FSS Survey Series: 2010/03

Northwest Herring Acoustic Survey Report

18 June – 07 July, 2010

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 2010 survey represents the third in the new time series (est. in 2008). The Irish component was carried out concurrently with the West of Scotland (MarLab) and Irish Sea surveys (AFBI) and 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

Organisation	Name	Capacity
FSS	Ciaran O'Donnell	Acoustics (SIC)
FSS	Eugene Mullins	Acoustics
FSS	Susan Beattie	Acoustics
GMIT	John Boyd	Acoustics
FSS	Mairead O'Sullivan	Biologist (Deck Sci)
FSS	Nigel Griffen	Biologist
FSS	Robert Bunn	Biologist
FSS	Michael McAuliffe	Biologist
IWDG	Laura Kavanagh	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)

2.2.2 Area of operation and survey design

The survey focused on the northwest and west coast of Ireland (ICES Divisions VIaS & VIaN and VIIb) as shown in Figure 1. The survey track commenced in the south and worked progressively northwards.

To keep in line with existing survey methodology (MarLab West of Scotland survey) acoustic surveying was only undertaken between 04:00 and 00:00 (daylight hours).

A systematic parallel transect design was adopted with a randomised start point. Transects were positioned running perpendicular to the lines of bathymetry where possible. Offshore, transects extended to the 250m depth contour and inshore to approximately the 30m depth contour. Transect spacing was set at 5nmi (nautical miles) in the main body of the survey and at 15nmi where transects were interlaced with the other vessels.

In total, the survey accounted for 2,004nmi (nautical miles), with 1,884nmi 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 ER60 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 3.3m below the vessels hull or 8.8m below the sea surface. Three additional operating frequencies were used during the survey (18, 120 and 200kHz) for trace recognition purposes, with the 38kHz data used solely to generate the abundance estimate.

While on survey 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 are employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

The ER60 was calibrated in Killary Harbour on the 19 June at the start of the survey. The results of the calibration are presented in Table 1. Prior to this the ER60 was last calibrated in March 2010 (O'Donnell *et al,* 2010).

2.3.4 Acoustic data acquisition

Acoustic data were observed and recorded onto the hard-drive of the processing unit. The "RAW files" are logged via a continuous Ethernet connection as "EK5" files to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external HDD and copied to DVD. Sonar Data's Echoview® Echolog (Version 4.8) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location are recorded for each transect start/end position within each strata. This log is used to monitor "off track events" during fishing operations and hydrographic stations.

2.3.5 Echogram scrutinisation

Acoustic data is backed up every 24 hrs and scrutinised using Sonar data's Echoview® (V 4.8) post processing software. Partitioning of data into the above categories was largely subjective and was viewed by scientists experienced in viewing echograms.

The NASC (Nautical Area Scattering Coefficient) values from each herring region were allocated to one of 4 categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

1. "<u>Definitely herring</u>" 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. "<u>Probably herring</u>" were attributed to smaller echo-traces that had not been fished but which had the characteristic of "definite" herring traces.
3. "<u>Herring in a mixture</u>" 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. "<u>Possibly herring</u>" were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

The "EK5" files were imported into Echoview for echo 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.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the 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 and an attempt was made to target marks in all areas of concentration not just high density shoals. 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 1m 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, 2010. 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

$B_T = \sum_{k}^{track \cdot fragment} \bar{n}_k w_k$, where w_k is a factor that takes into account the factors for transect and strata averaging, i.e., $w_k = \frac{1 n.mi}{l_{t_k}} \frac{l_{t_k}}{\sum_{t}^{stratum.s_k} l_{s_k,t}} area_{s_k} = \frac{1}{\sum_{t}^{stratum.s_k} l_{s_k,t}} area_{s_k}$

, 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 are 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 five hauls were carried out during the survey of which 16 contained herring (Figure 2, Table 2). Over 2,170 lengths, 1,545 length/weight measurements were taken in addition to the 935 individual herring that were aged during the survey. A total of 763 photographs and 660 additional otiliths collected for the Irish component of the SGHERWAY stock identification project.

3.1.2 Herring biomass and abundance

A full breakdown of the survey stock structure is presented by strata, age, length, biomass, abundance and area in Tables 4, 5 & 6 and Figures 3 & 4.

Herring	Abund (mils)	Biomass (t)	% contribution
Total estimate			
Definitely	371	54,201	28.1
Mixture	998	118,175	61.2
Probably	199	20,603	10.7
Total estimate	**1,568**	**192,979**	100
Possibly	17	2,772	
Possible estimate	1,585	195,751	
SSB Estimate			
Definelty	366	53,738	31.6
Mixture	639	97,536	57.3
Probably	175	18,880	11.1
SSB estimate	**1180**	**170,154**	100

3.1.3 Herring distribution

A full breakdown of school categorisation, number and biomass by strata is provided in Table 9.

Reference to ICES divisions is relevant only to the statistical rectangles covered during the survey which were grouped for presentation purposes and should not be taken to represent the division as a whole.

Within VIIb, herring were found distributed as thin mixed species layers in close proximity to the bottom interspersed with several high density regions (Figure 6a). Together these mixed species layers covered a wide geographical area and provided a significant contribution to the overall VIIb biomass. Herring were most frequently encountered in waters ranging from 100-140m. In previous years (2008-9) herring were observed at the shelf edge as large easily identifiable high density schools on or close to the bottom. Such shelf edge schools (180-250m) contained herring mixed with large (>300g) mackerel in various spawning states. During this survey herring were distributed in mixed layers with juvenile blue whiting and mackerel ranging from 150-300g and were located further inshore. Numerous high density surface feeding schools of mackerel and boarfish were also present in this area (Figures 5 & 6d-e). Herring within VIIb represented some of the largest individuals encountered during the survey ranging from 24-34cm with a mode of 29cm (Table 3).

In the southern area of VIaS low density mixed layers containing herring were observed near the shelf break and further inshore near traditional inshore spawning areas. Catches were often mixed with mackerel and juvenile blue whiting in deeper waters and juvenile mackerel further inshore. Single low density herring registrations were observed north of the Killala spawning grounds as in previous surveys.

Further north, single high density herring schools dominated and were observed in clusters to the east and west of the 09ºW and the 08ºW lines of latitude close inshore (Figure 3). Combined these areas contributed significantly to the VIaS biomass.

The largest contribution to the overall biomass recorded during the survey was distributed within the southern area of VIaN. Herring biomass was found composed of both single high density herring schools of mature fish and as mixed species high density scattering layers observed over several miles (Figure 6a). Biomass was distributed mainly in waters of 80-180m between 56º-57ºN. Juvenile herring (1-group) were well represented in catches to the east of 07ºW and so are prominent in the overall survey biomass (Figure 2, Table 3).

3.1.4 Herring stock structure

Age analysis of biological samples showed herring within the survey area to be composed of age from 1-9 years (winter rings), as shown in Figure 4 and Table 4.

The total stock biomass (TSB) broken down by ICES division represents 57% (110,900t) in VIaN, 25% in VIaS (49,000t) and the remaining 17% (33,200) in VIIb. Overall, the stock age profile is dominated by 2-ring (29%), 1-ring (17%) and 3-ring (11%). In terms of abundance total stock numbers (TSN) proportions are 2-ring (32%), 1-ring (34%) and 3-ring (9%) as shown in Tables 5 & 6, Figure 4.

Taken individually, the age structure within each division is noticeably different. A total of 11 herring hauls and 935 aged herring were used to determine the age structure for the survey stock (Figure 2, Table 3).

Within the southern area of VIaN ages ranged from 1-9 rings and the age structure was dominated by the high proportion of 1 and 2-ring fish of the 2008-2007 year classes which represented 29% and 20% of the total biomass and 51% and 21% of the abundance. The third highest ranked age component is 5-ring (2005 year class) which accounted for 11% of biomass and 6% of abundance.

In VIaS, ages ranged from 1-8-rings and were dominated by a high very proportion of 2-ring fish representing 60% of the total biomass and 66% of the abundance for this division. Three and 4-ring fish ranked second and third respectively contributing a much smaller proportion of 16% and 10% to the biomass and 14% and 8% to the abundance.

The northern area of VIIb was found to contain herring ranging from 2-9-rings and contained the highest relative contribution of older fish overall. Dominant age classes were ranked as 4, 5 and 3-rings representing 17%, 16% and 15% of the biomass and 18%, 15%, 17% of the abundance.

Combined maturity analysis indicates that 12% of the TSB is considered immature with a corresponding 25% of the TSN. In terms of biomass the SSB is 170,154t with a corresponding SSN of 1,180 million individuals. Maturity staging showed individuals from stage 1-4 and 8, with stage 2 and stage 8 as the most frequently encountered (Figure 4).

Overall, VIaN was found to contain the largest proportion of immature herring representing 20% of the biomass and 38% of the abundance for this area (Tables 6 & 7). Within VIaS and VIIb, which contained comparable biomass, proportions of immature fish were similar representing 1% of the total.

3.2 Secondary species

3.2.1 Boarfish

Boarfish (*Capros aper*) were encountered from 100-250m in two areas of distribution in the (Figure 5). The main area of abundance was located in the south and was characterised by numerous high density, near surface schools occurring over a wide geographical area (Figure 6e). This area also contained the bulk of boarfish biomass in 2009 but not in the high abundance observed during this survey. Boarfish schools were distinctive in shape, density and depth profile and so were readily identified during the analysis. In the southern area a total of 323 boarfish schools were identified out of a survey total of 343, accounting for 89% of the TSB for this area (Table 10).

Overall 1,486 individual length measurements and 452 length/weight measurements were recorded from 6 hauls (Table 2). Length ranged from 10-17.5cm with a corresponding weight range of 28-121g. Mean length was 13.5cm and mean weight 54g.

Boarfish	Abund (mils)	Biomass (t)	% contribution
Total estimate			
Definitely	5,243	99,000	100
Mixture	-	-	0
Probably	-	-	0
Total estimate	5,243	99,000	100

3.2.2 Mackerel

Mackerel were the most commonly observed species on the survey and were found in 88% of hauls. Mackerel were distributed over the entire survey area as single species schools and as mixed species scattering layers. On shelf schools were composed of mixed size classes and tended towards smaller individuals (<25cm). Areas of very high abundance containing surface feeding schools were observed from 53º30-54º30N often occurring over several nautical miles (Figure 6d). Further offshore at the shelf break, larger spawning fish were encountered mainly as mixed species schools.

In total 1,209 individual lengths and 1,147 length/weight measurements were recorded for mackerel from 21 hauls. Length ranged from 21-41cm with a corresponding weight range of 111-549g. Mean length was 25.6cm and mean weight 146g.

3.3 Oceanography

A total 41 CTD casts were made during the survey (Figure 7). All data were compiled to produce horizontal plots of temperature and salinity at the following depths; 5m, 20m, 40m and 60m subsurface (Figures 8-11).

Comparing data from 2009 and 2010 both temperature and salinity are broadly similar. However, the widest range of data points was observed in 2010, where cooler and fresher waters are more visible (Figure 12). That said coastal waters to the west of Ireland appear more saline than last year and this maybe due amongst others to the degree of influence of the Irish Shelf Front. The front is present year round in this highly dynamic region and acts as a boundary region between coastal and oceanic waters further offshore. Largely defined by the 35.3 isohaline the frontal boundary is located around 11ºW and varies seasonally (McMahon *et al*. 1995). The conditions observed during the survey would indicate the stronger influence of oceanic waters in costal areas as compared to previous years.

Herring were actively feeding closer to the bottom in shallower waters as compared to previous years where more surface feeding was encountered. Herring distribution overlapped with cooler more saline waters. Conditions at the shelf edge appeared slightly warmer than those recorded on shelf and this may have influenced the distribution of herring. Normally prominent high density shelf edge schools in the south were found closer to shore than in previous years and spread thinly over a wide geographical area. The

The prominence of the Islay Front is again evident in 2010 with influence noticeable to a depth of 60m plus (Figure 11).

3.4 Marine mammal and seabird survey

3.4.1 Cetacean activity

Eighty five hours of survey time were logged, with 60 hours (70.6%) at Beaufort Sea state three or less, 19 hours (22.4%) at sea state four and 6 hours (7%) at sea state five or higher.

Fifteen sightings were recorded, of at least four cetacean species and one species of elasmobranch totalling one hundred and twelve individual animals (Figure 15). Six sightings, totalling nineteen animals were made outside of logged hours.

Identified cetacean species included common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*), white-beaked dolphin (*Lagenorhynchus albirostris*) and minke whale (*Balaenoptera acutorostrata*) as shown in Table 12.

The identified species of elasmobranch was the basking shark (*Cetorhinus maximus*); a large male (7m+) was taken as by-catch at the surface during trawling, outside of logged hours (Figure 16). The animal was released alive but unfortunately injured although every effort was made to release the animal unharmed. A sample of the sharks mucous was taken for future genetic analysis.

One group of dolphins and one whale sighted together, outside of logged hours, could not be identified as they were observed too briefly in rough conditions (Beaufort Sea state 6+ and heavy swells).

Common dolphins were the most commonly encountered and abundant species recorded during the survey. Minke whale was the only species of whale encountered.

3.4.2 Environmental conditions

Environmental data was collected at 394 stations. Beaufort Sea state was recorded at ≤ 3 at 70.3% of the environmental stations and at ≥ 4 at 29.7% of the stations. Visibility of ≤ 5km was recorded at 1.3% of the stations, 6 – 10km at 15% of the stations, 11 – 15km at 92% of the stations, and at 16 – 20km+ at 71.5% of the stations. No swell was recorded at 41.1% of the stations, a light swell of 0 – 1m was recorded at 49.5%, a moderate swell of 1 – 2m at 5.6% and a heavy swell of 2m+ at 3.8% of the stations. No precipitation was recorded at 98% of the stations, with rainfall recorded at 2% of the stations.

Five and a half survey days were lost due to bad weather (sea state 6+, heavy swell of 2m+ and low visibility ≤ 500m) and one half day was lost while the ship anchored at Killary 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 (Figure 17).

Barn swallow (*Hirundo rustica),* Collared dove (*Streptopelia decaocto),* Fulmar (*Fulmarus glacialis),* Gannet (*Morus bassanus),* Great black backed gull (*Larus marinus),* 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),* Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), Shag (*Phalacrocorax aristotelis*), Storm petrel (*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. A total of 163nmi was dropped from the original survey design. Of this 93nmi occurred in the northern channel, an area that was to be co-surveyed with the RV *Corystes*. However, due to the significant time lag between vessels (9 days) effort was reallocated further north. The remaining 70nmi of track was dropped in the northern extreme due to time allowances caused by poor weather and trawl gear damage.

Within divisions VIaS & VIIb detected biomass increased by 4% from 2008-2009 and by 77% from 2009-2010 for comparable area coverage, timing and transect spacing. The estimate of abundance should be considered as robust due to the high level of ground coverage and trawling achieved in areas of high herring abundance especially regarding mixed species layers. The survey derived age profile closely resembles that observed from commercial sampling and has successfully tracked the progress of the strong 2008 year class. That said the VIIb the estimate may be an underestimate, though not considered large, due to uncertainties in whether the stock was fully contained within the southern limit.

In 2010 area coverage increased by approximately 5,000nmi^2 (to 14,600nmi^2) from previous years due to extension into VIaN. Over 57% of the TSB for the survey was located within VIaN in an area co-surveyed with the Scottish vessel. Both vessels showed good temporal and spatial alignment and trawling was undertaken to ensure a high degree of precision and area coverage. At the time of writing the results from the Scottish survey were not available for comparison.

Herring distribution was generally observed as numerous low/medium/high density registrations carpeted over a wide geographical area. The presence of cooler, more saline water on self may have influenced distribution over a wider area than normally observed. This carpeting effect when combined with high transect resolution would increase survey precision by increasing the 'hit' rate and reduced number of zero data points per ESDU. Overall, the level of precision of the estimate is considered good as reflected by the CV estimate of 25% which slightly lower than previous years.

4.2 Conclusions

Acoustically derived estimates of abundance are used as a relative index of abundance or 'snapshot' of the stock present within the survey area at the time of surveying. Variations between successive estimates are not uncommon and where possible sources of variation such as timing, area coverage and transect spacing are fixed. That said numerous biotic and abiotic factors no doubt heavily influence the distribution and feeding behaviour of herring.

Although significantly larger than previous estimates the survey findings can be considered robust due to high levels of sampling, high resolution coverage and duel-vessel coverage in areas of highest abundance.

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Table 1. Survey settings and calibration report (38kHz) for the Simrad ER60 echosounder. Northwest herring survey, June 2010.

Echo Sounder System Calibration

Vessel :	R/V Celtic Explorer	Date :	19/06/2010
Echo sounder :	ER60 PC	Locality :	Killary Harbour
Type of Sphere : WC-38,1	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) :	32 m

Calibration Version 2.1.0.11

Comments:
19.06.10

Reference Target:

TS	-33.50 dB	Min. Distance	15.00 m
TS Deviation	5 dB	Max. Distance	25.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.84 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.04 deg	Along. Beam Angle	6.99 deg
Athw. Offset Angle	- 0.03 deg	Along. Offset Angl	-0.07 deg
SaCorrection	-0.69 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.190 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 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.	9.3 dB/km	Sound Velocity	1502.4 m/s

Beam Model results:

Transducer Gain =	25.94 dB	SaCorrection =	-0.63 dB
Athw. Beam Angle =	6.68 deg	Along. Beam Angle =	6.77 deg
Athw. Offset Angle =	-0.11 deg	Along. Offset Angle=	-0.08 deg

Data deviation from beam model:
RMS = 0.23 dB
Max = 0.51 dB No. = 53 Athw. = -2.9 deg Along = -2.8 deg
Min = -0.83 dB No. = 302 Athw. = -4.0 deg Along = 2.6 deg

Data deviation from polynomial model:
RMS = 0.20 dB
Max = 0.74 dB No. = 113 Athw. = -4.6 deg Along = 1.2 deg
Min = -0.77 dB No. = 302 Athw. = -4.0 deg Along = 2.6 deg

Comments :
Flat calm conditions
Wind Force : 8 kn. **Wind Direction :** S (180 degrees)
Raw Data File: \\Expfiledstr\ER-60_Data\NWHAS_2010\RAW ER60 Files\Calibration\NWHAS_Mar_2010-D20070328-T135915.raw
Calibration File: \\Expfiledstr\ER-60_Data\ER-60\Calibrations_2010\NWHAS 2010\38 KHZ

Calibration : Ciaran O'Donnell

Table 2. Catch composition and position of hauls undertaken by the RV *Celtic Explorer*. Northwest herring survey, June 2010.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Boarfish %	Others^ %
1	19.06.10	53 32.27	010 59.55	20:58	135	80	15.0		16.0		0.6	83.4
2	20.06.10	53 32.50	011 53.59	06:10	280	65	2000.0		1.0	1.0	97.9	0.1
3	20.06.10	53 37.49	010 45.52	12:40	115	0	80.0	12.6				87.4
4	20.06.10	53 42.44	010 56.43	19:43	154	134	1500.0		3.6	0.1	92.0	4.3
5	21.06.10	53 47.44	010 52.57	09:25	158	10	1800.0	2.4	7.4			91.2
6	22.06.10	54 02.28	011 07.95	10:45	226	3	400.0		1.8			98.2
7	22.06.10	54 12.39	010 41.92	20:42	181	0	168.0	2.2	42.2			55.6
8*	23.06.10	54 26.59	008 46.86	18:25	62	0	0.0					
9	24.06.10	54 32.34	010 28.23	07:44	138	0	181.5	1.8	21.0			77.2
10*	24.06.10	54 32.11	009 02.61	16:30	70	60	12.0		100.0			
11	25.06.10	54 42.19	010 18.36	10:15	116	0	200.0	0.2	11.8		87.0	1.0
12	25.06.10	54 42.20	009 14.20	15:45	93	0	200.0	7.9	27.6			64.5
13	26.06.10	54 52.09	010 07.77	06:35	118	10	1000.0		12.4		87.4	0.2
14	26.06.10	54 52.20	009 02.11	12:10	72	0	1.4	6.5	56.7			36.8
15	26.06.10	54 57.17	008 59.64	17:00	75	8	6000.0	97.7	2.3			
16	27.06.10	55 06.84	008 47.00	12:20	83	0	8.7	10.8	85.0			4.2
17	27.06.10	55 06.98	009 48.33	19:55	113	0	63.0		73.1		26.0	0.9
18	28.06.10	55 14.52	008 04.24	10:30	45	0	3000.0	44.1	55.9			
19	29.06.10	55 21.70	007 55.01	09:55	61	0	1200.0	99.4	0.5			
20	30.06.10	55.31.88	007.46.43	11:05	60	0	2.0	3.3	23.9			72.8
21	01.07.10	56.01.98	007.45.75	20:07	135	0	56.5	79.8	16.1			5.1
22	02.07.10	56.17.11	006.47.28	10:15	69	66	185.0	53.8	20.3			25.9
23	02.07.10	56 16.39	007 30.87	15:34	138	5	750.0	6.8	9.9			83.3
24	03.07.10	56 31.92	008 11.18	12:05	161	0	500.0	98.8				1.2
25*	03.07.10	56 31.91	007 40.65	16:35	173	0	0.0					

* Indicates target schools not represented in the catch. ^ Includes non target demersal species and other taxa

Table 3. Length frequency of herring hauls used in the analysis. Northwest herring survey, June 2010.

Haul #	3	5	7	9	15	18	19	21	22	23	24
Division	VIIb	VIIb	VIIb	VIIb*	VIaS	VIaS	VIaS	VIaN	VIaN	VIaN	VIaN
Length (cm)											
16									2		
16.5									3		
17									5		
17.5									14		
18									23		
18.5									29	1	
19								2	15	3	
19.5						2		3	7	8	
20						5		10	1	23	
20.5					1	6		11		19	
21						13	1	14		11	
21.5						9	3	12		5	
22					2	14	9	9		7	
22.5					7	12	13	9		2	
23					14	9	9	7		3	
23.5					11	9	21	5		7	1
24	3				27	6	15	5		5	1
24.5	4				8	6	10	7		2	1
25	1	4			8	4	8	1			
25.5	7				7	3	4	1			
26	8			6	7	2	1	1		1	1
26.5	8			6	1	1	1				1
27	15			6	1	1	1				5
27.5	8	8		28	1		1				11
28	11	4	6	22	2		1			1	12
28.5	7	8	12	11							16
29	11	36	24	17						1	19
29.5	4	20	18	6						1	17
30	11	16	24								9
30.5		4									3
31			6								1
31.5	1										
32											
32.5											
33			6								
33.5	3										
34			6								
34.5											

* Haul located in VIaS border but age profile more similar to VIIb

Table 4. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Northwest herring survey, June 2010.

Length	Age (Rings)											Abundance	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	10	(millions)	000's t	(g)
16		5.8										5.84	0.21	36.2
16.5		8.8										8.76	0.35	39.7
17		16										16.06	0.7	43.4
17.5		42										42.33	2	47.3
18		69										68.61	3.53	51.5
18.5		89										89.01	4.97	55.9
19		56										55.52	3.36	60.5
19.5		45										45.2	2.96	65.4
20		68	5.3									73.19	5.17	70.6
20.5		65	2.7									67.68	5.14	76
21		33	27									60.13	4.91	81.7
21.5		16	31									47	4.12	87.7
22		6.4	50									56.2	5.28	94
22.5		4.8	58	1.6								64.41	6.47	100.5
23		1.1	68	2.3								70.98	7.62	107.4
23.5			81	2.6								83.86	9.61	114.6
24			93	21								114.69	14	122
24.5			47	15								61.19	7.95	129.8
25			21	7	7							34.86	4.81	138
25.5			12	11	8.9							31.84	4.66	146.4
26			7.4	13	9.2	7.4						36.74	5.7	155.3
26.5				7.3	8.2	3.6				0.9		19.97	3.28	164.4
27				9.8	22	2	2					35.33	6.15	173.9
27.5				13	23	19		3.9				59.58	10.95	183.8
28				21	13	17	7.6	3.8				62.87	12.2	194.1
28.5				7.9	6.6	13	18	7.9	2.7			56.69	11.6	204.7
29				1.2	2.5	22	28	12	9.8	6.2		82.42	17.78	215.7
29.5					2.7	14	15	14	11	4		59.39	13.49	227.1
30					4.6	3.5	5.7	15	8	3.5		40.06	9.57	238.9
30.5						1.3	5.3	1.3	1.3			9.36	2.35	251.1
31										2.9		2.9	0.77	263.7
31.5							1.2					1.16	0.32	276.7
32												0.0	0.0	0.0
32.5												0.0	0.0	0.0
33							0.4					0.35	0.11	318.4
33.5									2.3			2.31	0.77	333.2
34									0.4			0.35	0.12	348.4
SSN		152	496	133	106	102	84	57	35	15		**1179.14**		
SSB		12	55	21	19	21	18	13	8.2	3.2			**170.1**	
Mn wt (g)		63	111	158	179	201	218	220	234	228				
Mn L (cm)		19	23	26	27	29	29	29	30	30				

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

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
D9 36	0	0	0.9	2.2	2.8	2	1.8	1.3	1.3	0.4	0	12.7
D8 36	0	0	0.4	1	1.4	1.9	2	1.5	1.1	0.4	0	9.8
D8 37	0	0	0	0	0	0	0	0	0	0	0	0
D9 37	0	0	0	0.4	0.5	0.6	0.6	0.4	0.3	0.2	0	3
E0 37	0	0.1	2.9	1.2	0.9	0.7	0.4	0.2	0.1	0	0	6.5
E1 37	0	0	0.8	0.2	0.1	0	0	0	0	0	0	1.2
E1 38	0	0	0.3	0.1	0	0	0	0	0	0	0	0.5
E0 38	0	0.2	10	3.1	1.8	1	0.3	0.2	0.1	0	0	16.7
D9 38	0	0	0	1.1	1.2	1.4	0.8	0.5	0.2	0.1	0	5.3
E0 39	0	0	0.5	0.1	0.1	0	0	0	0	0	0	0.8
E1 39	0	0.6	6.7	1.6	0.9	0.3	0	0	0	0	0	10.1
E2 39	0	0.3	6.4	1.1	0.6	0.2	0	0	0	0	0	8.5
E3 40	0	0	0.9	0.2	0.1	0	0	0	0	0	0	1.2
E2 40	0	0.2	4.1	0.7	0.4	0.1	0	0	0	0	0	5.4
E1 40	0	0	0.3	0	0	0	0	0	0	0	0	0.4
E0 40	0	0	0	0	0	0	0	0	0	0	0	0
E0 41	0	0	0	0	0	0	0	0	0	0	0	0
E1 41	0	5	9.7	2	1.6	2.1	2	1.5	0.9	0.5	0	25.2
E2 41	0	9.5	10	1	0.3	0.3	0.2	0.2	0.1	0.1	0	21.7
E3 41	0	15.2	0	0	0	0	0	0	0	0	0	15.2
E2 42	0	2	1.5	2.3	2.8	4.4	4.4	3.1	1.8	1	0	23.2
E1 42	0	0	0.6	2.8	3.6	5.5	5.6	3.9	2.3	1.3	0	25.6
Total	0	33.1	56.0	21.0	19.2	20.7	18.2	12.7	8.3	4.0	0.0	193.0
TSB %	0	17.1	29.0	10.9	9.9	10.7	9.4	6.6	4.3	2.1	0.0	100.0
VIaN	0.0	28.6	19.7	7.3	7.5	11.1	11.0	7.8	4.6	2.6	0.0	100.0
VIaS	0.0	2.7	59.7	16.4	10.4	6.1	2.2	1.4	0.6	0.2	0.0	100.0
VIIb	0.0	0.3	15.1	15.1	17.2	15.7	14.5	10.2	8.4	3.0	0.0	100.0

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

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
D9 36	0.0	0.0	6.7	13.2	15.8	10.4	8.0	5.8	4.8	1.6	0.0	66.3
D8 36	0.0	0.0	2.9	5.9	7.8	9.1	9.1	6.6	4.7	1.9	0.0	47.9
D8 37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D9 37	0.0	0.0	0.1	2.0	2.5	3.1	2.7	1.8	1.3	0.8	0.0	14.3
E0 37	0.0	0.8	24.2	8.0	5.5	3.9	1.7	1.0	0.4	0.2	0.0	45.8
E1 37	0.0	0.2	6.7	1.6	0.7	0.3	0.0	0.0	0.0	0.0	0.0	9.6
E1 38	0.0	0.1	2.8	0.7	0.3	0.1	0.0	0.0	0.0	0.0	0.0	4.0
E0 38	0.0	2.7	84.0	21.4	11.4	5.6	1.6	1.0	0.3	0.2	0.0	128.3
D9 38	0.0	0.0	0.3	5.8	6.7	7.1	3.8	2.3	1.0	0.5	0.0	27.5
E0 39	0.0	0.1	4.2	1.0	0.5	0.2	0.0	0.0	0.0	0.0	0.0	6.0
E1 39	0.0	7.1	58.3	11.5	5.5	1.9	0.2	0.1	0.0	0.0	0.0	84.7
E2 39	0.0	3.0	56.5	8.0	3.6	0.9	0.1	0.1	0.0	0.0	0.0	72.2
E3 40	0.0	0.4	8.0	1.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	10.2
E2 40	0.0	1.9	35.8	5.1	2.3	0.6	0.1	0.1	0.0	0.0	0.0	45.8
E1 40	0.0	0.1	2.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3.0
E0 40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E0 41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E1 41	0.0	65.3	94.0	13.0	8.9	10.3	9.4	6.5	3.9	2.0	0.0	213.1
E2 41	0.0	129.8	98.5	7.5	1.8	1.6	1.1	0.7	0.5	0.2	0.0	241.8
E3 41	0.0	281.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	282.1
E2 42	0.0	31.1	13.6	12.4	14.8	21.2	20.3	13.8	8.2	4.3	0.0	139.6
E1 42	0.0	0.4	5.0	15.0	18.7	26.7	25.7	17.5	10.3	5.5	0.0	124.8
Total	0.0	524.8	504.3	133.3	107.4	103.0	83.7	57.6	35.3	17.5	0.0	1566.8
TSN %	0.0	33.5	32.2	8.5	6.9	6.6	5.3	3.7	2.3	1.1	0.0	100.0
Cv (%)	NA	67	25.6	25	30	35.3	40.2	40	40.5	40.7	NA	NA
VIaN	0.0	50.8	21.1	4.8	4.4	6.0	5.6	3.9	2.3	1.2	0.0	100.0
VIaS	0.0	4.1	66.1	14.4	8.1	4.3	1.5	1.0	0.3	0.2	0.0	100.0
VIIb	0.0	0.5	22.1	16.6	17.6	14.6	11.7	8.3	6.1	2.5	0.0	100.0

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

Strata	Imm	Mature	Spent	Total
D9 36	0.1	12.6	0	12.7
D8 36	0	9.7	0	9.8
D8 37	0	0	0	0
D9 37	0	3	0	3
E0 37	0.1	6.5	0	6.5
E1 37	0	1.2	0	1.2
E1 38	0	0.5	0	0.5
E0 38	0.1	16.6	0	16.7
D9 38	0.1	5.2	0	5.3
E0 39	0	0.8	0	0.8
E1 39	0.2	9.9	0	10.1
E2 39	0.1	8.5	0	8.5
E3 40	0	1.2	0	1.2
E2 40	0	5.4	0	5.4
E1 40	0	0.4	0	0.4
E0 40	0	0	0	0
E0 41	0	0	0	0
E1 41	1.9	23.3	0	25.2
E2 41	4.2	17.4	0	21.7
E3 41	14.4	0.8	0	15.2
E2 42	1.4	21.8	0	23.2
E1 42	0.2	25.4	0	25.6
Total	22.8	170.2	0.0	193.0
TSB %	11.8	88.2	0.0	100.0
VIaN	19.9	80.1	0.0	100.0
VIaS	1.0	99.0	0.0	100.0
VIIb	0.6	99.4	0.0	100.0

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

Strata	Imm	Mature	Spent	Total
D9 36	0.4	66.0	0.0	66.3
D8 36	0.3	47.6	0.0	47.9
D8 37	0.0	0.0	0.0	0.0
D9 37	0.2	14.1	0.0	14.3
E0 37	0.4	45.3	0.0	45.8
E1 37	0.1	9.5	0.0	9.6
E1 38	0.0	4.0	0.0	4.0
E0 38	1.0	127.3	0.0	128.3
D9 38	0.5	27.0	0.0	27.5
E0 39	0.0	6.0	0.0	6.0
E1 39	2.2	82.4	0.0	84.7
E2 39	0.6	71.6	0.0	72.2
E3 40	0.1	10.2	0.0	10.2
E2 40	0.4	45.4	0.0	45.8
E1 40	0.0	3.0	0.0	3.0
E0 40	0.0	0.0	0.0	0.0
E0 41	0.0	0.0	0.0	0.0
E1 41	25.3	187.8	0.0	213.1
E2 41	61.5	180.3	0.0	241.8
E3 41	270.6	11.5	0.0	282.1
E2 42	22.4	117.1	0.0	139.6
E1 42	1.0	123.7	0.0	124.8
Total	387.0	1179.8	0.0	1566.8
TSN %	24.7	75.3	0.0	100.0
VIaN	38.0	62.0	0.0	100.0
VIaS	1.3	98.7	0.0	100.0
VIIb	0.7	99.3	0.0	100.0

Table 9. Herring biomass and abundance by survey strata. Northwest herring survey, June 2010.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass (000's t)	SSB (000's t)	Abundance millions
D9 36	6	12	0	11	1	67	0	12.4	0.3	12.7	12.6	66.3
D8 36	6	21	0	21	0	67	0	9.8	0	9.8	9.7	47.9
D8 37	2	0	0	0	0	100	0	0	0	0	0	0.0
D9 37	6	24	1	20	3	17	0	2.5	0.5	3	3	14.3
E0 37	2	27	1	21	5	0	0.1	5.7	0.7	6.5	6.5	45.8
E1 37	2	7	1	6	0	0	0.2	1	0	1.2	1.2	9.6
E1 38	6	6	1	0	5	50	0.3	0	0.2	0.5	0.5	4.0
E0 38	6	46	5	30	11	17	8.4	7.1	1.2	16.8	16.6	128.3
D9 38	6	27	8	19	0	33	0.3	5	0	5.3	5.2	27.5
E0 39	6	5	2	2	1	67	0.5	0.1	0.1	0.8	0.8	6.0
E1 39	6	19	15	1	3	33	9.8	0.1	0.3	10.1	9.9	84.7
E2 39	3	18	12	4	2	0	6.9	1.4	0.1	8.5	8.5	72.2
E3 40	2	6	0	0	6	50	0	0	1.2	1.2	1.2	10.2
E2 40	2	6	4	0	2	50	5.1	0	0.4	5.4	5.4	45.8
E1 40	2	2	0	0	2	50	0	0	0.4	0.4	0.4	3.0
E0 40	2	0	0	0	0	100	0	0	0	0	0	0.0
E0 41	2	0	0	0	0	100	0	0	0	0	0	0.0
E1 41	2	12	0	10	2	0	0	9.9	15.3	25.2	23.3	213.1
E2 41	2	25	0	25	0	0	0	21.7	0	21.7	17.4	241.8
E3 41	2	6	0	6	0	50	0	15.2	0	15.2	0.8	282.1
E2 42	2	10	0	10	0	50	0	23.2	0	23.2	21.8	139.6
E1 42	2	43	17	26	0	0	22.5	3	0	25.6	25.4	124.8
Total	77	322	67	212	43	42	54.2	118.2	20.6	193	170.2	1566.8
Cv (%)	-	-	-	-	-	-	-	-	-	24.4	24.7	28.8

Table 10. Boarfish biomass and abundance by survey strata. Northwest herring survey, June 2010.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass (000's t)	Abundance millions
D9 36	6	65	65	0	0	0	16.3	0	0	16.3	898.9
D8 36	6	149	149	0	0	0	46.4	0	0	46.4	2476.4
D8 37	2	17	17	0	0	50	7.6	0	0	7.6	421.1
D9 37	6	92	92	0	0	17	18.1	0	0	18.1	919.9
E0 37	2	0	0	0	0	100	0	0	0	0	0.0
E1 37	2	0	0	0	0	100	0	0	0	0	0.0
E1 38	6	0	0	0	0	100	0	0	0	0	0.0
E0 38	6	0	0	0	0	100	0	0	0	0	0.0
D9 38	6	0	0	0	0	100	0	0	0	0	0.0
E0 39	6	0	0	0	0	100	0	0	0	0	0.0
E1 39	6	0	0	0	0	100	0	0	0	0	0.0
E2 39	3	0	0	0	0	100	0	0	0	0	0.0
E3 40	2	0	0	0	0	100	0	0	0	0	0.0
E2 40	2	0	0	0	0	50	0	0	0	0	0.0
E1 40	2	10	10	0	0	50	1.4	0	0	1.4	68.5
E0 40	2	0	0	0	0	100	0	0	0	0	0.0
E0 41	2	0	0	0	0	100	0	0	0	0	0.0
E1 41	2	0	0	0	0	100	0	0	0	0	0.0
E2 41	2	0	0	0	0	100	0	0	0	0	0.0
E3 41	2	0	0	0	0	100	0	0	0	0	0.0
E2 42	2	0	0	0	0	100	0	0	0	0	0.0
E1 42	2	10	10	0	0	50	9.2	0	0	9.2	458.4
Total	77	343	343	0	0	70	99	0	0	99	5243.2
Cv (%)	-	-	-	-	-	-	-	-	-	16	16

Table 11. Historic survey time series. Abundance (millions), TSB and SSB (tonnes), age in winter rings. Northwest herring survey, June 2010.

Winter rings	2008^	2009^	2010^	2010*
0	-	-	-	-
1	6.1	416.4	16.5	524.8
2	75.9	81.3	292.8	504.3
3	64.7	11.4	85.2	133.3
4	38.4	15.1	63.2	107.4
5	22.3	7.7	43.2	103.0
6	26.2	7.1	27.3	83.7
7	9.1	7.5	19.0	57.6
8	5.0	0.4	12.5	35.3
9	3.7	0.9	5.5	17.5
10+	-	-	-	-
TSN (mil)	251.4	547.7	565.2	1,566.9
TSB (t)	44,611	46,460	82,100	192,979
SSB (t)	43,006	20,906	81,400	170,154
CV	34.2	32.2	-	24.7

^ 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	70	4 – 20
Bottlenose dolphin	1	20	20
White-beaked dolphin	2	15	7 – 8
Minke whale	2	2	1
Basking shark	1	1	1
Unidentified dolphin	1	3	3
Unidentified whale	1	1	1

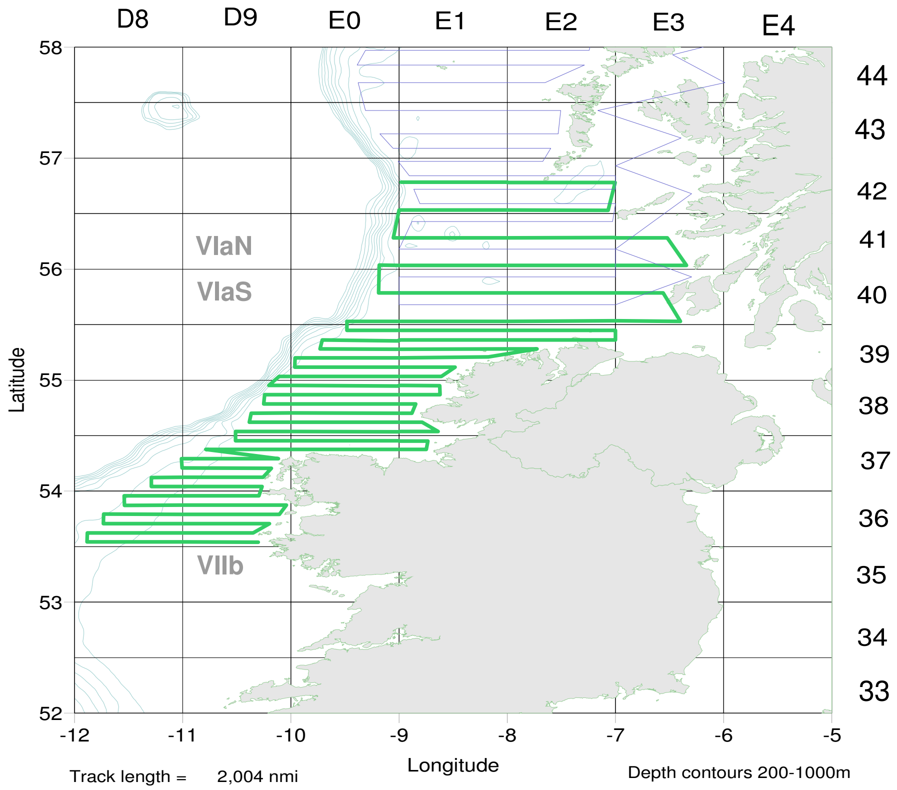


Figure 1. RV Celtic Explorer cruise track (green) showing interlacing transects with the Scottish vessel (blue). Northwest herring survey, June 2010.

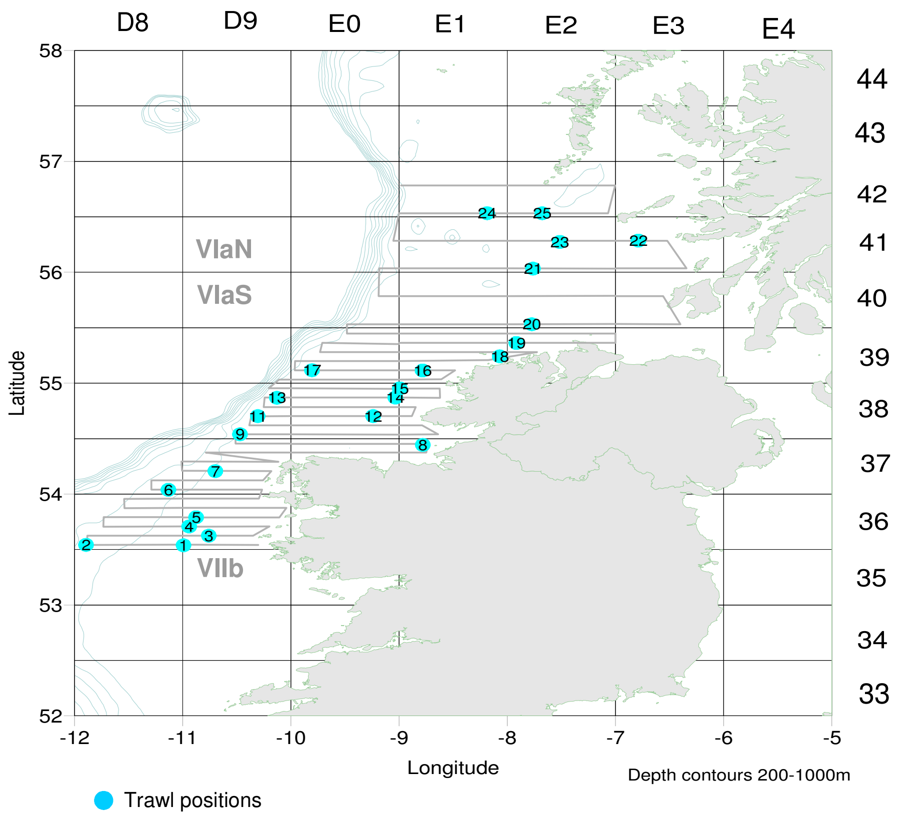


Figure 2. RV Celtic Explorer trawl stations. Northwest herring survey, June 2010.

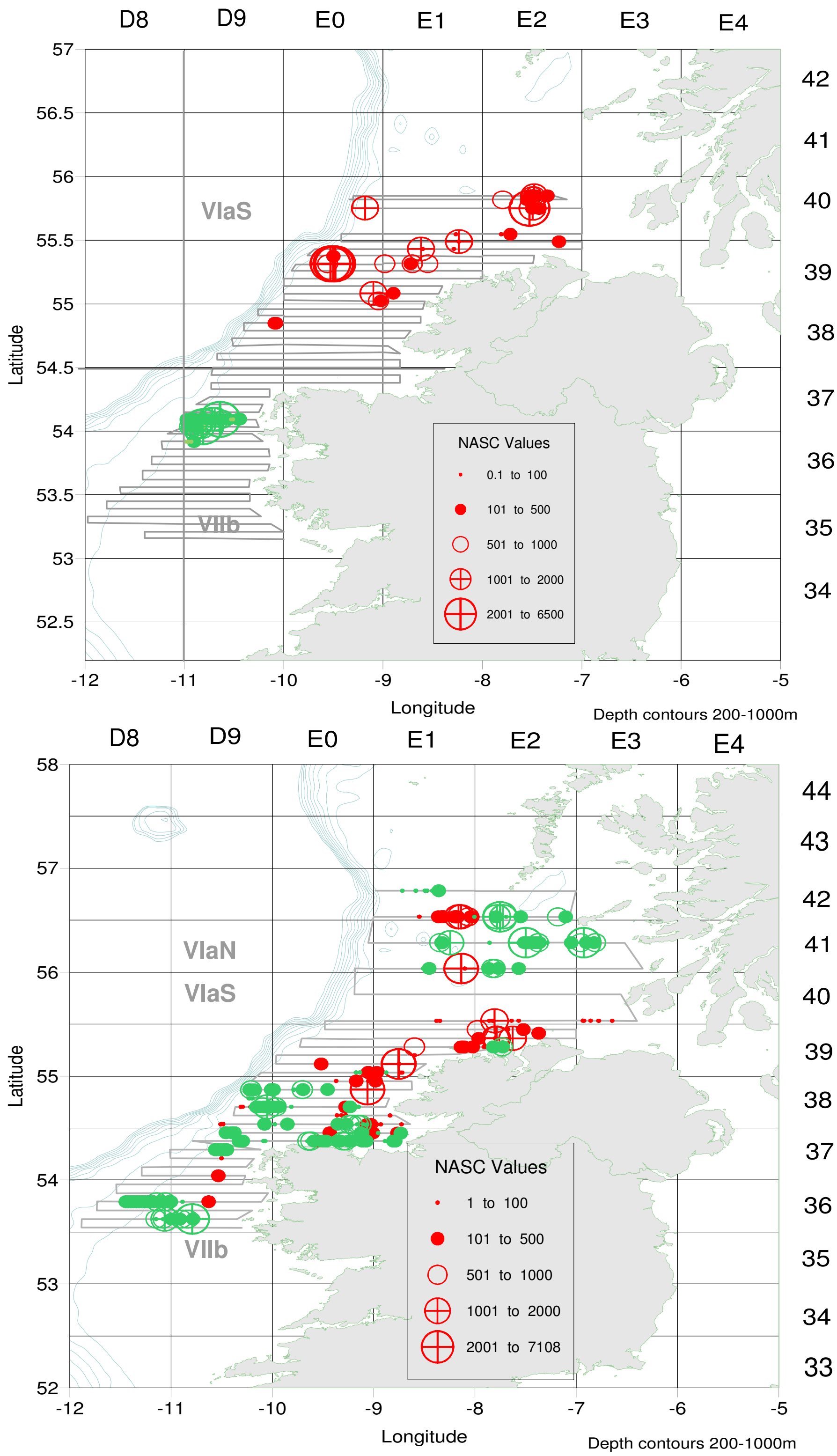


Figure 3. NASC plot of herring distribution. Top panel 2009 survey, bottom panel 2010 survey. Circle size proportional to NASC value. Red circles represent single herring schools, green circles represent herring occurring in mixed schools.

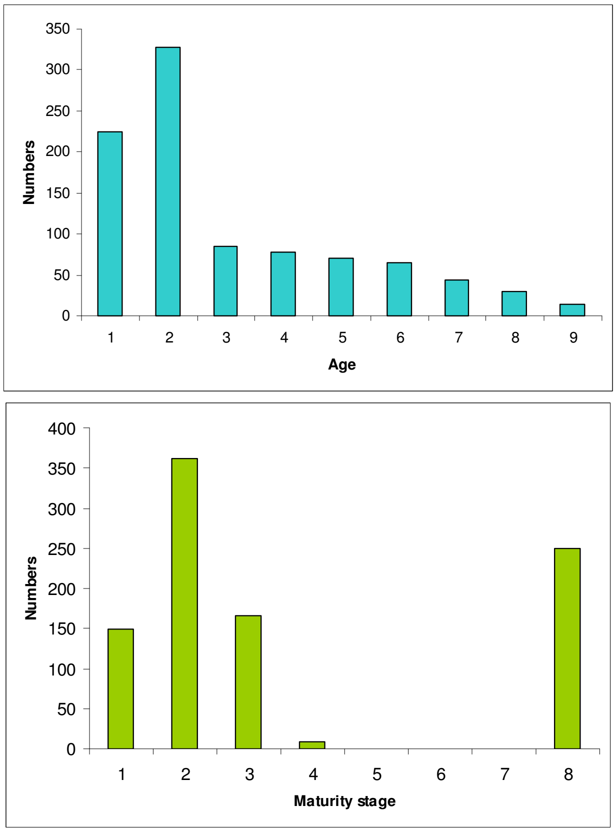


Figure 4. Percentage composition of herring samples at age (top panel) and maturity (bottom panel). Northwest herring survey, June 2010.

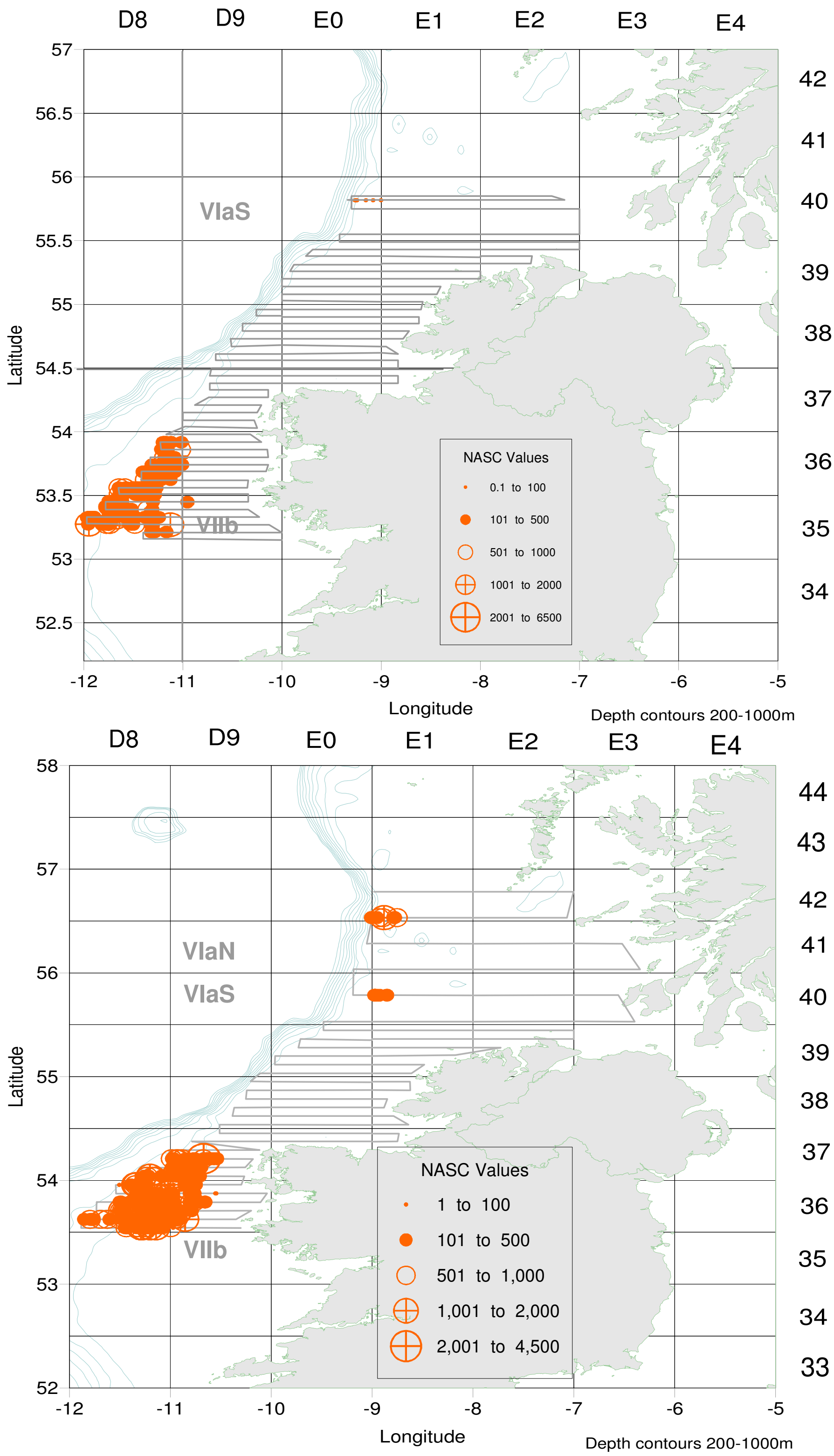
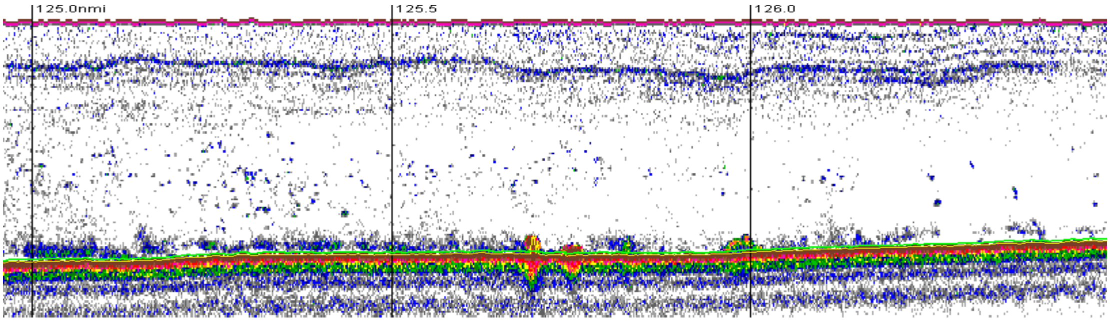
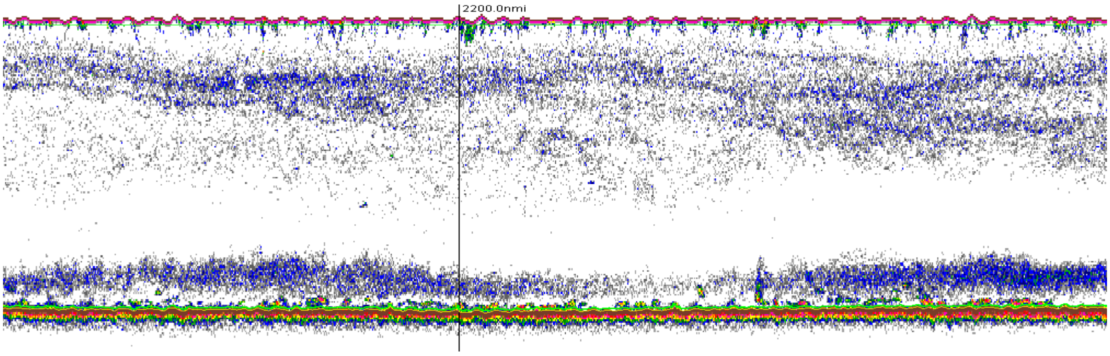


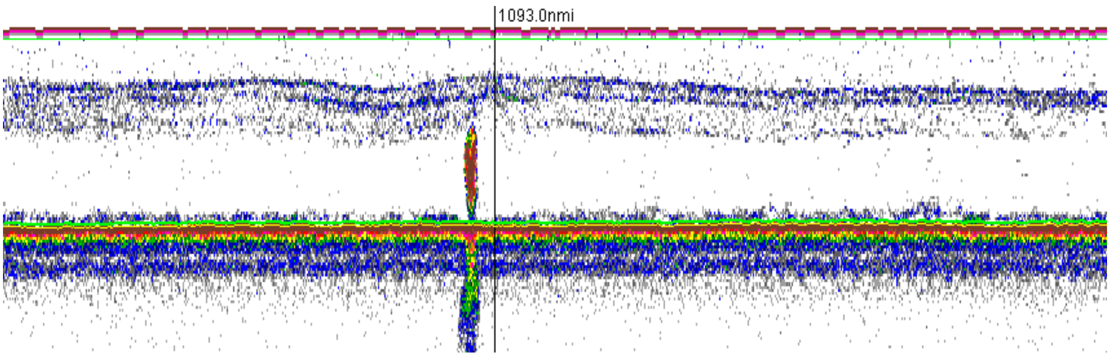
Figure 5. NASC plot of boarfish (*Capros aper*) distribution. Top panel 2009 survey, bottom panel 2010 survey. Circle size proportional to NASC value.



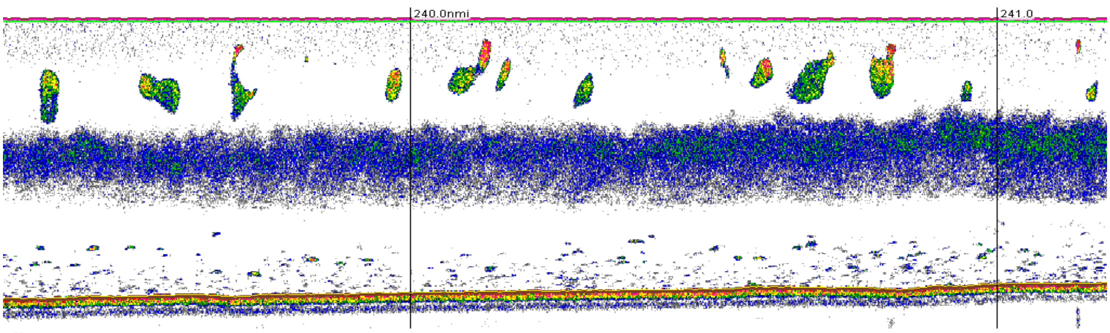
a). *Scattering layer containing herring recorded prior to **Haul 03** at 12:40 This type of scattering layer was typical of those encountered between 53º30N-54ºN in area VIIb. Bottom depth is 115m with targets extending from 0-10m off the bottom.*



b). *Bottom scattering layer containing herring recorded prior to **Haul 24** at 12:05 which extended for over 9nmi. This type of scattering layer was typical of those encountered between 55º-56ºN in the areas to the NW of the Stanton Banks. Bottom depth is 161m with targets extending from 0-8m off the bottom.*

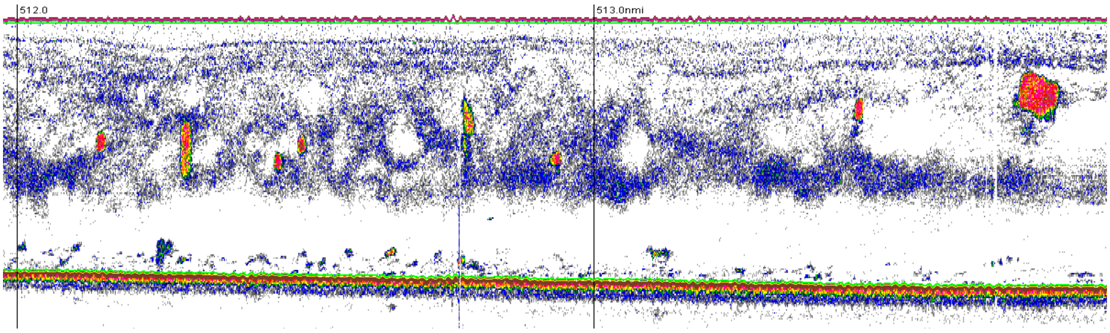


c). *High density herring school recorded prior to **Haul 014** at 12:10. Bottom depth is 72m with school extending from 0-40m off the bottom.*



d). *High-density surface mackerel schools encountered on shelf (90-150m depth between 53º30N and 54ºN. Bottom depth is 110m with targets occurring 10-25m from the surface.*

Figures 6a-d. Echotraces recorded prior to directed trawls. Northwest herring survey, June 2010. Note: vertical bands on echograms represent 1nmi (nautical mile) intervals.



e). *Very high-density schools of boarfish in surface waters, typical of those encountered along the shelf slopes from 53.30-54.30ºN. Recorded during **Haul 07** where actual target marks were located close to the bottom. Bottom depth is 180m with targets occurring 30-80m from the surface.*

Figures 6a-d. continued.

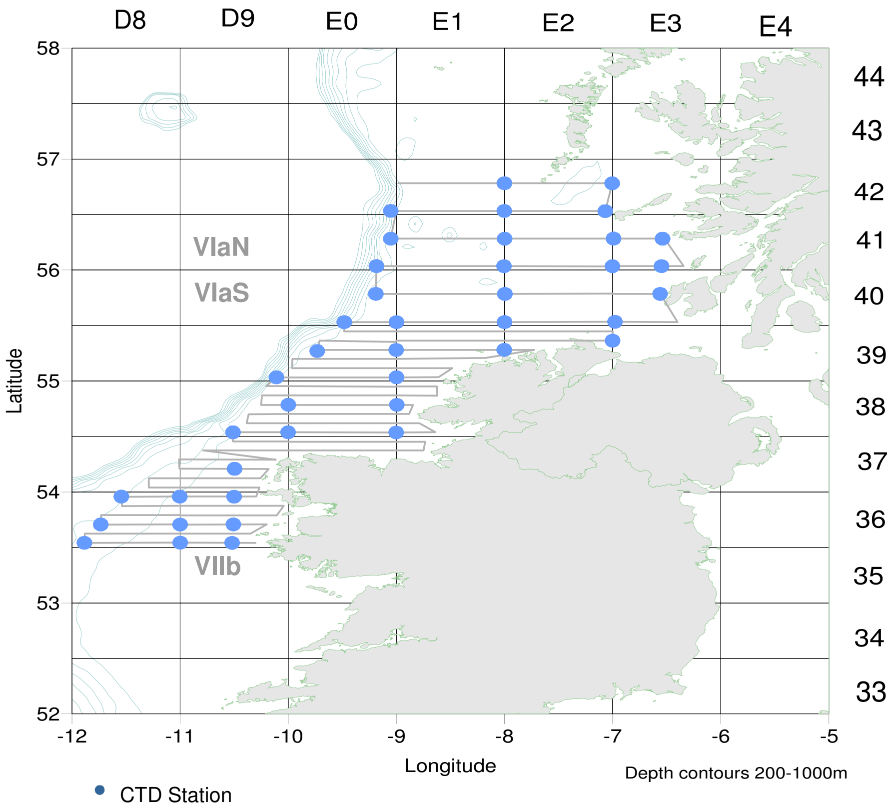


Figure 7. Location of CTD casts. Northwest herring survey, June 2010.

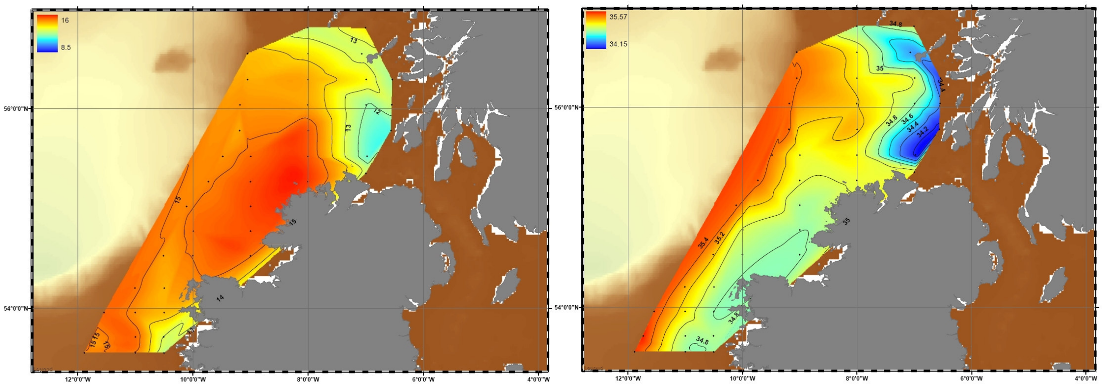


Figure 8. Horizontal temperature (left panel) and salinity (right panel) at 5m subsurface as derived from vertical CTD cast data. Northwest herring survey, June 2010.

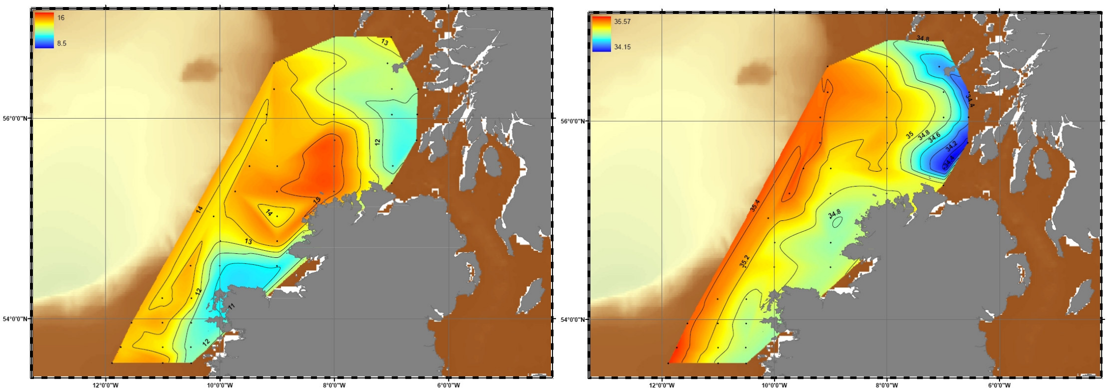


Figure 9. Horizontal temperature (left panel) and salinity (right panel) at 20m subsurface as derived from vertical CTD cast data. Northwest herring survey, June 2010.

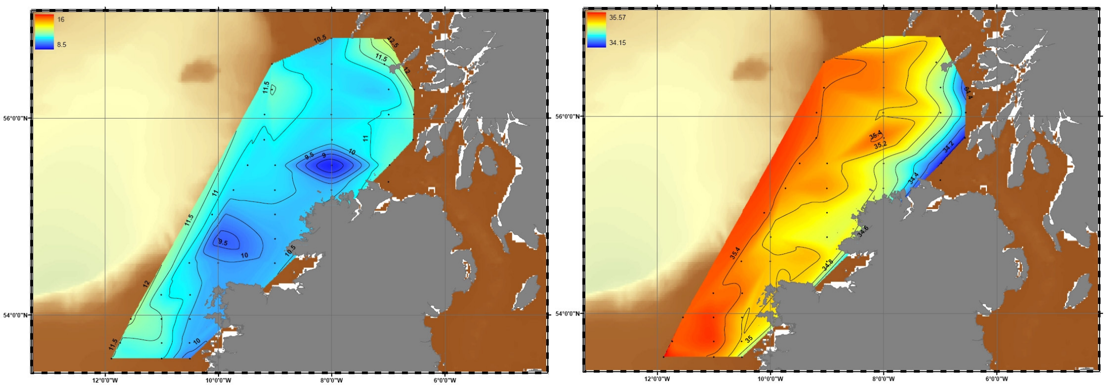


Figure 10. Horizontal temperature (left panel) and salinity (right panel) at 40m subsurface as derived from vertical CTD cast data. Northwest herring survey, June 2010.

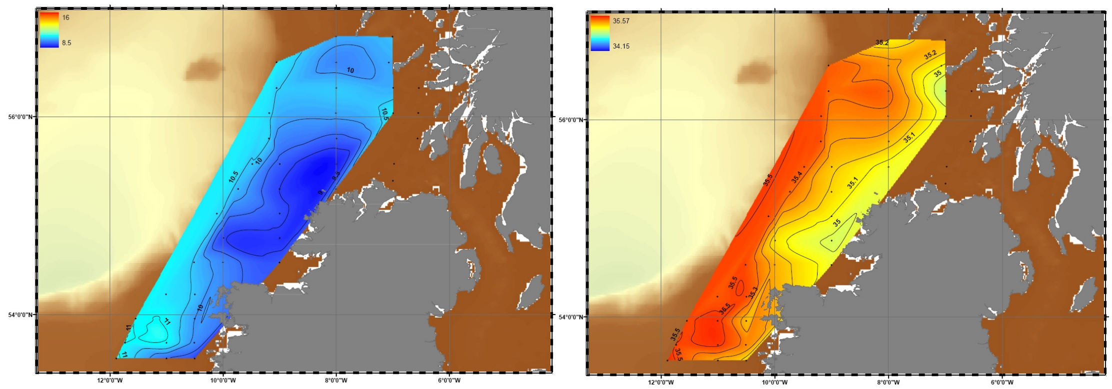


Figure 11. Horizontal distribution of temperature (top) and salinity (bottom) at 60m depth. 100 m depth contour shaded. Northwest herring survey, June 2010.

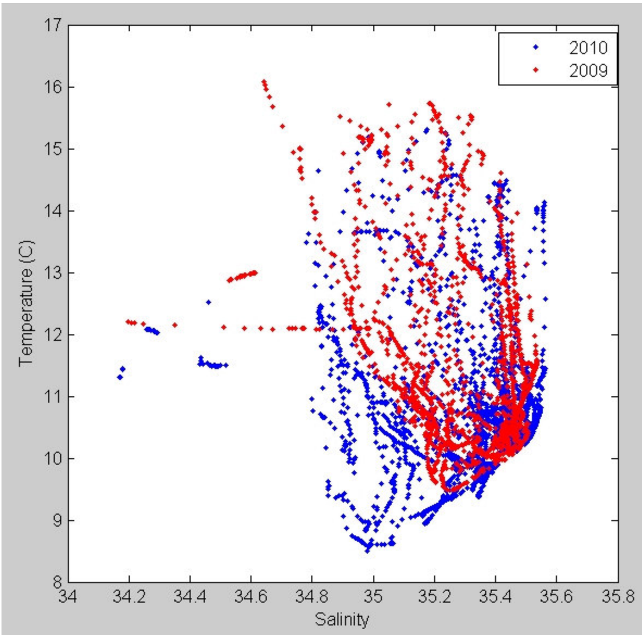


Figure 12. Comparative plot of temperature and salinity from individual vertical CTD casts taken during the 2009 and 2010 surveys. Northwest herring survey, June 2010.

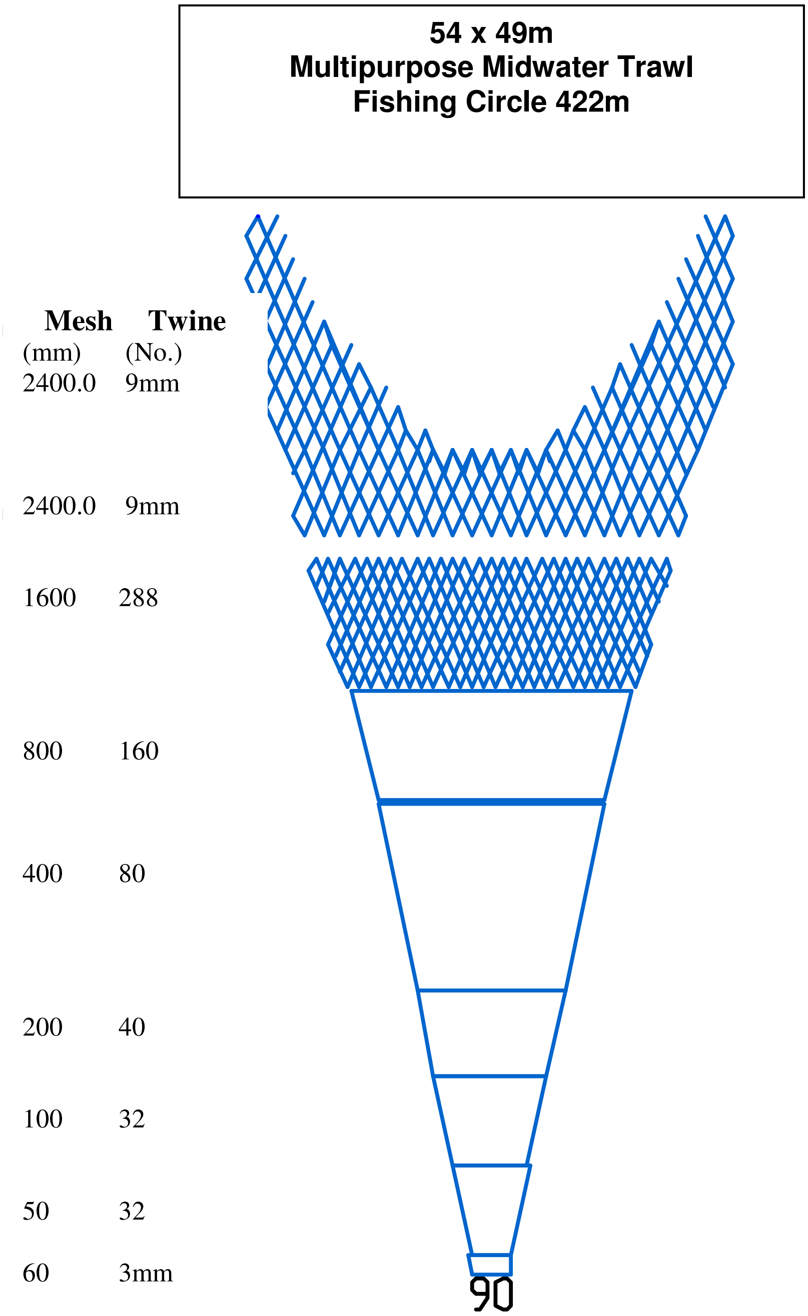


Figure 13. Celtic Explorer multi-purpose midwater trawl employed during the Northwest herring acoustic survey, June 2010.

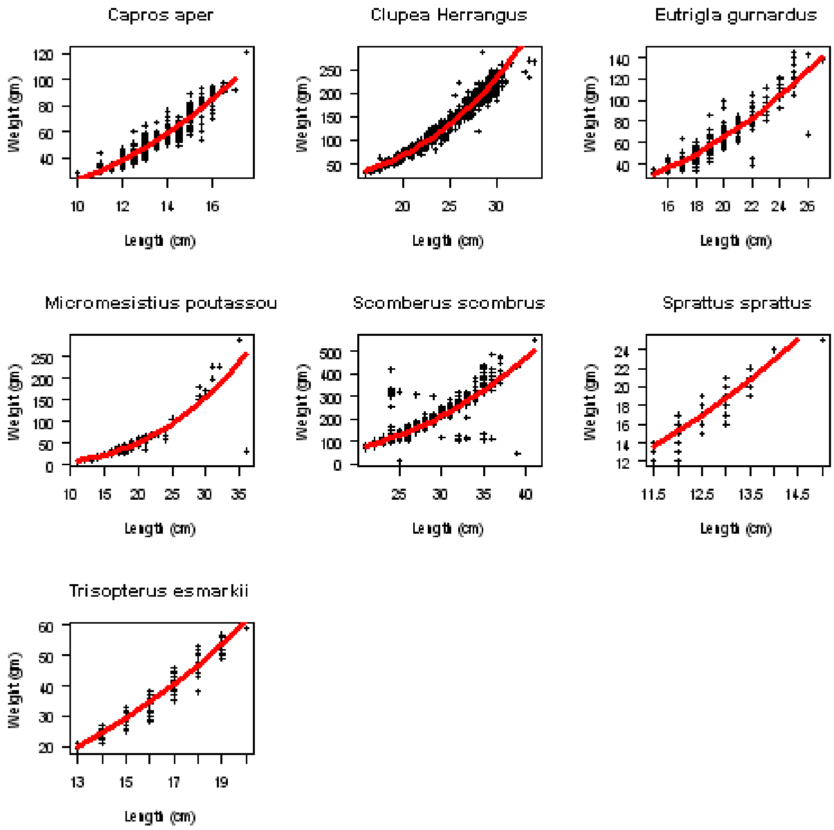


Figure 14. Length weight plots of major trawl component species used during the analysis. Northwest herring acoustic survey, June 2010.

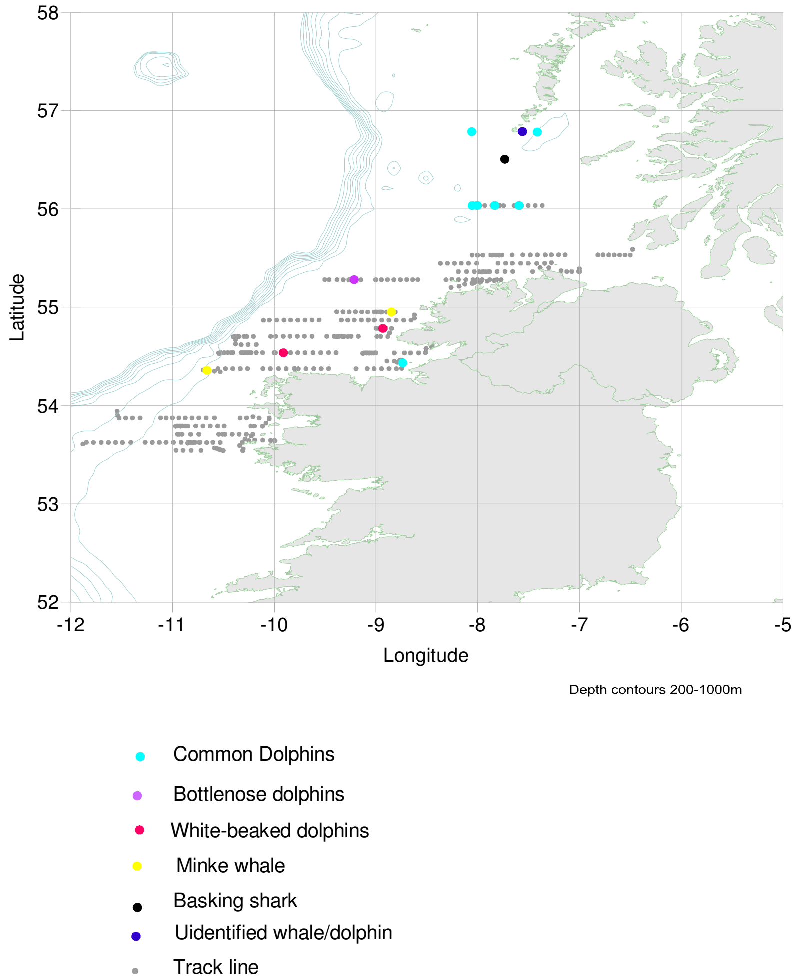


Figure 15. Distribution of ceatcean and shark species recorded during the survey.

Figure 16. Basking shark (*Cetorhinus maximus*), large male of 7m+ in length and ~3-4t in weight taken as by-catch to the southwest of Barra Head during Haul 24.

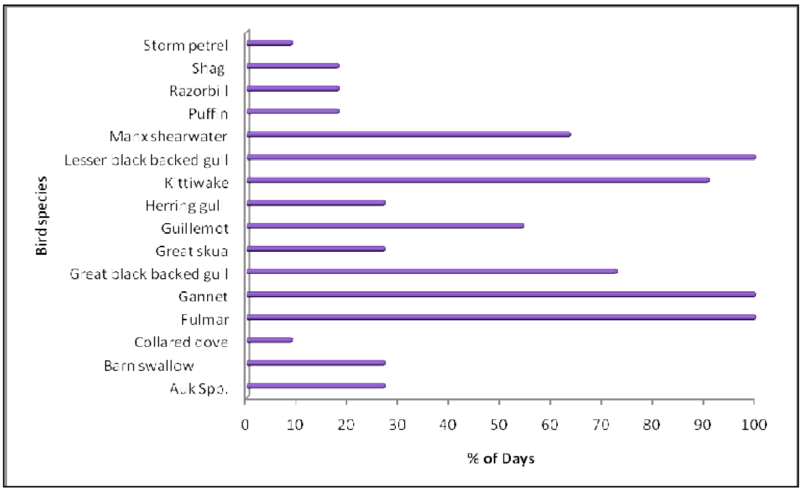


Figure 17. Percentage of days on which bird species were recorded, during 11 days of active surveying.