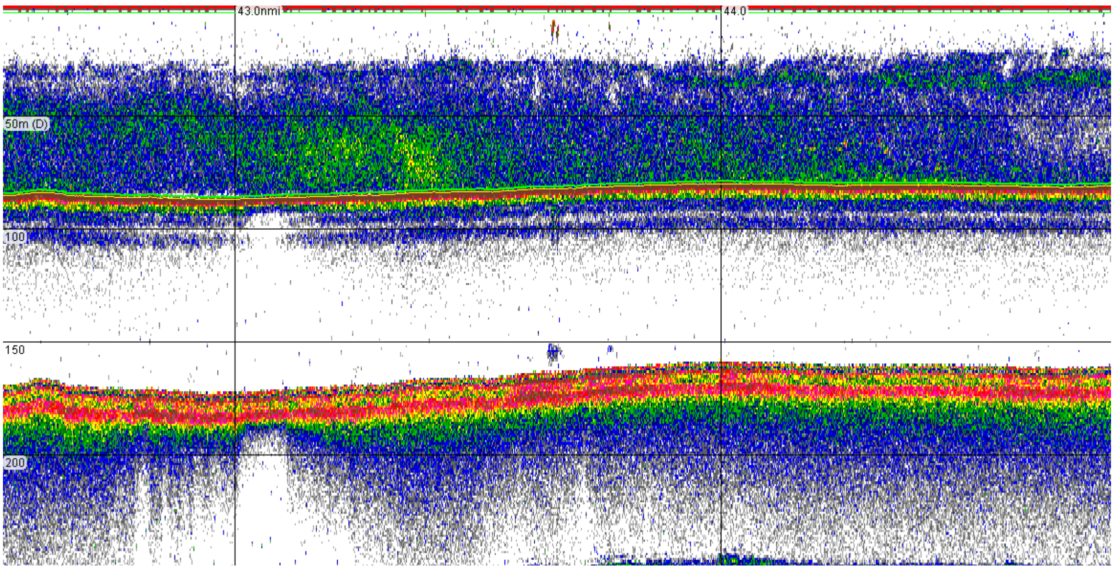
Haul 13. 30/6/12. Mixed species bottom layer similar to previous haul.



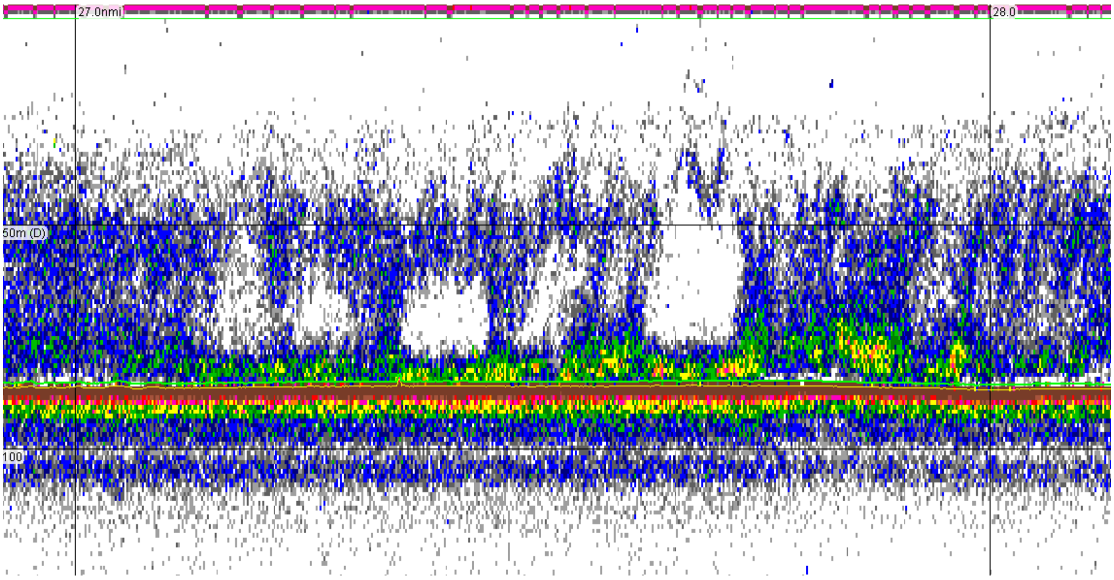
Haul 14. 30/6/12. Mid-water marks of boarfish over the slope. Sample also contained a small amount of mackerel and horse mackerel.



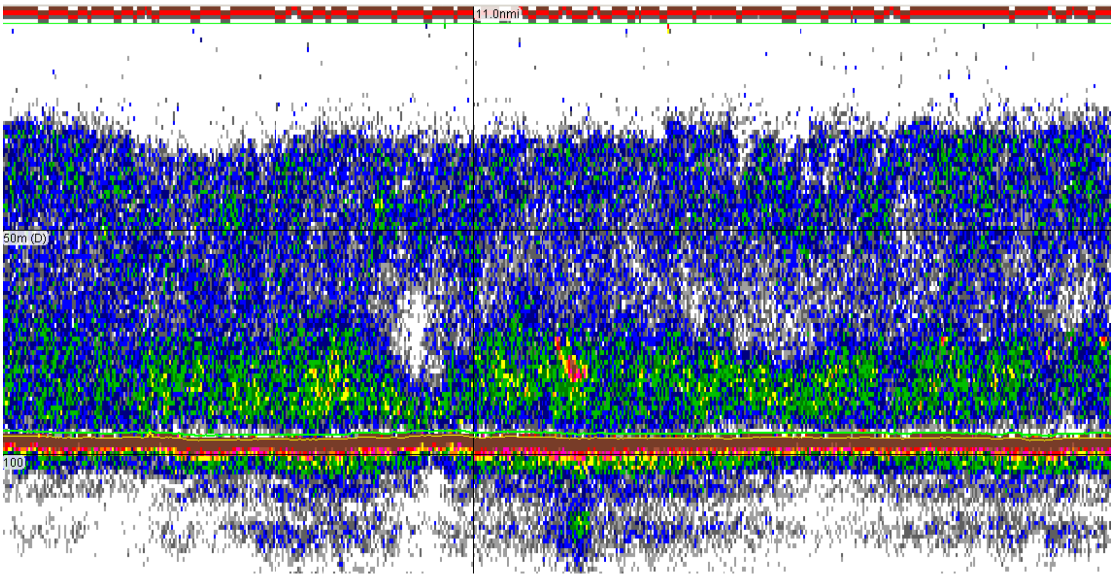
Haul 15. 1/7/12. Schools of horse mackerel.



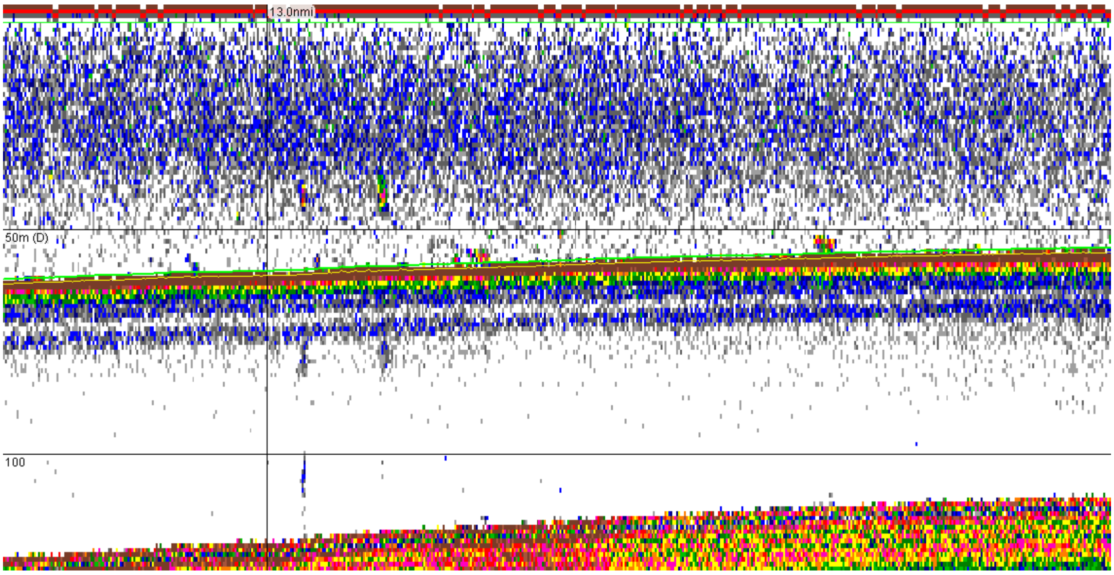
Haul 16. 2/7/12. Thin spike near the surface containing a mix of mackerel, herring and horse mackerel.



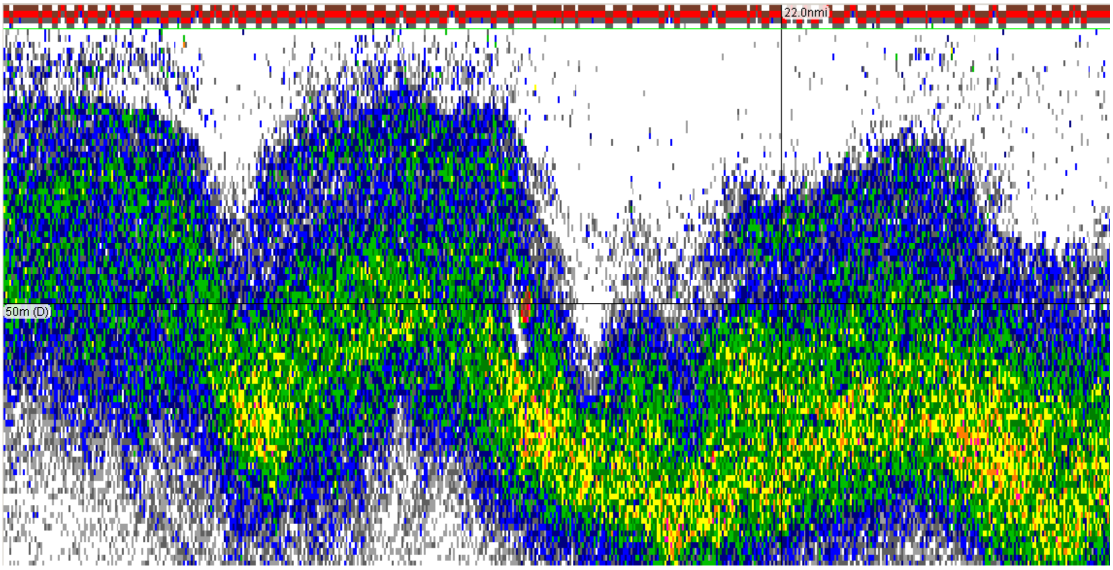
Haul 17. 2/7/12. The large hole in the plankton layer corresponded to a mark of fish seen on another transducer mounted on the ship's hull. A fishing haul produced almost 100% herring. It was concluded that the hull mounted echosounder had just captured the edge of the school while, due to its slightly different orientation, the 38kz survey echosounder had just missed it. This haul was used in the analysis and assigned to nearby herring schools.



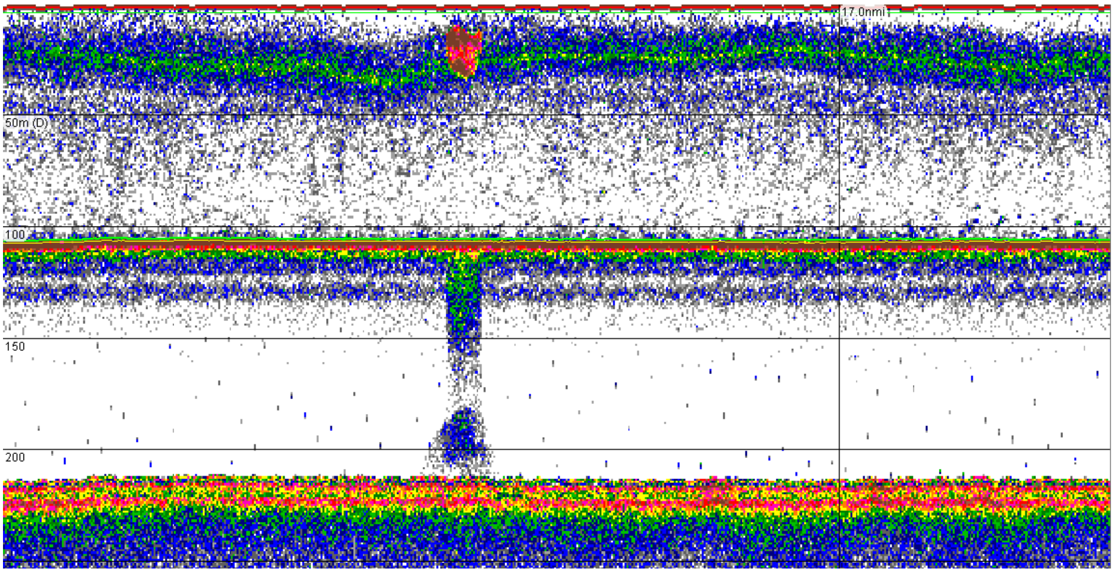
Haul 18. 2/7/12. A 2t Herring school caught 24nm north-west of Tory Island.



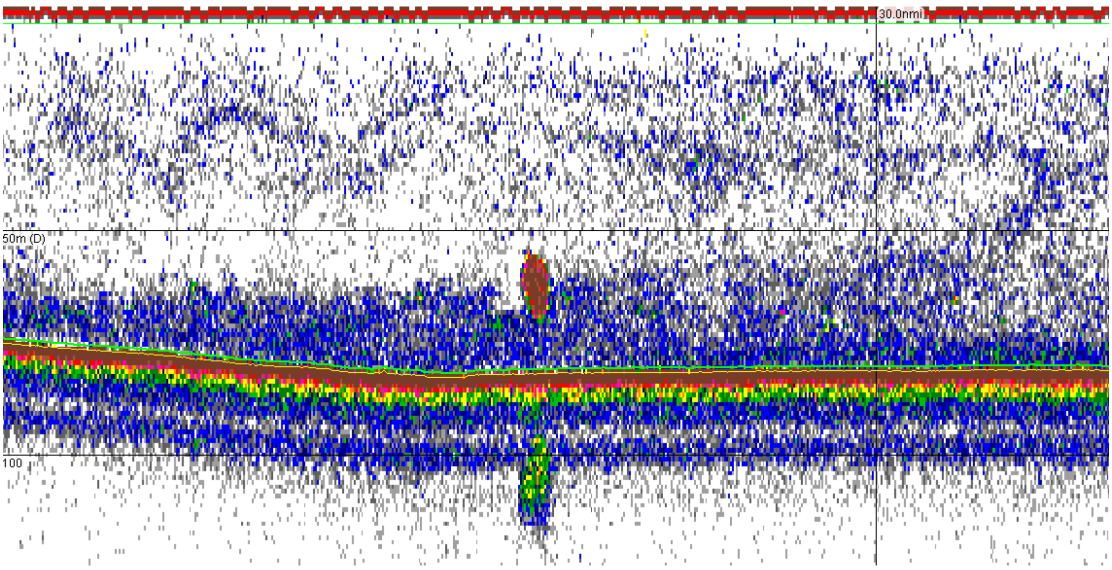
Haul 19. 3/7/12. Marks of herring seen on transect north of Inishowen. Larger marks were seen just off transect while fishing. 5.5t of herring caught in total.



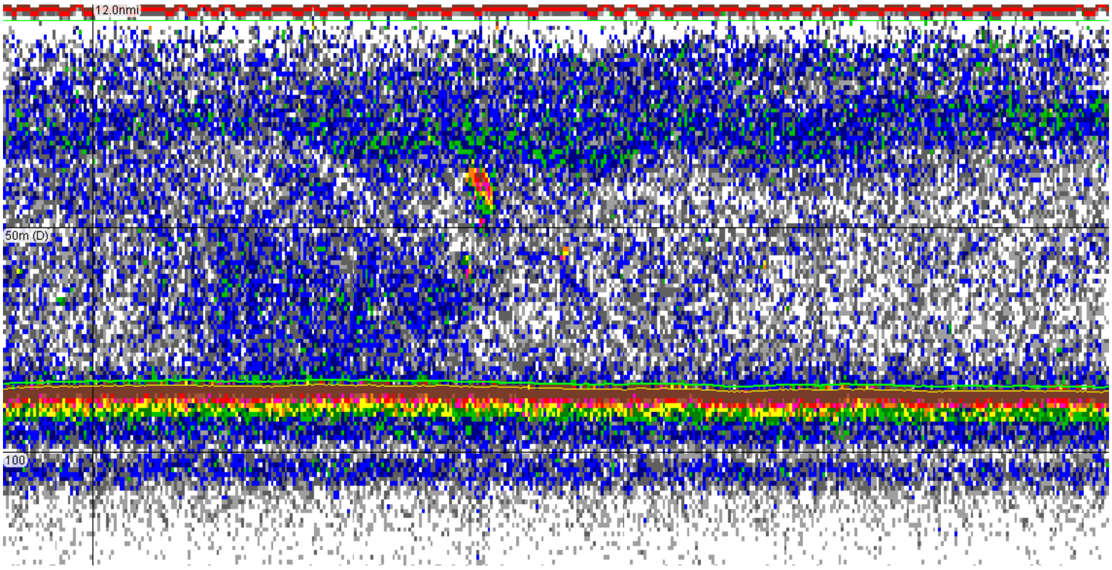
Haul 20. 3/7/12. Small dense mid-water school of mackerel mixed with boarfish (9%) and horse mackerel (5%).



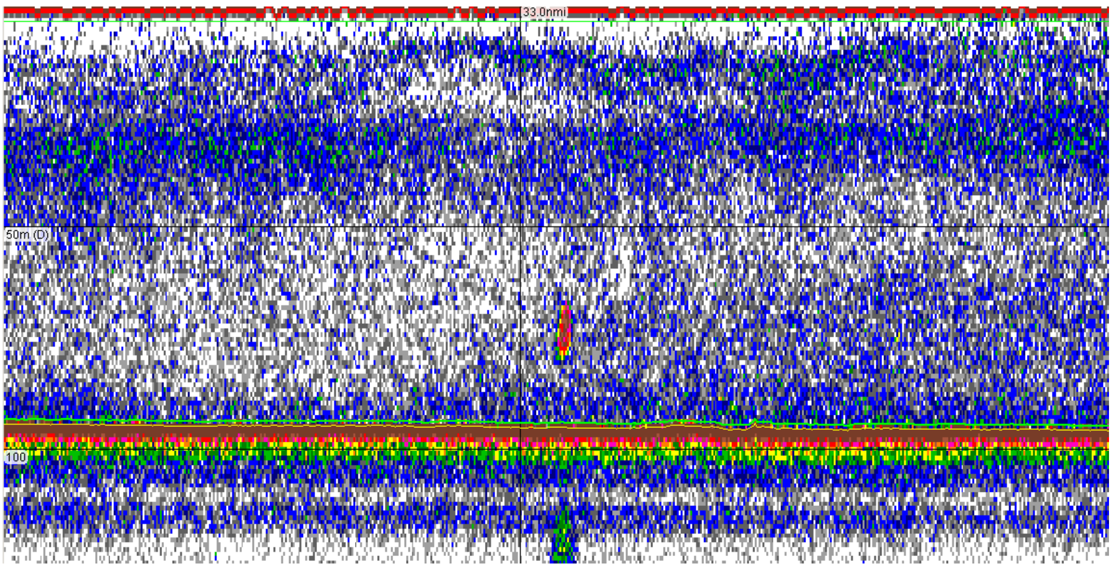
Haul 21. 3/7/12. The largest mark seen during the survey but the target was missed; 1t of mackerel and horse mackerel caught after towing for 50 minutes.



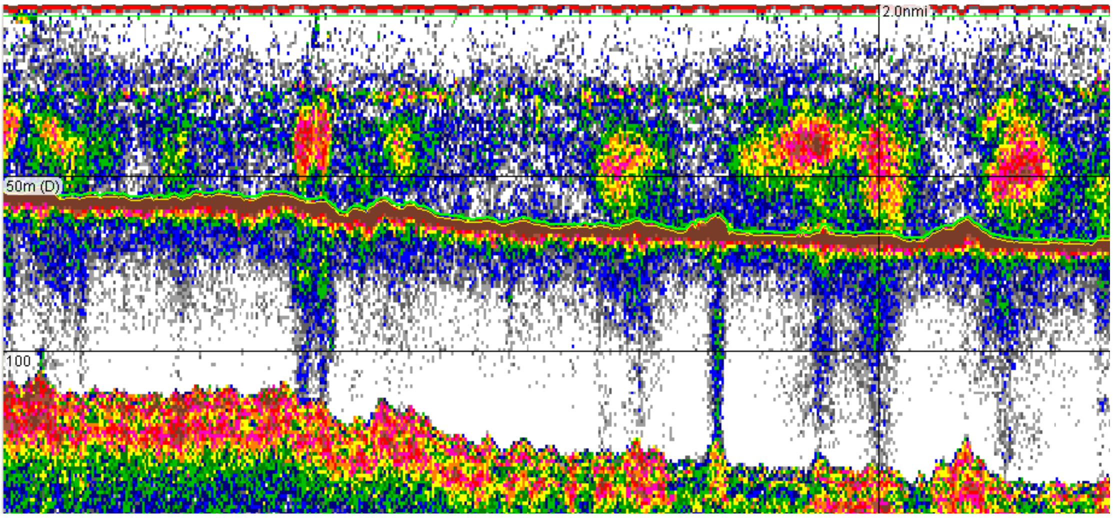
Haul 22. 4/7/12. A large, dense mark of herring 13nm west of Bloody Foreland.



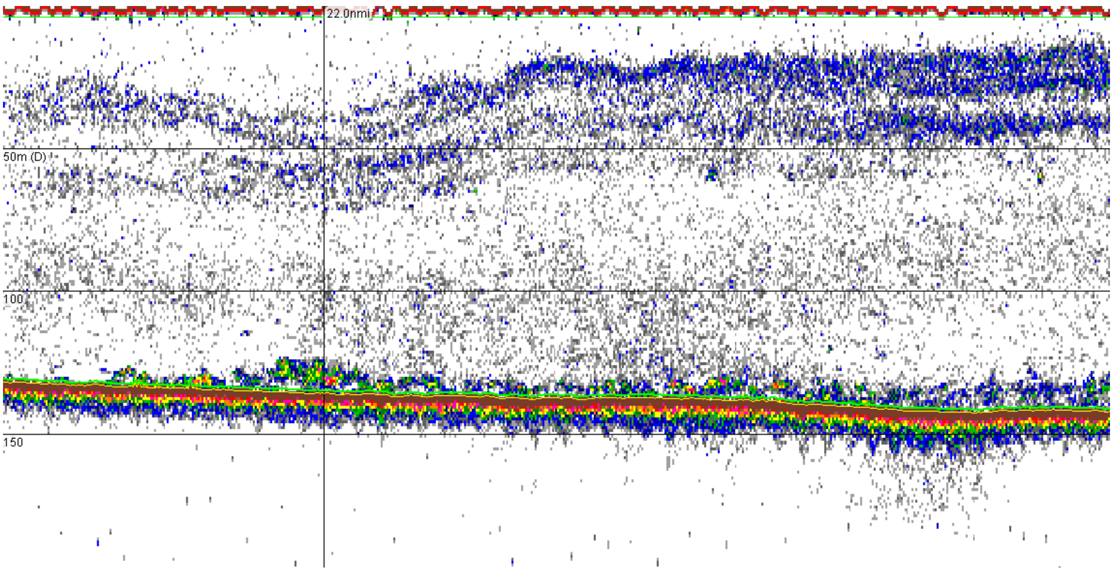
Haul 23. 5/7/12. School of herring, with some mackerel, mid-water west of Donegal.



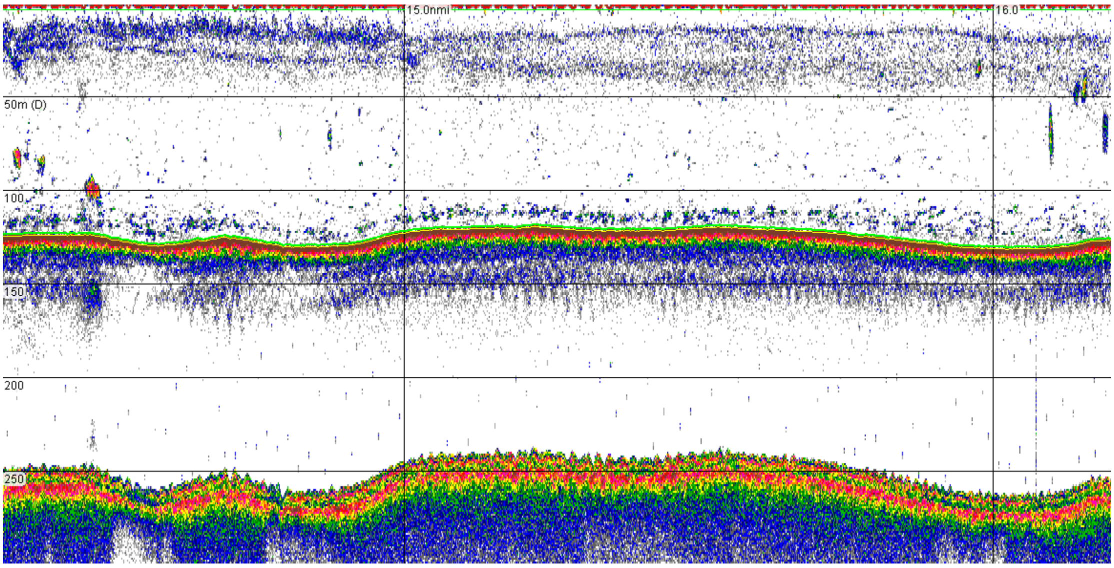
Haul 24. 5/7/12. 4t of herring west of Donegal.



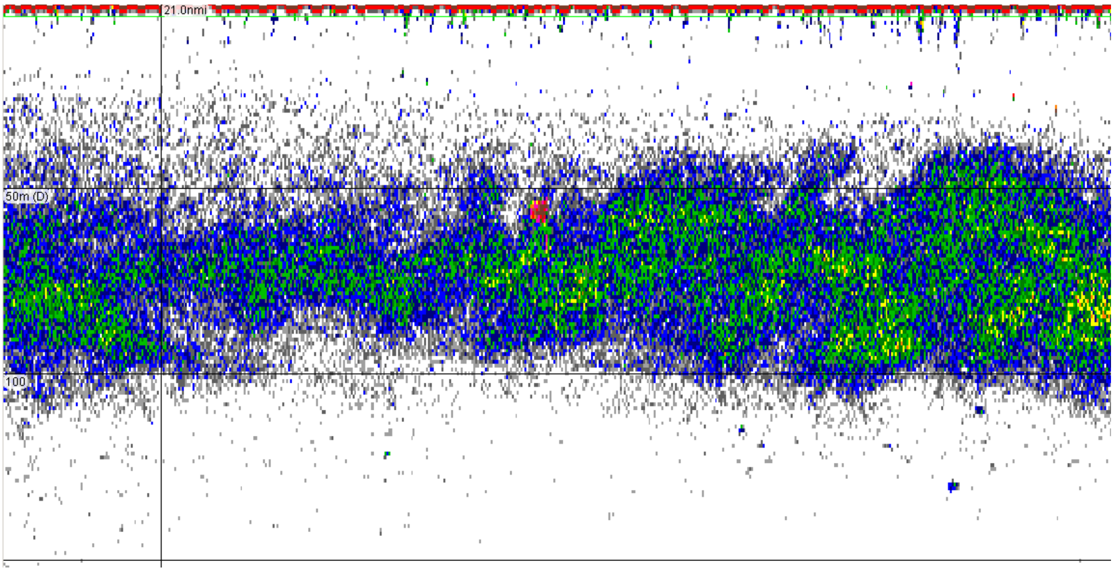
Haul 25. 6/7/12. Large, mid-water marks 3nm off Inishkea. Possibly sprat as the net was empty after 20 minutes of towing except for some very small sprat meshed near the cod end.



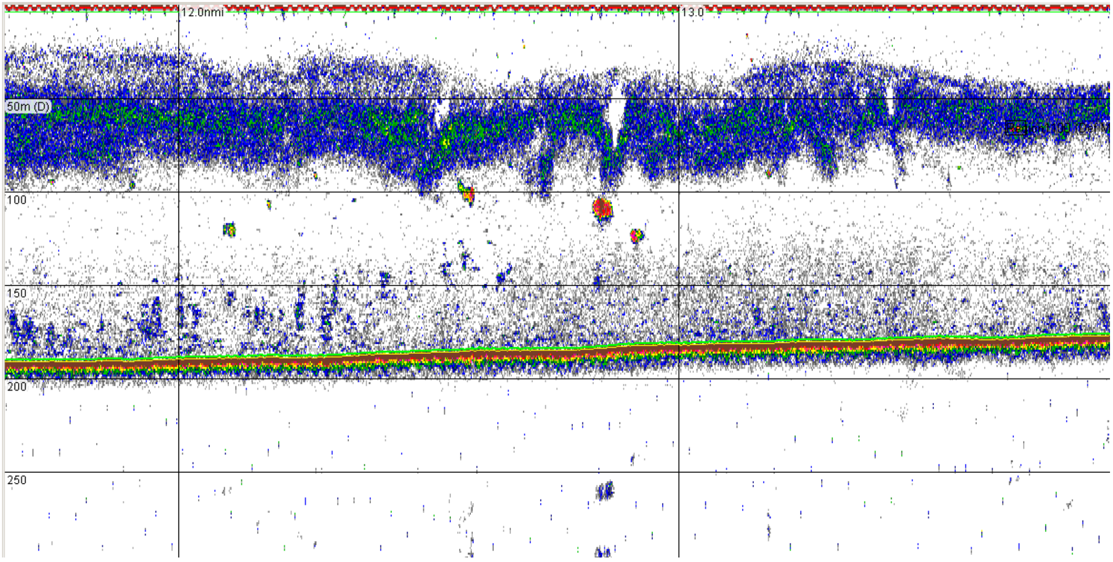
Haul 26. 7/7/12. A mix of species, mostly blue whiting, close to the seabed west of Achill Island.



Haul 27. 7/7/12. A number of mid-water marks 7.5nm south of the previous haul. Marks were not seen again once the fishing gear was deployed. Targets missed.



Haul 28. 8/7/12. A small, mid-water mark close to the shelf edge. Target missed.



Haul 29. 8/7/12. Marks similar to, and just south of, the previous haul. Target missed.