FSS Survey Series: 2011/03

Northwest Herring Acoustic Survey Report

18 June – 07 July, 2011

RV Celtic Explorer

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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 into single spawning stock survey was carried out early in quarter 1 which 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 2011 survey represents the forth 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 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 2 of 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
FSS	Ryan Saunders	Acoustics (SIC)
FSS	Eugene Mullins	Acoustics
FSS	Andy Campbell	Acoustics
FSS	Kieran McCann	Acoustics
FSS	Mairead O'Sullivan	Biologist (Deck Sci)
FSS	M. Blazwakowski	Biologist
FSS	Frankie. McDaid	Biologist
FSS	Michael McAuliffe	Biologist
IWDG	Enda McKeogh	Marine Mammal Obs.

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.

- Perform interlaced co-surveyed areas with other participant survey vessel(s)

- Collect detailed morphometric data on individual herring to contribute to stock discrimination studies for SGHERWAY

- Conduct a sighting survey of marine mammals and seabirds encountered during the survey (IWDG)

- Collect Boarfish (*Capros acer*) target strength measurements and 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.

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

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 position between the 30 m and 250 m depth contours. Transect spacing was set at 5 nmi in the main body of the survey and at 15 nmi where transects were interlaced with the other vessels.

In total, the survey accounted for 3,325 nmi, with around 3000 nmi 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 predominantly from 38 kHz data.

While on 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 in Donegal Bay (off St. John's Point) before the survey start point (18^{th} June). A second calibration was performed in Broadhaven 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 March 2011.

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 (V 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 a region which were defined by enclosing selecting marks or scatter that belonged to one of the four categories above. 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*) the TS/length relationships used for herring was applied in place of a species specific TS. Once an accurate TS for boarfish has been verified then this will be applied retrospectively to the data.

Boarfish TS = 20logL – 71.2 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.

2.3.8 Marine mammal and seabird survey

The survey was conducted on board the *R.V. Celtic Explorer* as an ancillary project of the FSS Northwest Herring Acoustic Survey from the 18 June-July 6, 2011. The survey area covered waters to the northwest and north of Ireland up into Scottish waters over Stanton bank to south of the Minch. The survey areas were opportunistic and based on predetermined locations chosen by the Marine Institute.

A single marine mammal observer was present on board during the survey and conducted watches from the crow’s nest located above the bridge, 18m above sea level. Observer effort focused on a 90º arc ahead of the ship; however sightings located up to 90º to port and starboard were also included. The observer scanned the area by eye and using 8 X 42 binoculars. Bearings to sightings were measured using an angle board and distances were estimated with the aid of a distance measuring stick. Environmental data were recorded every

15 minutes using Logger 2000 software (IFAW 2000). Sightings were also recorded using Logger 2000. Automated position data were obtained through a laptop computer linked to GPS receiver.

The survey vessel travelled at an average speed 10 knots when on acoustic survey and 3-4 knots when trawling. The vessel spent the majority of time on acoustic survey, towing on occasion when fish marks were detected. Tows lasted on average 30 minutes (in addition to 20 – 30 minutes for deploying and retrieving the net). CTDs were conducted during some of transects and during these the vessel remained stationary for 10 – 20 minutes.

Surveying was conducted up to Beaufort sea-state 6 and in visibility ≥ 500m. As this was a survey onboard a vessel of opportunity, the survey was conducted in ‘passing mode’ and cetaceans sighted were not approached. Sightings were identified to species level where possible, with species identifications being graded as definite, probable or possible. Where species identification could not be confirmed, sightings were downgraded (e.g. unidentified dolphin / unidentified whale / unidentified beaked whale etc.) according to criteria established for the IWDG’s cetacean sightings database (IWDG 2009).

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 there 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

$B_T = \sum_{k}^{track \cdot fragment} \overline{n}_k w_k$, 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 $\overline{n}_k$. The $\overline{n}_k w_k$ 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 six hauls were carried out during the survey of which 16 contained herring (Figure 2, Table 2). Over 3633 herring lengths were taken, together with 2231 length/weight measurements and 1346 individual age readings. Over 1000 photographs and 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	1,270	222,172	71
Herring in a mix	198	28,426	9
Probably Herring	440	62,707	20
Possibly Herring	576	110,692	
Total	**1,908**	**313,305**	**100**
Total including Possibly herring	2,484	423,997	
SSB herring			
Def Herring	1,187	212,546	68
Herring in a mix	134	22,393	7
Probably Herring	299	49,693	16
Possibly Herring	565	108,985	
Total	**1,620**	**284,632**	**100**
Total including Possibly herring	2,185	393,617	

In ICES area VIaN, total herring biomass (TSB) was 271,700 t and total herring abundance (TSN) was 1,583 million individuals. SSB and SSN were 255,600 t and 1,429 million individuals, respectively.

TSB was 34,200 t in ICES area VIaS, and TSN was 260 million individuals. This area comprised a SSB of 22,200 t and a SSN of 160 million individuals.

ICES area VIIb had the lowest biomass, with a TSB of 6,500 t and a TSN of 36 million individuals. SSB and SSN were 6,400 t and 35 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 schools were also distributed in the Minches sector off Mull and Lewis. The majority of herring detected in VIaN occurred in discrete, small, and often diffuse schools in close proximity to the seabed (see Appendix 1; Hauls 5 to 10). These schools often extended for several miles. Very few herring schools were observed in mid-water regions, or in the upper layers of the water column. Herring occasionally occurred in mixed-species assemblages, forming small schools along the seabed with juvenile blue whiting, mackerel, or Norway pout. These mixed schools were largely distributed away from the shelf-break in the southern-most regions of VIaN.

Few schools were observed in sector VIaS and most herring occurred north of 55.5°N. School-types in this region were very similar to those detected in VIaN. Only three herring schools were observed in waters off northern and western Ireland (south of 55.5°N), which contrasts markedly with the 2010 survey where relatively large quantities of herring were observed in close proximity to Donegal.

Similarly, very few herring were observed in VIIb. The majority of herring in this region occurred as a small component (c. 5 %) of schools comprised of horse mackerel and these schools were mainly situated off the coast of Mayo.

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 (>35%) and 4-ring (c. 20%) herring in terms of both biomass and abundance (Tables 5 and 6). This trend in stock structure was similar for all the regions surveyed, although the abundance/biomass of 2-ring herring was greater than 4-ring herring in VIaS (Table 6). Inspection of the length-frequency data showed that larger fish generally occurred in the more-northern regions in VIaN, whilst smaller fish (<23.5 cm) were present in regions further south in VIaS (Table 3).

Combined maturity analysis indicated that 9% of the TSB was immature, with this group comprising around 15% of the TSN. The greatest proportions of herring encountered during survey were spent fish (>60%; Tables 7 and 8). This trend was similar in VIaN and VIIb, though only two mixed-herring schools were observed in VIIb. In area VIaS, there was a greater proportion of immature fish than mature fish, which corresponds well with the presence of smaller fish in this region.

3.2 Secondary species

3.2.1 Boarfish

Boarfish (*Capros aper*) were encountered from 10-250 m and were distributed mainly in area VIIb close to the shelf-break off Mayo (Figure 5). The majority of boarfish that was detected acoustically occurred in small, discrete mid-water column schools (see Appendix 1; Haul 25 and 25). 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, 846 individual length measurements and 392 length/weight measurements were recorded from three hauls. Boarfish length ranged from 11-17 cm with a corresponding weight range of 10-112 g. Mean length was 13.8 cm and mean weight 59.1 g. None of the samples collected were deemed suitable for boarfish TS studies, as they were towed/hauled rapidly for prolonged periods during fishing, which would have mostly likely caused damage to their swimbladders. However, concurrent single target detection data were collected during two hauls that will be useful for estimating in situ target strength.

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. (2011) 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 over 73% 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 1,361 individual lengths and 1,088 length/weight measurements were recorded for mackerel from 19 hauls. Length ranged from 18-41 cm with a corresponding weight range of 42-636 g. Mean length was 25.0 cm and mean weight 147 g.

3.3 Oceanography

A total of 40 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 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 °C cf. 12.5 °C north of 56°N; Figure 6 and 7). This trend was also apparent at 40 m, with relatively high water temperatures (c. 14.5 °C) around the coast of Northern Ireland and off Mayo (Figure 8). At 60 m, the water temperature was much cooler throughout most of the survey sector (c. 10.5 °C), indicating that the water was well-stratified thermally in all regions except for those off Mayo (area VIIb; Figure 9). 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.

Eyeball comparisons with data from the 2010 survey suggest that surface temperatures around Ireland were lower in 2011 than in 2010 (maximum temperatures: 14.5 °C in 2011 cf. 16.0 °C in 2010). In general, the spatial pattern in temperature variation in 2010 was similar to that in 2011, with coastal waters around northwest Ireland being predominantly warmer than those in the northern and shelf-break regions.

3.4 Marine mammal and seabird survey

3.4.1 Cetacean activity

Fifteen sightings of three cetacean species and one seal species were recorded, totalling 77 individual animals (Table 12 and Figure 11). Seven common dolphins were logged outside of observer hours.

Identified cetacean species were common dolphin (*Delphinus delphis*) and minke whale (*Balaenoptera acutorostrata*) as shown in Table 12. Common dolphins were the most commonly encountered and abundant species recorded during the survey. Cetaceans were predominantly distributed inshore around the Hebrides and inside the Minches in area VIaN.

3.4.2 Environmental conditions

Environmental data was collected at 594 stations. Beaufort Sea state was recorded at ≤ 3 at 70.9% of the environmental stations and at ≥ 4 at 29.1% of the stations. Visibility of ≤ 5km was recorded at 13% of the stations, 6 – 10km at 2.2% of the stations, 11 – 15km at 5.4 of the stations, and at 16 – 20km+ at 79.5% of the stations. No swell was recorded at 64.3% of the stations, a light swell of 0 – 1m was recorded at 33.3% and a moderate swell of 1 – 2m at 2.4%. No precipitation was recorded at 88.6% of the stations, with rainfall recorded at 10.1% of the stations and fog/mist recorded at 1.3% of stations. One half survey days were lost due to bad weather (sea state 6+, heavy swell of 2m+) and one half day was lost while the ship anchored in Broadhaven bay for calibration of equipment.

3.4.3 Seabird activity

Daily species lists were made of all bird species observed on and around the survey vessel. Fifteen species of bird were observed during the survey.

Bonaparte's gull (*Chroicocephalus Philadelphia*), Collared dove (*Streptopelia decaocto*), Common tern (*Sterna hirundo*), Dunlin (*Calidris alpine*), Fulmar (*Fulmarus glacialis*), Gannet (*Morus bassanus*), Great black backed gull (*Larus marinus*), Great northern diver (*Gavia immer*), Great skua (*Stercirarius skua*), Guillemot (*Uria aalge*),Herring gull (*Larus argentatus*), Kittiwake (*Rissa tridactyla*), Lesser black backed gull (*Larus fuscus graellsii*), Manx shearwater (*Puffinus puffinus*), Pomaraine skua (*Stercorarius pomarinus*), Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), Stormpetrel (*Hydrobates pelagicus*).

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 22%, and our acoustic analyses were supported by a relatively high number of net hauls.

The 2011 survey was extended substantially to cover regions in VIaN that are usually surveyed by Marine Scotland. Therefore, estimates of abundance and biomass for the entire survey area, and for VIaN, are not strictly comparable to those from previous northwest herring surveys conducted by the Marine Institute. However, estimates from VIaN are comparable with those derived from the Scottish surveys in this region. Estimated TSB for VIaN in 2010 was 325, 392 t, with a TSN of 1,865 million individuals. SSB was estimated to be 308, 055 t in 2010. Results from our 2011 survey in this area were slightly lower than those obtained in 2010, but are still in accordance with results from the Scottish survey (TSB= 271, 700 t, TSN= 1,583 million and SSB= 256, 000 t). Our results further support the notion that the herring stock in VIaN has decreased substantially since 2008 and 2009. For example, estimates of TSB in 2009 were around 604, 895 t, which constitutes a reduction of 45% by 2011.

Abundance estimates from the Irish northwest herring surveys in areas VIaS and VIIb might be considered comparable, as these regions were surveyed with a high degree of spatial overlap between years. Very few herring schools were observed in regions VIaS and VIIb during the 2011 survey and estimates of herring abundance and biomass were low compared to those obtained in 2010. For example, TSB was around 14,800 t lower in VIaS in 2011 (30%) and TSB was reduced by 26,700 t in VIIb (80%). However, it is important to note the temporal mismatch inherent with the 2011 survey in these sectors. The 2011 survey started south of the Minches, surveying north to c. 58.6°N before progressing back southwards to Ireland. This additional coverage resulted in sectors VIaS and VIIb being surveyed around 11 days later in 2011 than in previous years. The temporal mismatch between these surveys makes it difficult to substantiate any firm conclusions about the status of herring stocks in areas VIaS and VIIb. 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 majority of herring had moved further north by the time areas VIaS and VIIb were surveyed in 2011, and that the observed reductions in biomass compared to the 2010 survey were simply a function of temporal aliasing.

During the 2011 survey, herring were predominantly distributed in area VIaN and very few schools were detected in VIaS and VIIb. The pattern of distribution in VIaN was similar to that observed in 2010 during the Scottish survey. In both these years, herring were predominantly distributed between 56 and 57°N and occurred in discrete, single-species schools. Several schools were observed off the Hebrides in 2011 and 2010, and relatively large herring schools were detected in the Minches region on these surveys. In regions VIaS and VIIb, the pattern of distribution was very different to that observed in previous years, where relatively large quantities of herring have been observed in these regions, particularly along the northern Irish coast and off the coast of Mayo. Although there are some possible issues with temporal aliasing in these regions, it is particularly interesting to note that the majority of herring schools detected during this survey were situated in regions north of 56°N where the water temperature (0- 40 m) was markedly cooler than that in regions further south (see Figures 3 and 9). Likewise, the distinct absence of herring in the warmer waters along north and northwest coast is also noteworthy. A further point of interest is that the water temperature around Ireland was markedly cooler compared to other years (by c. 1-1.5°), although the implications of this on herring distribution and abundance are unclear. Bio-physical interactions in the region are likely to be complex, and it was not possible substantiate any robust correlations between temperature and herring distribution based on our data. Results from the predator observations accorded well with the acoustic observations in that whales and dolphins were predominantly distributed in VIaN, and few predator species were seen in regions further south.

The survey derived herring age and length profiles that closely resembled those observed from commercial sampling, and has 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 successfully. There were relatively few juvenile fish on the survey and this is similar to observations from 2010 and 2009. However, there was a high proportion of spent (c. 65%) herring recorded during the 2011 survey that contrasts markedly with the 2010 survey, where no spent fish were observed. This could be indicative of strong spawning in the region that may lead to a large influx of juvenile herring into the population in 2012.

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 very few herring schools were observed in VIaS and VIIb.
- It was possible to track herring cohorts from the data and there is some evidence of successful recruitment within the northwest herring population. The majority of the population were mature and there were a high proportion of spent individuals.
- Secondary species observed regularly on the survey were Mackerel and boarfish.
- CTD data indicated the waters around Ireland were cooler than in previous years, though it is not clear what impact this had on the distribution of herring abundance and population dynamics.

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 2011.

```
# Calibration  Version  2.1.0.12
#
# Date:  18/06/2011
#
# Comments:
#   CE11008. St. Johns point, Donegal Bay. 18/6/11. 38 kHz
#
# Reference Target:
#   TS                  -33.50 dB       Min. Distance         10.00 m
#   TS Deviation          5.0 dB        Max. Distance         20.00 m
#
# Transducer:  ES38B  Serial No.   30227
#   Frequency           38000 Hz       Beamtype               Split
#   Gain                 26.32 dB      Two Way Beam Angle   -20.6 dB
#   Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#   Athw. Beam Angle     7.09 deg       Along. Beam Angle    7.01 deg
#   Athw. Offset Angle  -0.06 deg       Along. Offset Angle -0.07 deg
#   SaCorrection         -0.59 dB       Depth                 5.00  m
#
# Transceiver:  GPT  38 kHz 009072033933 1-1 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.   9.2 dB/km       Sound Velocity     1501.1 m/s
#
# Beam Model results:
#   Transducer Gain    = 25.92 dB       SaCorrection       = -0.64 dB
#   Athw. Beam Angle   = 6.95 deg       Along. Beam Angle  = 6.91 deg
#   Athw. Offset Angle =-0.04 deg       Along. Offset Angle=-0.06 deg
#
# Data deviation from beam model:
#   RMS =    0.22 dB
#   Max =    0.50 dB  No. =    98  Athw. = 3.4 deg  Along = -3.7 deg
#   Min =   -0.92 dB  No. =   173  Athw. =  1.6 deg  Along = 4.4 deg
#
# Data deviation from polynomial model:
#   RMS =    0.16 dB
#   Max =    0.53 dB  No. =   134  Athw. = -4.6 deg  Along = -1.2 deg
#   Min =   -0.67 dB  No. =   173  Athw. =  1.6 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 (m)	Bulk Catch (Kg)	Sampled (Kg)	Herring %	Mackerel %	Sprat %	Scad %	Others %
1	19-Jun	56 26.573	6 44.814	14:27	76	65	21.5	21.5	10.6	0.7	40.1	0.0	48.6
2	19-Jun	56 44.841	6 16.466	18:41	133	100	22.4	0.0	0.0	0.0	0.0	0.0	100.0
3	20-Jun	57 31.270	6 49.710	10:12	145	135	29.1	29.1	0.0	1.5	0.0	0.0	98.5
4	23-Jun	58 1.433	8 46.300	05:25	158	152	114.2	114.2	29.8	6.3	0.0	0.0	70.2
5	23-Jun	58 01.548	8 28.816	08:11	137	136	5000.0	199.2	100.0	0.0	0.0	0.0	0.0
6	24-Jun	57 31.045	8 35.055	05:59	156	154	300.0	191.3	86.0	0.0	0.0	0.0	14.0
7	24-Jun	57 01.047	8 49.931	20:52	135	120	7.0	7.0	51.4	18.1	0.0	0.0	30.5
8	25-Jun	57 1.229	8 16.126	04:42	132	126	85.6	85.6	81.2	3.6	0.0	0.0	15.2
9	26-Jun	56 39.742	8 29.520	09:15	116	107	300.0	277.3	85.7	1.5	0.0	0.0	12.8
10	27-Jun	56 23.759	8 28.131	07:29	136	133	400.0	187.2	100.0	0.0	0.0	0.0	0.0
11	27-Jun	56 16.181	7 21.343	18:26	78	75	10.8	10.8	10.0	83.6	0.0	0.0	6.4
12	28-Jun	56 8.770	8 10.150	10:10	109	108	53.7	53.7	18.0	79.5	0.0	0.0	2.5
13	28-Jun	56 1.174	8 53.316	17:55	130	125	Void haul						
14	28-Jun	56 1.156	8 49.574	22:08	130	50	500.0	207.0	92.2	7.8	0.0	0.0	0.0
15	29-Jun	55 53.235	7 52.287	16:16	144	143	300.0	148.9	1.8	6.9	0.0	0.0	91.3
16	29-Jun	55 53.190	7 59.063	19:12	165	2	288.0	144.0	0.4	0.0	0.0	0.0	99.6
17	30-Jun	55 45.381	8 49.429	07:25	108	103	1000.0	171.5	39.7	10.8	0.0	0.0	49.5
18	30-Jun	55 45.61	7 57.87	13:35	96	94	1000.0	158.5	50.3	36.0	0.0	0.0	13.7
19	01-Jul	55 38.23	9 1.25	08:15	94	84	185.0	185.0	0.0	33.4	0.0	3.8	66.6
20	02-Jul	55 23.22	8 33.64	08:25	94	84	95.0	95.0	4.7	95.3	0.0	0.0	0.0
21	02-Jul	55 15.801	9 26.778	17:46	106	76	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	04-Jul	54 38.540	8 57.250	08:35	87	67	13.3	13.3	0.0	97.1	0.2	0.0	2.7
23	04-Jul	54 16.108	10 17.951	04:48	102	102	245.7	245.7	8.9	3.8	0.0	85.4	1.9
24	06-Jul	54 0.944	10 45.521	05:46	160	148	44.5	45.1	0.5	9.1	0.0	0.0	90.4
25	07-Jul	53 38.980	11 9.051	09:10	164	125	10.4	10.4	0.0	99.0	0.0	0.0	1.0
26	07-Jul	53 31.263	11 32.603	15:46	200	100	1500.0	115.7	0.0	0.0	0.0	0.0	100.0

Table 3. Length-frequency of herring hauls used in the analysis. Northwest herring survey, June 2011.

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

Table 4. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Northwest herring survey, June 2011.

Length	Age (Rings)											Abund.	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	10	(mill)	000's t	(g)
16	0.8											0.75	0.03	39.5
16.5	0.8											0.75	0.03	43.2
17	0.8											0.75	0.04	47
17.5	3.8											3.77	0.19	51
18	6.0											6.03	0.33	55.3
18.5	11.1											11.09	0.66	59.8
19	14.6											14.63	0.94	64.5
19.5	11.6	7.2										18.79	1.31	69.5
20	6.5	4.1										10.57	0.79	74.7
20.5	11.3	8.5										19.8	1.59	80.2
21	3.0	11.1	0.5									14.55	1.25	85.9
21.5	10.7	17.4	1.3									29.45	2.71	91.9
22		24.2	8.1									32.21	3.16	98.1
22.5	1.3	25.0	15.8									42.16	4.41	104.6
23		25.0	30.7									55.67	6.2	111.4
23.5		15.0	35.1	1.2								51.32	6.08	118.5
24		12.1	45.4	1.5								59.04	7.43	125.9
24.5		18.4	58.5	2.3								79.15	10.57	133.5
25		11.1	84.3	8.0	1.6							104.98	14.85	141.5
25.5		16.6	175.7	28.2	1.6		1.6					223.54	33.47	149.7
26		4.7	134.8	47.0	3.2							189.84	30.05	158.3
26.5		2.1	92.4	60.1	6.4	2.1						163.07	27.26	167.2
27			35.8	60.8	10.8	3.5	5.3		1.8			117.99	20.81	176.4
27.5			15.0	51.1	22.6	7.6	4.5					100.86	18.75	185.9
28			17.0	48.1	12.8	10.0	7.0	1.4	1.4	2.8		100.51	19.68	195.8
28.5			1.7	42.8	18.1	19.8	23.0	13.2	8.2	1.7	1.7	130.19	26.82	206
29				23.9	19.4	34.3	31.4	28.3	9.0	4.4	1.5	152.24	32.96	216.5
29.5				5.8	10.5	23.3	28.0	16.3	9.3	9.3		102.47	23.3	227.4
30					4.1	16.5	12.3	9.6	10.9	4.1		57.46	13.71	238.6
30.5						5.6	3.7	1.9				11.17	2.79	250.2
31							1.0		1.0			1.92	0.5	262.2
31.5						1.1						1.14	0.31	274.5
32						0.3						0.28	0.08	287.2
32.5							0.3					0.31	0.09	300.2
37							0.3					0.26	0.11	435.7
SSN	0.8	90.8	664.2	376.5	110.2	123.3	117.7	70.1	41.4	22.3	3.2	1620.6		
SSB	0.1	11.8	100.8	67.8	21.8	26.7	25.5	15.5	9.2	4.9	0.7		284.632	
Mn wt. (g)	70.7	112.2	148.3	179.7	197.6	216.5	216.4	220.5	221.3	221.7	211.0			
Mn L (cm)	19.8	23.2	25.6	27.4	28.3	29.2	29.2	29.4	29.5	29.5	29.0			

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
36 D8	0	0	0	0	0	0	0	0	0	0	0	0
36 D9	0	0	0	0	0	0	0	0	0	0	0	0
37 D8	0	0	0	0	0	0	0	0	0	0	0	0
37 D9	0	0.1	1.8	1.8	0.6	0.7	0.8	0.4	0.2	0.1	0	6.6
37 E0	0	0	0	0	0	0	0	0	0	0	0	0
37 E1	0	0	0	0	0	0	0	0	0	0	0	0
38 D9	0	0	0	0	0	0	0	0	0	0	0	0
38 E0	0	0	0	0	0	0	0	0	0	0	0	0
38 E1	1.1	2.4	3.7	0.5	0.1	0	0	0	0	0	0	7.9
39 D9	0	0	0	0	0	0	0	0	0	0	0	0
39 E0	0.1	0.5	1.8	0.4	0.1	0	0	0	0	0	0	3
39 E1	0	0	0	0	0	0	0	0	0	0	0	0
39 E2	0	0	0	0	0	0	0	0	0	0	0	0
39 E3	0	0	0	0	0	0	0	0	0	0	0	0
40 E0	0	0	0	0	0	0	0	0	0	0	0	0
40 E1	0.4	2.4	7.1	1.5	0.2	0.1	0.3	0.1	0.1	0	0	12.2
40 E2	1.6	3.5	5.4	0.7	0.1	0	0	0	0	0	0	11.3
40 E3	0	0	0	0	0	0	0	0	0	0	0	0
41 E0	0	0.2	0.9	0.2	0	0	0	0	0	0	0	1.4
41 E1	0.4	4.8	20.3	7.6	2.1	2.5	2.5	1.4	0.9	0.5	0	43.2
41 E2	1.1	3.6	6	1	0.2	0.2	0.2	0.1	0.1	0.1	0	12.7
41 E3	1	0.7	0.7	0.1	0	0	0	0	0	0	0	2.5
42 E0	0	0.1	0.1	0	0	0	0	0	0	0	0	0.3
42 E1	0	1.8	26.5	15.2	3.5	3.3	2.8	1.5	1	0.5	0.1	56.2
42 E2	0	0	0	0	0	0	0	0	0	0	0	0.1
42 E3	0	0	0	0	0	0	0	0	0	0	0	0
43 E0	0	0.1	2.3	1.9	0.5	0.5	0.4	0.3	0.2	0.1	0	6.3
43 E1	0	0.6	8	5.9	1.7	1.7	1.6	0.9	0.6	0.3	0	21.4
43 E2	0	0.6	7	4.9	1.5	1.5	1.4	0.8	0.5	0.3	0	18.5
43 E3	0	0	0	0	0	0	0	0	0	0	0	0
44 E0	0	0.1	2	1.9	0.7	1.1	1	0.6	0.4	0.2	0	8.1
44 E1	0	0.4	7.8	8.3	3	4.3	4	2.5	1.4	0.8	0.1	32.6
44 E2	0	0	0.3	0.6	0.3	0.4	0.4	0.2	0.1	0.1	0	2.5
44 E3	0	0.4	5.9	10.1	4.6	6.6	6.4	4.2	2.3	1.3	0.2	41.9
44 E4	0	0	0	0	0	0	0	0	0	0	0	0
45 E0	0	0	0	0	0	0	0	0	0	0	0	0
45 E1	0	0.1	1.8	2.4	1	1.6	1.5	1	0.6	0.3	0	10.3
45 E2	0	0	0.5	0.9	0.4	0.6	0.6	0.4	0.2	0.1	0	3.6
45 E3	0	0	0	0	0	0	0	0	0	0	0	0
45 E4	0	0	0	0	0	0	0	0	0	0	0	0
46 E1	0	0	0	0	0	0	0	0	0	0	0	0
46 E2	0	0	0	0	0	0	0	0	0	0	0	0
46 E3	0	0	0	0	0	0	0	0	0	0	0	0
46 E4	0	0.1	1.5	2.6	1.2	1.7	1.6	1.1	0.6	0.3	0.1	10.6
Total	**5.8**	**22.7**	**111.5**	**68.5**	**21.9**	**26.8**	**25.6**	**15.6**	**9.2**	**5**	**0.7**	**313.3**
%	1.9	7.3	35.6	21.9	7	8.6	8.2	5	2.9	1.6	0.2	100

VIaN	2.5	13.6	91.6	63.6	20.7	26	24.4	15	8.9	4.9	0.5	**271.7**
VIaS	3.2	8.8	18	3.1	0.5	0.1	0.3	0.1	0.1	0	0	**34.2**
VIIb	0	0.1	1.8	1.8	0.6	0.7	0.8	0.4	0.2	0.1	0	**6.5**

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
36 D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36 D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 D9	0.0	0.9	11.5	9.8	3.3	3.3	3.4	1.8	1.0	0.6	0.1	35.5
37 E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38 D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38 E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38 E1	15.8	24.1	28.9	3.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0	72.4
39 D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39 E0	0.9	4.6	13.1	2.5	0.4	0.2	0.2	0.1	0.1	0.0	0.0	22.1
39 E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39 E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40 E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40 E1	5.2	22.1	51.7	9.1	1.3	0.6	1.0	0.3	0.3	0.1	0.0	91.6
40 E2	22.7	34.7	41.6	4.5	0.5	0.1	0.1	0.0	0.0	0.0	0.0	104.1
40 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41 E0	0.5	2.2	6.3	1.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	10.6
41 E1	5.7	41.9	141.6	44.2	10.9	11.5	11.4	6.4	4.1	2.3	0.2	280.1
41 E2	15.7	34.5	46.9	6.0	1.2	1.1	1.0	0.6	0.3	0.3	0.0	107.6
41 E3	15.6	7.8	5.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.6
42 E0	0.0	0.7	1.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	2.2
42 E1	0.0	12.1	169.7	87.8	18.7	15.5	13.4	6.7	4.5	2.2	0.3	331.1
42 E2	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
42 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43 E0	0.0	0.4	13.7	10.9	2.6	2.5	2.0	1.2	0.9	0.4	0.0	34.8
43 E1	0.0	3.9	51.0	33.0	8.9	8.1	7.5	4.2	2.9	1.5	0.2	121.3
43 E2	0.0	4.0	45.2	27.5	7.7	6.9	6.7	3.6	2.4	1.3	0.2	105.5
43 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44 E0	0.0	0.8	12.3	10.5	3.6	4.9	4.7	2.9	1.7	0.9	0.1	42.4
44 E1	0.0	2.7	48.7	44.8	15.2	19.5	18.4	11.4	6.2	3.4	0.5	170.8
44 E2	0.0	0.2	2.2	3.1	1.3	1.8	1.7	1.1	0.6	0.3	0.1	12.4
44 E3	0.0	3.1	36.6	52.2	22.1	30.3	29.6	19.2	10.3	5.7	1.0	210.1
44 E4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45 E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45 E1	0.0	0.9	11.4	12.5	5.1	7.1	6.9	4.5	2.6	1.4	0.2	52.6
45 E2	0.0	0.3	3.2	4.5	1.9	2.6	2.6	1.7	0.9	0.5	0.1	18.3
45 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45 E4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46 E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46 E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46 E4	0.0	0.8	9.3	13.2	5.6	7.7	7.5	4.9	2.6	1.4	0.3	53.3
Total	**82.1**	**202.5**	**752.0**	**381.0**	**110.8**	**124.0**	**118.4**	**70.7**	**41.6**	**22.3**	**3.2**	**1908.7**
%	4.3	10.6	39.4	20.0	5.8	6.5	6.2	3.7	2.2	1.2	0.2	100.0
Cv (%)	56.4	34.7	23.2	26.4	27.1	28.7	28.4	29.3	28.6	28.3	30.4	22.3

VIaN	37.5	116.3	605.2	352.1	105.1	119.7	113.7	68.5	40.2	21.6	3.1	**1583**
VIaS	44.6	85.4	135.4	19.2	2.4	1.0	1.4	0.4	0.4	0.1	0.0	**290.2**
VIIb	0.0	0.9	11.5	9.8	3.3	3.3	3.4	1.8	1.0	0.6	0.1	**35.5**

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

Strata	Immature	Mature	Spent	Total
36 D8	0	0	0	0
36 D9	0	0	0	0
37 D8	0	0	0	0
37 D9	0.1	2	4.5	6.6
37 E0	0	0	0	0
37 E1	0	0	0	0
38 D9	0	0	0	0
38 E0	0	0	0	0
38 E1	3.7	1.1	3.1	7.9
39 D9	0	0	0	0
39 E0	0.6	0.6	1.8	3
39 E1	0	0	0	0
39 E2	0	0	0	0
39 E3	0	0	0	0
40 E0	0	0	0	0
40 E1	2.9	2.4	6.9	12.2
40 E2	5.3	1.6	4.4	11.3
40 E3	0	0	0	0
41 E0	0.3	0.3	0.9	1.4
41 E1	5.3	10.5	27.4	43.2
41 E2	5	2.2	5.5	12.7
41 E3	1.7	0.2	0.5	2.5
42 E0	0.1	0.1	0.2	0.3
42 E1	1.4	14.6	40.2	56.2
42 E2	0	0	0	0.1
42 E3	0	0	0	0
43 E0	0	1.6	4.6	6.3
43 E1	0.5	5.9	15.1	21.4
43 E2	0.5	5.2	12.8	18.5
43 E3	0	0	0	0
44 E0	0.1	2.3	5.7	8.1
44 E1	0.4	9.6	22.6	32.6
44 E2	0	0.8	1.7	2.5
44 E3	0.5	12.9	28.5	41.9
44 E4	0	0	0	0
45 E0	0	0	0	0
45 E1	0.1	3.1	7.1	10.3
45 E2	0	1.1	2.5	3.6
45 E3	0	0	0	0
45 E4	0	0	0	0
46 E1	0	0	0	0
46 E2	0	0	0	0
46 E3	0	0	0	0
46 E4	0.1	3.3	7.2	10.6
Total	**28.7**	**81.3**	**203.3**	**313.3**
%	9.2	25.9	64.9	100

VIaN	16	73.7	182.5	**272.2**
VIaS	12.5	5.7	16.2	**34.4**
VIIb	0.1	2	4.5	**6.6**

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

Strata	Immature	Mature	Spent	Total
36 D8	0.0	0.0	0.0	0.0
36 D9	0.0	0.0	0.0	0.0
37 D8	0.0	0.0	0.0	0.0
37 D9	0.7	10.4	24.4	35.5
37 E0	0.0	0.0	0.0	0.0
37 E1	0.0	0.0	0.0	0.0
38 D9	0.0	0.0	0.0	0.0
38 E0	0.0	0.0	0.0	0.0
38 E1	41.4	8.4	22.6	72.4
39 D9	0.0	0.0	0.0	0.0
39 E0	5.6	4.2	12.3	22.1
39 E1	0.0	0.0	0.0	0.0
39 E2	0.0	0.0	0.0	0.0
39 E3	0.0	0.0	0.0	0.0
40 E0	0.0	0.0	0.0	0.0
40 E1	28.1	16.4	47.1	91.6
40 E2	59.5	12.1	32.6	104.1
40 E3	0.0	0.0	0.0	0.0
41 E0	2.7	2.0	5.9	10.6
41 E1	48.2	63.4	168.5	280.1
41 E2	52.8	15.6	39.2	107.6
41 E3	23.8	1.7	4.1	29.6
42 E0	0.8	0.4	1.0	2.2
42 E1	9.5	84.2	237.4	331.1
42 E2	0.0	0.1	0.3	0.4
42 E3	0.0	0.0	0.0	0.0
43 E0	0.3	8.9	25.7	34.8
43 E1	3.2	32.8	85.3	121.3
43 E2	3.3	29.0	73.1	105.5
43 E3	0.0	0.0	0.0	0.0
44 E0	0.6	12.1	29.7	42.4
44 E1	2.2	49.8	118.9	170.8
44 E2	0.2	3.8	8.4	12.4
44 E3	3.3	64.1	142.7	210.1
44 E4	0.0	0.0	0.0	0.0
45 E0	0.0	0.0	0.0	0.0
45 E1	0.9	15.5	36.3	52.6
45 E2	0.3	5.6	12.4	18.3
45 E3	0.0	0.0	0.0	0.0
45 E4	0.0	0.0	0.0	0.0
46 E1	0.0	0.0	0.0	0.0
46 E2	0.0	0.0	0.0	0.0
46 E3	0.0	0.0	0.0	0.0
46 E4	0.8	16.3	36.2	53.3
Total	288.1	456.6	1164.0	1908.7
%	15.1	23.9	61.0	100.0

VIaN	152.88	405.138	1025.009	**1583.027**
VIaS	134.529	41.119	114.546	**290.194**
VIIb	0.736	10.35	24.415	**35.501**

Table 9. Herring biomass and abundance by survey strata. Northwest herring survey, June 2011.

Strata	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. (mill.)
36 D8	4	0	0	0	0	100	0	0	0	0	0	0
36 D9	4	0	0	0	0	100	0	0	0	0	0	0
37 D8	2	0	0	0	0	100	0	0	0	0	0	0
37 D9	4	3	0	3	0	50	0	6.6	0	6.6	6.5	35.5
37 E0	1	0	0	0	0	100	0	0	0	0	0	0
37 E1	1	0	0	0	0	100	0	0	0	0	0	0
38 D9	2	0	0	0	0	100	0	0	0	0	0	0
38 E0	2	0	0	0	0	100	0	0	0	0	0	0
38 E1	2	3	0	0	3	50	0	0	7.9	7.9	4.2	72.4
39 D9	2	0	0	0	0	100	0	0	0	0	0	0.0
39 E0	4	2	0	0	2	75	0	0	3	3	2.4	22.1
39 E1	4	0	0	0	0	100	0	0	0	0	0	0.0
39 E2	1	0	0	0	0	100	0	0	0	0	0	0.0
39 E3	1	0	0	0	0	100	0	0	0	0	0	0.0
40 E0	4	0	0	0	0	100	0	0	0	0	0	0.0
40 E1	4	17	1	16	0	50	10	2.1	0	12.2	9.3	91.6
40 E2	4	15	12	0	3	50	1.7	0	9.6	11.3	6	104.1
40 E3	3	0	0	0	0	100	0	0	0	0	0	0.0
41 E0	4	2	2	0	0	75	1.4	0	0	1.4	1.2	10.6
41 E1	4	242	215	27	0	0	37.7	5.5	0	43.2	37.9	280.1
41 E2	4	109	0	92	17	25	0	5.8	6.9	12.7	7.7	107.6
41 E3	4	40	0	36	4	25	0	1.9	0.6	2.5	0.7	29.6
42 E0	4	1	0	1	0	75	0	0.3	0	0.3	0.2	2.2
42 E1	4	285	284	1	0	0	56.1	0.1	0	56.2	54.8	331.1
42 E2	6	2	2	0	0	83	0.1	0	0	0.1	0.1	0.4
42 E3	3	0	0	0	0	100	0	0	0	0	0	0.0
43 E0	2	1	1	0	0	50	6.3	0	0	6.3	6.3	34.8
43 E1	2	78	73	1	4	50	20.8	0	0.6	21.4	21	121.3
43 E2	4	2	1	0	1	50	0	0	18.5	18.5	18	105.5
43 E3	3	0	0	0	0	100	0	0	0	0	0	0
44 E0	2	13	0	12	1	0	0	2.6	5.5	8.1	8	42.4
44 E1	2	103	102	1	0	50	32.6	0	0	32.6	32.3	170.8
44 E2	2	3	3	0	0	50	2.5	0	0	2.5	2.4	12.4
44 E3	6	7	6	0	1	67	41.7	0	0.2	41.9	41.4	210.1
44 E4	4	0	0	0	0	100	0	0	0	0	0	0.0
45 E0	1	0	0	0	0	100	0	0	0	0	0	0.0
45 E1	3	35	7	28	0	67	6.9	3.5	0	10.3	10.2	52.6
45 E2	3	2	2	0	0	67	3.6	0	0	3.6	3.6	18.3
45 E3	5	0	0	0	0	100	0	0	0	0	0	0
45 E4	4	0	0	0	0	100	0	0	0	0	0	0
46 E1	1	0	0	0	0	100	0	0	0	0	0	0
46 E2	1	0	0	0	0	100	0	0	0	0	0	0
46 E3	1	0	0	0	0	100	0	0	0	0	0	0
46 E4	2	15	1	0	14	0	0.6	0	10	10.6	10.5	53.3
Total	130	980	712	218	50	70	222.2	28.4	62.7	313.3	284.6	1908.7
Cv (%)	-	-	-	-	-	-	-	-	-	22.9	22.4	22.3

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 2011.

Winter rings	2008	2009	2010	2011
0	-	-	-	-
1	6.1	416.4	16.5	44.6
2	75.9	81.3	292.8	86.3
3	64.7	11.4	85.2	146.8
4	38.4	15.1	63.2	28.9
5	22.3	7.7	43.2	5.7
6	26.2	7.1	27.3	4.3
7	9.1	7.5	19.0	4.8
8	5.0	0.4	12.5	2.1
9	3.7	0.9	5.5	1.4
10+	-	-	-	0.8
TSN (mil)	251.4	547.7	565.2	325.7
TSB (t)	44,611	46,460	82,100	40,700
SSB (t)	43,006	20,906	81,400	28,600
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 survey coverage in VIaN was much greater than that in 2010.

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

^ Survey coverage: VIaS & VIIb

* Survey coverage: VIaS, VIaN & VIIb

Table 12: Sightings, counts and group size ranges for cetaceans sighted during the survey.

Species	No. of Sightings	No. of Individuals	Range of Group Size
Common dolphin	7	65	2 – 25
Minke whale	6	8	1-2
Unidentified dolphin	1	3	-
Unidentified seal	1	1	-

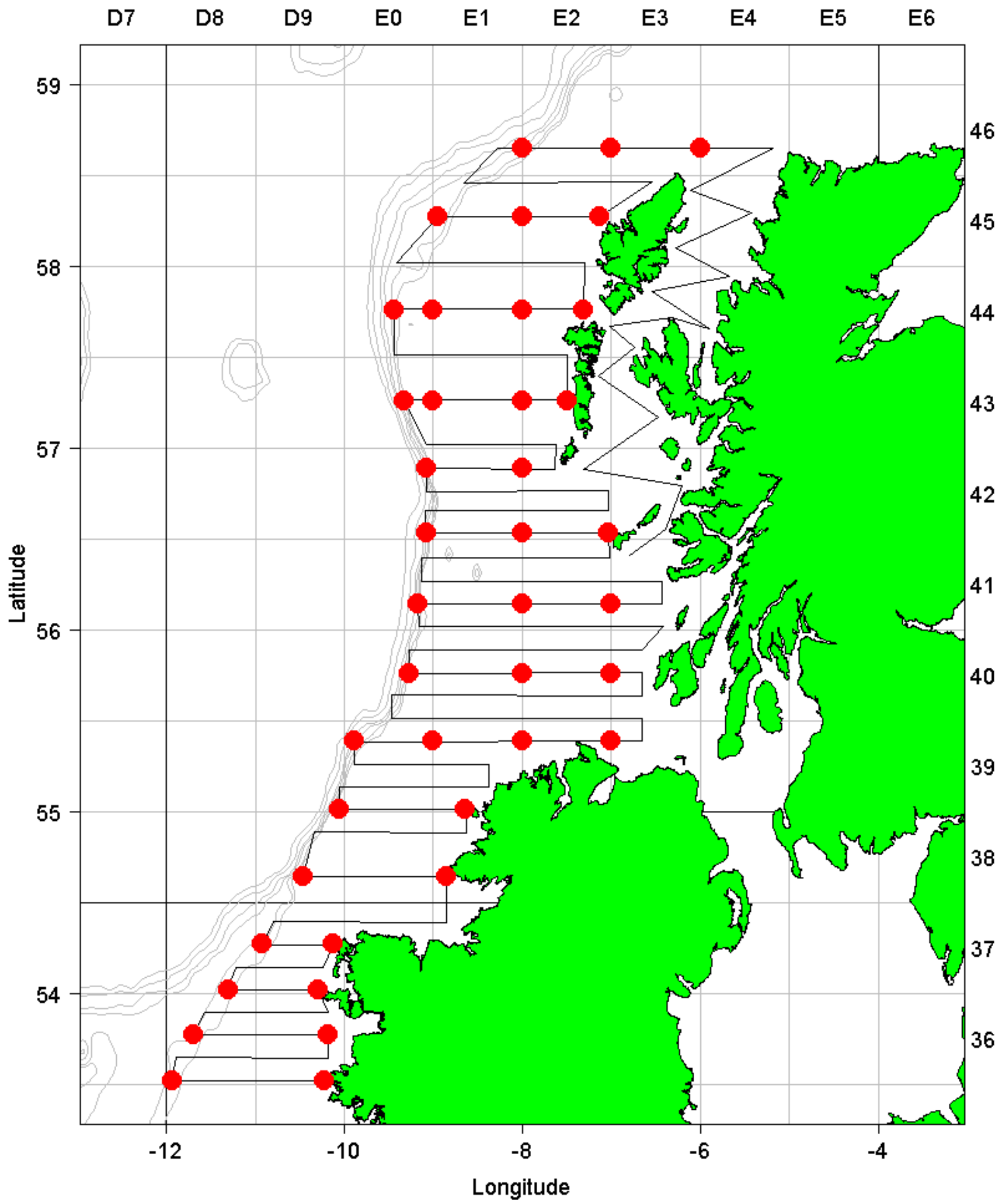


Figure 1. RV Celtic Explorer cruise track during the Northwest herring survey, June 2011. Red circles are the hydrographic stations.

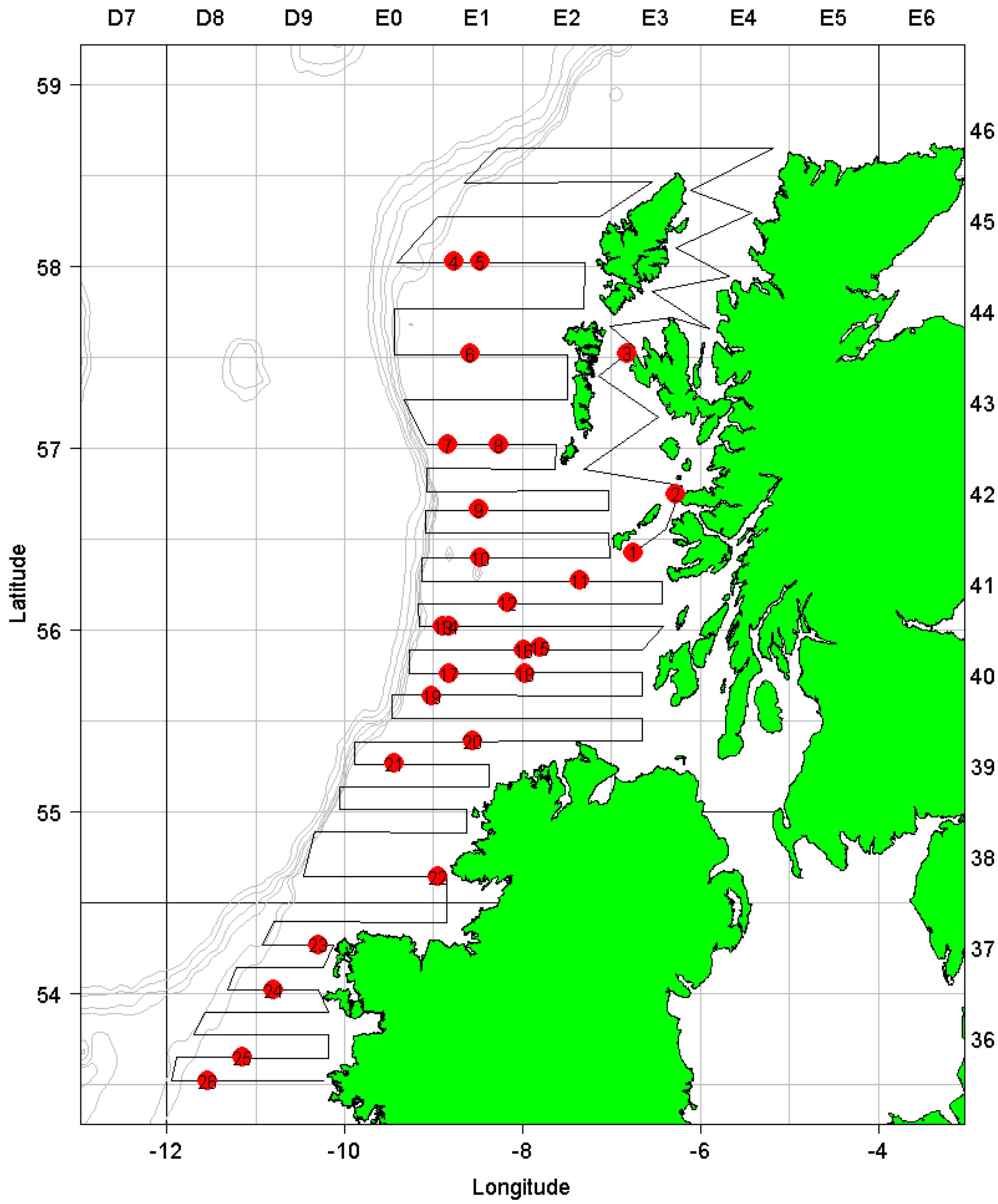


Figure 2. RV Celtic Explorer fishing trawl stations. Northwest herring survey, June 2011.

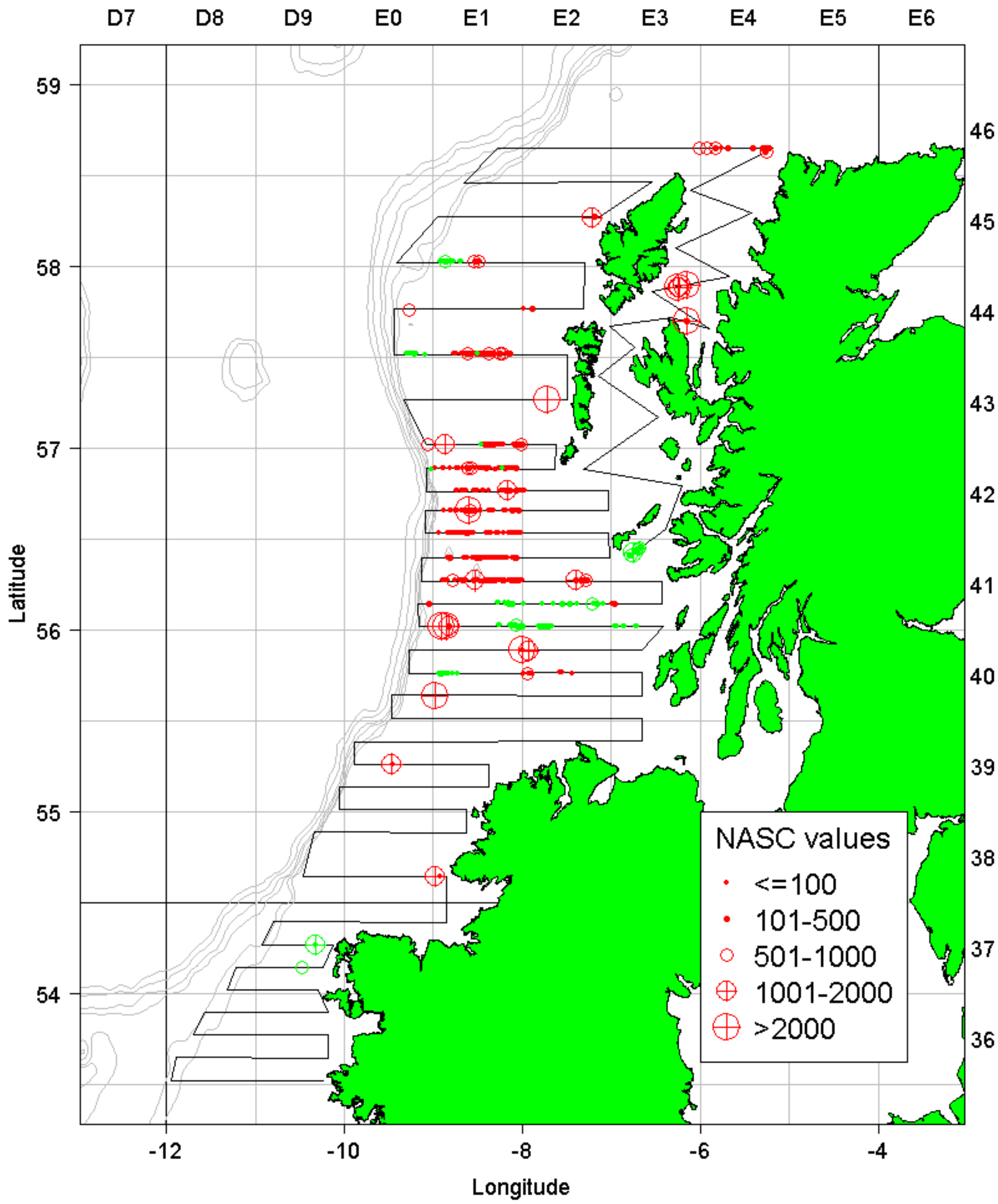


Figure 3. NASC plot of herring distribution during the 2011 survey. Red circles represent single herring schools ("definitely and "probably" herring categories). Green circles represent herring occurring in mixed schools.

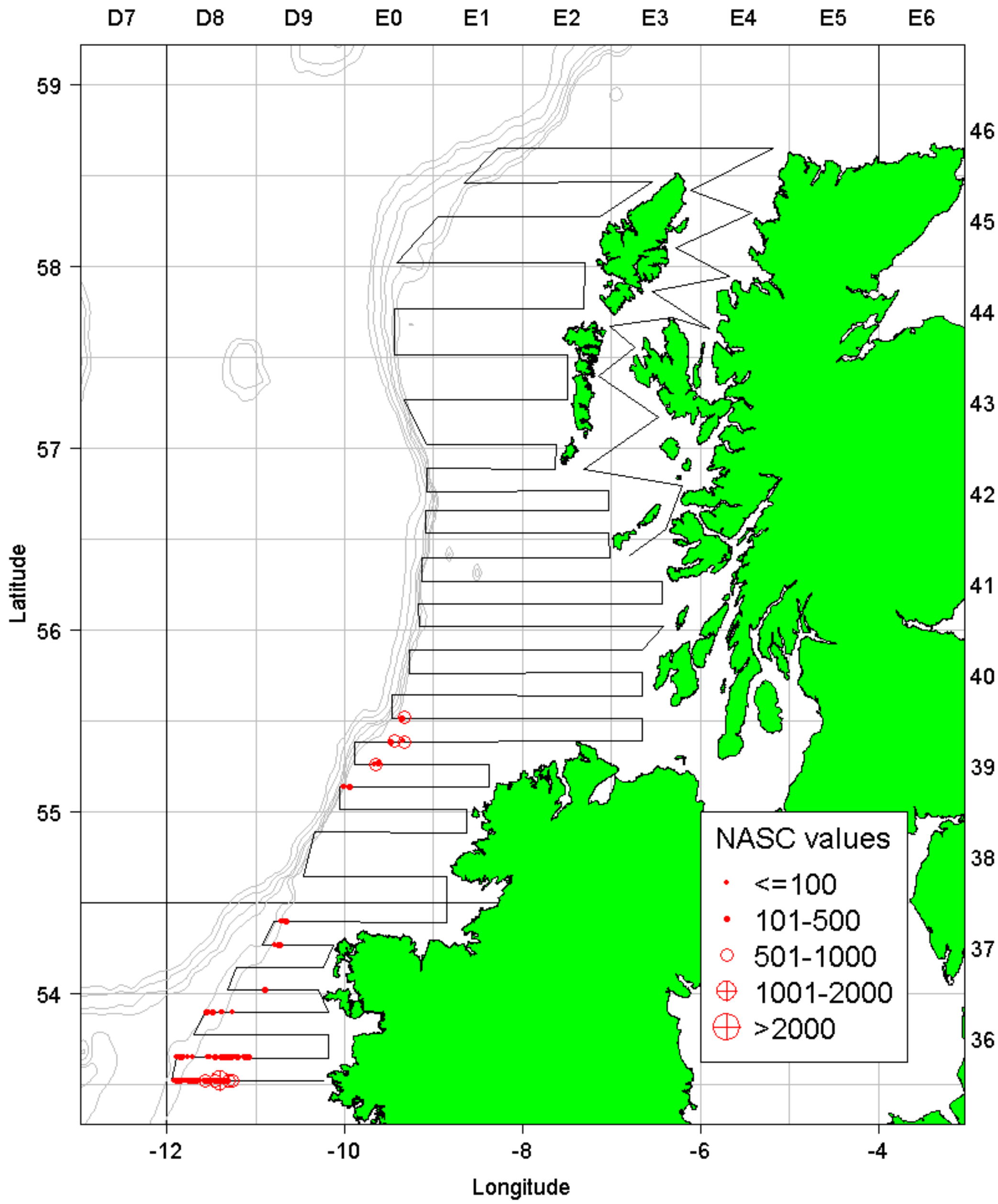


Figure 4. NASC plot of boarfish (*Capros aper*) distribution during the 2011 Northwest herring survey.

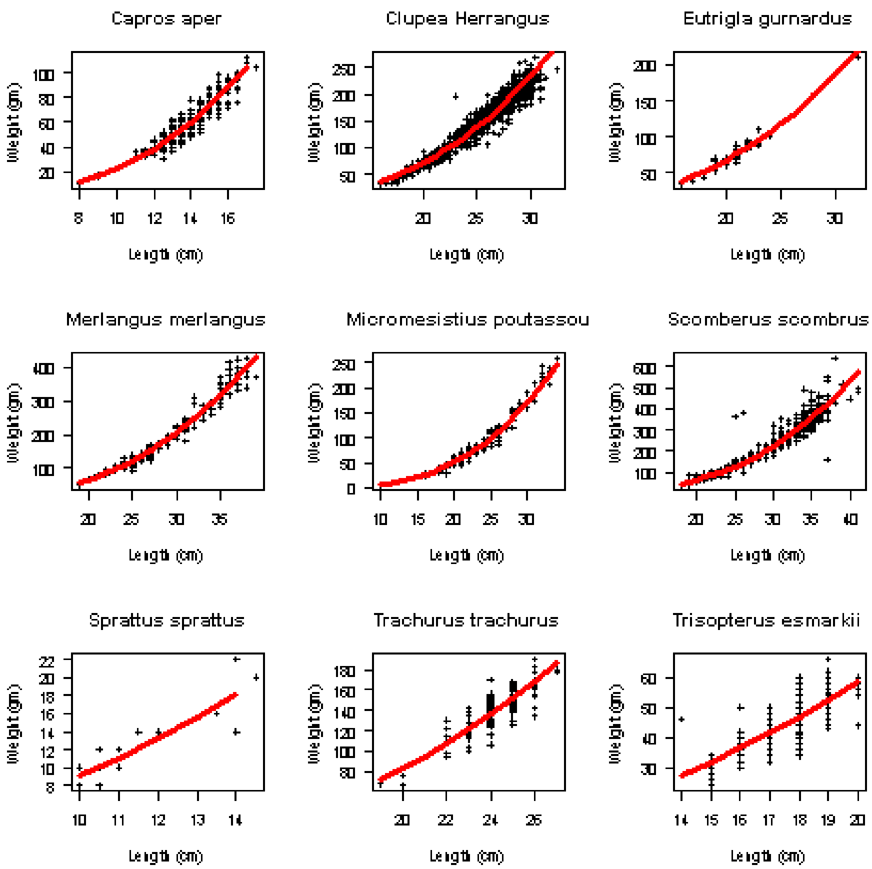


Figure 5. Length-weight plots of major species encountered during the Northwest herring acoustic survey, June 2011.

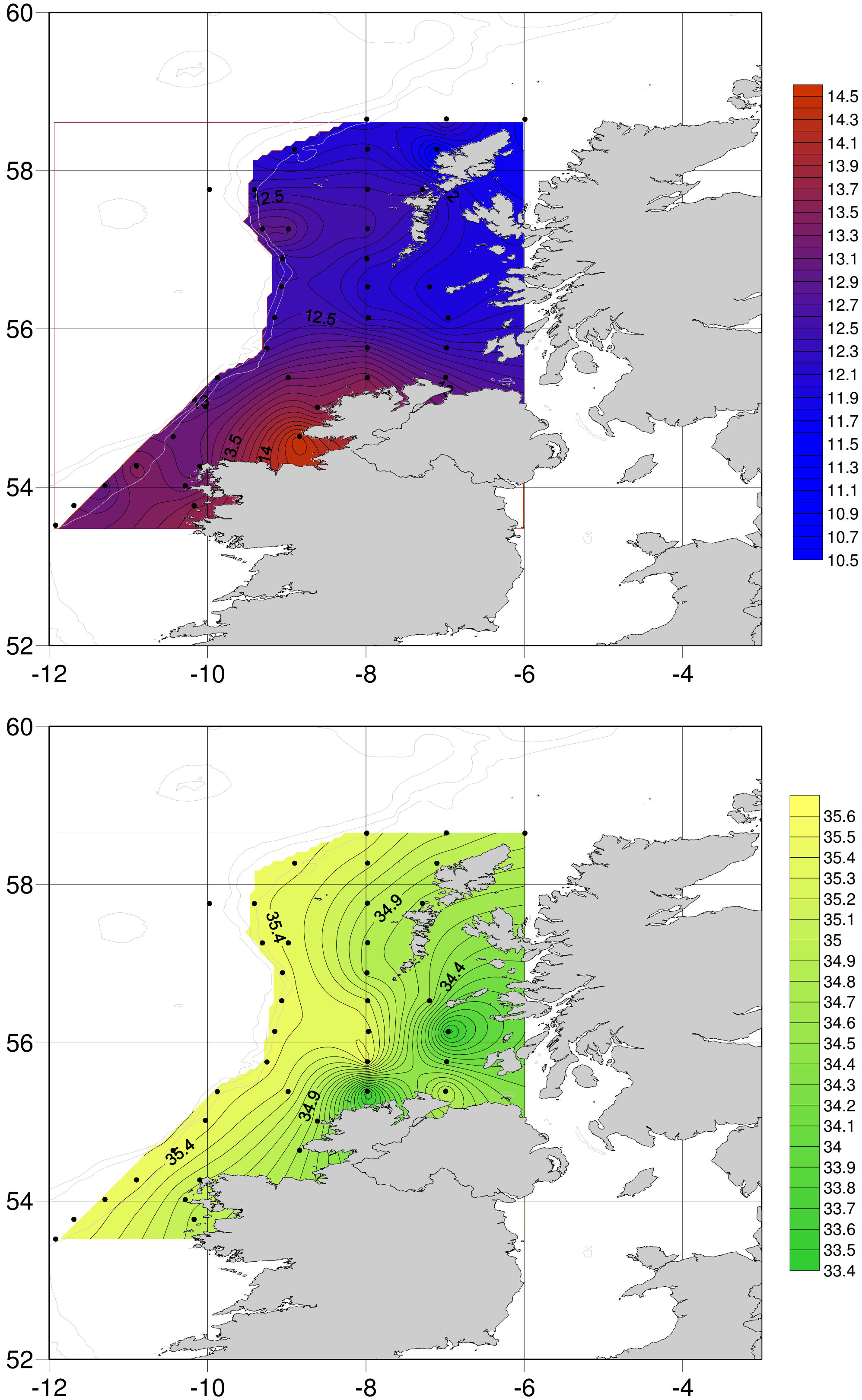


Figure 6. Horizontal temperature (top panel) and salinity (bottom panel) at 5 m subsurface as derived from vertical CTD cast data. Northwest herring survey, June 2011.

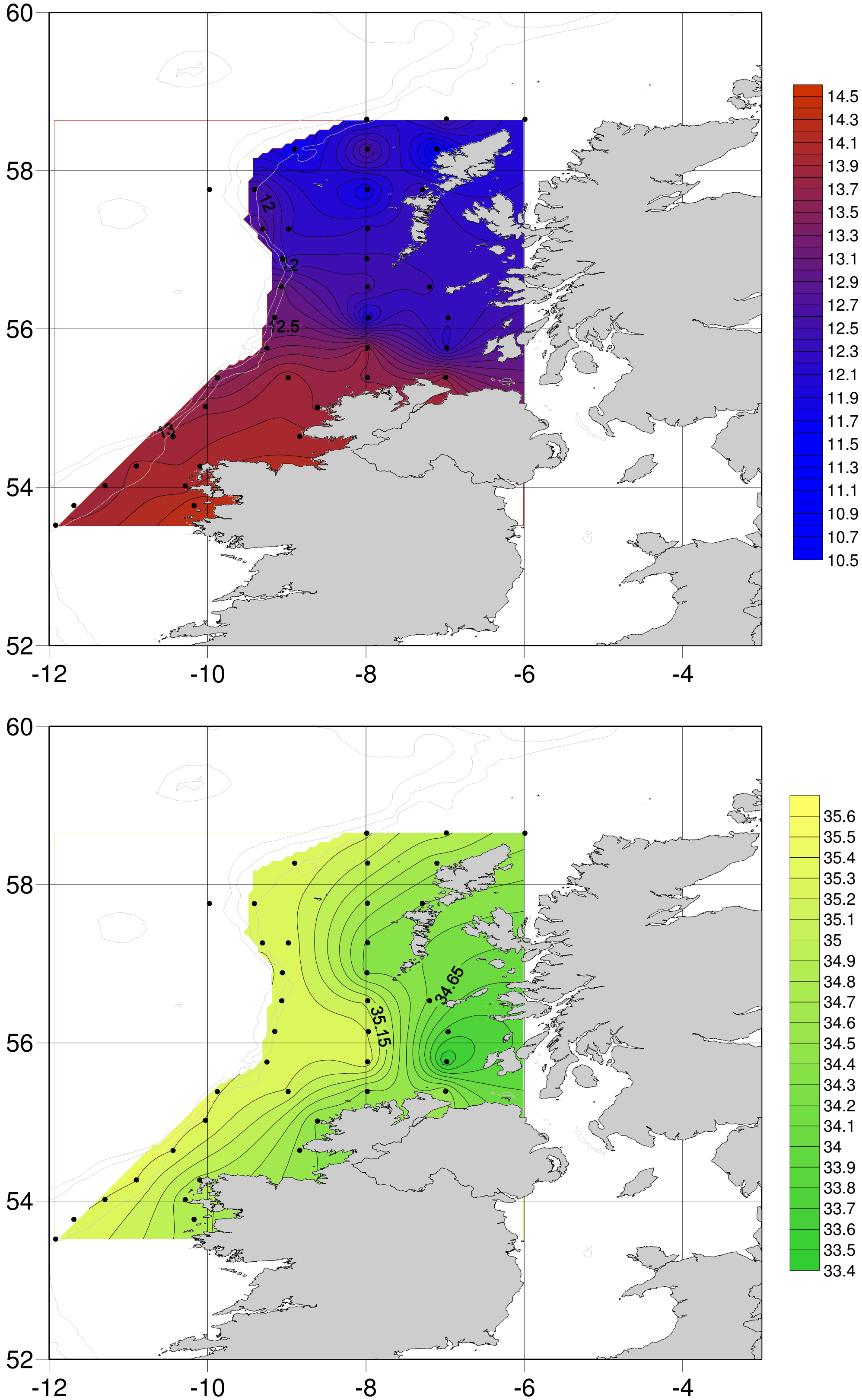


Figure 7. Horizontal temperature (top panel) and salinity (bottom panel) at 20m subsurface as derived from vertical CTD cast data. Northwest herring survey, June 2011.

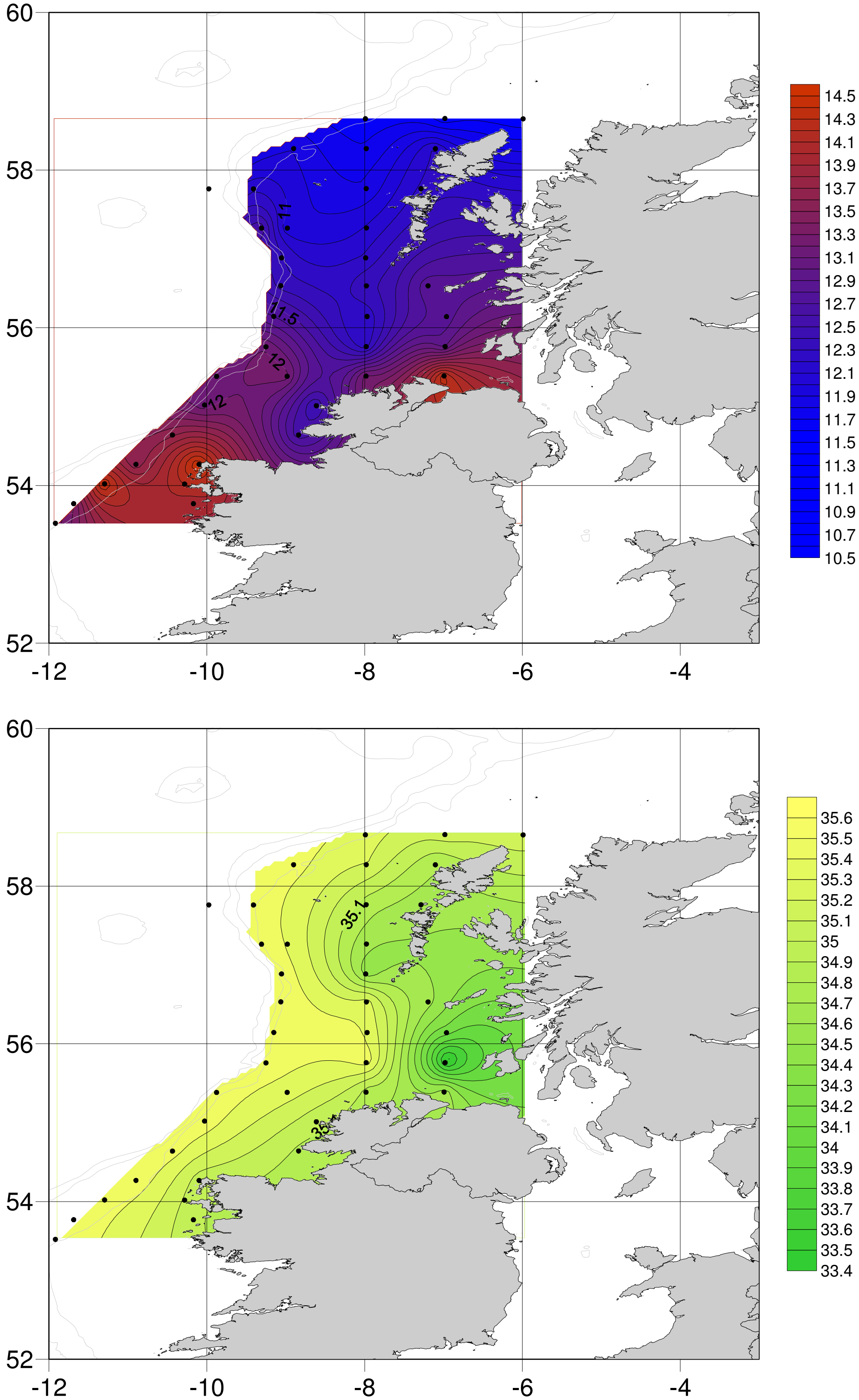


Figure 8. Horizontal temperature (top panel) and salinity (bottom panel) at 40m subsurface as derived from vertical CTD cast data. Northwest herring survey, June 2011.

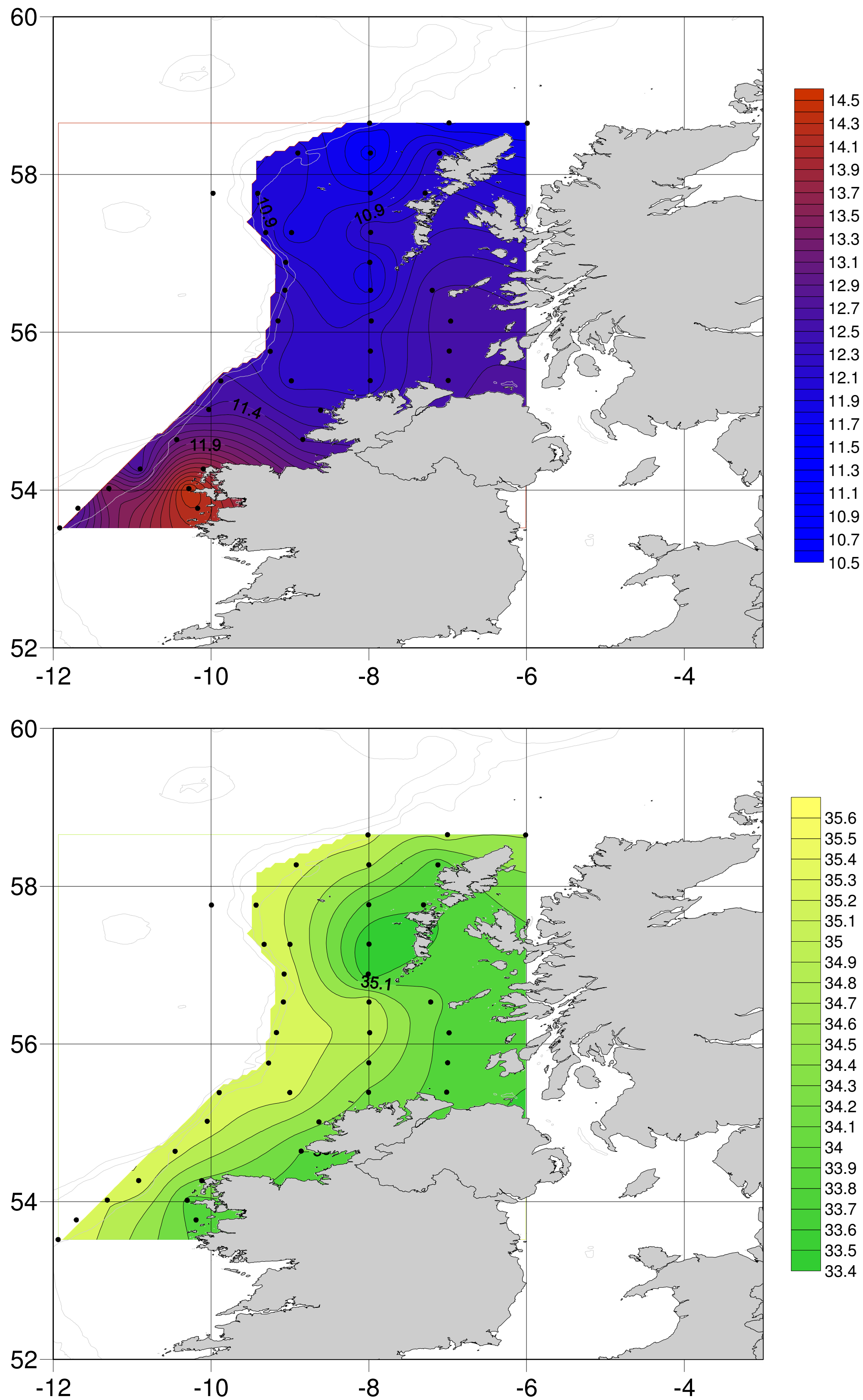


Figure 9. Horizontal distribution of temperature (top) and salinity (bottom) at 60m depth. 100 m depth contour shaded. Northwest herring survey, June 2011.

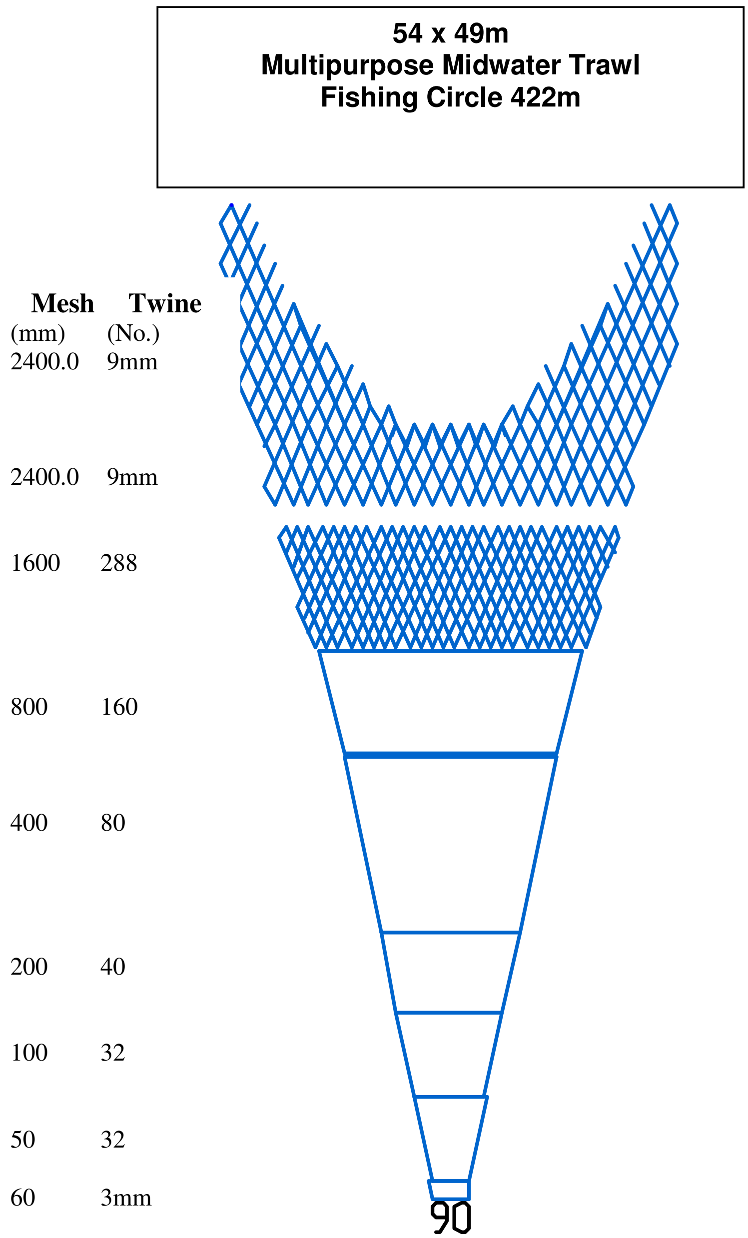


Figure 10. Celtic Explorer multi-purpose midwater trawl employed during the Northwest herring acoustic survey, June 2010.

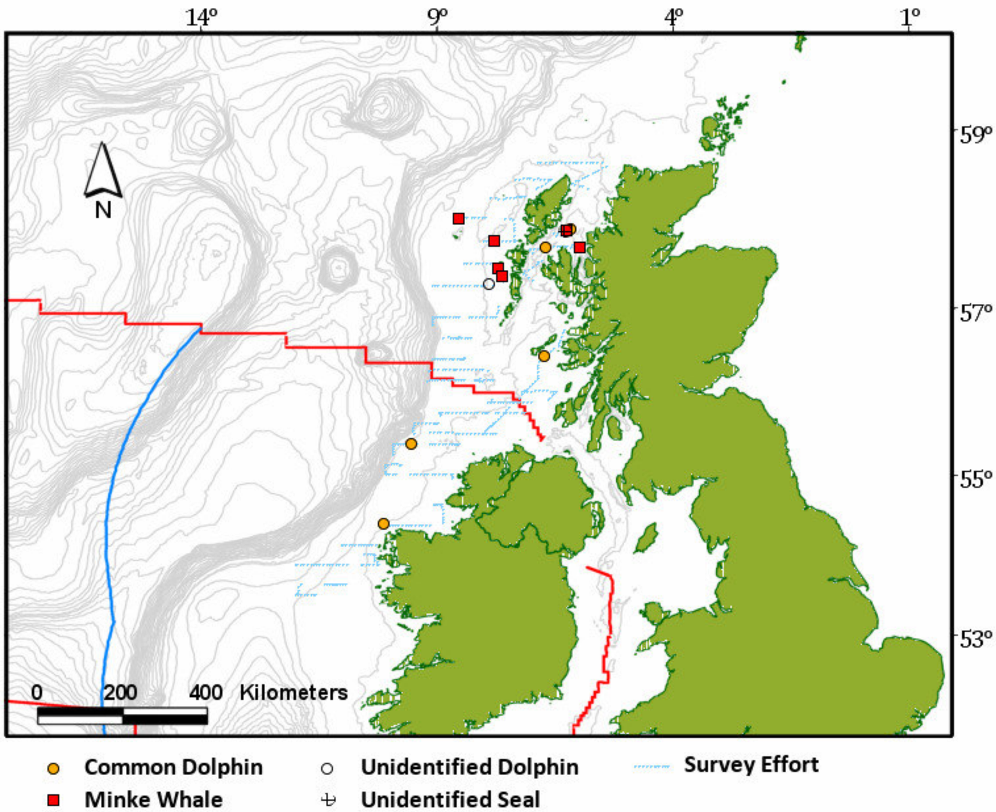
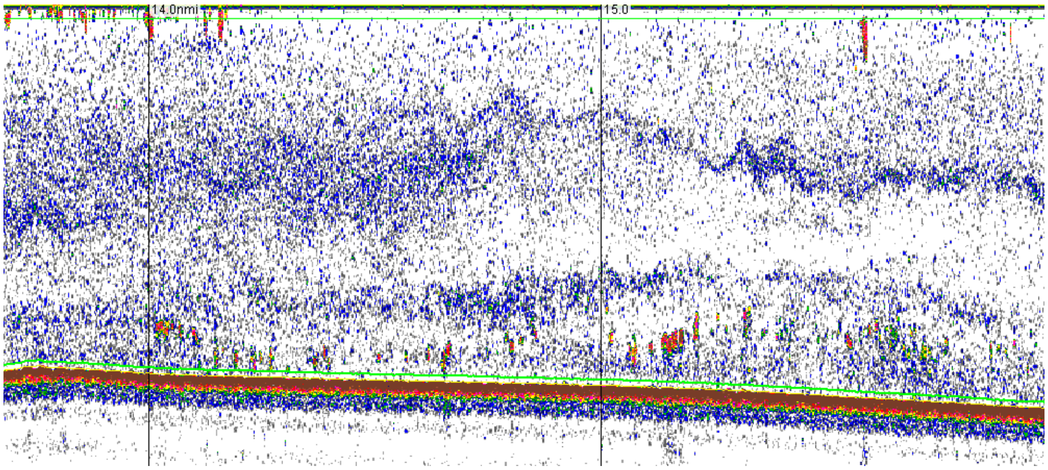
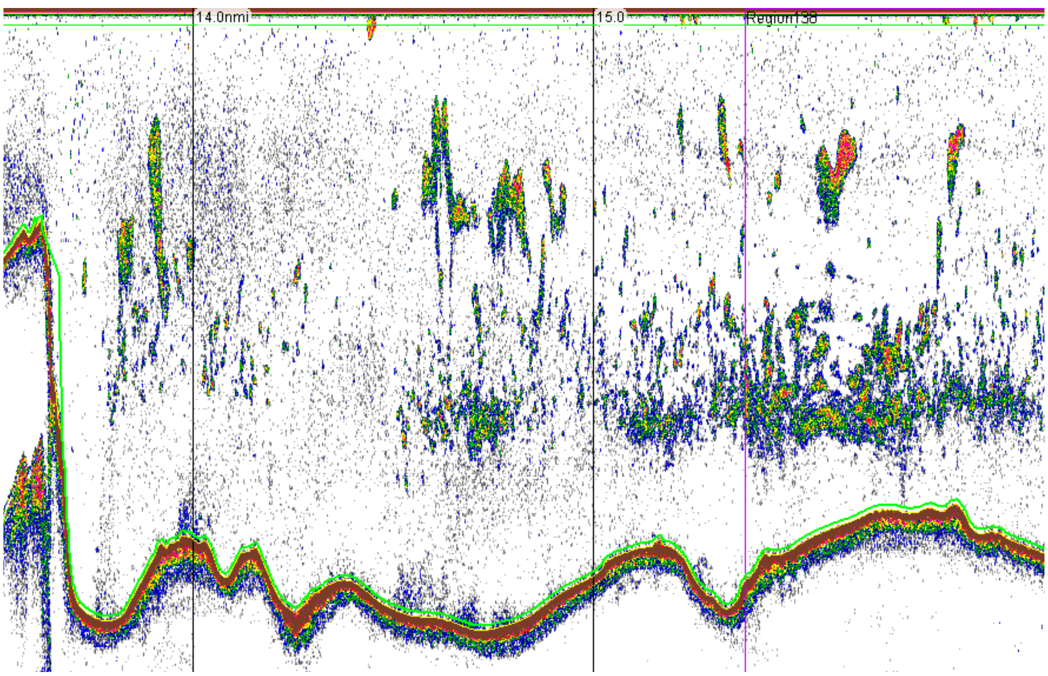


Figure 11. Distribution of ceatcean species recorded during the survey.

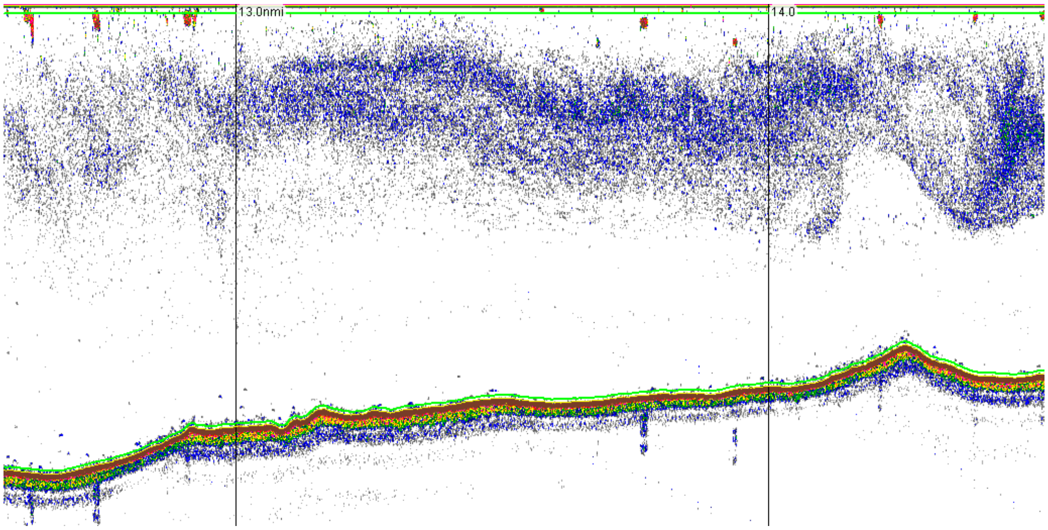
Appendix 1: Echograms prior to fishing



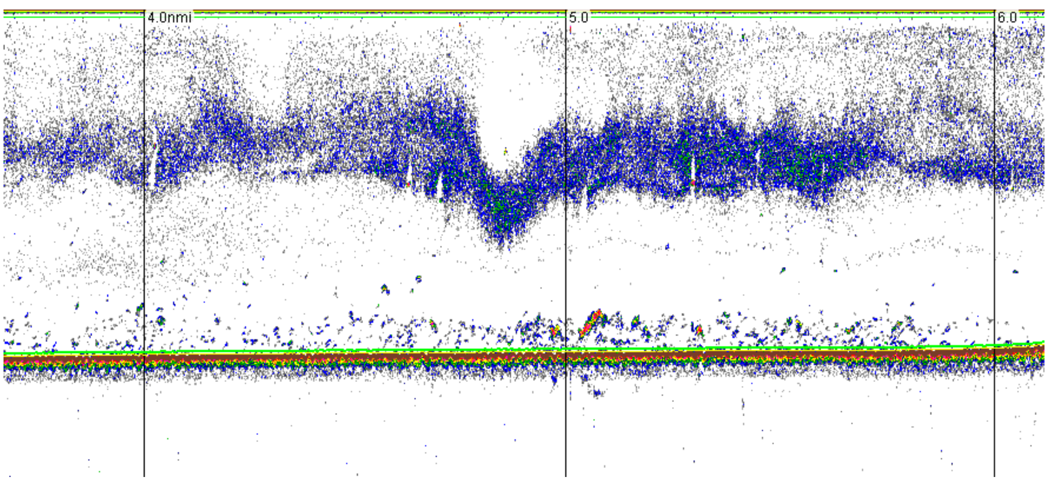
Haul 1. 19/6/11. A mixture of sprat, whiting and herring were caught at the start of the Minches.



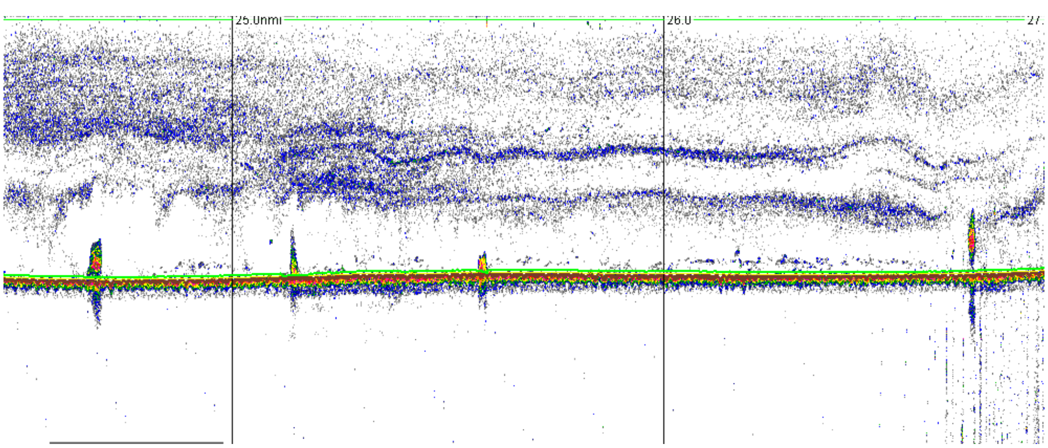
Haul 2. 19/6/11. Mid-water net haul off Mull in the Minches. Main targets were missed and a small quantity of whiting were caught.



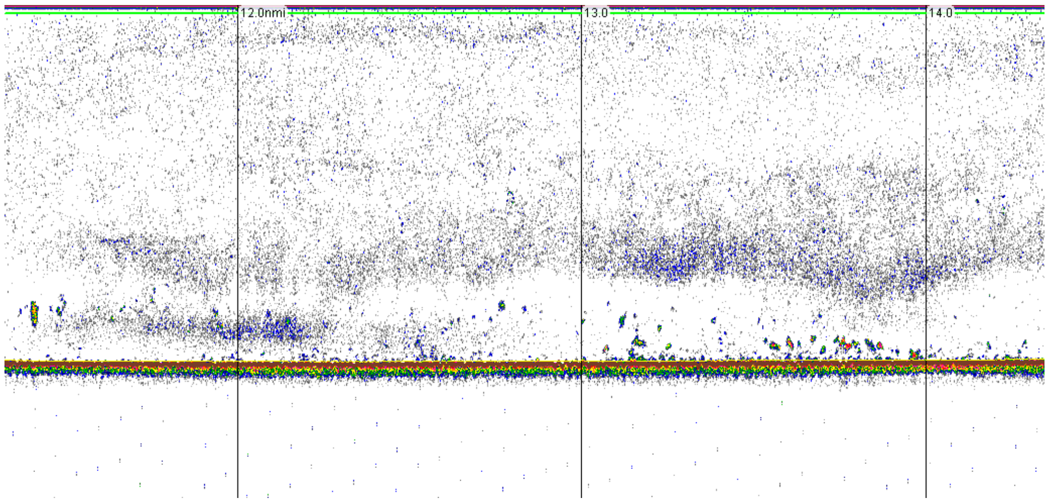
Haul 3. 20/6/11. Surface Schools west of Dunvegan Head, Minches. Main targets probably missed and haul comprised mostly jellies.



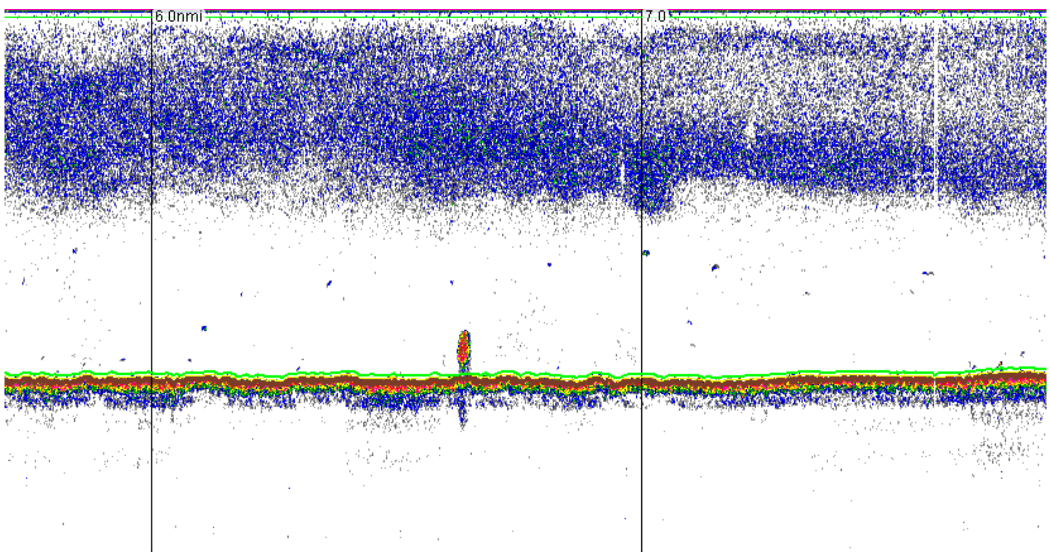
Haul 4. 23/6/11. Mixture of herring and blue whiting close to the seabed off Lewis.



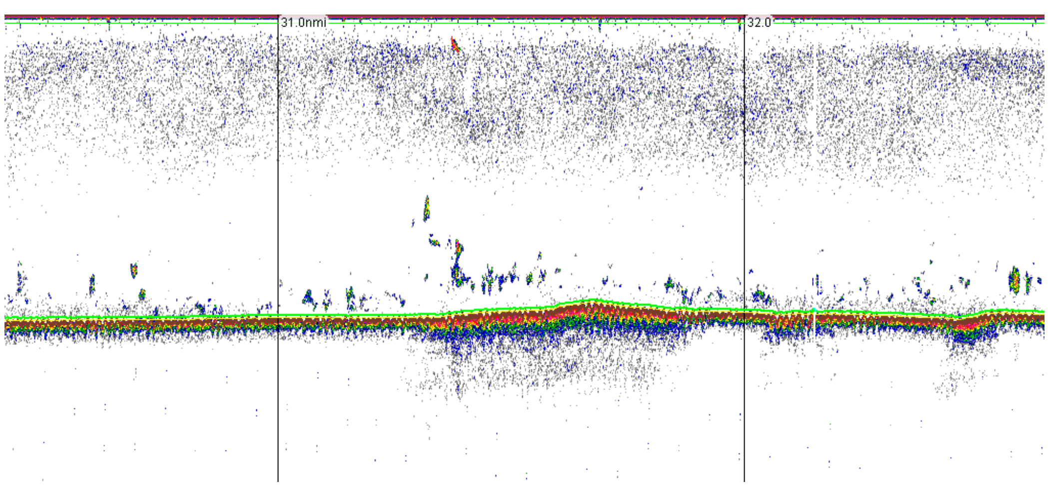
Haul 5. 23/6/11. 5 ton of herring caught off Lewis.



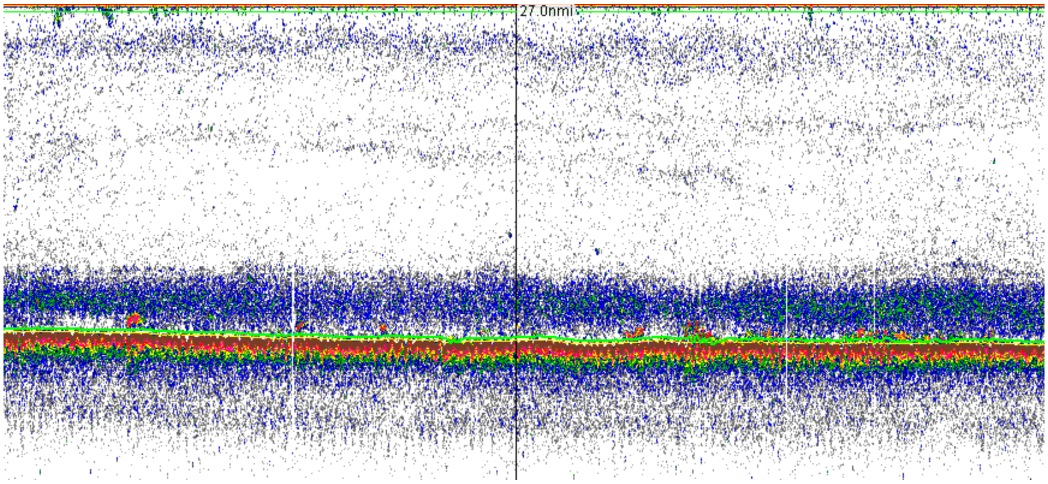
Haul 6. 24/6/11. Small schools of herring caught of Uist.



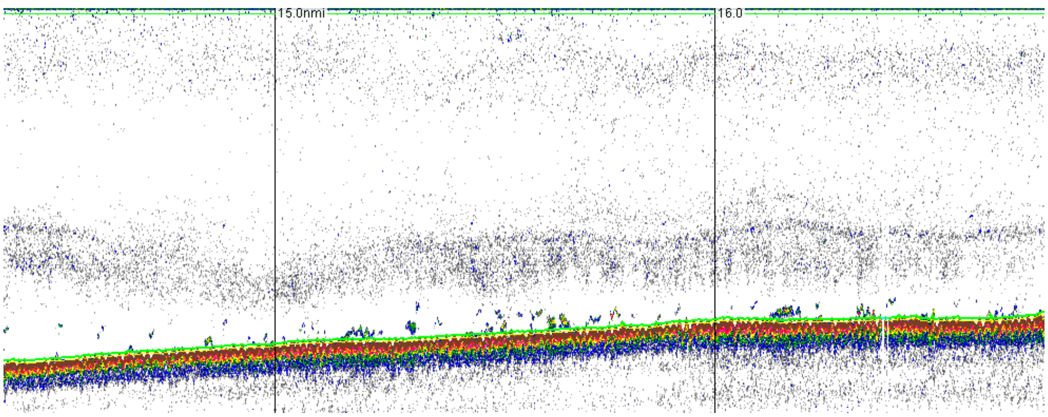
Haul 7. 24/6/11. Herring school caught off Barra.



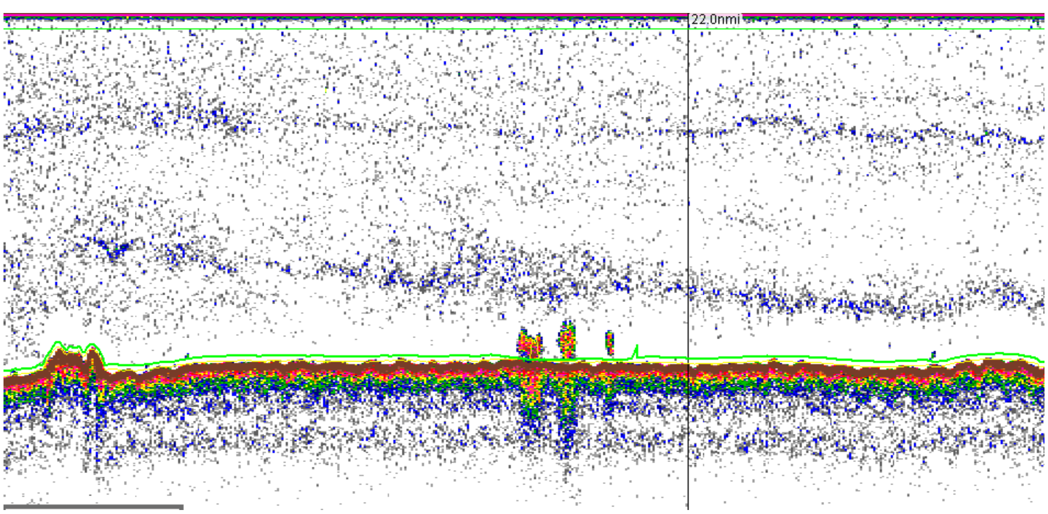
Haul 8. 25/6/11. Small schools of herring caught off Barra



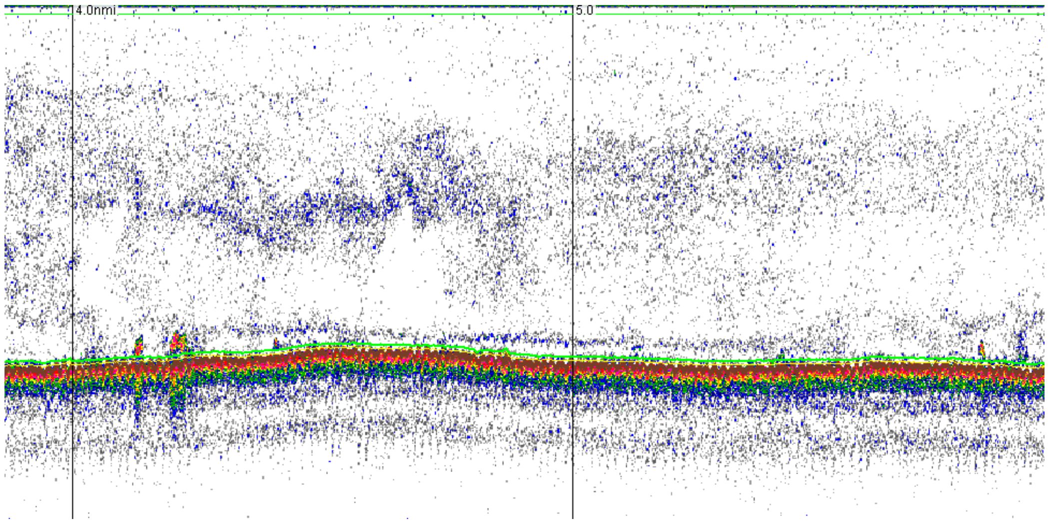
Haul 9. 26/6/11. Small herring schools along the seabed off Coll.



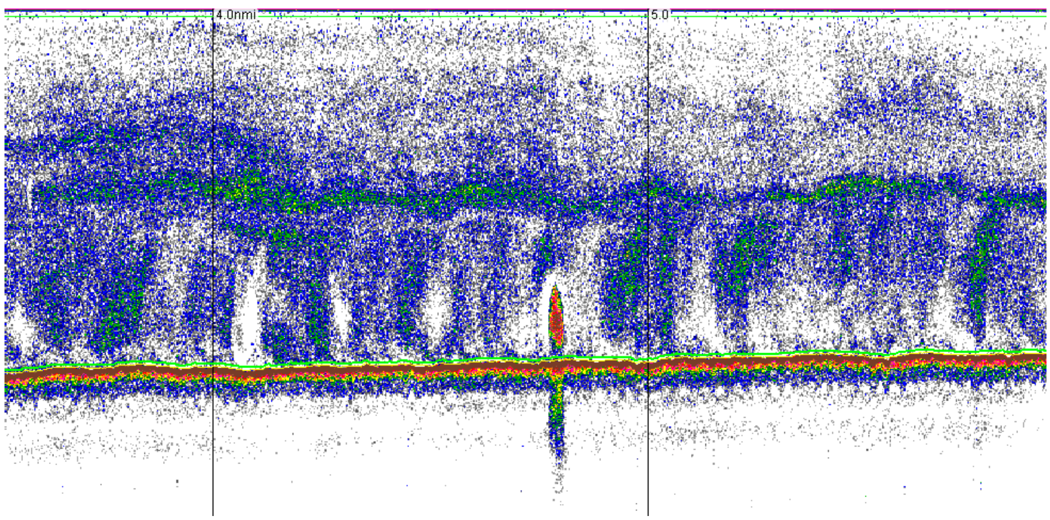
Haul 10. 27/6/11. Small schools of herring caught off Tiree.



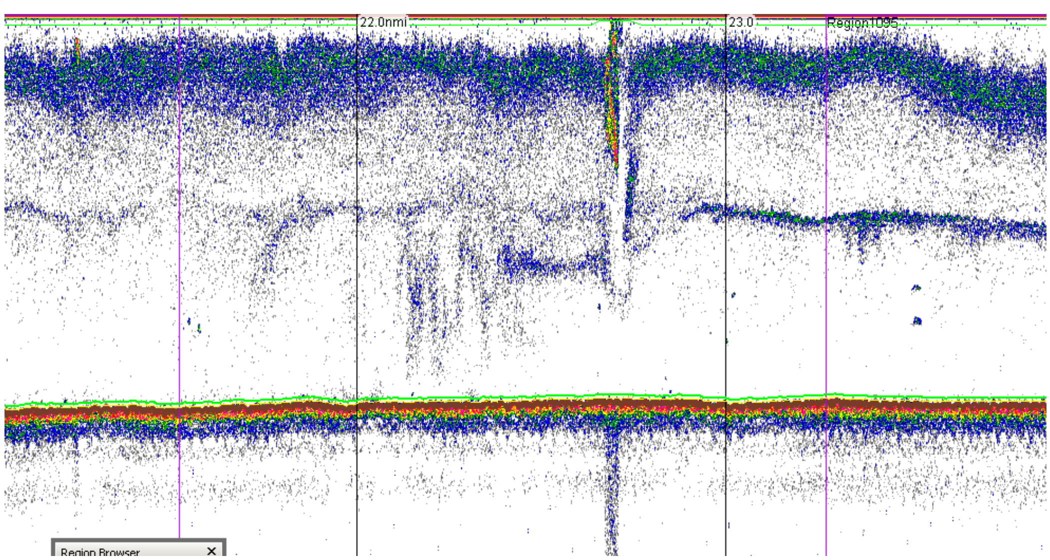
Haul 11. 27/6/11. Targets probably missed during fishing. Haul comprised mostly mackerel with around 10% herring.



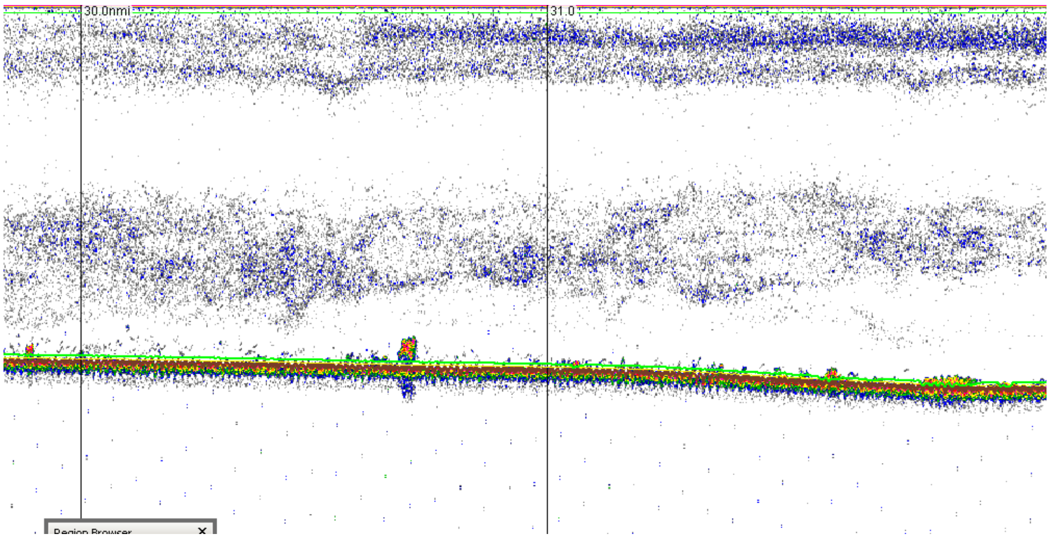
Haul 12. 28/6/11. Small schools of mackerel mixed with herring (18%) off Mull.



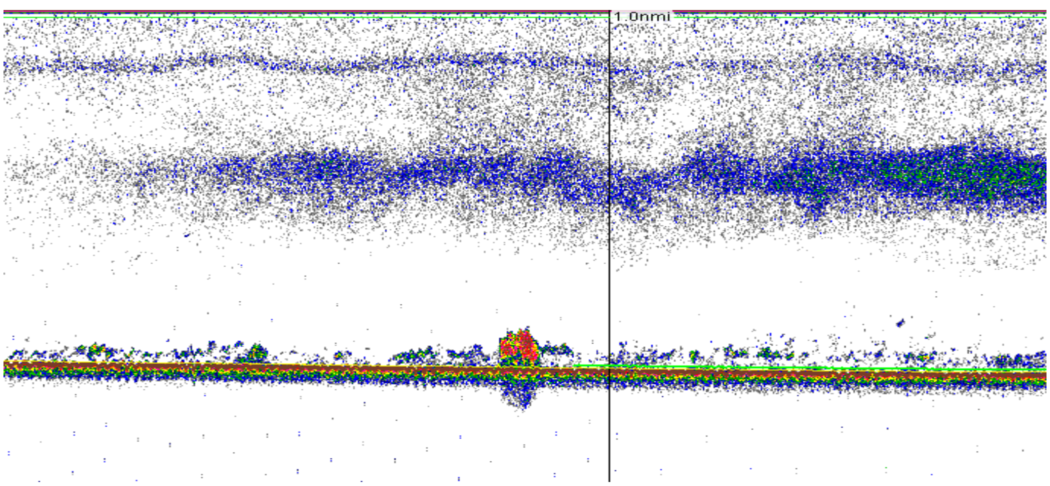
Haul 13. 28/6/11. Void net haul. Net failed to open on deployment. No targets caught.



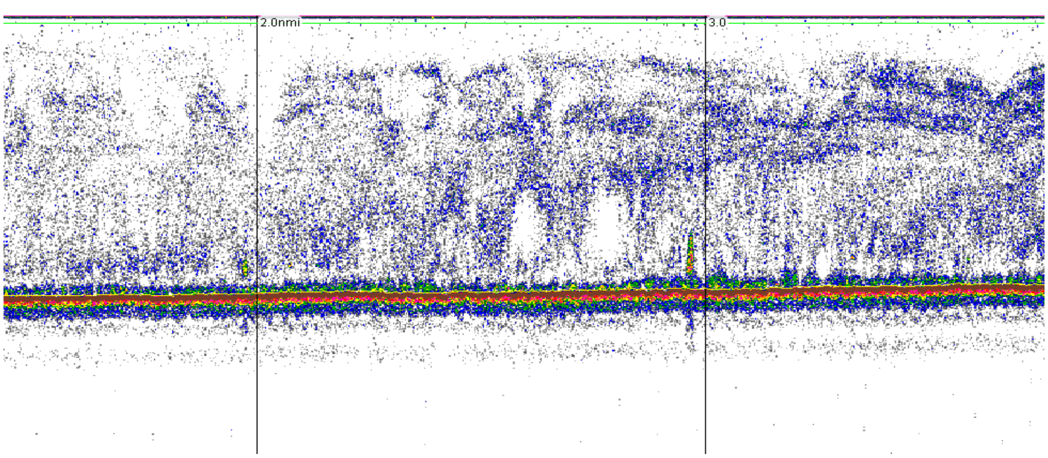
Haul 14. 28/6/11. Tall school of herring caught west of Stanton Banks.



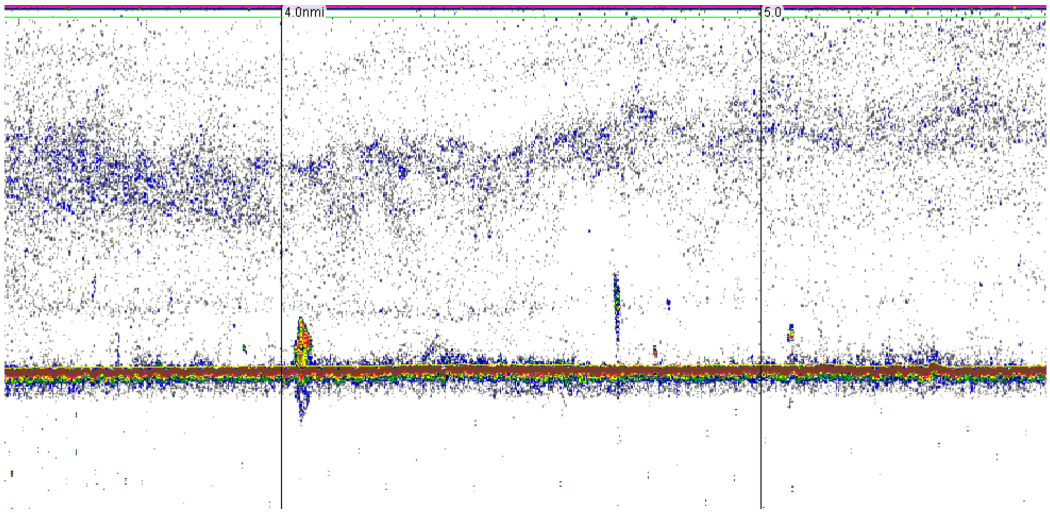
Haul 15. 29/6/11. Schools of Norway Pout caught west off Jura.



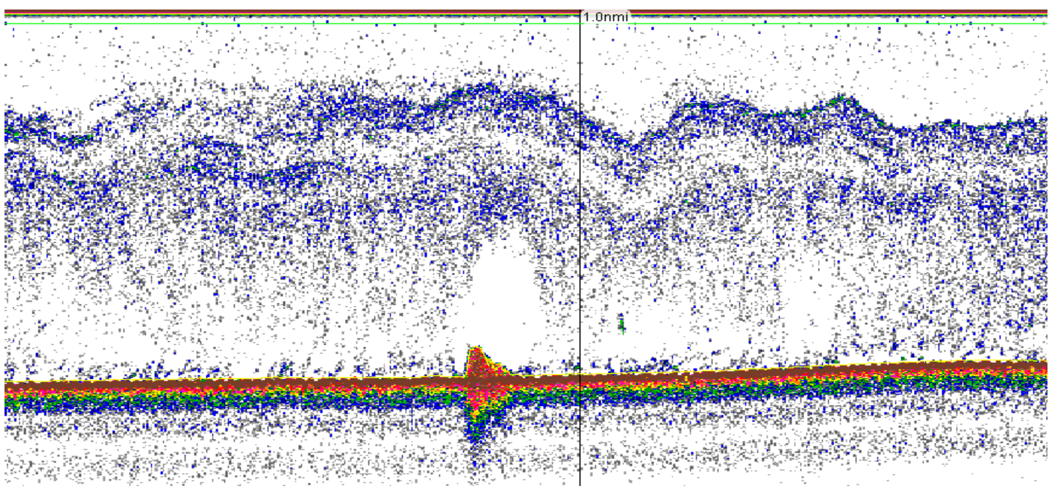
Haul 16. 29/6/11. School of Norway Pout caught west of Jura.



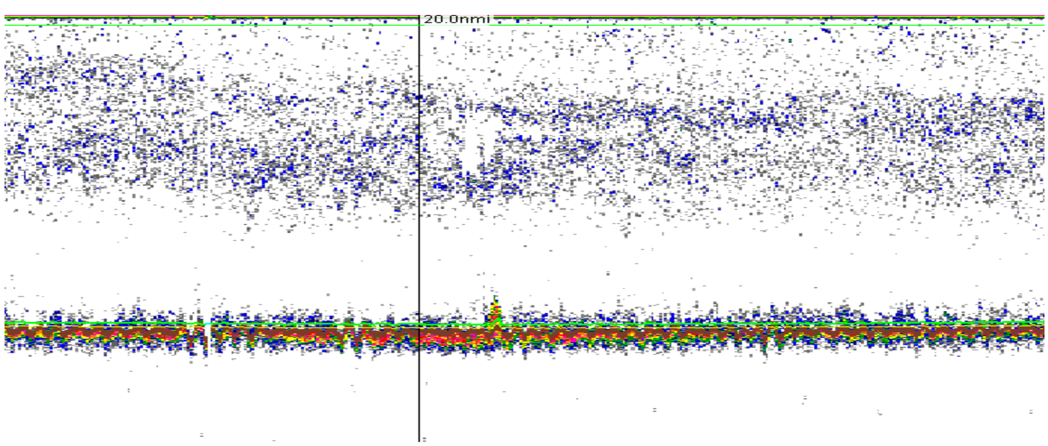
Haul 17. 30/6/11. A mixture of herring and boarfish caught tight to the seabed west of Islay.



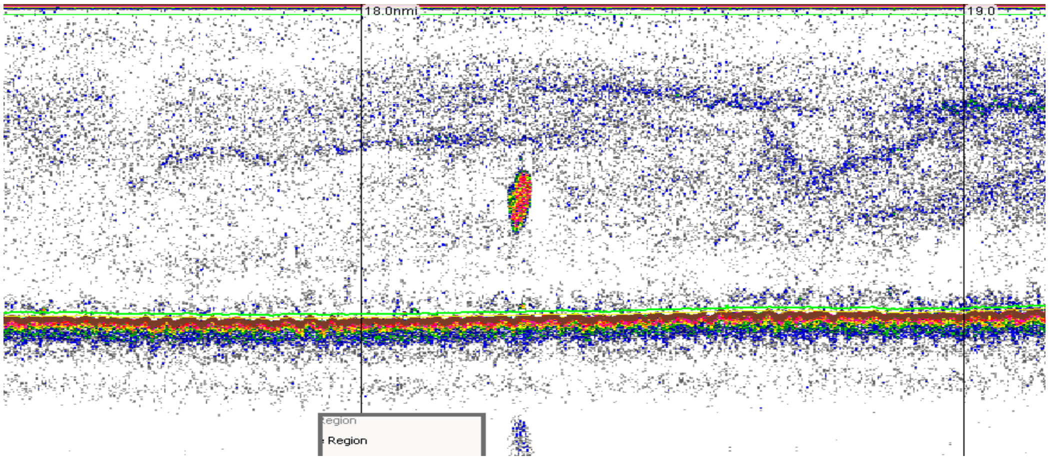
Haul 18. 30/6/11. Herring school caught 32 miles north of Horn Head.



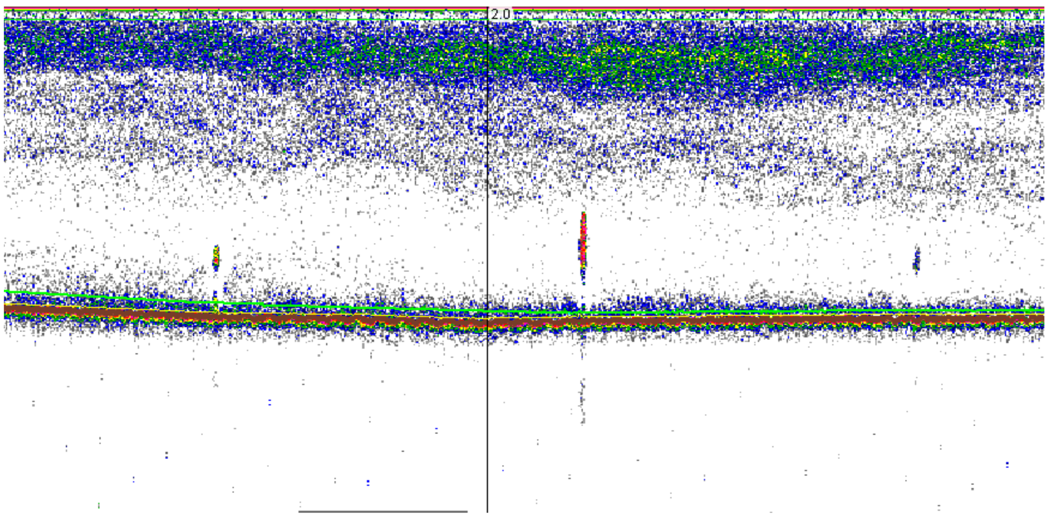
Haul 19. 1/7/11. School missed during fishing. Net catch was boarfish and mackerel.



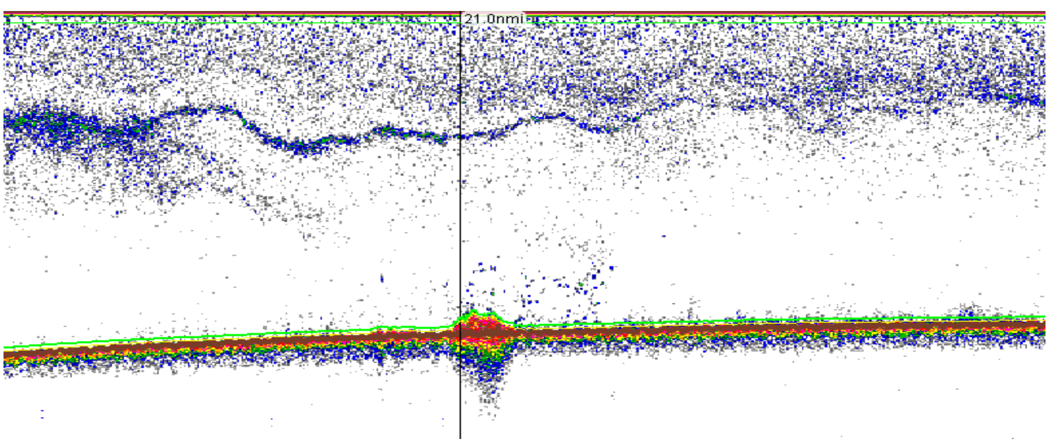
Haul 20. 2/7/11. Small schools of mackerel along the seabed with a small proportion of herring (5%). Off Donegal.



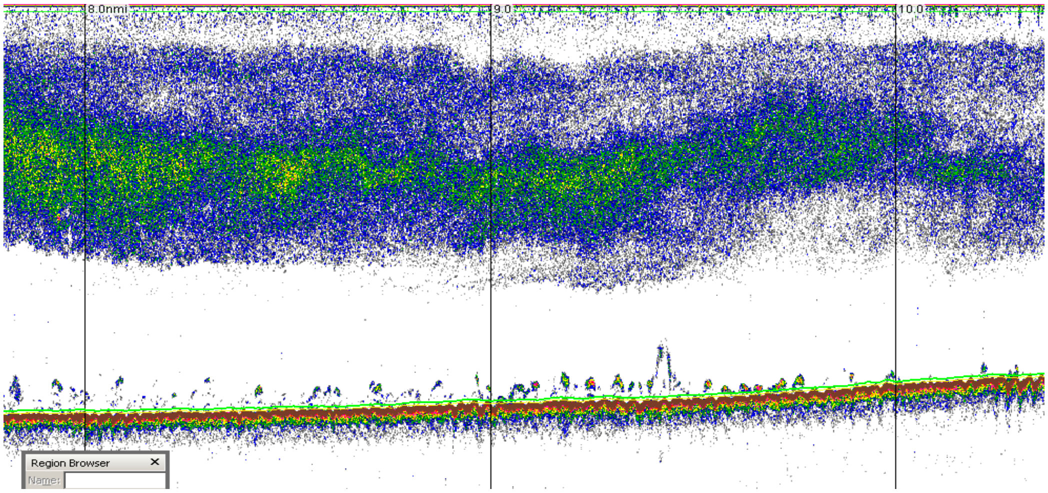
Haul 21. 2/7/11/ Target missed and zero catch.



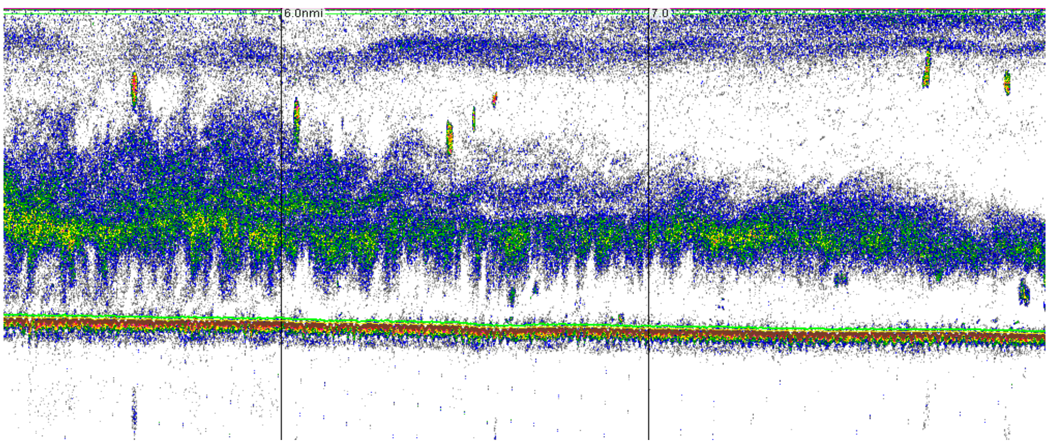
Haul 22. 3/7/11. Targets missed. Mostly mackerel in the small net catch.



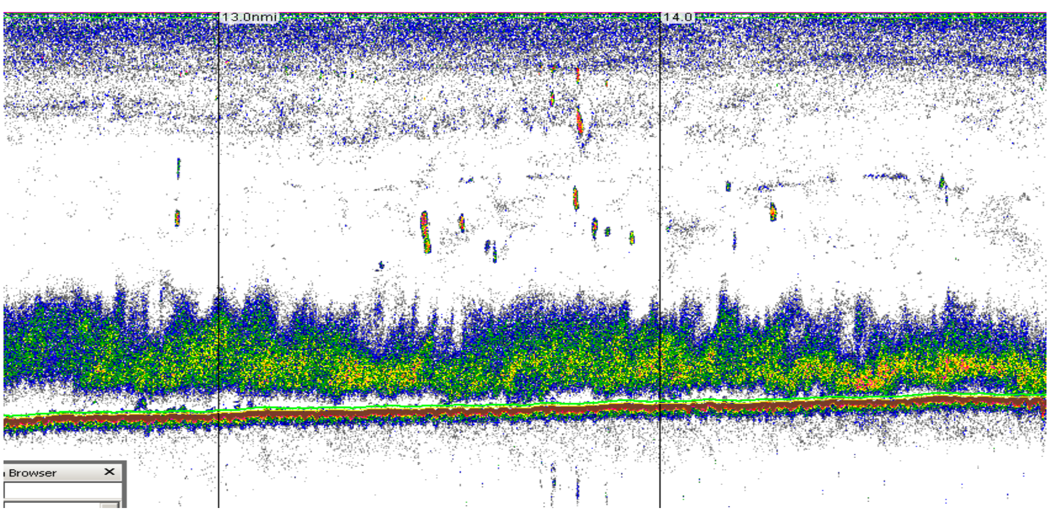
Haul 23. 4/6/11. School of horse mackerel pressed close to the seabead off Mayo



Haul 24. 6/7/11. Mixed species caught west of Achill. Net haul comprised mostly blue whiting.



Haul 25. 7/7/11. Small schools of boarfish targeted of 33 miles west of Inishboffin. Problems with net sounder resulted in low catch.



Haul 26. 7/7/11. Schools of boarfish caught off Mayo.