# FSS Survey Series: 2008/03

# Celtic Sea Herring Acoustic Survey Cruise Report 2008

The Bull Rock, Co. Cork

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# 1 Introduction

In the southwest of Ireland and the Celtic Sea (ICES Divisions VIIaS, g & j), herring are an important commercial species to the pelagic and polyvalent fleet. The local fleet is composed dry hold polyvalent vessels and a small number of purpose built RSW (Refrigerated seawater) vessels. The stock is composed of both autumn and winter spawning components and the fishery targets pre-spawning and spawning aggregations. The Irish commercial fishery has historically taken place within 1-20nmi (nautical miles) of the coast and focused on aggregated schools within the spawning cycle. In recent years the larger RSW vessels have actively targeted offshore summer feeding aggregations in the south Celtic Sea. In VIIj, the fishery traditionally begins in mid September and is concentrated within several miles of the shore including many bays and inlets. The VIIaS fishery peaks towards the year end in December, but may be active from mid October depending on location. In VIIg, along the south coast herring are targeted from October to January at a number of known spawning sites and surrounding areas. Overall, the protracted spawning period of the two components extends from October through to January, with annual variation of up to 3 weeks. Spawning occurs in successive waves in a number of well known locations including large scale grounds and small discreet spawning beds.

During the 2008/2009 season 5 pairs of both polyvalent and dedicated RSW vessels participated in the autumn fishery.

The stock structure and discrimination of herring in this area is not fully understood. It is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea and tagging studies have shown linkages between these areas. For the purpose of stock assessment and management divisions VIIaS, VIIg & j have been combined since 1982. For a period in the 1970s and1980s, larval surveys were conducted for herring in this area. However, since 1989, acoustic surveys have been carried out, and currently are the only tuning indices available for this stock. In the Celtic Sea and VIIj, herring acoustic surveys have been carried out since 1989, and this survey represents the 18$^{th}$ in the overall acoustic series or the fourth in the modified time series.

The geographical confines of the annual 21 day survey have been modified in recent years to include areas to the south of the main winter spawning grounds in an effort to identify the whereabouts of winter spawning fish before the annual inshore spawning migration. Spatial resolution of acoustic transects has been increased over the entire south coast survey area. The acoustic component of the survey has been further complimented by detailed hydrographic and marine mammal and seabird work programs first initiated during this survey in 2004.

# 2 Materials and Methods

## 2.1 Scientific Personnel

| Organisation | Name | Capacity |
|---|---|---|
| FSS | Ciaran O'Donnell | Acoustics (SIC) |
| FSS | Breandan O'Hea | Acoustics |
| FSS | Ryan Saunders | Acoustics |
| FSS | Susan Beattie | Acoustics |
| FSS | Dermot Fee | Biologist |
| FSS | Tobi Rapp | Biologist |
| FSS | Kieran Mc Cann | Biologist (Deck Sci) |
| FSS | John Harrington | Biologist |
| IWDG | Dave Wall | Marine Mammal Obs. |

## 2.2 Survey Plan

### 2.2.1 Survey objectives

The primary survey objectives are listed below:

- Carry out a pre-determined survey cruise track
- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock
- Collect ancillary information on secondary pelagic species such as sprat and pilchard to determine biomass and abundance within the survey area
- Collect physical oceanography data as horizontal and vertical profiles from a deployed sensor array.
- Survey by visual observations marine mammals and seabird abundance and distribution during the survey

### 2.2.2 Area of operation

The autumn 2008 survey covered the area from Loop Head in ICES Division VIIb (Figure 1) in Co. Clare and extended south along the western seaboard covering the main bays and inlets in Divisions VIIj & VIIg. The survey started in the north and worked in a southerly direction to facilitate temporal progression of spawning within stock components.

The survey was broken into 2 main components (Table 1). The first, a broad scale survey, was carried out to contain the stock within the survey confines and was based on the distribution of herring from previous years surveys (O'Donnell *et al.,* 2004; 2005a; 2005b; 2006; 2007). The broad scale survey was composed of 10 strata and formed an integral component of the overall survey. Broad scale outer lying areas form an important transit area for herring migrating to and from inshore spawning areas and from offshore summer feeding grounds. The second component of the survey focused exclusively on known spawning areas and was made up of 6 strata.

### 2.2.3 Survey design

A parallel transect design was adopted with transects running perpendicular to the coastline and lines of bathymetry, where possible, within each strata. Offshore extension reached up to 65nmi (nautical miles). Transects resolution was set at between 2 - 4nmi for the broad scale survey and increased to 1nmi for the spawning ground surveys. Bay areas were surveyed using a zigzag transect approach to maximise geographical coverage within these confined areas.

Transect start points within each stratum are randomised each year using a random number generator within established baseline stratum bounds.

In total the combined survey accounted for 3,161nmi, with 2,572nmi of integrateable acoustic transect data collected.

## 2.3 Equipment and system details and specifications

### 2.3.1 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FSS on previous surveys (O'Donnell *et al.,* 2004). The settings used on the *Celtic Explorer* acoustic array are shown in Table 2.

Acoustic data were collected using the Simrad ER60 scientific echosounder. The Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8m below the sea surface. Three other 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.

Whilst on survey track the vessel is normally propelled 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). During fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

### 2.3.2 Calibration of acoustic equipment

A calibration of the ER60 was carried out in Bantry Bay on the 10$^{th}$ of October; the calibration report is included in Annex 1. The ER60 was last calibrated in Irish coastal waters 7 months prior to the survey start (O'Donnell *et al,* 2008).

## 2.4 Survey protocols

### 2.4.1 Acoustic data acquisition

Acoustic data were observed and recorded onto the hard-drive of the processing unit using the equipment settings from previous surveys (Table 2). The "RAW files" were 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 DVD. Sonar Data's Echoview® Echolog (Version 4) 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 (GPS position) data was recorded for each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

### 2.4.2 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Sonar data's Echoview® (V 4) post processing software. Partitioning of data into the categories shown below was largely subjective and was viewed by a scientist 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. "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 midwater 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 that 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.

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.

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

| | | |
|---|---|---|
| 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)

### 2.4.3 Biological sampling

A single pelagic midwater trawl with the dimensions of 19m in length (LOA) and 6m at the wing ends and a fishing circle of 330 m was employed during the survey (Figure 22). Mesh size in the wings was 3.3 m through to 5 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 9 m, 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. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, sprat and pilchard were taken to the nearest 0.5 cm below. Age, length, weight, sex and maturity data were recorded for individual herring within a random 50 fish sample from each trawl haul, where possible. 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. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allowed samples at or below 1m from the bottom to be taken in areas of clean ground.

### 2.4.4 Oceanographic data collection

Oceanographic 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 at 1m subsurface and 3m above the seabed. Coverage was broken down into 4 main hydrographic transects with CTD casts undertaken on selected transects in each of the target strata. Hydrographic stations were equally spread at 6-10nmi spacing on each transect where possible (Figure 9).

### 2.4.5 Marine mammal and seabird observations

During the survey an observer kept a daylight watch on marine mammal and seabird sightings from the crow's nest (18m above sea level).

During cetacean observations, watch effort was focused on an area dead ahead of the vessel and $45^o$ to either side using a transect approach. Sightings in an area up to $90^o$ either side of the vessel were recorded. The area was constantly scanned during these hours by eye and with binoculars. Ship's position, course and speed were recorded, environmental conditions were recorded every 15 minutes and included, sea state, visibility, cloud cover, swell height, precipitation, wind speed and wind direction. For each sighting the following data were recorded: time, location, species, distance, bearing and number of animals (adults, juveniles and calves) and behaviour. Relative abundance (RA) of cetaceans was calculated in terms of number of animals sighted per hour surveyed (aph). RA calculations for porpoise, dolphin species and minke whales were made using data collected in ≤ Beaufort sea state 3. RA calculations for large whale species were made using data collected in ≤ Beaufort Sea state 5.

## 2.5 Analysis methods

### 2.5.1 Echogram partitioning

The analysis produced density values of numbers and biomass per nautical mile squared for each transect and mark category for each target species. These were then averaged over each stratum (weighted by transect length) and a biomass and abundance estimated by applying the stratum area and summing the strata estimates. Note that interconnecting inshore and offshore inter-transects were not included in the analysis. Total estimates and age and maturity breakdowns were calculated. Coefficient of variation (cv, standard error divided by the estimate) was estimated in the usual way after assuming that transects were identically distributed within a stratum and that they were statistically independent. CV were not reported for quantities that were unlikely to be used in a stock assessment (e.g., biomass of spent fish).

Biomass was calculated from numbers using length-weight relationships determined from the trawl samples taken during the survey for each of the analysis areas.

Herring weight (grams) = $0.00648 * L^{3.351}$ (L = length in cm)

Mackerel weight (grams) = $0.01118 * L^{3.032}$ (L = length in cm)

Sprat weight (grams) = $0.02404 * L^{3.192}$ (L = length in cm)

### 2.5.2 Abundance estimate

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

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

,where *l* is the transect length and $\overline{n}$ 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 j$^{th}$ track fragment.

Hauls are assigned with there own stratification that may 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. 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 $n_{s,t,j}$.

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

, 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 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 Celtic Sea herring stock

### 3.1.1 Herring biomass and abundance

The results presented below represent the relative biomass and abundance of herring recorded within the survey area at the time of surveying and serve as a relative index of stock abundance and biomass.

Stock abundance and biomass estimate are presented by biomass at age and numbers (Table 6 & 7), maturity (Table 8 & 9) and by length at age (Tables 5 and 10). The length frequency of survey hauls used to generate both TSB and SSB estimates are presented in Table 4. School counts by category and strata are presented in Table 11.

The overall estimate of abundance was generated from a total of 461 positively identified schools as compared to 307 in schools in 2007. Over 40% (189 schools) were represented by the 'definitely' herring category, 35% (164 schools) to the 'mixture' herring category and over 25% (108 schools) to the herring 'probably' category (Table 11). In general schools were of higher density and more numerous than observed during in 2007. In 2008 40% of schools contributed over 83% to the TSB compared to 46% of schools representing 25% of the TSB in 2007.

| Herring | Millions | Biomass (t) | % contribution |
|---|---|---|---|
| *Total estimate* | | | |
| Definitely | 570 | 77,939 | 83.5 |
| Mixture | 163 | 11,208 | 12.0 |
| Probably | 36 | 4,172 | 4.5 |
| **Total estimate** | 769 | 93,319 | 100 |
| Possibly | 0 | 0 | |
| Possible estimate | 0 | 0 | |
| | | | |
| *SSB Estimate* | | | |
| **Definelty** | 567 | 77,860 | 85.7 |
| **Probably** | 31 | 4,057 | 4.5 |
| **Mixture** | 73 | 8,938 | 9.8 |
| | | | |
| **SSB estimate** | 671 | 90,855 | 100 |

The TSB estimate was composed of over 83% of schools from the 'definitely' herring category identified through trawling and should be considered robust in terms of positive school identification. A small component, only 12% of the TSB, for herring was obtained from herring mixed schools and less than 5% was assigned to 'probably'. No herring schools were assigned to the 'possibly category'. Extensive trawling was carried out during the survey to target not only obvious herring school types but also mixed species layers and schools.

Of the 18 strata surveyed (7 spawning boxes and 11 back ground areas), 7 strata produced no herring at all (Table 11). In total spawning box strata contributed a small amount (4.3% to the TSB and 4.2% to the SSB) as compared to the broad scale strata which contained over 89% of the TSB and 87% of the SSB. Overall, just 3% of the

TSB was made up of juvenile herring which were distributed exclusively in the broad scale strata along the south coast. In 2007, the TSB was made up of 13% juveniles.

### 3.1.2 Herring distribution

A total of 32 trawl hauls were carried out over the course of the survey (Figure 2 & Table 3). Of this, 21 contained herring and 15 contained over 50% of herring by weight of bulk catch.

Overall, herring schools were found to be mainly distributed off the south coast between 7-8ºW (Figure 3). Off the south coast herring schools were observed from close inshore to far offshore. A higher proportion of schools were of medium to high density schools (Figure 8b-d) than observed in 2007. Diurnal schooling behaviour was observed; with daytime schools occurring in some areas as small marks close to the seabed with larger, high density schools forming at night. Large daytime schools were also observed.

Broad scale strata along the south coast were found to contain the greatest biomass observed. Offshore, herring were observed as two distinct bands at 20 and 50nmi offshore. Inshore spawning areas contributed to a much lower degree than during the 2007 survey. This maybe reflected by the maturity state of herring observed during the survey which was dominated by pre-spawning fish (Figure 7), indicating that spawning had yet to take place.

No herring were found in the southwest of the survey area with the exception of strata within Dingle Bay where the only actively spawning were observed. Early in the survey commercial vessels had been actively fishing around Strata 16 and reported good catches of herring. However, no fish were observed when this area was covered during the first or second passes of this area during a 10 day interval. Reports from the whitefish fleet working to the south of the Strata 16 and outside the survey area reported large schools of herring midway through the survey.

### 3.1.3 Herring stock composition

In total 968 herring were aged during the survey, 6,174 individuals length and over 1,300 length and weight measurements were recorded from the 15 hauls containing herring (Tables 3, 4 & 5).

Herring age samples ranged from 1-7 winter rings (Figure 7, Tables 6 & 7). The dominant ages were 2 and 4-winter ring fish respectively with the former accounting for over 38% of the total TSB by weight and over 38% by numbers (TSN). 4-winter ring fish accounted for 27% of TSB and 21% of TSN (total stock numbers). 3-winter ring herring were the third most abundant (17.7% TSB and 14.5% TSN). 1-winter ring fish ranked the fourth most abundant with over 6.2% TSB and over 8% TSN (Tables 6 & 7). In total, 5 strata were found to contain herring aged 0-7 winter rings (Table 11).

Herring maturity, as determined from trawl samples, showed the majority of the stock to be either in a pre-spawning state or immature (Figure 7). Only a small proportion of spawning individuals were encountered during the survey in Dingle Bay and no spent fish were encountered (Figure 7, Tables 8 & 9).

## 3.2 Secondary pelagic species

During the scrutinisation process acoustic data were categorised for secondary and tertiary target species according to the existing categories established for herring (see section 2.4.2) and from visual recognition and trawl data. Mackerel (*Scomber scrombrus*) was the most abundant species encountered overall occurring in over 80% of trawl catches (Table 3). Mackerel catches were dominated by juveniles. The amount of single mackerel schools observed was low (Figure 6), with the majority occurring as mixed schools. No biomass was determined for mackerel.

Borefish (*Capros aper*) schools were observed off the southwest (Figure 8a) in deeper waters (>70m). This is consistent with the distribution of this species from previous surveys. No biomass was produced for this species during the survey.

The distribution and abundance of horse mackerel (*Trachurus trachurus*) schools in the southwest area were notably scare during the 2008 survey as compared to the previous year and as a result no biomass was determined. Horse mackerel and borefish schools, although having different behavioural patterns, are often distributed in the same areas.

### 3.2.1 Sprat abundance and biomass

| Sprat | Millions | Biomass (t) | % contribution |
|---|---|---|---|
| *Total estimate* | | | |
| **Definitely** | 93 | 690 | 12.6 |
| **Mixture** | 447 | 4,803 | 87.4 |
| **Probably** | 0 | 0 | 0.0 |
| **Total estimate** | 540 | 5,493 | 100 |

Sprat distribution is presented in Figure 4 for the "Definitely" and "Probably Sprat" category but does not include the "Sprat in a mix" which accounted for over 84% of the total recorded biomass. Abundance and biomass by stratum are presented in Table 13. Overall, sprat biomass and distribution was low but compared to previous 2007. The size distribution of sprat was small and ranged 6.5-14.5cm, with a mean length of 11cm and mean weight of 11g. In general sprat in many areas appeared in poor condition and small as compared to the previous year.

75% of the 174 sprat schools identified occurred as mixed schools with the remaining 24% made up of single sprat schools. Dingle and Kenmare Bays contributed most to the sprat biomass accounting for 52% and 40% of TSB respectively. Less than 10% of the TSB was recorded within Stratum 8 as compared to 79% in 2007. This area is commonly associated with high cetacean activity during late October and November (see section 3.4.1) which are thought to be feeding on sprat aggregations. Cetacean activity normally reaches a peak during the second week of November in line with the aggregations of sprat within this area.

Overall, the low biomass detected during the survey should be treated with a degree of caution and is not a true reflection of the state of the stock as a productive sprat fishery normally takes pace later into November In the weeks following the survey.

### 3.2.2 Pilchard abundance and biomass

| Pilchard | Millions | Biomass (t) | % contribution |
|---|---|---|---|
| *Total estimate* | | | |
| Definitely | 0 | 0 | 0.0 |
| Mixture | 0 | 0 | 0.0 |
| Probably | 2 | 259 | 100.0 |
| **Total estimate** | 2 | 259 | 100 |

Pilchard distribution is presented in Figure 5 ("Definitely" and "Probably" only). Abundance and biomass by stratum are presented in Table 14. In total 10 schools were recorded. Pilchard distribution and biomass was very lower in 2008 and lower than 2007. The highest abundance was observed in Dingle Bay and accounted all the recorded biomass. A smaller amount was observed around Hook Head in Co. Waterford (Stratum 12) where several individuals were taken in a trawl haul. This area produced almost 75% of the biomass in 2007. Of the pilchard encountered size ranged from 13-25cm, with a mean length of 20.5cm.

## 3.3 Oceanography

### 3.3.1 Oceanography

A total of 61 hydrographic stations were carried out during the survey (Figure 9).

Horizontal temperature and salinity plots are presented for 5, 20, 40 and 60m depth profiles (Figures 10-13). The surface temperature plot shows an anomalous cold patch in the vicinity of the mouth of the river Bandon (~ 8.5 W) and this data is confirmed by the underway temperature record. One possible source for the cold signal is the plume of the Bandon, but I would have expected a fresher salinity signal there if that were the case.

Surface water is colder and fresher than for the same survey last year. The freshwater influence from Waterford Harbour is noticeable on surface salinity plot. The water column is more mixed than last year though there is still a noticeable thermocline and the northern flank of the cold, saline pool in the Celtic Sea is evident in the 40 and 60 metre plan views and in the Tramore section. Another interesting feature is the strong temperature (and salinity) gradient noticeable normal to the coast in the 40m and 60m plan view maps. In last year's data the gradient was roughly parallel to the coast. The cold oceanic water seems to have encroached much closer to the coast in the southwest than it did last year. The bottom density contour map is indicative of the Irish coastal current (westward geostrophic current).

Vertical contour plots for set transects running north/south are presented in Figures 14-16, additional composite transects of offshore stations are presented in Figures 17 & 18.

## 3.4 Marine mammal and seabird observations

Environmental data was collected at 519 stations. Sea state was ≤ 3 at 31.4% of environmental stations and ≤ 4 at 61.2% of stations. Visibility was >5km at 78% of stations, 1–5km at 18.5% of stations and <1km at 3.5% of stations. Swell of 2m+ was recorded at 12.5% of stations. Rainfall was recorded at 4% of stations and fog/mist was recorded at 7.9% of stations. One full survey day and three half days were lost due to bad weather (sea state 7+ and very heavy swell) and one day was lost while the ship anchored at Castletownbere for calibration of equipment.

### 3.4.1 Marine mammal sightings

127 hours of survey time were logged with 66% (83.8 hrs) of this at Beaufort sea state three or less. 115 sightings of at least nine cetacean species, totalling 2,427 individuals were recorded

101.6 hours of survey time were logged with 25.6% (25.98 hrs) of this at Beaufort sea state three or less; 44.5% (45.2 hrs) at Beaufort sea state four or less and 68.7% (69.75hrs) at Beaufort sea state five or less. 102 sightings of at least four cetacean species, totalling 1914 individuals were recorded (Figures 20-21).

Identified small-toothed cetacean species were common dolphin (*Delphinus delphis*) and harbour porpoise (*Phocoena phocoena*). The distribution of dolphins and porpoise is similar to that recorded in previous years.

An anomalously pigmented common dolphin was sighted among a group of 40 common dolphins inshore, off the Old Head of Kinsale on the 22$^{nd}$ October. The animal was melanistic with most of the pattern on its body replaced by black or dark grey. This is the first time an animal displaying such melanism has been sighted during these surveys, although animals displaying lesser degrees of anomalous pigmentation have been noted. A female common dolphin with a young calf was sighted among a group of common dolphins on the 21$^{st}$ October.

In a continuing effort to eliminate dolphin bycatch recorded during the survey in previous years, two DDD02F pingers (STM Products S.r.l., Verona, Italy) were attached to the footrope of the trawl. These pingers (supplied by BIM) emit random modulated signals in the frequency range 1 – 500 KHz. As in 2007 (the first year these pingers were used) no dolphin bycatch was recorded during this survey and it is hoped that the continued use of the pingers will prevent future bycatch of common dolphins.

Four groups of dolphins sighted could not be identified to species due either to the distance at which the sighting was made or to the short duration of the encounter.

Identified whale species were fin whale (*Balaenoptera physalus*) and minke whale (*Balaenoptera acutorostrata*).

Most of the recorded fin whale activity took place south of Galley Head and Southeast of Ram Head. It is thought that the whales were feeding on sprat and young herring at both these locations. Minke whales were recorded south of Galley, at the entrance to Dingle Bay and at the Saltee Islands; these are all areas in which they have been recorded in previous years.

Common dolphins were by far the most commonly encountered and abundant species recorded during the survey. Fin whales were the most commonly encountered and abundant whale species recorded (Table 15).

### 3.4.2 Seabird sightings

Daily species lists were made of all seabird species seen around the survey vessel. 18 seabird species were recorded during the survey (Figure 22): Razorbill (*Alca torda*); guillemot (*Uria aalge*); puffin (*Fratercula arctica*); gannet (*Morus bassanus*); fulmar (*Fulmarus glacialis*); Manx shearwater (*Puffinus puffinus*); sooty shearwater (*Puffinus griseus*); kittiwake (*Rissa tridactyla*); lesser black backed gull (*Larus fuscus*); great black-backed gull (*Larus marinus*); herring gull (*Larus argentatus*); black-headed gull (*Larus ridibundus*); great skua (*Stercorarius skua*); pomarine skua (*Stercorarius pomarinus*); parasitic skua (*Stercorarius parasiticus*); storm petrel (*Hydrobates pelagicus*); shag (*Phalacrocorax aristotelis*) and great northern diver (*Gavia immer*).

# 4 Discussion and Conclusions

## 4.1 Discussion

Overall the aims of the survey were carried out as planned. Poor weather conditions prevented the completion of the Kerry Head spawning box at the end of the survey. However, extensive trawling was carried out in areas of high abundance and this was further backed up by comprehensive hydrographic sampling.

The 2008 estimate of herring abundance is almost double the observed biomass from the previous survey. Herring biomass was spread over a wide area off the southern coast from close inshore out to 50nmi. Three visible bands of distribution were visible, one inshore and with the two more at 30nmi and 50nmi.

The abundance estimate for herring can be considered robust due to the high rate of trawl sampling carried out and the positive identification of numerous medium to high density homogenous herring marks. This is reflected in the overall CV for the SBB (20%) as compared to the 2007 survey estimate where fewer schools made up the estimate, leading to a CV of 25%.

The greatest abundance was observed within 20nmi of the coast and is comparable to observations in 2007. However, in 2008 almost 39% of the recorded biomass was observed more than 20nmi offshore along the south coast as compared to 4% in 2007.

In 2008 as in 2007, the maturity state of the stock where the greatest biomass was encountered was made up of pre-spawning fish. Moreover herring were found to be some way off spawning (stage 4 & 3 respectively) and as indicated from comparing samples from offshore and inshore schools.

Communications with the pelagic and demersal fleets working in the Celtic Sea report the herring were very abundant this year. Landings data from the pelagic fleet show that areas covered during survey and yielded little herring biomass had been the focus of fishing effort in the weeks prior to the start of the survey (namely Stratum 16, 'The Stags'). Large herring schools were also reported by demersal fishermen south of the 'Stags' in the western Celtic Sea after the survey. Inshore in a known and surveyed spawning stratum this area had been the focus of the pelagic fleet for a number of weeks prior to the survey. This inshore stratum was surveyed twice during the survey with a 10 day interval and on both occasions produced very little biomass. Information from fishermen indicates that herring were still moving inshore after the survey had passed that were not included in the snapshot biomass.

## 4.2 Conclusions

The large herring biomass encountered during the 2008 survey is no doubt exceptional in the recent time series (2004/05 to present). However, in the last decade the TSB has exceeded 89,000t on four separate occasions and ranged from 89,000t ((2003/04) to a maximum of 111,000t (1998/99). Biomass estimates for this stock have shown large fluctuations between years and it is these high TSB years combined with the median years which create excessive noise in the assessment.

The timing of the survey has been fixed since 2004, whereas the herring migration from offshore feeding grounds is not. This can lead to a match/mismatch in terms of peak abundance and survey timing. In 2008, the survey ‘snapshot’ appears to have coincided with peak abundance on the grounds.

The presence of herring on the main autumn spawning grounds can extend for up to 3 months and overlaps with the arrival of the smaller winter spawning component. During this time biomass on the spawning grounds is replenished by several waves of migration. The survey is designed to contain the stock within its boundaries. As a result the 2008 biomass is likely to contain an un-quantified proportion of the winter spawning component. As no survey is currently undertaken on this stock component it is impossible to determine the contribution of each component during overlap years.

The hydrographic conditions encountered during this year’s survey show sea surface temperature to be slightly lower than in previous years. Overall, the trend in mean annual temperature in the Celtic Sea is increasing. A preliminary look at sea surface temperature in October across years (1998-2008) shows no correlation between cooler years and increased recorded biomass. Herring are known to use temperature as one of the cues for the onset of spawning migrations. However, this alone is not responsible and cannot be accurately used to predict peak abundance.

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# 5 Tables and Figures

**Table 1.** Survey Strata details. Celtic Sea herring acoustic survey, October 2008.

| Strata no. | Strata name | Survey type | Transect type | Total transects | Active transects | Transect spacing | Total transect distance (nmi) | Strata area (nmi2) |
|---|---|---|---|---|---|---|---|---|
| **1 (a,b)** | SW Shannon | Broad scale | Parallel | 26 | 14 | 4 | 197 | 727 |
| **2** | Inside Shannon | Broad scale | Zigzag | 7 | 7 | \ | 43 | 39 |
| **3** | Dingle | Broad scale | Zigzag | 9 | 9 | \ | 77 | 99 |
| **4 (a,b)** | SW corner | Broad scale | Parallel | 15 | 8 | 4 | 191 | 548 |
| **5** | Kenmare | Broad scale | Zigzag | 7 | 7 | \ | 39 | 61 |
| **6** | Bantry | Broad scale | Zigzag | 8 | 7 | \ | 39 | 34 |
| **7** | Dunmanus | Broad scale | Zigzag | 7 | 7 | \ | 14 | 9 |
| **8** | Mizen area | Broad scale | Parallel | 27 | 14 | 4 | 253 | 770 |
| **9** | Offshore CS | Broad scale | Parallel | 63 | 32 | 2 | 1039 | 1932 |
| **10 (a,b,c,d,e)** | Inshore CS | Broad scale | Parallel | 61 | 34 | 2 | 652 | 1106 |
| **11** | Baginbun | Spawning grd | Parallel | 17 | 9 | 1 | 48 | 29 |
| **12** | Tramore | Spawning grd | Parallel | 31 | 16 | 1 | 116 | 85 |
| **13** | Waterford Hbr | Broad scale | Zigzag | 4 | 4 | \ | 12 | 4 |
| **14** | Ballycotton | Spawning grd | Parallel | 32 | 16 | 1 | 110 | 104 |
| **15** | Daunt | Spawning grd | Parallel | 25 | 13 | 1 | 75 | 69 |
| **16** | Stags | Spawning grd | Parallel | 9 | 5 | 1 | 8 | 16 |
| **17** | Dingle_S | Spawning grd | Parallel | 11 | 6 | 1 | 24 | 9 |
| **18** | Dingle_N | Spawning grd | Parallel | 11 | 6 | 1 | 21 | 7 |
| | | | Total | 370 | 214 | | 2957 | 5645 |

**Table 2.** Settings for the Simrad ER60 echosounder, employed during the Celtic Sea herring acoustic survey, October 2008.

| | | |
|---|---|---|
| Echo sounder: | | Simrad ER 60 |
| Frequency: | | 38 kHz |
| Transducer: | | ES 38B- Serial |
| Absorption Coefficient: | | 0.067 dB/Km (manual) |
| Pulse length: | | 1.024 m/s |
| Bandwidth: | | 2.43 KHz |
| Transmitting Power: | | 2000 W (Max) |
| Angle Sensitivity: | | 13.9 dB |
| 2- way beam angle: | | -21.69° |
| Gain: | | 25.82 |
| SA Correction: | | -0.7 |
| 3 dB Beam W | Alongship: | 7.10° |
| | Athwartship: | 7.18° |
| Max Range: | | 200m |

Note: Calibration report available (38KHz) in Appendix 1

**Table 3.** Catch table from directed trawl hauls. Celtic Sea herring acoustic survey, October 2008.

| No. | Date | Lat. N | Lon. W | Time | Bottom (m) | Target (m) | Bulk Catch (Kg) | Herring % | Mackerel % | Scad % | Sprat % | Pilchard % | Others* % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 06.10.08 | 52 23.25 | 010 20.37 | 18:05 | 96 | 0 | <1 | | 100.0 | | | | |
| 2 | 07.10.08 | 51 56.79 | 010 27.22 | 09:07 | 80 | 2 | 47 | | 63.0 | | 35.0 | | 2.0 |
| 3 | 07.10.08 | 51 56.78 | 010 28.32 | 11:26 | 64 | 14 | 17 | 3.0 | 57.0 | | 25.0 | | 15.0 |
| 4 | 07.10.08 | 51 59.04 | 010 30.10 | 18:00 | 80 | 4 | 150 | | 81.0 | 1.0 | 17.0 | | 1.0 |
| 5 | 08.10.08 | 51 41.84 | 010 06.46 | 08:50 | 52 | 2 | 110 | | 20.0 | | 79.0 | | 1.0 |
| 6 | 08.10.08 | 51 32.09 | 010 30.54 | 19:00 | 131 | 55 | 2250 | | | | | | 100.0 |
| 7 | 09.10.08 | 51 13.68 | 009 38.96 | 10:56 | 100 | 10 | <1 | | 60.0 | | | | 40.0 |
| 8 | 11.10.08 | 51 24.96 | 009 00.98 | 08:40 | 80 | 40 | 27 | | 69.0 | 1.0 | 27.0 | | 3.0 |
| 9 | 11.10.08 | 51 26.32 | 008 55.02 | 12:05 | 93 | 20 | 24 | | 71.0 | | 27.0 | | 2.0 |
| 10 | 12.10.08 | 51 20.92 | 008 18.67 | 03:55 | 92 | 60 | 0 | | | | | | |
| 11 | 12.10.08 | 51 14.92 | 008 15.47 | 10:21 | 89 | 25 | 132 | 13.0 | 79.0 | | 0.1 | | 7.9 |
| 12 | 13.10.08 | 51 28.35 | 007 58.86 | 01:15 | 86 | 0 | 250 | 99.5 | | | 0.01 | | 0.5 |
| 13 | 13.10.08 | 51 29.21 | 007 56.12 | 08:45 | 80 | 20 | 1000 | 99.5 | | | | | 0.5 |
| 14 | 13.10.08 | 51 09.75 | 007 52.80 | 13:55 | 100 | 20 | 51 | 83.0 | 0.5 | 0.1 | 16.0 | | 0.4 |
| 15 | 14.10.08 | 51 30.47 | 007 42.58 | 01:04 | 80 | 10 | 81 | 98.2 | 1.0 | | 0.0 | | 0.7 |
| 16 | 14.10.08 | 51 26.23 | 007 36.58 | 10:12 | 82 | 0 | 150 | 99.0 | | | 0.4 | | 0.6 |
| 17 | 15.10.08 | 51 28.64 | 007 23.40 | 11:56 | 85 | 15 | 63 | 25.1 | 59.7 | 13.8 | | | 1.4 |
| 18 | 15.10.08 | 51 39.19 | 007 16.82 | 15:27 | 77 | 10 | 150 | 77.3 | 22.6 | | | | 0.1 |
| 19 | 15.10.08 | 51 40.86 | 007 10.12 | 22:55 | 70 | 60 | 250 | 84.2 | 15.8 | | | | |
| 20 | 16.10.08 | 51 16.44 | 006 36.89 | 10:45 | 81 | 5 | 3500 | 90.6 | 9.4 | | | | |
| 21 | 16.10.08 | 51 47.41 | 006 56.91 | 14:50 | 74 | 10 | 250 | | 100.0 | | | | |
| 22 | 17.10.08 | 51 58.91 | 006 50.85 | 10:21 | 64 | 15 | 24 | 51.0 | 7.7 | 0.1 | 34.0 | | 7.2 |
| 23 | 17.10.08 | 51 00.41 | 006 57.83 | 19:10 | 62 | 20 | 2700 | 76.6 | 23.4 | | | | |
| 24 | 17.10.08 | 52 01.21 | 007 00.64 | 23:22 | 46 | 0 | 1000 | 46.3 | 53.4 | | | | 0.2 |
| 25 | 18.10.08 | 51 46.63 | 007 16.86 | 10:30 | 75 | 10 | 600 | 2.1 | 4.0 | | 85.0 | | 8.8 |
| 26 | 18.10.08 | 51 52.99 | 007 19.67 | 13:26 | 65 | 20 | 500 | 92.0 | 8.0 | | | | |
| 27 | 18.10.08 | 52 05.74 | 007 17.36 | 17:10 | 25 | 0 | 0 | | | | | | |
| 28 | 19.10.08 | 52 01.87 | 007 26.60 | 15:45 | 32 | 4 | 350 | 47.0 | 52.0 | | 0.1 | | 0.9 |
| 29 | 19.10.08 | 52 00.52 | 007 30.08 | 18:50 | 34 | 0 | 1200 | 90.1 | 9.7 | | | | 1.2 |
| 30 | 20.10.08 | 51 55.47 | 007 32.96 | 03:28 | 42 | 0 | 39 | 80.2 | 1.1 | 0.56 | | 5.4 | 12.74 |
| 31 | 20.10.08 | 51 51.83 | 007 41.15 | 13:37 | 50 | 10 | 300 | 93.1 | 8.7 | | | | |

**Table 3.** Continued

| No. | Date | Lat. N | Lon. W | Time | Bottom (m) | Target (m) | Bulk Catch (Kg) | Herring % | Mackerel % | Scad % | Sprat % | Pilchard % | Others* % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 23.10.08 | 52 01.49 | 010 13.20 | 03:00 | 34 | 0 | 600 | 56.75 | 43.1 | 0.15 | | | |

**Table 4.** Length frequency (%) of herring hauls used for calculating 'definitely' and 'probably' abundance categories. Celtic Sea herring acoustic survey, October 2008.

| Length (cm) | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 25 | 26 | 28 | 29 | 30 | 31 | 32 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | | | | 2 | | | | | | | | | | | | | | | | | |
| 12.5 | | | | 18 | | | 2 | | | | 7 | | | | | | | | | | 27 |
| 13 | 5 | | | 26 | | | 2 | | | | 23 | | | | | | | | | | 56 |
| 13.5 | 13 | | | 48 | | | 25 | | | | 12 | | | 1 | | | | | | | 99 |
| 14 | 35 | | | 57 | | | 42 | | | | 27 | | | 10 | | | | 1 | | | 172 |
| 14.5 | 60 | | | 60 | | 5 | 60 | | | | 28 | | | 23 | | | | 2 | | | 238 |
| 15 | 35 | | | 24 | | 2 | 34 | | | | 31 | | | 36 | | 4 | | 1 | | | 167 |
| 15.5 | 18 | | | 6 | | 1 | 15 | | | | 29 | | | 29 | | 2 | | 1 | | | 101 |
| 16 | 1 | | | 1 | | 4 | 2 | | | | 12 | | | 16 | | 2 | | 1 | | | 39 |
| 16.5 | 1 | | | | | 1 | | | | | 2 | | | 4 | | 9 | 1 | 2 | | | 20 |
| 17 | 1 | | | | | 2 | | | | | 1 | | | 1 | | 20 | 1 | 4 | | | 30 |
| 17.5 | 1 | | | | | 5 | | | | | 1 | | | 1 | | 27 | 1 | 9 | | | 45 |
| 18 | 1 | | | | | 7 | | | | | 3 | | | | | 52 | 7 | 13 | | | 83 |
| 18.5 | 3 | | | | | 19 | | | | | 2 | | | | | 60 | 6 | 18 | | | 108 |
| 19 | 3 | | | | | 34 | | | 4 | 1 | 7 | | | | | 47 | 16 | 27 | | | 139 |
| 19.5 | 1 | | | | | 44 | | | 7 | 2 | 8 | | | | | 43 | 23 | 28 | | | 156 |
| 20 | 1 | | | | | 60 | | | 15 | 1 | 10 | | 1 | | | 45 | 27 | 38 | | | 198 |
| 20.5 | 2 | | | | | 38 | | 1 | 17 | 11 | 14 | 1 | 1 | | | 40 | 37 | 26 | | | 188 |
| 21 | 1 | 1 | | | 4 | 46 | | 2 | 31 | 27 | 10 | 3 | 8 | | | 33 | 50 | 32 | | | 248 |
| 21.5 | 1 | 3 | 1 | | 2 | 42 | | 6 | 35 | 24 | 13 | 4 | 4 | | 2 | 24 | 60 | 16 | | | 237 |
| 22 | | 2 | 1 | | 13 | 29 | | 19 | 44 | 33 | 8 | 10 | 14 | | 4 | 18 | 52 | 9 | | | 256 |
| 22.5 | | 4 | 1 | | 9 | 16 | | 24 | 50 | 33 | 4 | 13 | 18 | | 7 | 10 | 46 | 9 | | | 244 |
| 23 | | 12 | 3 | | 34 | 3 | | 50 | 52 | 50 | 5 | 26 | 24 | | 23 | 8 | 43 | 2 | 2 | 1 | 338 |
| 23.5 | | 27 | 11 | | 39 | 1 | | 49 | 52 | 47 | 4 | 25 | 45 | | 27 | 1 | 32 | 1 | 10 | 2 | 373 |
| 24 | | 35 | 13 | | 60 | | | 60 | 60 | 60 | 1 | 60 | 41 | | 30 | 2 | 18 | | 18 | 3 | 461 |
| 24.5 | | 46 | 30 | | 47 | | | 37 | 39 | 30 | | 47 | 38 | | 43 | 3 | 13 | | 33 | 7 | 413 |
| 25 | | 39 | 43 | | 24 | | | 29 | 29 | 41 | | 57 | 44 | | 39 | 2 | 2 | | 38 | 13 | 400 |
| 25.5 | | 60 | 60 | | 43 | | | 20 | 39 | 23 | | 49 | 41 | | 60 | | 1 | | 60 | 18 | 474 |
| 26 | | 44 | 40 | | 28 | | | 13 | 16 | 9 | | 50 | 29 | | 47 | | 1 | | 54 | 22 | 353 |
| 26.5 | | 57 | 40 | | 28 | | | 7 | 14 | 5 | | 30 | 17 | | 41 | | | | 28 | 60 | 327 |
| 27 | | 9 | 21 | | 8 | | | 2 | 2 | 1 | | 12 | 8 | | 8 | | | | 15 | 44 | 130 |
| 27.5 | | 10 | 9 | | 3 | | | 3 | 4 | 1 | | 8 | 2 | | 2 | | | | 5 | 29 | 76 |
| 28 | | 1 | 5 | | 3 | | | | 1 | 1 | | 3 | 3 | | 1 | | | | 1 | 21 | 40 |
| 28.5 | | | 2 | | | | | | | | | 3 | 1 | | | | | | 1 | 14 | 21 |
| 29 | | | 1 | | | | | | | | | 1 | 1 | | | | | | | 3 | 6 |
| 29.5 | | | | | | | | | | | | 1 | | | | | | | | 1 | 2 |
| **Totals** | **178** | **350** | **280** | **196** | **345** | **359** | **178** | **322** | **511** | **400** | **232** | **401** | **339** | **121** | **334** | **452** | **437** | **240** | **265** | **234** | **6,174** |

**Table 5.** Herring Age length key from combined trawl samples. Celtic Sea herring acoustic survey, October 2008.

| Age (rings)<br>Length (cm) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **12.5** | 1 | | | | | | | | | | **1** |
| **13** | 4 | | | | | | | | | | **4** |
| **13.5** | 6 | | | | | | | | | | **6** |
| **14** | 16 | | | | | | | | | | **16** |
| **14.5** | 43 | | | | | | | | | | **43** |
| **15** | 55 | | | | | | | | | | **55** |
| **15.5** | 59 | | | | | | | | | | **59** |
| **16** | 28 | | | | | | | | | | **28** |
| **16.5** | 6 | | | | | | | | | | **6** |
| **17** | 7 | | | | | | | | | | **7** |
| **17.5** | 4 | | | | | | | | | | **4** |
| **19.5** | | 2 | | | | | | | | | **2** |
| **20** | | 2 | | | | | | | | | **2** |
| **20.5** | | 4 | | | | | | | | | **4** |
| **21** | | 7 | 1 | | | | | | | | **8** |
| **21.5** | | 16 | 1 | | | | | | | | **17** |
| **22** | | 11 | 4 | | | | | | | | **15** |
| **22.5** | | 13 | 32 | | 1 | | | | | | **46** |
| **23** | | 3 | 29 | 1 | | | | | | | **33** |
| **23.5** | | | 63 | 1 | 2 | | | | | | **66** |
| **24** | | | 64 | 13 | 4 | | | | | | **81** |
| **24.5** | | 1 | 54 | 20 | 9 | | | | | | **84** |
| **25** | | | 25 | 31 | 33 | 1 | | | | | **90** |
| **25.5** | | | 17 | 23 | 45 | 4 | | | | | **89** |
| **26** | | | 6 | 18 | 51 | 9 | | | | | **84** |
| **26.5** | | | | 10 | 33 | 10 | | | | | **53** |
| **27** | | | 2 | 13 | 15 | 4 | 2 | 3 | | | **39** |
| **27.5** | | | | 2 | 5 | 5 | 4 | 2 | | | **18** |
| **28** | | | | 2 | 2 | 2 | 3 | 1 | | | **10** |
| **28.5** | | | | | 1 | 1 | 1 | 2 | | | **5** |
| **29** | | | | | | | 1 | 1 | | | **2** |
| **29.5** | | | | | | | 1 | 1 | | | **2** |
| | | | | | | | | | | | **0** |
| **Total** | **218** | **59** | **298** | **134** | **201** | **36** | **12** | **10** | **0** | **0** | **968** |
| **%** | **22.5** | **6.1** | **30.8** | **13.8** | **20.8** | **3.7** | **1.2** | **1.0** | **0** | **0** | **100** |

**Table 6.** Total biomass (000's tonnes) of herring at age (winter rings), by strata as derived from acoustic estimate of abundance**.** Celtic Sea herring acoustic survey, October 2008.

| Strata | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 2.1 | 2.3 | 15 | 5.9 | 8.8 | 1.5 | 0.3 | 0.2 | 0 | 0 | 36.1 |
| 10 | 0.4 | 3.3 | 20.2 | 9.8 | 15.1 | 2.7 | 0.8 | 0.6 | 0 | 0 | 52.9 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0.2 | 0.3 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.6 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0.4 | 0.3 | 0.5 | 0.1 | 0 | 0 | 0 | 0 | 1.4 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 18 | 0 | 0 | 0.2 | 0.4 | 0.9 | 0.3 | 0.2 | 0.2 | 0 | 0 | 2.2 |
| Total | 2.5 | 5.8 | 36.1 | 16.6 | 25.5 | 4.6 | 1.3 | 1 | 0 | 0 | 93.3 |
| % | 2.7 | 6.2 | 38.7 | 17.7 | 27.4 | 4.9 | 1.4 | 1.1 | 0 | 0 | 100 |

**Table 7.** Herring abundance (millions) at age (winter rings), by strata as derived from acoustic estimate of abundance. Celtic Sea herring acoustic survey, October 2008.

| Strata | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0.067 | 0.006 | 0.014 | 0.034 | 0.067 | 0.02 | 0.01 | 0.01 | 0 | 0 | 0.2 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0.102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 9 | 80.873 | 25.724 | 123.714 | 40.35 | 56.62 | 8.71 | 1.3 | 0.93 | 0 | 0 | 338.2 |
| 10 | 17.097 | 36.408 | 164.546 | 65.71 | 96.12 | 15.6 | 3.71 | 3.07 | 0 | 0 | 402.3 |
| 11 | 0.072 | 0.013 | 0.019 | 0.002 | 0.002 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 12 | 0.451 | 1.841 | 2.243 | 0.376 | 0.429 | 0.06 | 0.02 | 0.02 | 0 | 0 | 5.4 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0.022 | 2.818 | 2.182 | 3.433 | 0.47 | 0.09 | 0.09 | 0 | 0 | 9.1 |
| 15 | 0 | 0.002 | 0.05 | 0.045 | 0.078 | 0.02 | 0 | 0 | 0 | 0 | 0.2 |
| 16 | 0 | 0.001 | 0.037 | 0.034 | 0.059 | 0.01 | 0 | 0 | 0 | 0 | 0.1 |
| 17 | 0 | 0 | 0.03 | 0.071 | 0.141 | 0.05 | 0.03 | 0.02 | 0 | 0 | 0.3 |
| 18 | 0.067 | 0.015 | 1.066 | 2.567 | 5.065 | 1.78 | 1.03 | 0.85 | 0 | 0 | 12.4 |
| Total | 98.7 | 64.0 | 294.5 | 111.4 | 162.0 | 26.7 | 6.2 | 5.0 | 0.0 | 0.0 | 768.6 |
| % | 12.8 | 8.3 | 38.3 | 14.5 | 21.1 | 3.5 | 0.8 | 0.6 | 0.0 | 0.0 | 100 |
| Cv (%) | 42.1 | 27.1 | 21.8 | 20.4 | 19.8 | 20.9 | 28.9 | 28.2 | - | - | - |

**Table 8.** Herring biomass (000's tonnes) at maturity by strata. Totals do not account for the "possibly" herring classification. Celtic Sea herring acoustic survey, October 2008.

| Strata | Imm | Mature | Spent | Total |
|---|---|---|---|---|
| **1** | 0 | 0 | 0 | 0 |
| **2** | 0 | 0 | 0 | 0 |
| **3** | 0 | 0 | 0 | 0 |
| **4** | 0 | 0 | 0 | 0 |
| **5** | 0 | 0 | 0 | 0 |
| **6** | 0 | 0 | 0 | 0 |
| **7** | 0 | 0 | 0 | 0 |
| **8** | 0 | 0 | 0 | 0 |
| **9** | 2 | 32.9 | 1.2 | 36.1 |
| **10** | 0.4 | 50.1 | 2.4 | 52.9 |
| **11** | 0 | 0 | 0 | 0 |
| **12** | 0 | 0.5 | 0 | 0.6 |
| **13** | 0 | 0 | 0 | 0 |
| **14** | 0 | 1.3 | 0.1 | 1.4 |
| **15** | 0 | 0 | 0 | 0 |
| **16** | 0 | 0 | 0 | 0 |
| **17** | 0 | 0.1 | 0 | 0.1 |
| **18** | 0 | 1.9 | 0.3 | 2.2 |
| **Total** | 2.5 | 86.8 | 4 | 93.3 |
| **%** | 2.6 | 93 | 4.3 | 100 |

**Table 9**. Herring abundance (millions) at maturity by strata. Totals do not account for the possibly herring classification. Celtic Sea herring acoustic survey, October 2008.

| Strata | Imm | Mature | Spent | Total |
|---|---|---|---|---|
| **1** | 0 | 0 | 0 | 0 |
| **2** | 0 | 0 | 0 | 0 |
| **3** | 0.1 | 0.1 | 0.0 | 0.2 |
| **4** | 0 | 0 | 0 | 0 |
| **5** | 0 | 0 | 0 | 0 |
| **6** | 0 | 0 | 0 | 0 |
| **7** | 0 | 0 | 0 | 0 |
| **8** | 0.1 | 0 | 0 | 0.1 |
| **9** | 79.4 | 251.7 | 7.2 | 338.2 |
| **10** | 17.0 | 371.4 | 13.9 | 402.3 |
| **11** | 0.1 | 0.0 | 0 | 0.1 |
| **12** | 0.5 | 4.9 | 0.1 | 5.4 |
| **13** | 0 | 0 | 0 | 0 |
| **14** | 0 | 8.7 | 0.4 | 9.1 |
| **15** | 0 | 0.2 | 0.0 | 0.2 |
| **16** | 0 | 0.1 | 0.0 | 0.1 |
| **17** | 0 | 0.3 | 0.1 | 0.3 |
| **18** | 0.1 | 10.6 | 1.8 | 12.4 |
| **Total** | 97.1 | 648.1 | 23.4 | 768.6 |
| **%** | 12.6 | 84.3 | 3.0 | 100 |

**Table 10.** Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Celtic Sea herring acoustic survey, October 2008.

| Length (cm) | Age (Rings) 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Abundance (millions) | Biomass 000's t | Mn wt (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **12.5** | 0.91 | - | - | - | - | - | - | - | - | - | 0.91 | 0.01 | 14.4 |
| **13** | 2.39 | - | - | - | - | - | - | - | - | - | 2.39 | 0.04 | 16.4 |
| **13.5** | 6.09 | - | - | - | - | - | - | - | - | - | 6.09 | 0.11 | 18.6 |
| **14** | 12.7 | - | - | - | - | - | - | - | - | - | 12.74 | 0.27 | 21 |
| **14.5** | 22.6 | - | - | - | - | - | - | - | - | - | 22.61 | 0.53 | 23.5 |
| **15** | 28.2 | - | - | - | - | - | - | - | - | - | 28.21 | 0.74 | 26.3 |
| **15.5** | 16.8 | - | - | - | - | - | - | - | - | - | 16.76 | 0.49 | 29.3 |
| **16** | 7.93 | - | - | - | - | - | - | - | - | - | 7.93 | 0.26 | 32.6 |
| **16.5** | 0.9 | - | - | - | - | - | - | - | - | - | 0.9 | 0.03 | 36 |
| **17** | 0.15 | - | - | - | - | - | - | - | - | - | 0.15 | 0.01 | 39.8 |
| **17.5** | 0.04 | - | - | - | - | - | - | - | - | - | 0.04 | - | 43.8 |
| **18** | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **18.5** | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **19** | - | 0.38 | - | - | - | - | - | - | - | - | 0.38 | 0.02 | 57.4 |
| **19.5** | - | 0.61 | - | - | - | - | - | - | - | - | 0.61 | 0.04 | 62.6 |
| **20** | - | 2.09 | - | - | - | - | - | - | - | - | 2.09 | 0.14 | 68.1 |
| **20.5** | - | 4.39 | - | - | - | - | - | - | - | - | 4.39 | 0.32 | 73.9 |
| **21** | - | 6.97 | 1 | - | - | - | - | - | - | - | 7.97 | 0.64 | 80 |
| **21.5** | - | 16.8 | 1.05 | - | - | - | - | - | - | - | 17.86 | 1.55 | 86.5 |
| **22** | - | 18.3 | 6.67 | - | - | - | - | - | - | - | 24.98 | 2.33 | 93.3 |
| **22.5** | - | 8.98 | 22.1 | - | 0.7 | - | - | - | - | - | 31.76 | 3.19 | 100.5 |
| **23** | - | 4.53 | 43.8 | 1.49 | - | - | - | - | - | - | 49.79 | 5.39 | 108.1 |
| **23.5** | - | - | 62.3 | 0.98 | 1.96 | - | - | - | - | - | 65.28 | 7.58 | 116.1 |
| **24** | - | - | 65.7 | 13.3 | 4.08 | - | - | - | - | - | 83.13 | 10.35 | 124.5 |
| **24.5** | - | 0.96 | 51.6 | 19.1 | 8.58 | - | - | - | - | - | 80.22 | 10.7 | 133.4 |
| **25** | - | - | 19.3 | 23.8 | 25.4 | 0.76 | - | - | - | - | 69.23 | 9.87 | 142.6 |
| **25.5** | - | - | 15.6 | 21.1 | 41.3 | 3.68 | - | - | - | - | 81.68 | 12.44 | 152.3 |
| **26** | - | - | 4.36 | 13.1 | 37.3 | 6.57 | - | - | - | - | 61.36 | 9.97 | 162.4 |
| **26.5** | - | - | - | 9.11 | 30 | 9.11 | - | - | - | - | 48.24 | 8.35 | 173 |
| **27** | - | - | 1.09 | 7.12 | 8.23 | 2.2 | 1.09 | 1.65 | - | - | 21.39 | 3.94 | 184.1 |
| **27.5** | - | - | - | 1.14 | 2.87 | 2.87 | 2.29 | 1.14 | - | - | 10.31 | 2.02 | 195.7 |
| **28** | - | - | - | 1.09 | 1.09 | 1.09 | 1.63 | 0.54 | - | - | 5.45 | 1.13 | 207.8 |
| **28.5** | - | - | - | - | 0.47 | 0.47 | 0.47 | 0.94 | - | - | 2.34 | 0.52 | 220.3 |
| **29** | - | - | - | - | - | - | 0.46 | 0.46 | - | - | 0.92 | 0.21 | 233.4 |
| **29.5** | - | - | - | - | - | - | 0.23 | 0.23 | - | - | 0.45 | 0.11 | 247.1 |
| **30** | - | - | - | - | - | - | 0.03 | 0.03 | - | - | 0.05 | 0.01 | 261.3 |
| **TSN (mil)** | 2.08 | 63.5 | 295 | 111 | 162 | 26.8 | 6.19 | 4.98 | - | - | 671.48 | - | - |
| **TSB ('000s t)** | 0.06 | 5.74 | 36.1 | 16.6 | 25.5 | 4.61 | 1.26 | 1.02 | - | - | - | 90.855 | - |
| **Mean Wt (g)** | 25.3 | 90.1 | 123 | 149 | 158 | 172 | 204 | 204 | - | - | - | - | - |
| **Mean length (cm)** | 15 | 22 | 24.1 | 25.5 | 26 | 26.7 | 28.1 | 28.1 | - | - | - | - | - |

**Table 11.** Herring biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2008.

| Category Stratum | No. transects | No. schools | Def schools | Mix schools | Prob schools | % zeros | Def Biomass | Mix Biomass | Prob Biomass | Biomass (t) | SSB (t) | Abundance millions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 14 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2** | 7 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **3** | 9 | 6 | 0 | 6 | 0 | 89 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| **4** | 8 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **5** | 7 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **6** | 7 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7** | 5 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8** | 14 | 20 | 0 | 20 | 0 | 71 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| **9** | 32 | 199 | 72 | 89 | 38 | 31 | 26.5 | 7.4 | 2.2 | 36.1 | 34.1 | 338.2 |
| **10** | 34 | 211 | 111 | 46 | 54 | 44 | 47.9 | 3.7 | 1.3 | 52.9 | 52.5 | 402.3 |
| **11** | 8 | 1 | 0 | 1 | 0 | 88 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| **12** | 17 | 8 | 0 | 0 | 8 | 82 | 0 | 0 | 0.6 | 0.6 | 0.5 | 5.4 |
| **13** | 4 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **14** | 16 | 4 | 4 | 0 | 0 | 88 | 1.4 | 0 | 0 | 1.4 | 1.4 | 9.1 |
| **15** | 13 | 3 | 0 | 0 | 3 | 92 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| **16** | 5 | 5 | 0 | 0 | 5 | 80 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| **17** | 6 | 1 | 0 | 1 | 0 | 83 | 0 | 0.1 | 0 | 0.1 | 0.1 | 0.3 |
| **18** | 6 | 3 | 2 | 1 | 0 | 83 | 2.2 | 0 | 0 | 2.2 | 2.2 | 12.4 |
| **Total** | 212 | 461 | 189 | 164 | 108 | 74 | 77.9 | 11.2 | 4.2 | 93.3 | 90.9 | 768.6 |
| **Cv (%)** | - | - | - | - | - | - | - | - | - | 19.6 | 20 | 19.2 |

**Table 12.** Celtic Sea and VIIj Herring acoustic survey time series. Abundance (millions), TSB and SSB (000's tonnes). Age in winter rings.

| Season | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age (Rings)** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
| **0** | 202 | 3 | - | 0 | - | 25 | 40 | 0 | 24 | - | 2 | - | 1 | 2 |
| **1** | 25 | 164 | - | 30 | - | 102 | 28 | 42 | 13 | - | 65 | 21 | 106 | 63 |
| **2** | 157 | 795 | - | 186 | - | 112 | 187 | 185 | 62 | - | 137 | 211 | 70 | 295 |
| **3** | 38 | 262 | - | 133 | - | 13 | 213 | 151 | 60 | - | 28 | 48 | 220 | 111 |
| **4** | 34 | 53 | - | 165 | - | 2 | 42 | 30 | 17 | - | 54 | 14 | 31 | 162 |
| **5** | 5 | 43 | - | 87 | - | 1 | 47 | 7 | 5 | - | 22 | 11 | 9 | 27 |
| **6** | 3 | 1 | - | 25 | - | 0 | 33 | 7 | 1 | - | 5 | 1 | 13 | 6 |
| **7** | 1 | 15 | - | 24 | - | 0 | 24 | 3 | 0 | - | 1 | - | 4 | 5 |
| **8** | 2 | 0 | - | 4 | - | 0 | 15 | 0 | 0 | - | 0 | - | 1 | - |
| **9** | 2 | 2 | - | 2 | - | 0 | 52 | 0 | 0 | - | 0 | - | 0 | - |
| **Abundance** | 469 | 1338 | - | 656 | | 256 | 681 | 423 | 183 | | 312 | 305 | 454 | 671 |
| **SSB** | 36 | 151 | | 100 | | 20 | 95 | 41 | 20 | | 33 | 36 | 46 | 93 |
| **CV** | 53 | 26 | | 36 | | 100 | 88 | 49 | 34 | | 48 | 35 | 25 | 20 |

**Table 13.** Sprat biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2008.

| Category Stratum | No. transects | No. schools | Def schools | Mix schools | % zeros | Def Biomass | Mix Biomass | Prob Biomass | Biomass (t) | Abundance millions |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 14 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **2** | 7 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **3** | 9 | 109 | 34 | 75 | 11 | 0.7 | 2 | 0.2 | 2.7 | 337.6 |
| **4** | 8 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **5** | 7 | 43 | 0 | 43 | 29 | 0 | 2.2 | 0 | 2.2 | 126.5 |
| **6** | 7 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **7** | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **8** | 14 | 12 | 0 | 12 | 93 | 0 | 0.5 | 0 | 0.5 | 66.5 |
| **9** | 32 | 10 | 9 | 1 | 94 | 0 | 0.1 | 0 | 0.1 | 9.4 |
| **10** | 34 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **11** | 8 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **12** | 17 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **13** | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **14** | 16 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **15** | 13 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **16** | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **17** | 6 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **18** | 6 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **Total** | 212 | 174 | 43 | 131 | 92 | 0.7 | 4.8 | 0.3 | 5.5 | 540 |
| **Cv (%)** | - | - | - | - | - | - | - | - | 27.9 | 25 |

**Table 14.** Pilchard biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2008.

| Category Stratum | No. transects | No. schools | Def schools | Mix schools | Prob schools | % zeros | Def Biomass | Mix Biomass | Prob Biomass | Biomass (t) | Abundance millions |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 14 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **2** | 7 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **3** | 9 | 1 | 0 | 0 | 1 | 89 | 0 | 0 | 0.2 | 0.2 | 1.835 |
| **4** | 8 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **5** | 7 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **6** | 7 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **7** | 5 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **8** | 14 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **9** | 32 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **10** | 34 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **11** | 8 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0.00 |
| **12** | 17 | 9 | 0 | 0 | 9 | 88 | 0 | 0 | 0 | 0 | 0.31 |
| **13** | 4 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **14** | 16 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **15** | 13 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **16** | 5 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **17** | 6 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **18** | 6 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| **Total** | 212 | 10 | 0 | 0 | 10 | 99 | 0 | 0 | 0.3 | 0.3 | 2.142 |
| **Cv (%)** | - | - | - | - | - | - | - | - | - | 76 | 76 |

**Table 15.** Sightings, counts and group size ranges for cetaceans sighted during current survey. Celtic Sea herring acoustic survey, October 2008.

| **Species** | **No. Sightings** | **No. Individuals** | **Range of Group Size** |
|---|---|---|---|
| *Common dolphin* | 78 | 1849 | 2-350 |
| *Harbour porpoise* | 3 | 7 | 1-3 |
| | | | |
| *Fin whale* | 9 | 28 | 1-8 |
| *Minke whale* | 7 | 7 | |
| | | | |
| *Unidentified dolphin* | 4 | 22 | 2-10 |

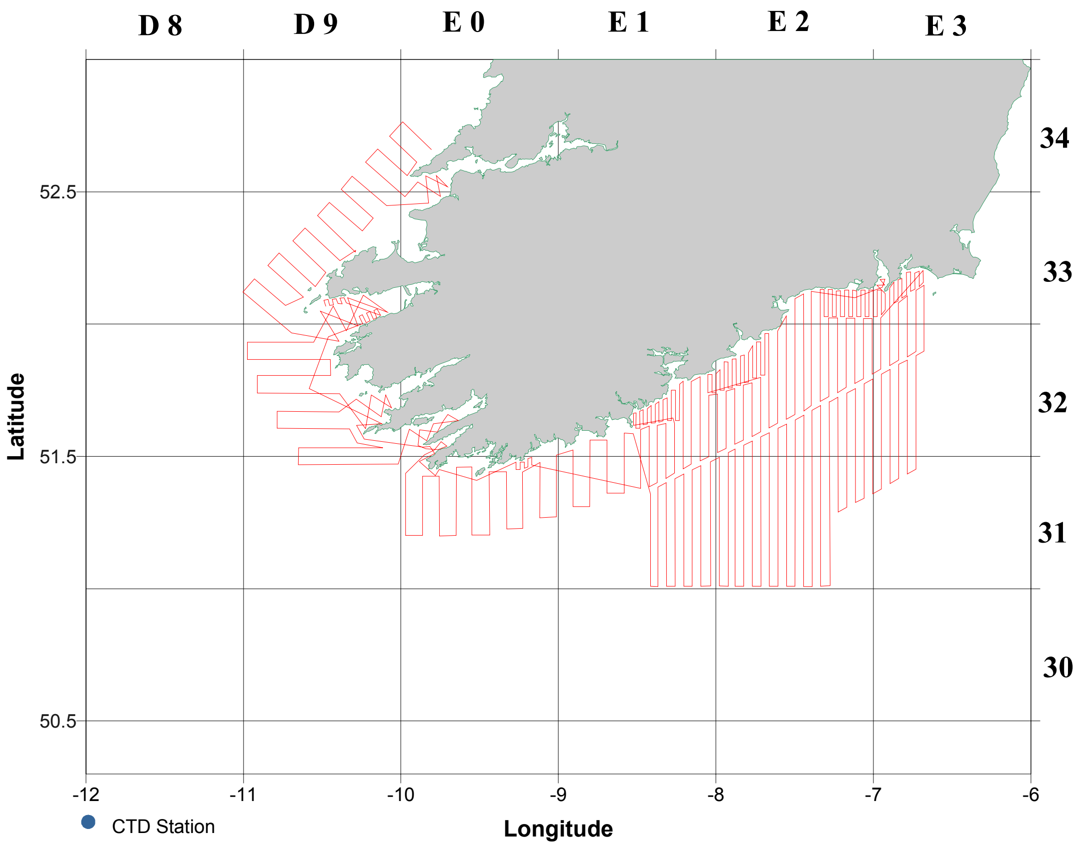



**Figure 1.** Cruise track (red line) during the Celtic Sea herring acoustic survey, October 2008.

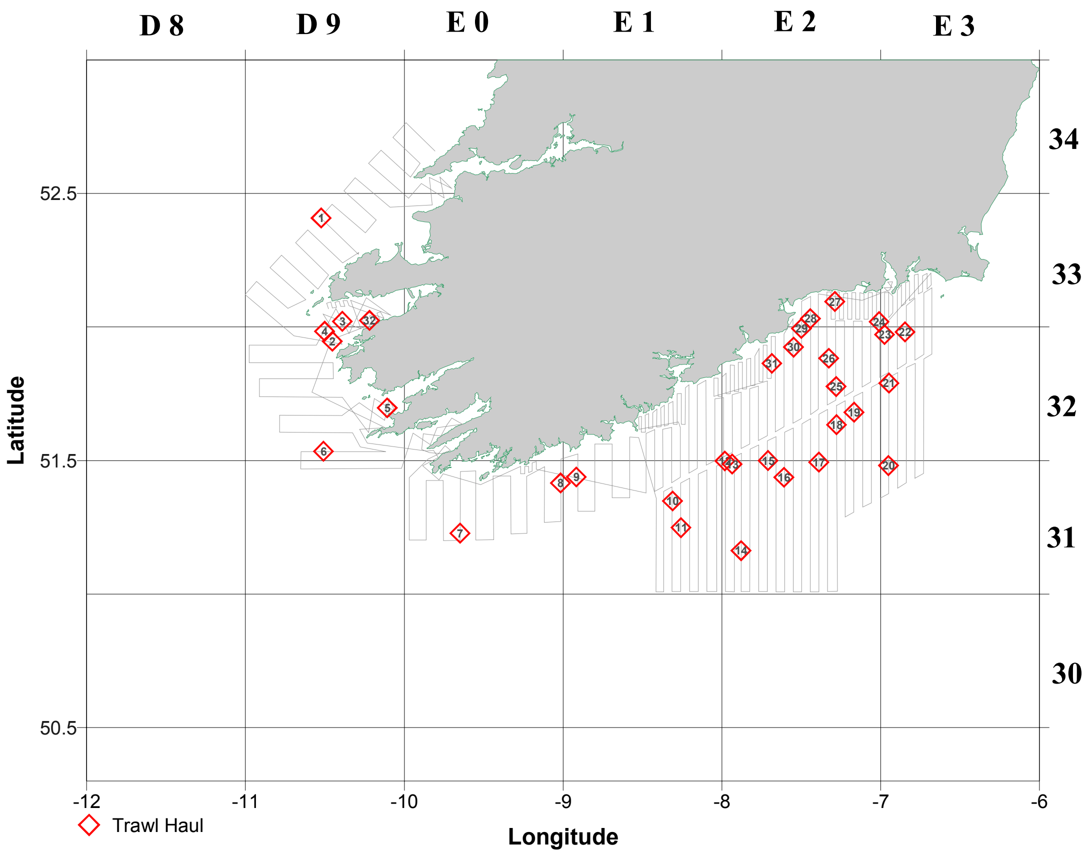



**Figure 2.** Haul positions. Celtic Sea herring acoustic survey, October 2008.

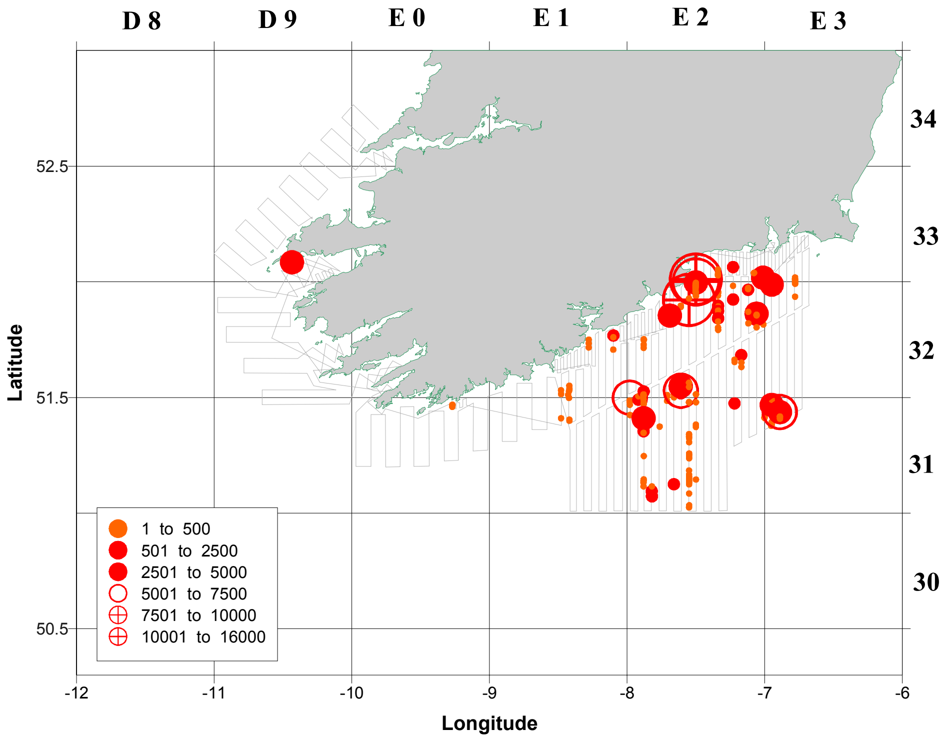



**Figure 3.** Weighted herring NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” categories. Celtic Sea herring acoustic survey, October 2008.

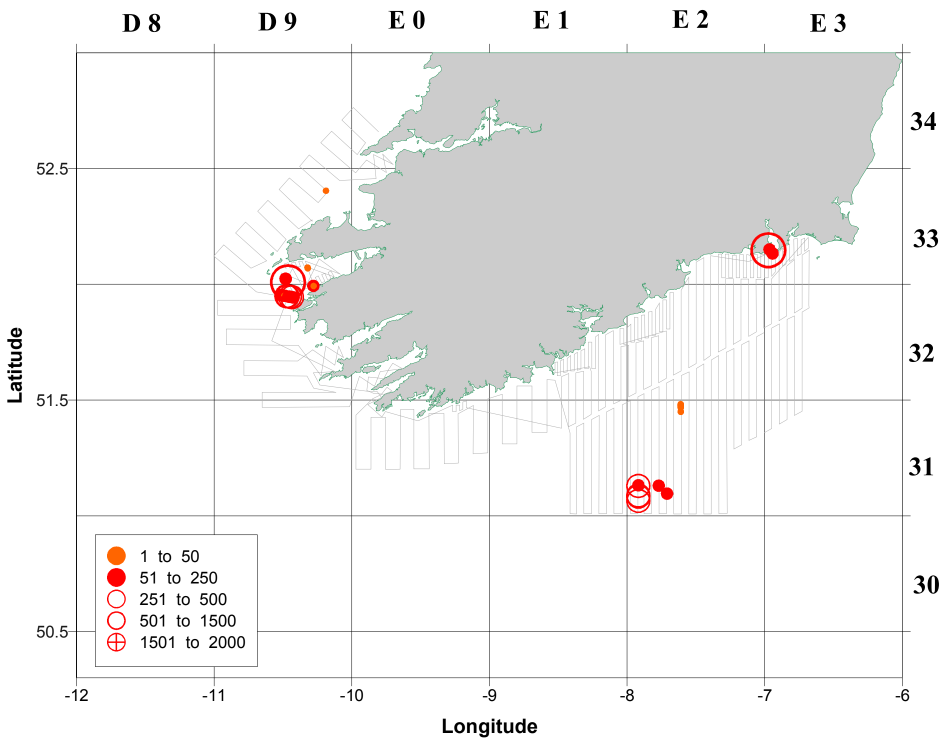



**Figure 4.** Weighted Sprat NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” categories. Celtic Sea herring acoustic survey, October 2008.

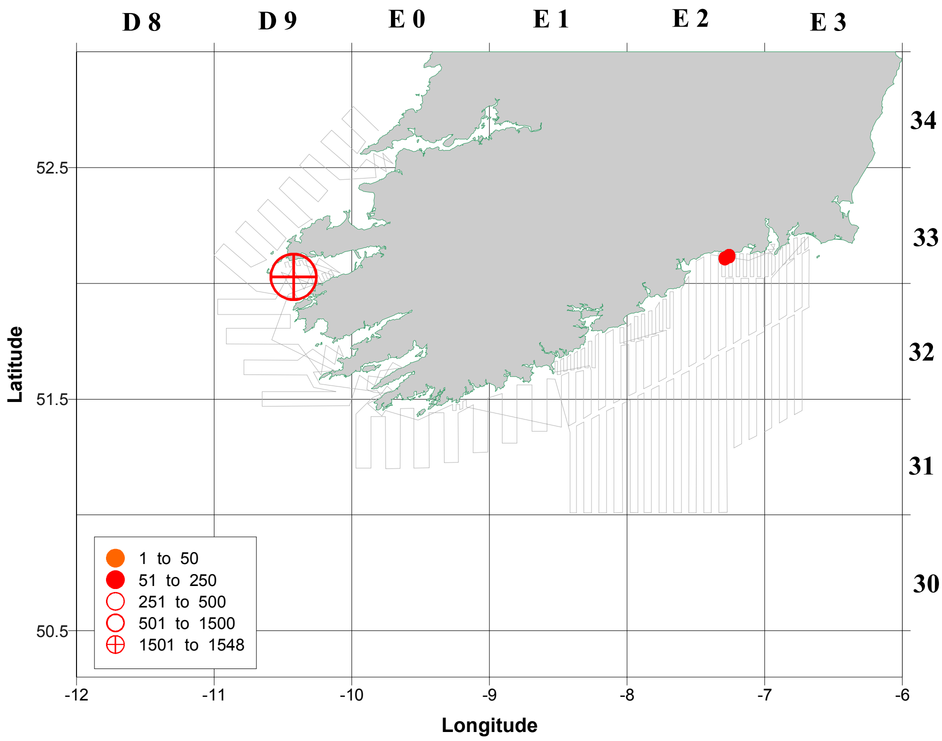



**Figure 5.** Weighted Pilchard NASC (Nautical area scattering coefficient) plot showing the distribution of "definitely" and "probably" categories. Celtic Sea herring acoustic survey, October 2008.

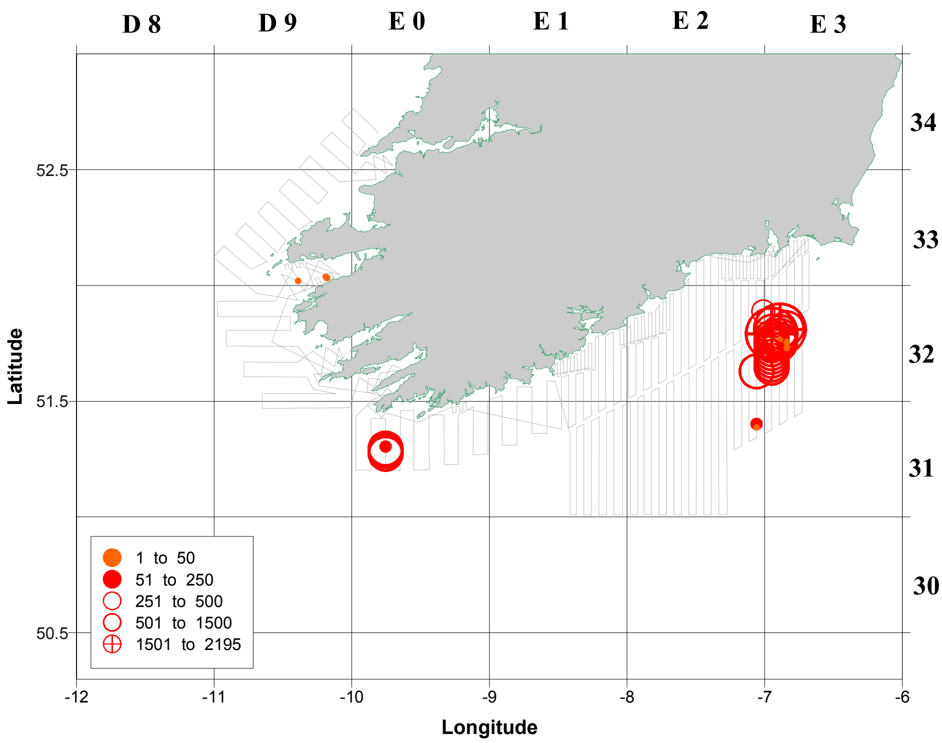
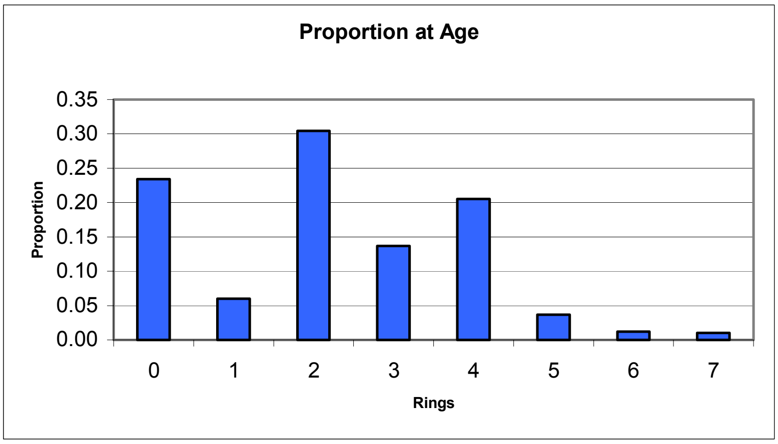



**Figure 6.** Weighted Mackerel NASC (Nautical area scattering coefficient) plot showing the distribution of "definitely" and "probably" categories. Note: No biomass was was estimated for this species.



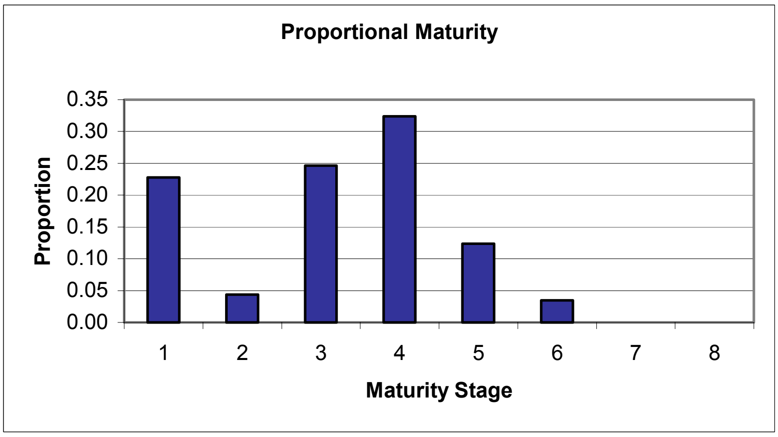
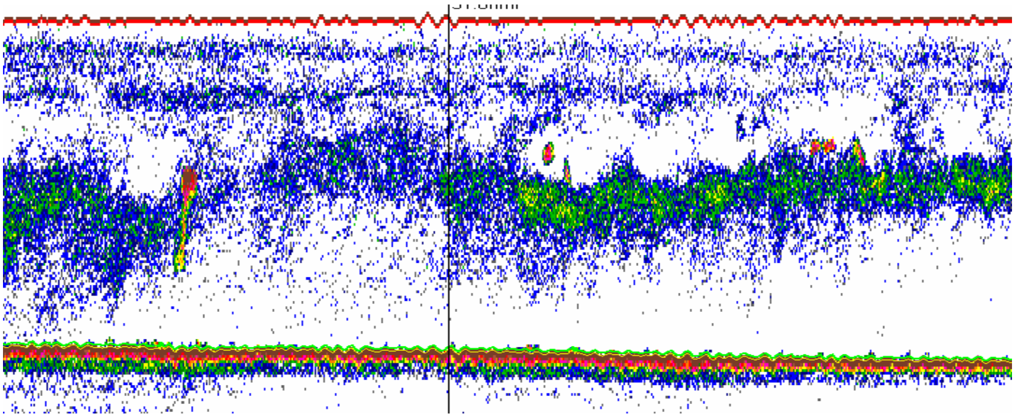
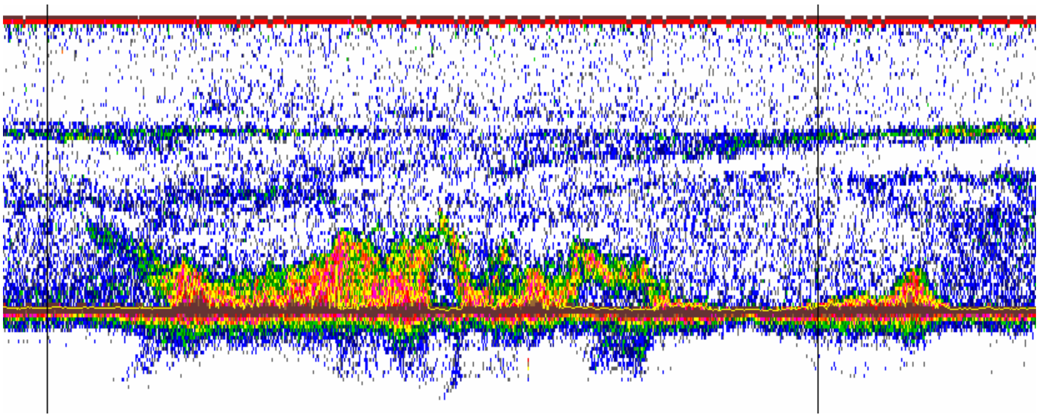



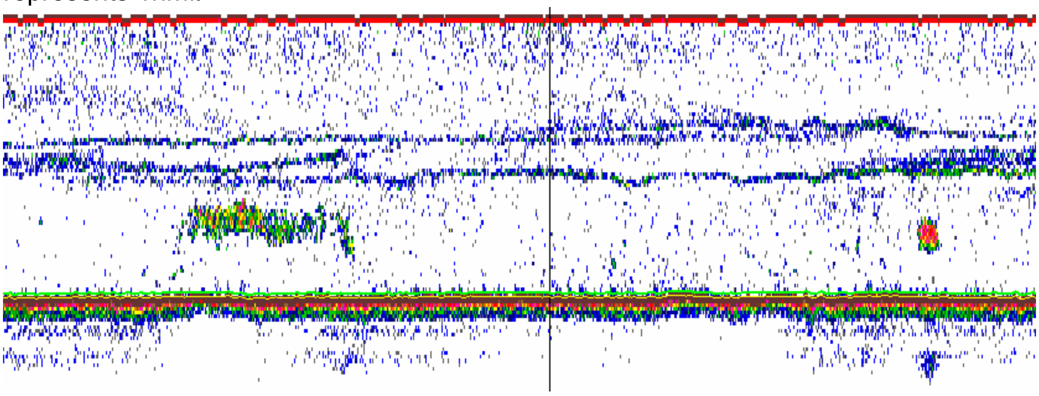

**Figure 7.** Breakdown of herring ages (above) and maturity (below) from combined survey trawl stations. Celtic Sea herring acoustic survey, October 2008.



a). ***Borefish*** marks (red) recorded prior to Haul 06 (Stratum 4). Water depth is 131m with marks extending to 30m. Note:

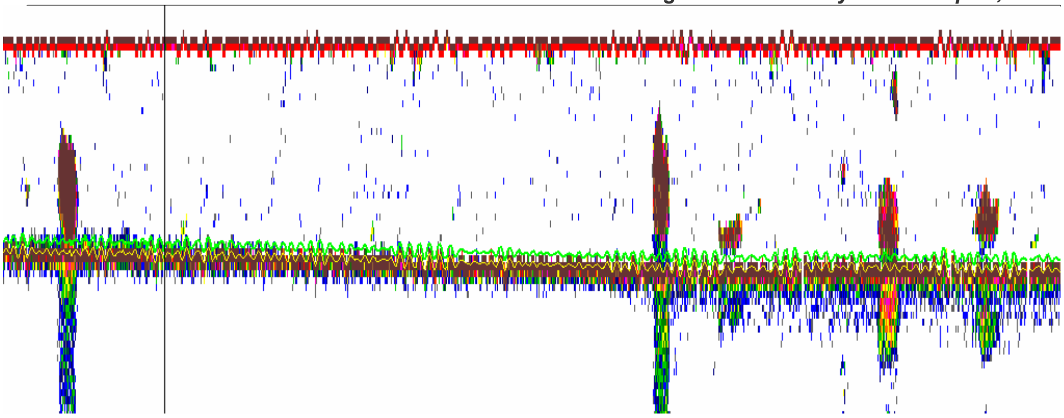


b). Large ***Herring*** mark recorded 25nmi offshore (pre-spawning fish, stage 3/4) 20m tall, water depth 86m (Haul 12, Stratum 9). Note: Distance between black vertical lines represents 1nmi.



c). Medium density ***Herring*** mark typical of those encountered offshore, stratum 9 (pre-spawning fish, stage 3/4) 8m tall, water depth 80m (Haul 15, Stratum 9).

**Figure 8.** Echograms (a-d) of main pelagic species encountered. Celtic Sea herring acoustic survey, October 2008.



d). High density ***Herring*** schools observed inshore. These marks were up to 22m tall in 34m water depth (Haul 29, Stratum 10) and contained pre-spawning herring (stage 3). Other large high density marks were observed off track on the sonar in the surrounding area.

**Figure 8.** continued.

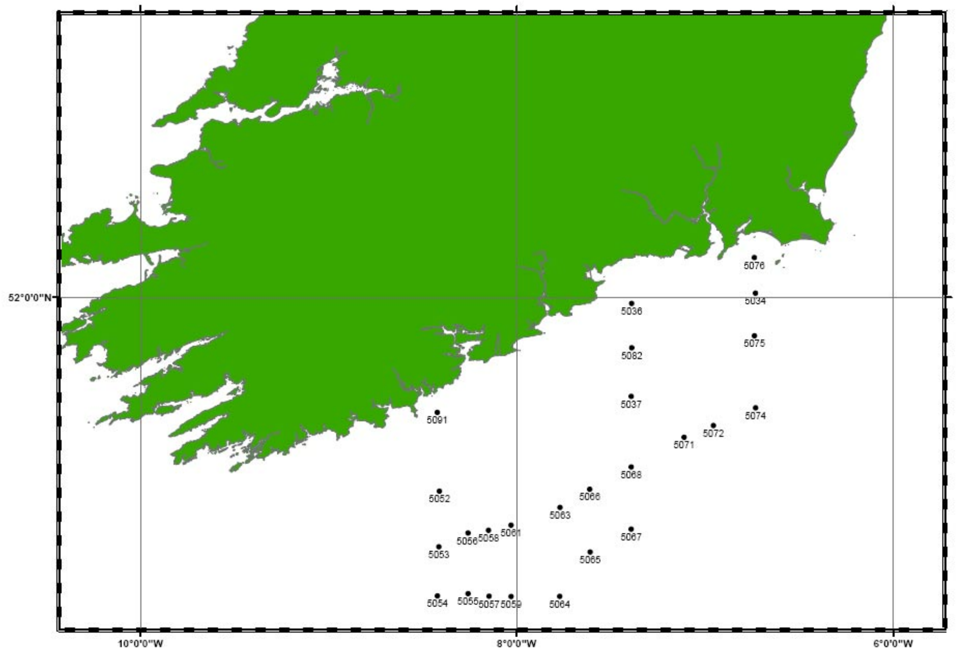
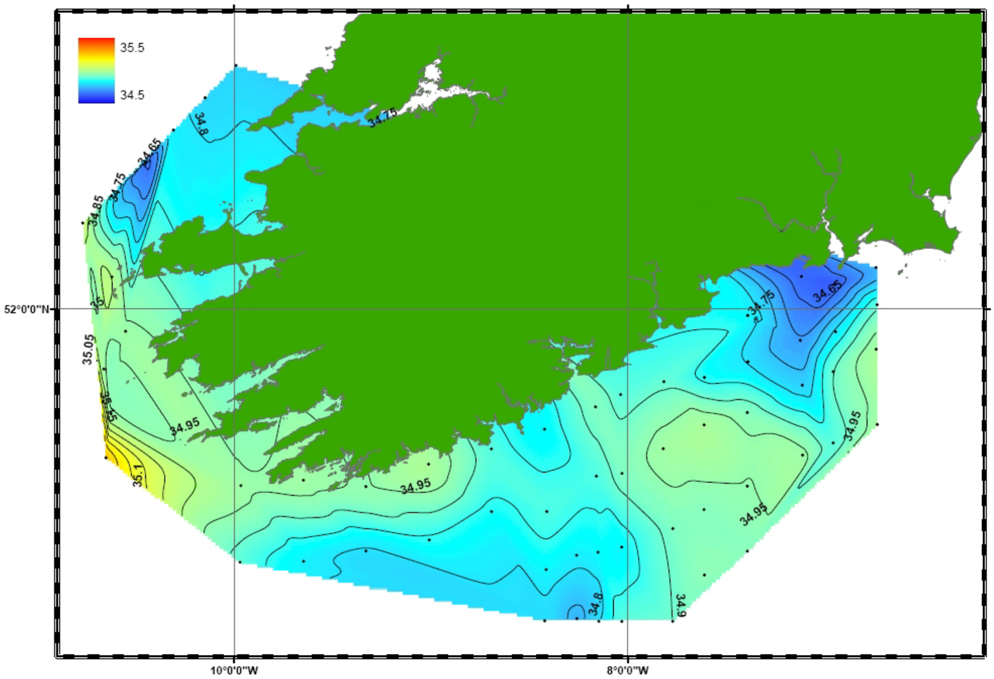



**Figure 9.** Position of the 61 vertical CTD casts undertaken during the survey. Celtic Sea herring acoustic survey, October 2008.



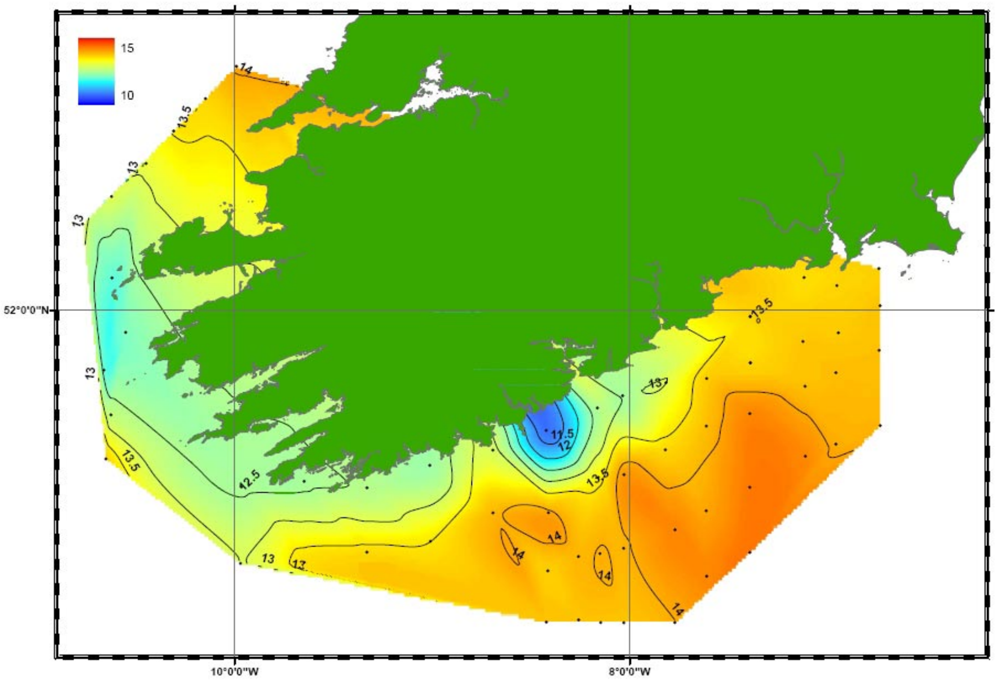




**Figure 10.** Horizontal salinity (above) and temperature (below) distribution taken at 5m subsurface from combined CTD cast data. Celtic Sea herring acoustic survey, October 2008.

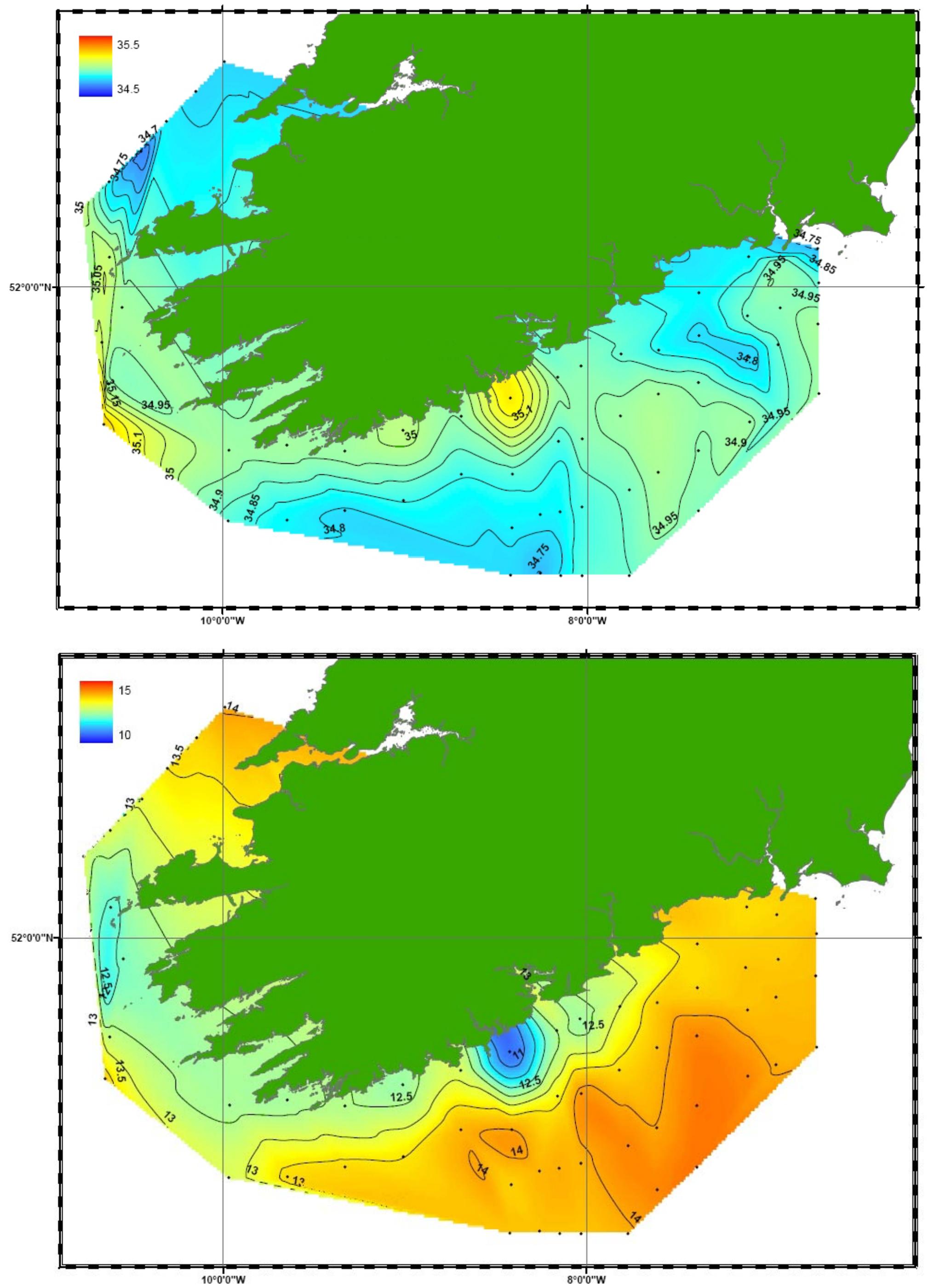



**Figure 11.** Horizontal salinity (above) and temperature (below) distribution taken at 20m subsurface from combined CTD cast data. Celtic Sea herring acoustic survey, October 2008.

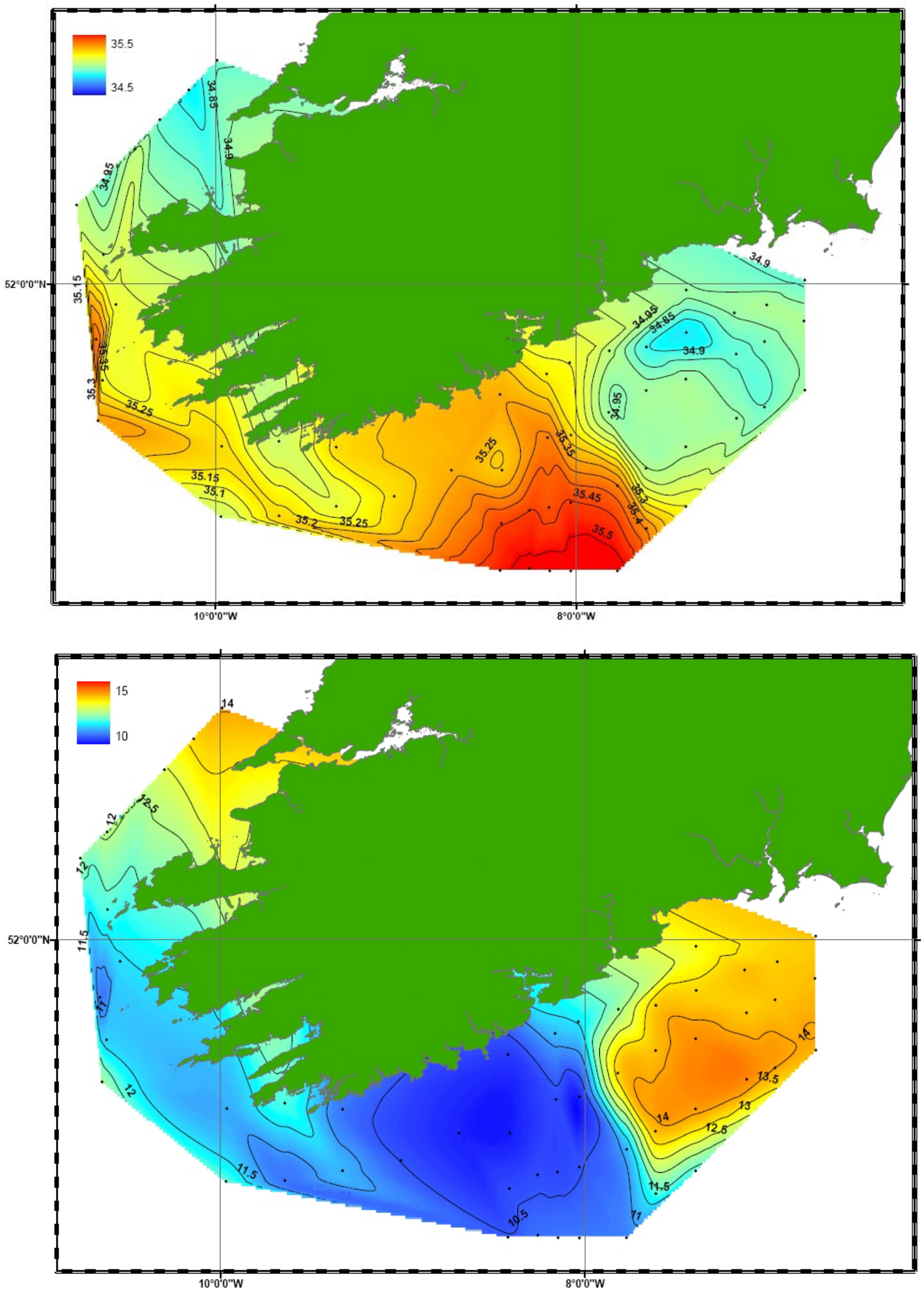



**Figure 12.** Horizontal salinity (above) and temperature (below) distribution taken at 40m subsurface from combined CTD cast data. Celtic Sea herring acoustic survey, October 2008.

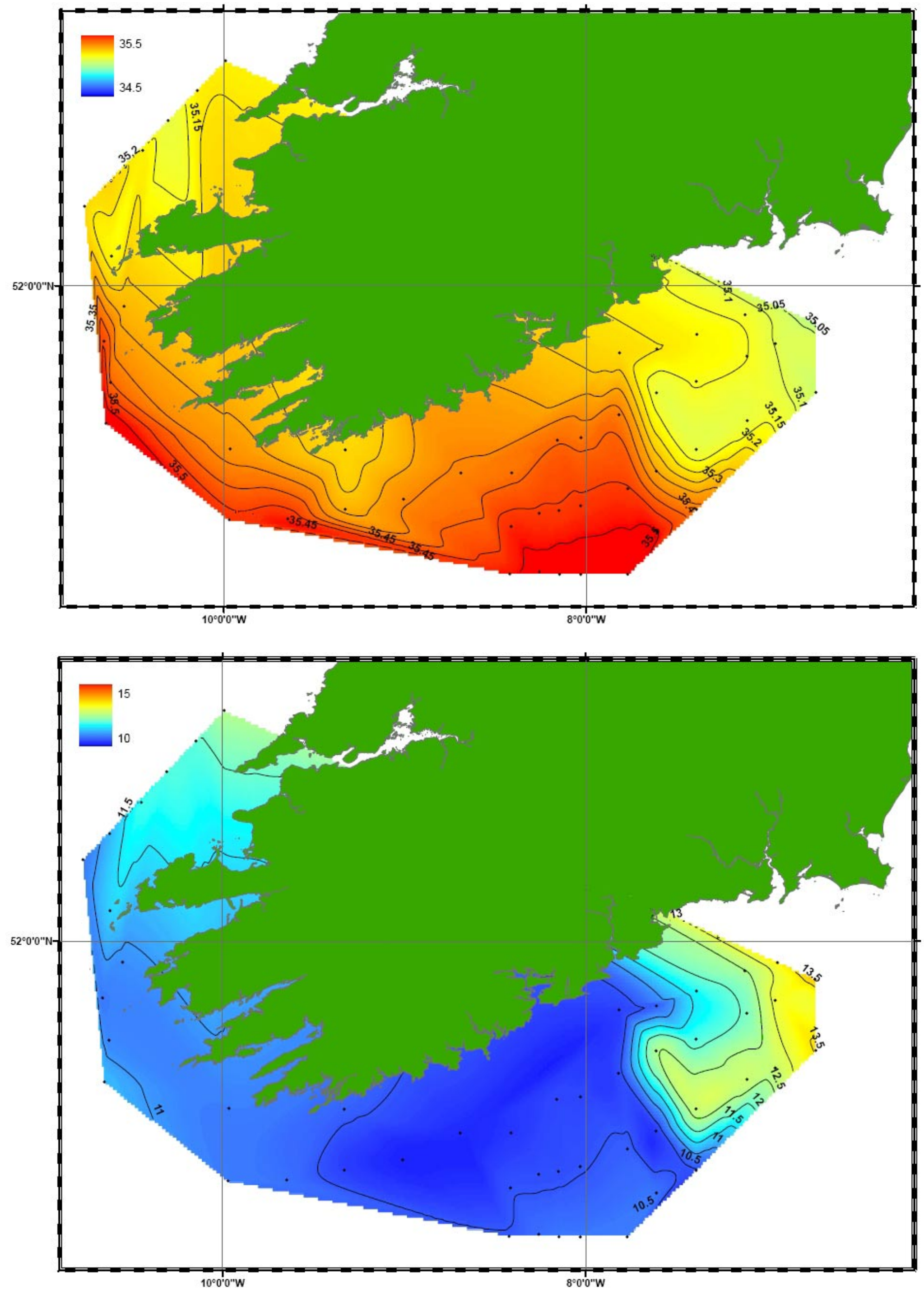



**Figure 13.** Horizontal salinity (above) and temperature (below) distribution taken at 60m subsurface from combined CTD cast data. Celtic Sea herring acoustic survey, October 2008.

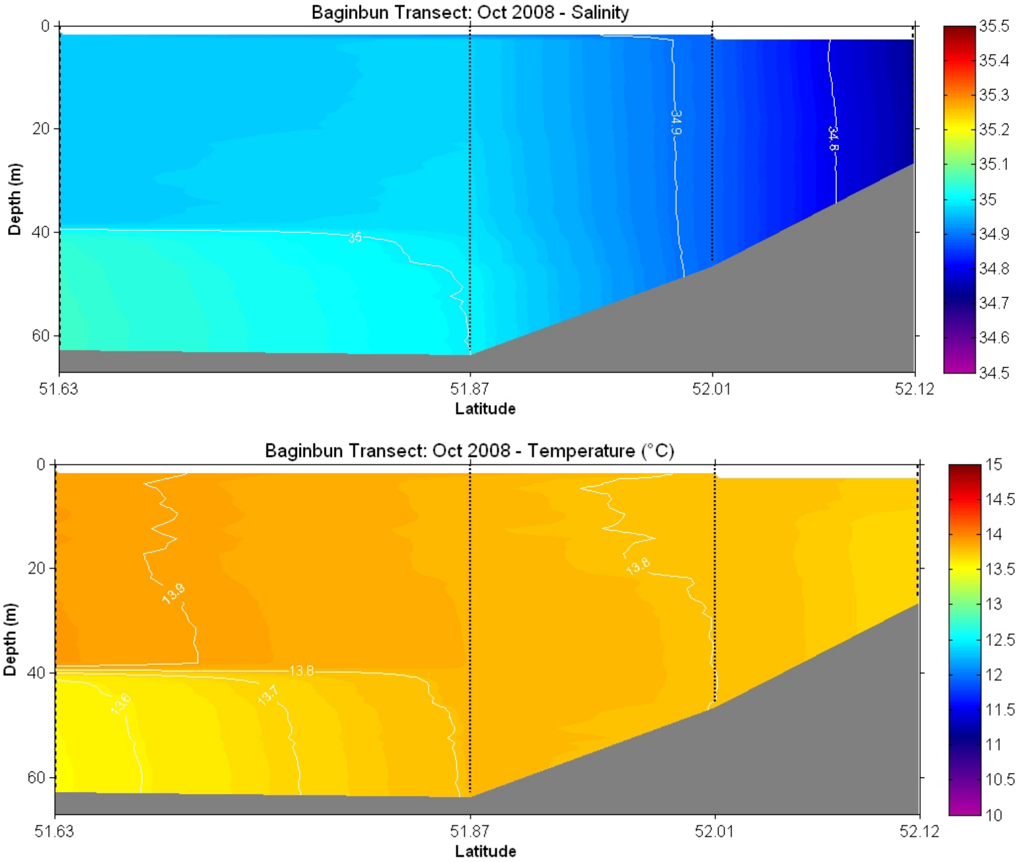



**Figure 14.** Vertical distribution of temperature (above) and salinity (below) along the Baginbun transect (stations 5074-5076). Celtic Sea herring acoustic survey, October 2008.

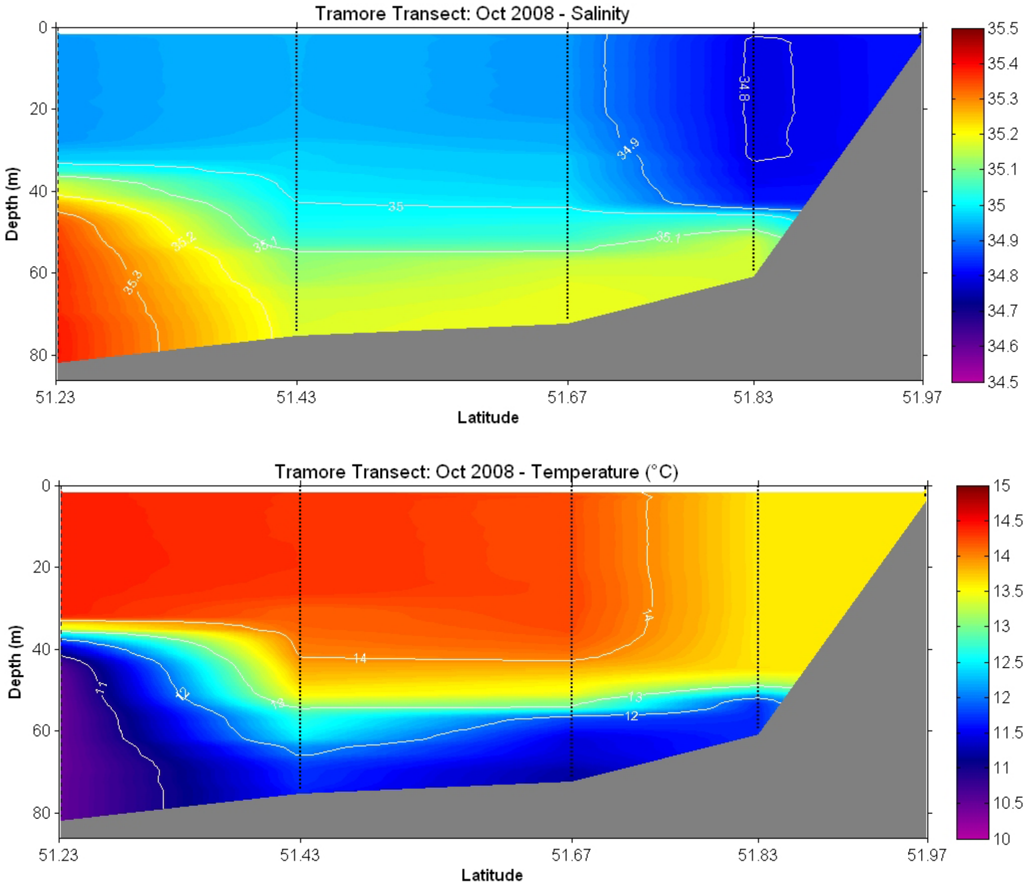



**Figure 15.** Vertical distribution of temperature (above) and salinity (below) along the Tramore transect (stations 5067-5036). Celtic Sea herring acoustic survey, October 2008.

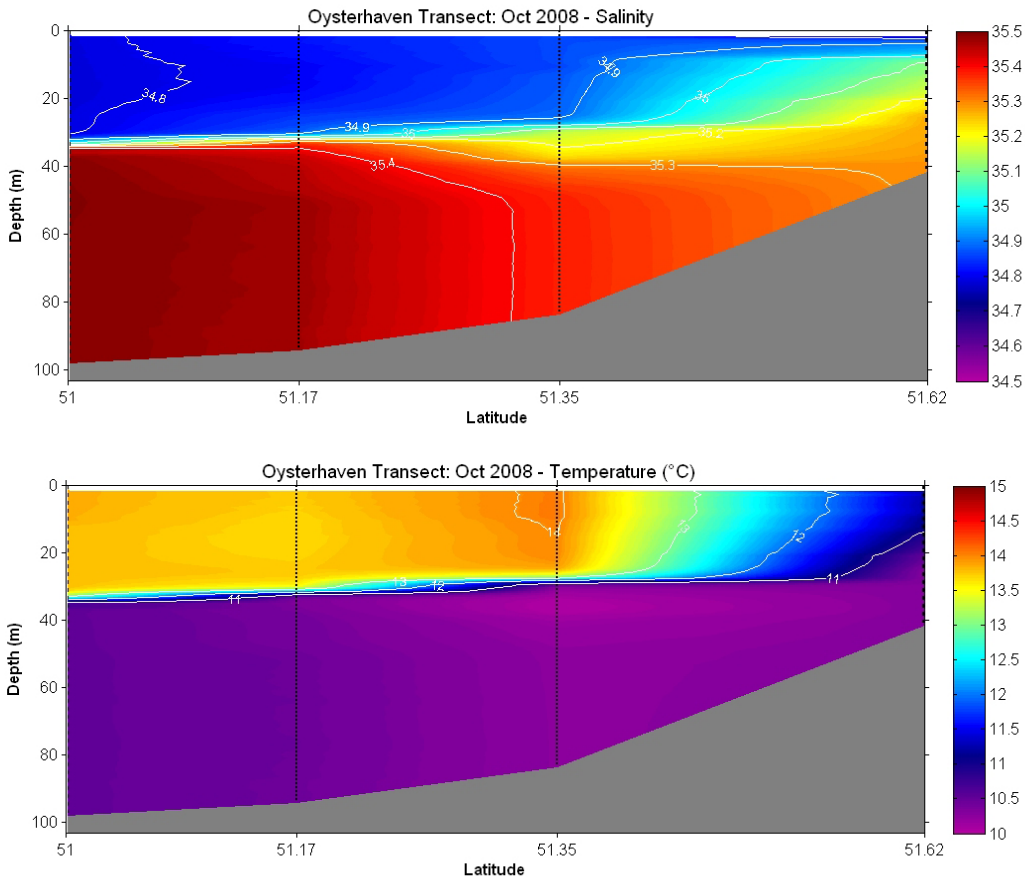



**Figure 16.** Vertical distribution of temperature (above) and salinity (below) along the Oysterhaven transect (stations 5054-5091). Celtic Sea herring acoustic survey, October 2008.

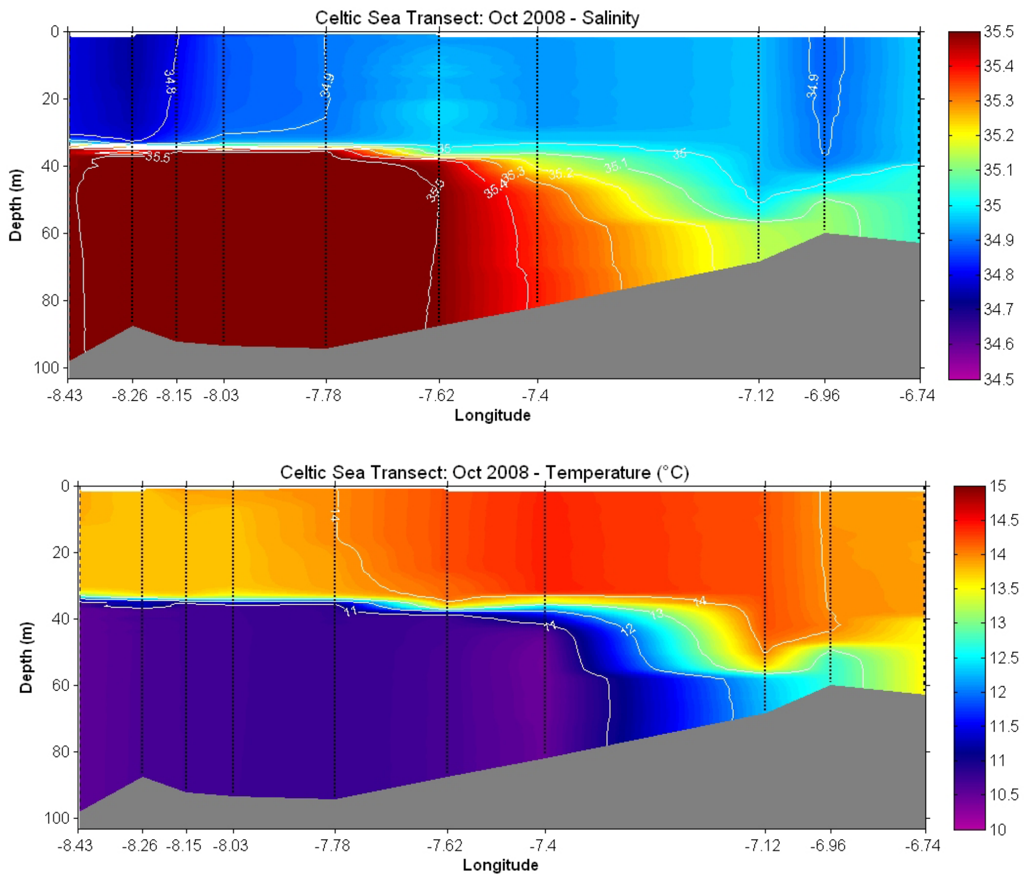



**Figure 17.** Vertical distribution of temperature (above) and salinity (below) along the Celtic Sea_1 transect (stations 5054 east to 5064 northeast to 5067 on to 5071, 5072 and 5074). Celtic Sea herring acoustic survey, October 2008.

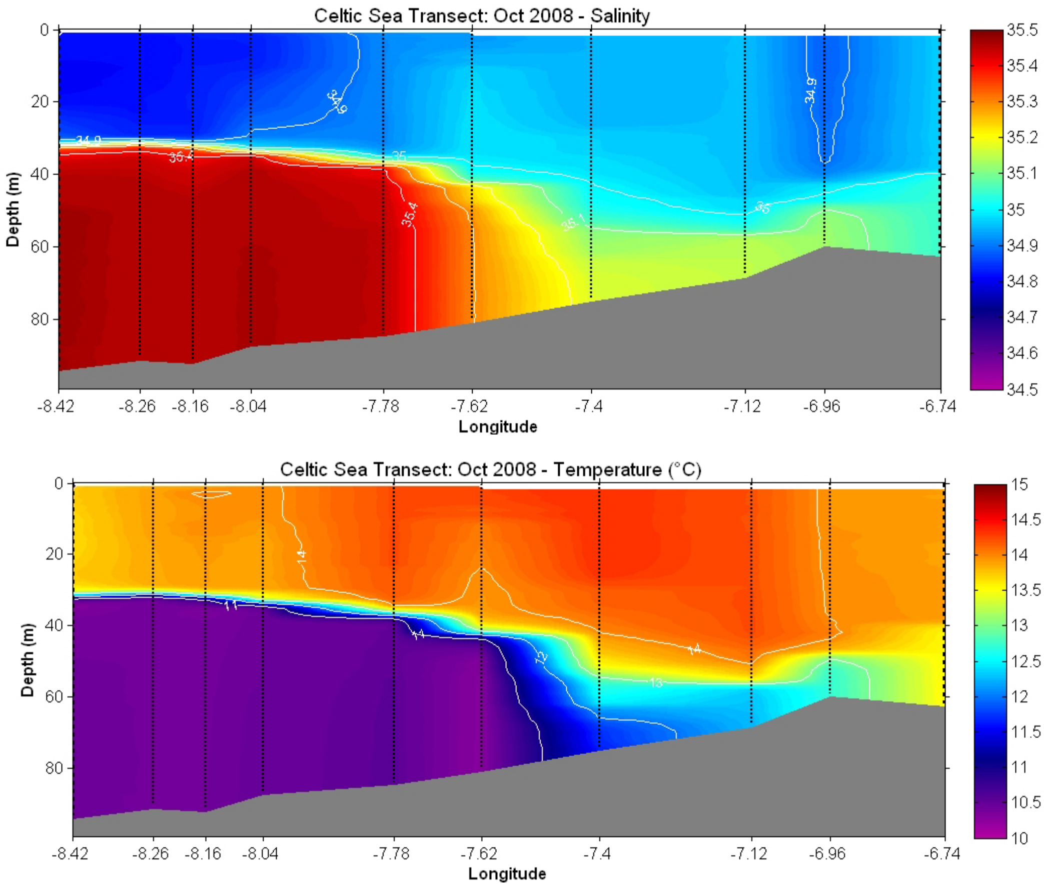



**Figure 18.** Vertical distribution of temperature (above) and salinity (below) along the Celtic Sea_2 transect (stations 5053 east northeast to 5074). Celtic Sea herring acoustic survey, October 2008.

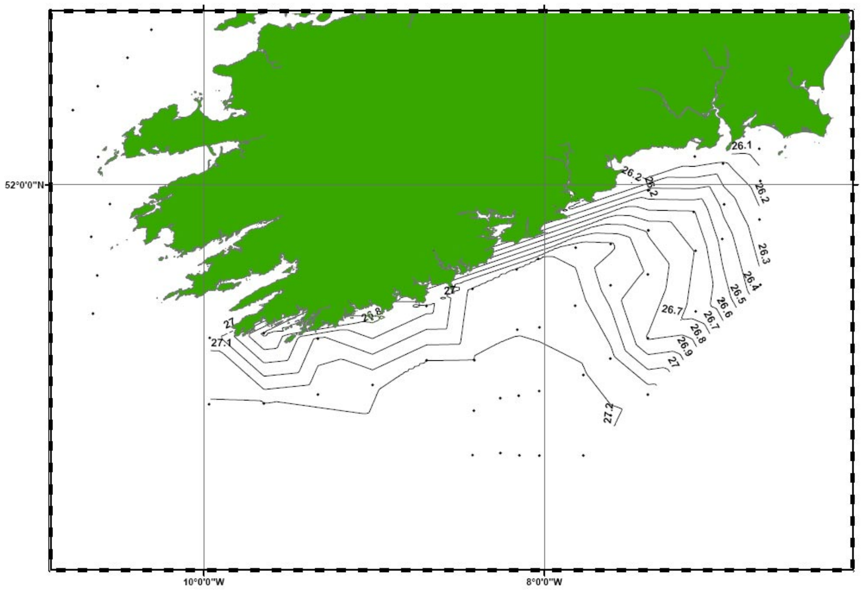



**Figure 18.** Bottom density plot of combined CTD data. Celtic Sea herring acoustic survey, October 2008.

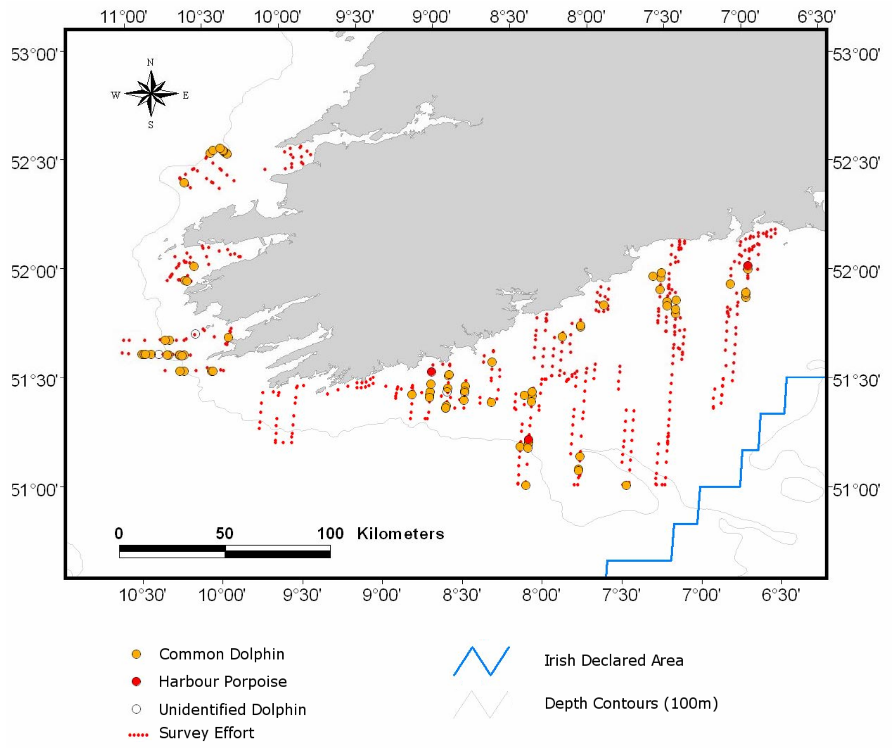



**Figure 19.** Distribution of dolphin and seal sightings. Celtic Sea herring acoustic survey, October 2008.

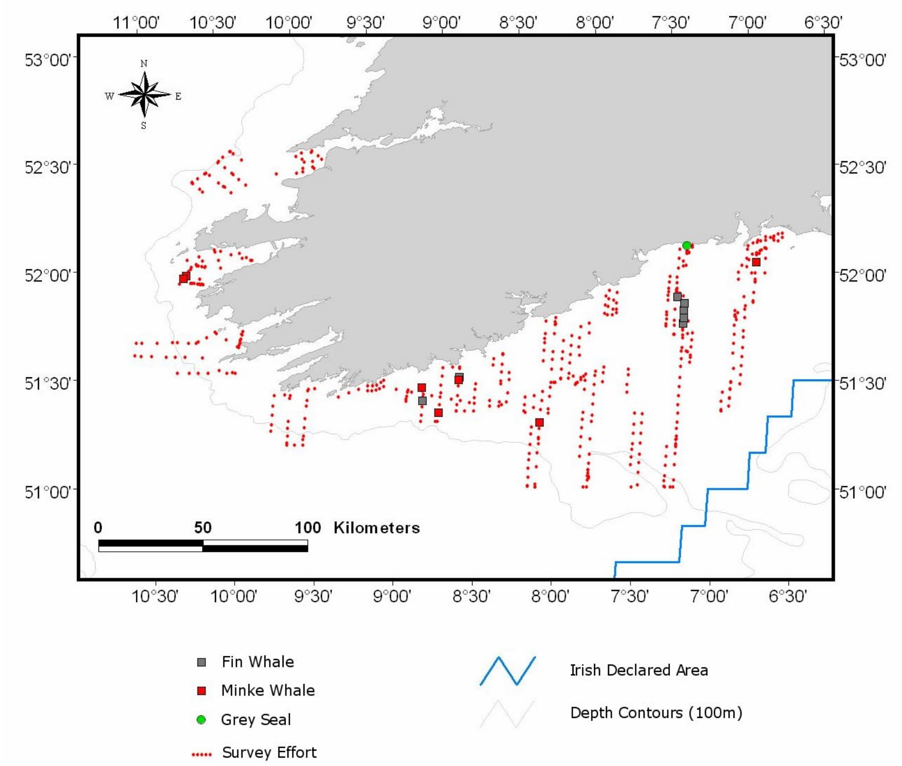


**Figure 20.** Distribution of whale sightings. Celtic Sea herring acoustic survey, October 2008.

**2008**

**October**

| | 6 | 7 | 8 | 9 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Auk Species (all)** | x | x | x | x | x | x | x | x | | x | x | x | x | x | x | x |
| **Razorbill** | | | | | x | | | | | | | | | x | x | x |
| **Guillemot** | x | | x | x | x | x | x | | | x | x | x | x | x | x | x |
| **Puffin** | | | x | | | | | x | | | | | | | | |
| **Gannet** | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **Fulmar** | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **Manx Shearwater** | x | | | x | x | x | | | | | | | | | | |
| **Sooty Shearwater** | | x | x | x | x | x | x | x | | | | | x | | | x |
| **Kittiwake** | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **Lesser Black-backed Gull** | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **Great Black-backed Gull** | | x | x | | x | x | x | | x | x | x | x | x | x | x | x |
| **Herring Gull** | | x | | | | | | | | | x | x | x | x | | x |
| **Black-headed Gull** | | | | | | x | | | | | | | | | | |
| **Great Skua** | x | x | x | x | x | x | x | x | x | x | | x | x | | | |
| **Pomarine Skua** | | x | | | | | | | | | | | | | | |
| **Parasitic Skua** | | | | | x | x | | x | x | x | | x | | | | |
| **Storm-petrel** | x | x | x | x | | x | | | | | | | | | | |
| **Tern Species (all)** | | | | | | | | | x | | | | | | | |
| **Shag** | x | x | x | | x | | | | | | x | | | x | | |
| **Great Northern Diver** | | | | | | | | | | | | x | | | x | |
| | *Shannon* | *Dingle Bay* | *West of Bantry* | *Mizen / Fastnet* | *Galley / Old Head* | *Offshore Kinsale Gas Field* | *Offshire south of Youghal* | *Offshore South of Ardmore* | *Offshore South of Tramore* | *Offshore South of Hook Hd.* | *Hook Head / Saltees* | *Tramore* | *Mine Head* | *Youghal* | *East of Roches Point* | *West of Roches Point to Stags* |

**Figure 21.** Percentage of days on which 15 bird species were recorded. Celtic Sea herring acoustic survey, October 2008.

**HERRING MIDWATER TRAWL**

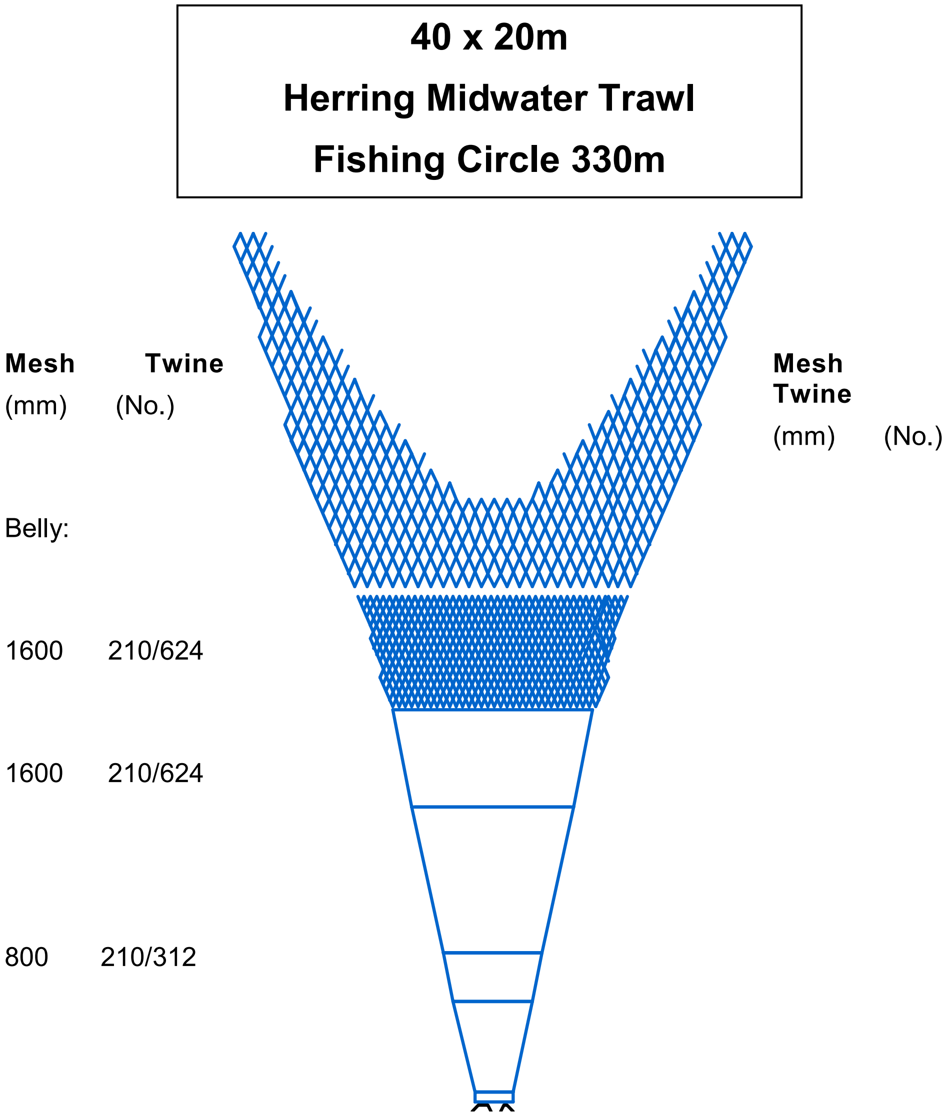



**Figure 22.** Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey, October 2008.

Note: All mesh sizes given in half meshes, schematic does not show 32m brailer.

# Annex 1: Calibration report

**Table 1.** Calibration result of the Simrad ER60 ES38B (38 KHz) split beam transducer.

## Echo Sounder System Calibration

| | | | |
|---|---|---|---|
| Vessel : | R/V Celtic Explorer | Date : | 10/10/2008 |
| Echo sounder : | ER60 PC | Locality : | Bantry Bay |
| Type of Sphere : WC-38,1 | $TS_{Sphere}$: -33.50 dB (Corrected for soundvelocity or t,S) | Depth(Sea floor) : | 20 m |

Calibration Version 2.1.0.11

**Comments:**
10.10.08

**Reference Target:**

| | | | |
|---|---|---|---|
| TS | -33.50 dB | Min. Distance | 15.00 m |
| TS Deviation | 5 dB | Max. Distance | 20.00 m |

**Transducer: ES38B Serial No. 30227**

| | | | |
|---|---|---|---|
| Frequency | 38000 Hz | Beamtype | Split |
| Gain | 25.73 dB | Two Way Beam Angle | -20.6 dB |
| Athw. Angle Sens. | 21.90 | Along. Angle Sens. | 21.90 |
| Athw. Beam Angle | 7.05 deg | Along. Beam Angle | 6.96 deg |
| Athw. Offset Angle | 0.01 deg | Along. Offset Angl | 0.07 deg |
| SaCorrection | -0.73 dB | Depth | 8.8 m |

**Transceiver: GPT 38 kHz 009072033933 1 ES38B**

| | | | |
|---|---|---|---|
| Pulse Duration | 1.024 ms | Sample Interval | 0.191 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. | 9.8 dB/km | Sound Velocity | 1493.9 m/s |

**Beam Model results:**

| | | | |
|---|---|---|---|
| Transducer Gain = | 25.77 dB | SaCorrection = | -0.65 dB |
| Athw. Beam Angle = | 7.18 deg | Along. Beam Angle = | 6.99 deg |
| Athw. Offset Angle = | -0.03 deg | Along. Offset Angle= | -0.05 deg |

**Data deviation from beam model:**
RMS = 0.12 dB
Max = 0.29 dB No. = 94 Athw. = 3.3 deg Along = 3.3 deg
Min = -0.58 dB No. = 173 Athw. = 1.2 deg Along = -4.9 deg

**Data deviation from polynomial model:**
RMS = 0.06 dB
Max = 0.20 dB No. = 75 Athw. = -4.5 deg Along = 0.3 deg
Min = -0.22 dB No. = 73 Athw. = -4.9 deg Along = -0.8 deg

**Comments :**
Flat calm conditions
**Wind Force :** 16 kn. **Wind Direction :** S (180 degrees)
**Raw Data File:** \\Expfileclstr\ER-60_Data\CSHAS_2008\RAW ER60 Files\Calibration\CS_Oct_2008-D20070328-T135915.raw
**Calibration File:** \\Expfileclstr\ER-60_Data\ER-60\Calibrations_2008\CSHAS 08\38 KHZ

**Responsible :** Ciaran O'Donnell