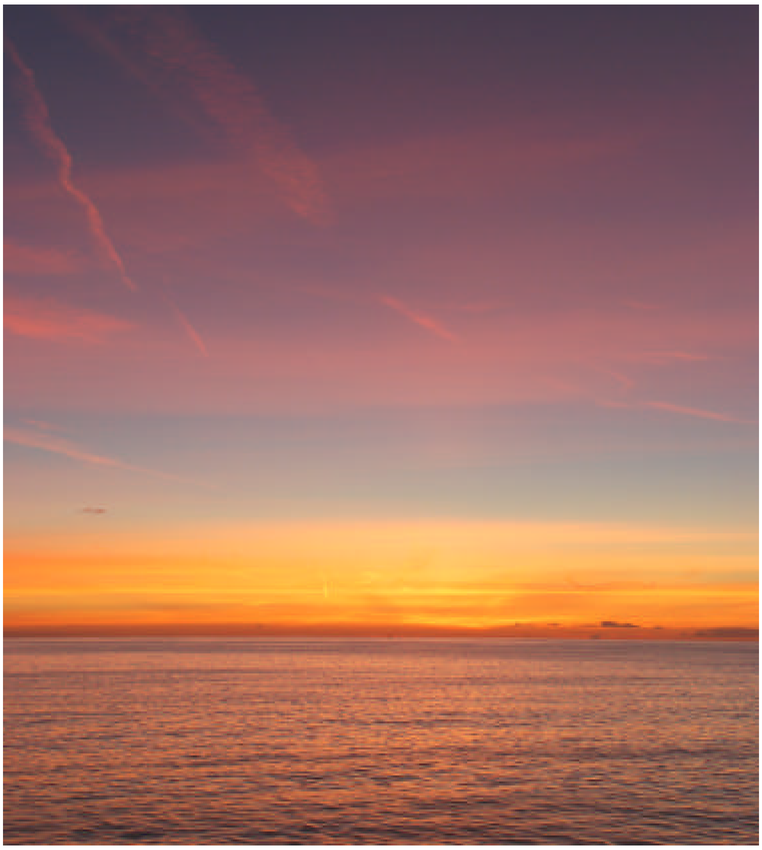
Celtic Sea Herring Acoustic Survey Cruise Report and Biomass Estimate, 2007



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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 early October 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.

The TAC (total allowable catch) for the 2007/2008 season (1 April – 31 March) was 9,393 t relating to an Irish quota of 8,117 t, a reduction of 15% from the 2006. During the 2007/2008 season 6 pairs of both polyvalent and dedicated RSW vessels participated in the autumn fishery. Current management regulations include the rotational closure of selected spawning grounds. Spawning grounds are divided into three main zones for management purposes; A (Southwest region- autumn spawners), B (Cork Harbour- autumn and winter spawners) and C (Waterford and Baginbun- winter spawners). During the current season area B was closed to fishing, in 2008/09 area C will be closed.

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 17th in the overall acoustic series or the third 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

Name	Organisation	Role
Ciaran O'Donnell	MI-FSS	Cruise Leader
Afra Egan	MI-FSS	Acoustics
Deirdre Lynch	MI-FSS	Acoustics
Turloch Smith	MI-FSS	Acoustics
John Boyd	MI-OSS	Biologist/Hydrography
Tobi Rapp	MI-FSS	Biologist
Deirdre Hoare	MI-FSS	Biologist
Oral Hanniffy	MI-FSS	Biologist
Dave Wall	IWDG	Marine Mammals

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 VIIb, 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 2007 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). 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 65 nmi (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 3,159 nmi, with 2,934 nmi 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 Dunmanus Bay on the 9th of October; the calibration report is included in Annex 1. The ER60 was last calibrated in Irish coastal waters some 7 months prior to the survey start (O'Donnell *et al,* 2007).

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 3.45) 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 3.45) 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 mid-water and in the case of spawning shoals very dense aggregations in close proximity to the seabed).

2. "Probably herring" were attributed to smaller echo-traces that had not been fished but which had the characteristic of "definite" herring traces.

3. "Herring in a mixture" were attributed to NASC values arising from all fish traces in which herring were thought to be contained, owing to the presence of a proportion of herring within the nearest trawl haul or within a haul 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 (Version 3.2) 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 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 18). 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 11 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 100 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 5m 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) = $0.00257^* L^{3.355}$ (L = length in cm)

Mackerel weight (grams) = $0.00935^* L^{2.917}$ (L = length in cm)

Sprat weight (grams) = $0.00429^* L^{3.265}$ (L = length in cm)

Horse mackerel weight (grams) = $0.32973^* L^{1.816}$ (L = length in cm)

Pilchard weight (grams) = $0.00298^* L^{3.368}$ (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

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

,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.

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 $n_{s,t,j}$.

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

, where *i* indexes length bins, p_i is the proportion of herring in the i^{th} length bin, and is given by $\sum_{spe}^{species} \sum_{i} p_{spe,i} 10^{(a+b\log10(L_{spe,i}))/10}$

, 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

$$\sum_{i} p_{herring,i} 10^{(073+20\log10(L_{herring,i}))/10} .$$

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

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

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

The variance for the total is the sum of strata variances.

The total biomass can be obtained directly from the track fragment mean biomass by

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

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

Estimates 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 confines at the time of surveying and serve as an index of stock size as opposed to absolute abundance and biomass.

The overall estimate of abundance was generated from a total of 307 positively identified schools. Over 51% (159 schools) were represented by the 'definitely' herring category, 33% (104 schools) to the 'mixture' herring category and less than 15% (44 schools) to the herring 'probably' category (Table 11). The majority of schools encountered were relatively small in size and more numerous than in 2006 where a total of 145 schools were observed. Of the total number of schools, almost 46% (143) contributed to only 25% of the overall TSB (total stock biomass).

Herring	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	312	39708	74.6
Mixture	121	10917	20.5
Probably	21	2587	4.9
Total estimate	454	53212	100
Possibly	5	449	
Possible estimate	459	53661	
SSB Estimate			
Definelty	286	37616	81.0
Probably	19	2417	5.2
Mixture	58	6412	13.8
SSB estimate	363	46445	100

Overall, the TSB estimate was composed of over 74% of the 'definitely' herring category meaning schools were either positively identified by trawling or were in close proximity to herring bearing trawl stations. Extensive trawling was carried out during the survey to target not only obvious herring school types but also mixed species layers. Over 20% of the TSB of herring was obtained from herring found in mixed assemblages or schools. Estimates of abundance based on mixed species assemblages are deemed somewhat less reliable than homogeneous schools due to difficulties in isolating single species within layers. However, as only a small contribution of the TSB was determined from the "herring in a mix" category this places more confidence in the accuracy of the final results. Those schools not positively identified by trawling or not in close proximity to a trawl station were classified as "probably" herring following the established scrutinisation protocol and contributed to 5% of the overall TSB.

Of the 19 strata surveyed (8 spawning boxes and 11 back ground areas), 12 strata produced no herring at all (Table 11). In total spawning areas contributed over 43% to the TSB by weight and over 46% to the SSB (spawning stock biomass) by weight.

Overall, almost 13% of the TSB was made up of juvenile herring as compared to just over 3% during the same period in 2006.

Survey data were analysed to produce an estimate of herring abundance within the survey area as follows:

The stock abundance and biomass estimate are broken down and 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 is presented in Table 4. School counts by category and strata are presented in Table 11.

3.1.2 Herring distribution

A total of 37 trawl hauls were carried out over the course of the survey (Figure 2 & Table 3). Of this, 21 contained herring and 12 contained over 50% of herring by weight of bulk catch.

Overall, herring schools were found to be made up of either loose scattering layers close to the bottom and carpeted over a discreet area or as loose low to medium density single schools. Diurnal schooling behaviour was observed, with day time favouring small marks close to the seabed (Figure 8b-c). Herring schools were observed (on survey) and reported (by the fleet) as being highly mobile and difficult to target with the trawl. This may be attributed to a number of factors including pre-spawning state, fishing effort or the unseasonable calm weather conditions.

Of the 19 strata surveyed only 7 were found to contain herring at the time of the survey, with all identified herring biomass distributed along the south coast in Divisions VIIaS & VIIg. Of the 7 strata containing herring, 4 were spawning boxes and 3 were broad scale survey areas (Table 11, Figure 3). Herring were found to be mainly distributed within coastal waters (<20nmi). Inshore areas between 06°40W and 08°W (Ballycotton and Baginbun) were found to contain over 82% of the total recorded herring biomass. Overall, strata 10 and 14 (Inshore Celtic Sea broad scale and Ballycotton spawning box respectively) contributed most to the total herring biomass estimate with 76.3% of the recorded TSB and 75.9% of the SSB. Stratum 14 contained less high density schools (36) of mature fish than was recorded in stratum 10 which contained 128 recorded mixed schools of mature and juvenile herring.

No herring were found in the southwest of the survey area (strata 1-7, 17-19) including bays and inlets which serve as important nursery grounds for juvenile herring. Juvenile herring are often encountered in bays and estuaries in mixed schools with sprat. The distribution of sprat recordings was very limited (Figure 5, Table 13) as compared to previous years. In stratum 8 close to the southwest corner, a small number of low density schools were recorded. However, one particular high density school was also observed contributing over 13% to the TSB and 15% of the SSB. This school represented the 8th largest school recorded during the survey. The appearance of high density schools within this stratum is consistent with fleet activity and reports at this time.

Offshore distribution outside of 30mni was limited to small discreet patches south of Cork, Ballycotton and Tramore, which when combined contributed little to the overall biomass estimate (4.2% of TSB and 4.3% of SSB respectively).

3.1.3 Herring stock composition

In total 943 herring were aged during the survey, 4,364 individuals length and over 2,000 length and weight measurements were recorded from the 21 hauls containing herring (Tables 3, 4 & 5).

Herring age samples ranged from 1-8 winter rings (Figure 7, Tables 6 & 7). The dominant winter rings were 3 and 1-winter ring fish respectively with the former accounting for over 53% of the total TSB by weight and over 48% by numbers (TSN). 1-winter ring fish ranked the next most abundant with over 14% by weight and over 23% by numbers of the TSB. The 2 and 4-winter ring fish made up 14% and 8.4% by weight and over 15% and over 6% of the TSB estimate by numbers respectively (Tables 6 & 7). Strata 14 contained not only the greatest herring biomass both by weight and numbers but also the second largest range of age cohorts (1-7 winter rings).

Herring maturity, as determined from trawl samples, showed a significant proportion of the stock to be either in a pre-spawning state or immature (Figure 4). Indeed no actively spawning or spent fish were encountered during the entire survey. Over 13% of the TSB was made up of juvenile herring and over 20% of the TSN (total stock numbers), as compared to 3% of the TSB in 2006. Overall, the greatest abundance of juvenile fish was encountered in Stratum 10 which also contributed the second highest abundance of mature fish observed during the survey (Figure 3, Tables 8, 9 & 11).

3.2 Secondary pelagic species

During the scrutinisation process acoustic data were categorised for secondary and tertiary target species according to the existing nomenclature categories established for herring (see section 2.4.2) and from visual recognition and Sv response signals. Mackerel was the most abundant species encountered during this survey (Figure 6). However, due to uncertainties in accurately determining mackerel biomass and abundance from acoustic data it was not deemed prudent to include these data here.

3.2.1 Sprat abundance and biomass

Sprat	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	97	1549	80.7
Mixture	35	369	19.3
Probably	0	0	0.0
Total estimate	132	1918	100

Sprat distribution is presented in Figure 4 for the "Definitely Sprat" category but does not include the "Sprat in a mix" which accounted for over 20% of the total recorded biomass. Abundance and biomass by stratum are presented in Table 13. Overall, sprat biomass and distribution was very low compared to previous years especially in the bay areas where abundance is normally highest. Only 10.5% of TSB was recorded from Bantry Bay, a normally productive area. In total 23 schools were identified, 20 of which were mixed schools and 3 categorised as "Definitely Sprat". Over 79% of the TSB was recorded within Stratum 8 as positively identified single schools. This area is commonly associated with sprat and relatively high cetacean activity during the survey (see section 3.4.1). Of the sprat encountered length classes ranged from 6-16cm, with the main modes occurring at 12 and 10cm respectively. Visual inspection showed fish to be in good conditions, appearing as large plump fish, especially in the larger size classes (>12cm).

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. In the weeks immediately following the survey a significant sprat fishery developed along the Co. Cork coast.

3.2.2 Pilchard abundance and biomass

Pilchard	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	5	551	71.4
Mixture	1	179	23.2
Probably	0	42	5.4
Total estimate	6	772	100

Pilchard distribution is presented in Figure 5 ("Definitely Pilchard" and "Probably Pilchard" only). Abundance and biomass by stratum are presented in Table 14. In total 14 schools were recorded. Pilchard distribution was found to be greatest around Hook Head in Co. Waterford (Stratum 12) where several single large high density marks were observed (Figure 8a) accounting for over 75% of the recorded TSB. Stratum 11 contained the remaining 25% of the recorded TSB as mixed schools. Pilchard marks are characterised as having a very similar target response to herring and the schools show greater gear avoidance when targeted. Of the pilchard encountered size ranged from 12.5-26cm, with visible modes at 23 and 24cm respectively.

3.3 Oceanography

3.3.1 Physical oceanography

A total of 64 hydrographic stations were carried out during the survey (Figure 9). IFigure 10 shows the temperature and salinity distribution of the surface waters in the Celtic Sea at the time of the survey.

The distribution plots show sea surface temperatures in the central Celtic Sea of up to 15.75°C and surface salinities > 35ppt (parts per thousand). Temperatures and salinities decrease towards the coastal area with surface waters in these shallower waters displaying temperatures averaging 14.5°C and salinities ranging between 34.7 and 34.8ppt. Particular low salinities of <34.6ppt can be found off Waterford harbour. The lower temperatures and salinities are due to freshwater run off from the main rivers that discharge into the Celtic Sea such as the Nore, Barrow and Suir Estuary in Waterford, the Blackwater Estuary and the Lee estuary in Cork Harbour. The horizontal distribution of salinity and temperature changes at 50m (Figure 11). Temperatures at 50 metres depth in the inshore areas have not decreased significantly from the surface waters and are still ranging between 13.5 to 14°C. Lower salinities than in the surrounding waters of <35ppt can still be observed at this depth, although the difference in salinity is not as strong as at the surface layer. Further offshore there is a strong temperature gradient at 50 metres and temperatures at this depth are decreasing to <10.5 °C in the central Celtic Sea stations.

A better understanding of the hydrograhic structure of the water column can be obtained from the vertical oceanographic transects which were carried out off Baginbun, Tramore and Oysterhaven (Figures 12-14). The Baginbun section shows well mixed inshore waters with temperatures above 14°C in the upper 40-50 meters. Fresh surface water likely to originate from Waterford harbour (Nore, Barrow and Suir Estuary) is present in the two inshore stations up to a water depth of ca. 40 metres. Some stratification is occurring in the deeper stations with colder more saline water lying below 40-50 metres depth. The offshore stratification is much more apparent in the Tramore and Oysterhaven section. Here, waters are well mixed in the coastal stations up to a water depth of between 40 and 60 metres. In deeper waters the water column is strongly stratified. The thermocline occurs at around 40 metres and results in a temperature change of up to five degrees.

A dense pool of cold saline water is isolated below the seasonal thermocline in the central Celtic Sea stations– this is a known feature in the Celtic Sea and explains the strong horizontal temperature gradient between the stratified offshore stations and the well mixed inshore stations. Surface pockets of lower salinities are apparent along the two more western transects (Oysterhaven and Tramore) both in the inshore stations but also offshore. Thus the freshwater influence is not only derived from rivers discharging into the Irish coast but also from further offshore such as the Severn Estuary and the Irish Sea.

3.4 Marine mammal and seabird observations

Environmental data was collected at 584 stations. Survey conditions were generally excellent, with sea state = 3 at 65.1% of environmental stations (and = 2 at 44.2% of stations). Visibility was good (>5km) at 68.5% of stations, moderate (1–5km) at 26.9% of stations and poor (<1km) at 4.6% of stations. A heavy swell (2m+) was recorded at only 8.7% of stations. Rainfall was recorded at 6.7% of stations and fog/mist was recorded at 13% of stations.

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 (Figures 15 & 16).

Identified cetacean species were harbour porpoise (Phocoena phocoena), common dolphin (Delphinus delphis), bottlenose dolphin (Tursiops truncatus), Risso's dolphin (Grampus griseus), pilot whale (Globicephala melas), Atlantic white-sided dolphin (Lagenorhynchus acutus), minke whale (Balaenoptera acutorostrata), fin whale (Balaenoptera physalus) and humpback whale (Megaptera novaeangliae). Sightings of unidentified dolphin species were mostly thought to be of common dolphins and sightings of unidentified whale blows were thought to be of fin whales in both cases. Grey seals (Halichoerus grypus) were sighted on three occasions.

Common dolphins were the most commonly encountered and abundant dolphin species recorded during the survey. Minke whales were the most commonly encountered and abundant whale species recorded (Table 15). A single humpback whale recorded south of Helvick Head on the 18th of October was believed to be the whale known as HBIRL#3 ('Boomerang'). This whale has been sighted off the south coast every year since 2001 and was last sighted prior to this survey on the 31st July 2007 in Waterford Harbour.

In an 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 foot-rope of the trawl. These pingers emit random modulated signals in the frequency range 1 – 500 KHz. No dolphin bycatch was recorded during this survey. Dolphins observed in the vicinity of the vessel as the pingers entered the water showed no obvious reaction to their activation. However these dolphins may have been outside of the effective operating area of the pingers at the time. As bycatch has not been recorded in all years (previous bycatch of common dolphins having occurred in 2004 & 2006) it remains to be seen whether the use of these pingers will result in the successful deterrence of dolphin bycatch in future surveys.

3.4.2 Seabird sightings

Daily species lists were made of all seabird species seen around the survey vessel. 15 bird species were recorded during the survey (Figure 17): lesser black backed gull (Larus fuscus), great black-backed gull (Larus marinus), herring gull (Larus argentatus), great skua (Stercorarius skua), Pomerine skua (Stercorarius pomarinus), parasitic skua (Stercorarius parasiticus), gannet (Morus bassanus), fulmar (Fulmarus glacialis), razorbill (Alca torda), brown guillemot (Uria aalge), sooty shearwater (Puffinus griseus), Manx shearwater (Puffinus puffinus), kittiwake (Rissa tridactyla), storm petrel (Hydrobates pelagicus) and shag (Phalacrocorax aristotelis).

4 Discussion and Conclusions

4.1 Discussion

Overall the aims of the survey were carried out to the full extent as originally planned. Calm weather conditions dominated throughout with winds of less than 20Kts recorded on over 85% of survey days and a mean significant swell height of less than 2m. As a result the cruise track was completed in good time which allowed for extensive trawling in addition to extended hydrographic coverage.

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 density homogenous herring marks. This is reflected in the overall CV for the SBB (25%) as compared to the 2006 survey estimate where fewer higher density marks were observed, leading to a CV of 35%.

Catchability of herring schools was again an issue in 2007, as in 2006. Targeted schools were difficult to get into the net during trawling and were often observed to swim ahead of the net. This required mean towing speeds of 5 Kts and above to secure a sample. In many instances during daylight hours schooling behaviour was characterised by thin layers (<1.5m) of herring carpeted tight on the bottom. In such instances some herring biomass may remain undetected due to the effects of acoustic shadowing.

From the SSB one particular mark is worthy of note, contributing 15% to the biomass and was observed in a broad scale stratum in the southwest (stratum 8, Mizen area), well away from any other significant schools. When tallied with fleet activity and landings data for this area this school does not appear unusual. Herring schools had been targeted in the general area to the south of stratum 16, the inshore spawning box associated with this area, for some days prior to the *Explorer's* arrival. Reports from fishermen indicated that these particular herring were forming large highly mobile schools. Some 6 days after our departure 350 tonnes was taken from this area during a single nights fishing.

The 20% contribution of mixed herring schools to the TSB can be in someway be attributed to the abundance of small mackerel observed during the survey. In the southeast of the survey area mackerel were particularly abundant occurring within mixed schools containing herring. This was most noted within 25nmi of the coast. Extensive trawling on schools thought to be 'classic herring' school types within a localised area revealed the schools were often mixed with mackerel of the 0-3 yr year classes and in some case contributing nearly 50% of the catch.

4.2 Conclusions

Almost 95% of the recorded herring biomass was recorded within 20nmi of the coast; indicating that the stock was well contained within the survey confines. The absence of actively spawning and spent fish across the survey is unusual for early autumn. Sea surface temperature and salinity profiles of the survey area are similar to those recorded in 2006, with no large coastal variations. In 2007 as in 2006, cooler waters appear along coastal fringes where the bulk of herring biomass was distributed. All mature herring encountered during the survey were in an early pre-spawning state and could be regarded as components of the winter spawning stock. The early seasonal migration into cooler coastal waters may be one of the abiotic triggers associated with the onset of spawning state maturation. However, further analysis over a longer time series would be required to determine the degree of correlation between water temperature and spawning migrations in the Celtic Sea.

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References\Bibliography

Anon. (1994). Report of the planning group for herring surveys. *ICES C.M. 1994/H:3*

Anon (2002) Underwater noise of research vessels. Review and recommendations. 2002. ICES No. 209

Dalen, J. and Nakken, O. (1983) "On the application of the echo integration method" ICES CM 1983/B:19

Foote, K.G. (1987). Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am.* 82: 981-987

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N. and Simmonds, E.J. (1987). Calibration of acoustic instruments for fish density estimation: a practical guide. *Int. Coun. Explor. Sea. Coop. Res. Rep.* 144: 57 pp

IWDG (2004b) Cetacean Distribution and Relative Abundance Survey during North-westHerring Acoustic Survey 2004. *http://www.iwdg.ie/downloads/CEHerringAcousticSurvey2004.PDF*

O'Donnell, C., Griffin, K., Lynch D., Ullgren J., Goddijn L., Wall D. & Mackey M. (2004). Celtic Sea Herring Acoustic Survey Cruise Report, 2004.

O'Donnell, C. Doonan I. & Lynch D. (2005a) Celtic Sea Herring Acoustic Survey Cruise Report, FV Regina Ponti 2005.

O'Donnell, C. Doonan I., Lynch D., Dransfeld, L. & Wall D. (2005b) Celtic Sea Herring Acoustic Survey Cruise Report, RV Celtic explorer 2005.

O'Donnell, C., Doonan, I., Lynch, D., Egan, A., Boyd, J., Wall, D. and Ulgren, J (2006) Celtic Sea Herring Acoustic Survey Cruise Report, 2006.

O'Donnell, C., Mullins E., Johnston, G., Ullgren J., Beattie, S., Heino, M. & Anthonypil-lai, V. (2007) Blue whiting Acoustic Survey Cruise Report.

Wall D., O'Brien J., Meade J. & Allen B.M. (2006) Summer distribution and relative abundance of cetaceans off the west coast of Ireland. Biology and Environment: Proceedings of the Royal Irish Academy, 106B (2), 135 - 142.

5 Tables and Figures

Table 1. Survey Strata details. Celtic Sea herring acoustic survey, October 2007.

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	200	727
2	Inside Shannon	Broad scale	Zigzag	7	7	\	40	39
3	Dingle	Broad scale	Zigzag	9	9	\	70	99
4 (a,b)	SW corner	Broad scale	Parallel	15	8	4	178	548
5	Kenmare	Broad scale	Zigzag	7	7	\	44	61
6	Bantry	Broad scale	Zigzag	8	7	\	41	34
7	Dunmanus	Broad scale	Zigzag	7	7	\	18	9
8	Mizen area	Broad scale	Parallel	27	14	4	249	770
9	Offshore CS	Broad scale	Parallel	63	32	2	1028	1932
10 (a,b,c,d,e)	Inshore CS	Broad scale	Parallel	61	34	2	582	1106
11	Baginbun	Spawning grd	Parallel	17	9	1	47	29
12	Tramore	Spawning grd	Parallel	31	16	1	109	85
13	Waterford Hbr	Broad scale	Zigzag	4	4	\	7	4
14	Ballycotton	Spawning grd	Parallel	32	16	1	123	104
15	Daunt	Spawning grd	Parallel	25	13	1	80	69
16	Stags	Spawning grd	Parallel	9	10	1	14	16
17	Dingle_S	Spawning grd	Parallel	11	6	1	16	9
18	Dingle_N	Spawning grd	Parallel	11	6	1	13	7
19	Kerry Head	Spawning grd	Parallel	23	12	1	75	61
			Total	393	231		2934	5706

Table 2. Settings for the Simrad ER60 echosounder, employed during the Celtic Sea herring acoustic survey, October 2007.

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:	500m

Note: Calibration report available (38KHz) in Annex

Table 3. Catch table from directed trawl hauls. Celtic Sea herring acoustic survey, October 2007.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	06.10.07	52 35.35	10 01.17	10:13	88	0	70		90.8		0.2		9.0
2	07.10.07	52 17.89	10 17.98	00:08	74	12	100		0.5	96.5			3.0
3	07.10.07	52 00.35	10 21.26	13:40	58	4	80		90.9				9.1
4	07.10.07	52 05.83	10 16.40	16:00	30	0	60		100.0				
5	08.10.07	51 43.13	10 05.17	07:38	60	15	35		3.4		96.0		0.6
6	08.10.07	51 37.39	09 44.33	23:10	51	10	33	0.5	2.8		82.8		14.0
7	10.10.07	51 13.62	09 31.79	00:05	104	0	1	93.0					7.0
8	10.10.07	51 30.50	08 53.37	11:12	74	5		3.2	63.0		33.0		
9	10.10.07	51 30.74	08 40.42	15:42	82	0			79.0		21.0		
10	11.10.07	51 07.04	08 24.23	00:00	106	70	2		90.0		10.0		
11	11.10.07	51 16.08	08 14.66	08:58	106	8	26.8	100.0					
12	12.10.07	51 20.60	07 52.36	09:30	95	8	120	100.0					
13	12.10.07	51 02.83	07 48.97	13:52	95	4	2		86.9				13.1
14	12.10.07	51 23.88	07 49.18	17:12	83	4	30	63.0	25.0		6.0		5.0
15	13.10.07	51 33.46	07 36.57	12:03	75	4	46		92.8		6.8		0.4
16	13.10.07	51 19.51	07 33.38	14:50	90	2	6.8	47.0	53.0				
17	14.10.07	51 32.02	07 20.32	09:21	83	10	124	75.0	16.0		7.7		1.3
18	14.10.07	51 02.50	07 20.60	12:20	100	2	7.5		99.9				0.1
19	15.10.07	51 28.37	07 01.44	09:13	86	10	31.6	5.4	20.1		71.1		3.4
20	15.10.07	51 29.98	06 58.38	12:36	80	0	47	8.5	42.3		41.5		7.7

Table 3. Continued

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
21	16.10.07	52 01.08	06 39.56	07:25	52	0	650	55.0	43.0				2.0
22	16.10.07	51 53.90	06 51.30	14:15	70	0	550	99.2			0.8		
23	16.10.07	52 09.21	06 40.99	21:55	25	10	71		32.1			67.8	0.1
24	17.10.07	51 53.79	07 03.92	04:20	66	0		85.9	1.9			2.9	9.3
25	17.10.07	52 01.27	07 07.13	07:50	50	10	87.89	84.2	13.3		0.2		2.3
26	17.10.07	51 58.41	07 16.87	12:41	60	5	1000	73.8	26.2				
27	17.10.07	51 47.64	07 20.07	15:52	77	0	1000		99.5		0.3		0.2
28	17.10.07	52 01.94	07 20.05	18:28	50	0	400	77.9	22.0		0.1		
29	18.10.07	52 05.34	07 10.43	00:45	29	10	1500	94.7	5.2				0.1
30	18.10.07	52 03.73	07 00.88	07:04	35	0	15		1.17			97.69	1.14
31	18.10.07	52 04.65	07 23.32	12:29	44	0	1700	98.6	1.4				
32	18.10.07	52 04.00	07 26.60	20:30	23	2	120	39.29	10.41		48.45	0.5	1.35
33	19.10.07	51 52.78	07 3870	07:45	28	2	80	84.1	15.9				
34	19.10.07	51 50.66	07 53.87	16:48	27	0	108	98.02	0.71			1.27	
35	20.10.07	51 43.30	08 13.58	19:35	30	2	0						
36	22.10.07	52 05.09	10 24.95	14:02	45	0	150		97.8				2.2
37	22.10.07	52 05.19	10 24.74	15:40	44	0	120		100				

Table 4. Length frequency (%) of herring hauls used for calculating 'definitely' and 'probably' abundance categories. Celtic Sea herring acoustic survey, October 2007.

Length (cm)	Haul 7	11	12	17	24	25	26	29	31	33	34	Totals
13.5					1							**1**
14					3							**3**
14.5					1							**1**
15					3							**3**
15.5					4							**4**
16					2							**2**
16.5					12							**12**
17					34							**34**
17.5					60							**60**
18					37							**37**
18.5					17							**17**
19			1		14							**15**
19.5			11		3		5					**19**
20		3	30	1	6	7	21			1		**69**
20.5		1	60	1	2	5	39			5		**113**
21		5	38	2		13	51	4		5		**118**
21.5		5	50	3		4	60	7	2	7		**138**
22		2	24	5		20	50	13	3	5	1	**123**
22.5		11	10	13		10	32	2	4	12	3	**97**
23	2	16	10	17		23	20	17	3	15	2	**125**
23.5	3	12	10	31		30	26	12	4	29	7	**164**
24	13	21	4	60		60	28	31	7	38	28	**290**
24.5	28	30	11	41		53	35	33	21	60	44	**356**
25	20	47	9	19		42	29	60	21	55	60	**362**
25.5	13	29	15	9		22	17	47	20	24	52	**248**
26	9	22	6	7		6	8	42	6	18	17	**141**
26.5	6	11	6	2		3	4	17	3	7	13	**72**
27	10	7	2			4	2	14	3	3	8	**53**
27.5	1	1				2	3	6	1	3	11	**28**
28	1	2				1		3	1		4	**12**
28.5	1							2	1		2	**6**
Totals	**107**	**225**	**297**	**211**	**199**	**305**	**430**	**310**	**100**	**287**	**252**	**2723**

Table 5. Herring Age length key from combined trawl samples. Celtic Sea herring acoustic survey, October 2007.

Age (rings) Length (cm)	0	1	2	3	4	5	6	7	8	9	Total
14	1										**1**
14.5	2										**2**
15	5										**5**
15.5	7										**7**
16	18										**18**
16.5	11										**11**
17	7										**7**
17.5	3										**3**
18	1										**1**
18.5		2									**2**
19		4									**4**
19.5		18									**18**
20		27									**27**
20.5		32									**32**
21		42	1	1							**44**
21.5		33	6								**39**
22		25	9								**34**
22.5		17	10	2							**29**
23		4	32	3							**39**
23.5		1	22	13							**36**
24			27	47							**74**
24.5			25	101	5	1					**132**
25			8	125	6						**139**
25.5			2	97	15		2				**116**
26			2	26	16						**44**
26.5				11	8	4	4				**27**
27				2	4	7	7	2	1		**23**
27.5				1	2	2	8	3			**16**
28						2	5	2			**9**
28.5						1	1	1			**3**
29									1		**1**
29.5											**0**
Total	**55**	**205**	**144**	**429**	**56**	**17**	**27**	**8**	**2**	**0**	**943**
%	**5.8**	**21.7**	**15.3**	**45.5**	**5.9**	**1.8**	**2.9**	**0.8**	**0.2**	**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 2007.

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	0.8	4.2	0.7	0.4	0.5	0.1	0.1	0	6.9
9	0	0.8	0.5	1.4	0.2	0	0.1	0	0	0	3
10	0	5.5	3.3	9.2	1.3	0.4	0.6	0.2	0	0	20.4
11	0	0	0	0	0	0	0	0	0	0	0
12	0	1.1	0.5	1.2	0.2	0.1	0.1	0	0	0	3.1
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0.5	2.4	12.6	2.1	0.7	1.1	0.3	0	0	19.7
15	0	0	0	0	0	0	0	0	0	0	0.1
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
Total	0	7.9	7.5	28.7	4.5	1.5	2.3	0.7	0.2	0	53.2
%	0	14.8	14.1	53.9	8.4	2.8	4.2	1.3	0.4	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 2007.

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	0.14	7.26	32.5	4.99	2.29	2.63	0.77	0.68	0	51.221
9	0	10.9	4.59	10.7	1.31	0.29	0.38	0.08	0.02	0	28.32
10	0.46	74.1	31.9	71.2	8.95	2.18	3.23	0.9	0.12	0	193.08
11	0	0.09	0.04	0.04	0	0	0	0	0	0	0.178
12	0.05	14.8	4.61	9.63	1.32	0.33	0.49	0.14	0.02	0	31.358
13	0	0	0	0	0	0	0	0	0	0	0
14	0	5.95	21.3	95.9	14	3.87	6.38	1.77	0.18	0	149.36
15	0	0.05	0.1	0.29	0.05	0.01	0.01	0	0	0	0.517
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
Total	0.51	106	69.8	220	30.6	8.97	13.1	3.65	1.02	0	454.03
%	0.11	23.3	15.4	48.5	6.75	1.98	2.89	0.8	0.22	0	100
Cv (%)	31.1	27.3	21.6	25.4	27.2	31.8	30.8	32.9	60.1		

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 2007.

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	0.1	6.9	0	6.9
9	0.7	2.3	0	3
10	4.6	15.8	0	20.4
11	0	0	0	0
12	0.9	2.2	0	3.1
13	0	0	0	0
14	0.5	19.2	0	19.7
15	0	0.1	0	0.1
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
Total	6.8	46.4	0	53.2
%	12.7	87.3	0	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 2007.

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	0.425	50.795	0	51.2
9	9.53	18.79	0	28.3
10	62.975	130.1	0	193
11	0.074	0.104	0	0.18
12	13.038	18.32	0	31.4
13	0	0	0	0
14	5.263	144.094	0	149
15	0.043	0.474	0	0.52
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
Total	91.348	362.678	0	454
%	20.12	79.88	0	100

Table 10. Herring length at age (winter rings) as abundance (millions) and biomass (000’s tonnes). Celtic Sea herring acoustic survey, October 2007.

Length (cm)	Age (Rings) 0	1	2	3	4	5	6	7	8	9	Abundance (millions)	Biomass 000's t	Mn wt (g)
13.5	0.03	-	-	-	-	-	-	-	-	-	0.03	-	17
14	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	-	-	-	-	-	-	-	-	-	-	-	-	-
15	0.07	-	-	-	-	-	-	-	-	-	0.07	-	24
15.5	0.1	-	-	-	-	-	-	-	-	-	0.1	-	26.8
16	-	-	-	-	-	-	-	-	-	-	-	-	-
16.5	0.03	-	-	-	-	-	-	-	-	-	0.03	-	32.9
17	0.03	-	-	-	-	-	-	-	-	-	0.03	-	36.4
17.5	0.25	-	-	-	-	-	-	-	-	-	0.25	0.01	40
18	-	-	-	-	-	-	-	-	-	-	-	-	-
18.5	-	0.37	-	-	-	-	-	-	-	-	0.37	0.02	48.1
19	-	1.65	-	-	-	-	-	-	-	-	1.65	0.09	52.5
19.5	-	6.11	-	-	-	-	-	-	-	-	6.11	0.35	57.3
20	-	14.7	-	-	-	-	-	-	-	-	14.65	0.91	62.3
20.5	-	16.4	-	-	-	-	-	-	-	-	16.37	1.11	67.6
21	-	22	0.53	0.53	-	-	-	-	-	-	23.05	1.69	73.2
21.5	-	19	3.46	-	-	-	-	-	-	-	22.5	1.78	79.2
22	-	15.5	5.58	-	-	-	-	-	-	-	21.07	1.8	85.4
22.5	-	8.35	4.91	0.98	-	-	-	-	-	-	14.24	1.31	92.1
23	-	1.49	11.9	1.11	-	-	-	-	-	-	14.49	1.43	99
23.5	-	0.5	11	6.48	-	-	-	-	-	-	17.96	1.91	106.3
24	-	-	14.3	25	-	-	-	-	-	-	39.29	4.48	114
24.5	-	-	11.7	47.5	2.36	0.5	-	-	-	-	62.12	7.59	122.1
25	-	-	4.2	65.1	3.11	-	-	-	-	-	72.4	9.46	130.6
25.5	-	-	1.02	50	7.71	-	1.02	-	-	-	59.72	8.33	139.5
26	-	-	1.16	15.3	9.42	-	-	-	-	-	25.87	3.85	148.8
26.5	-	-	-	6.87	4.99	2.5	2.5	-	-	-	16.85	2.67	158.5
27	-	-	-	1.1	2.2	3.84	3.84	1.1	0.54	-	12.63	2.13	168.7
27.5	-	-	-	0.42	0.84	0.84	3.35	1.26	-	-	6.7	1.2	179.3
28	-	-	-	-	-	0.74	1.86	0.74	-	-	3.34	0.64	190.4
28.5	-	-	-	-	-	0.39	0.39	0.39	-	-	1.18	0.24	201.9
29	-	-	-	-	-	0.16	0.16	0.16	-	-	0.47	0.1	213.9
29.5	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	0.47	-	0.47	0.11	239.5
SSN	-	26.9	60.7	218	30.4	8.96	13.1	3.65	1.02	-	362.68	-	-
SSB	-	2.23	6.72	28.4	4.45	1.51	2.25	0.67	0.21	-	-	46.444	-
Mn wt (g)	33.2	74.4	108	130	146	168	172	182	202	-	-	-	-
Mn L (cm)	16.7	21.3	23.8	25.2	26.1	27.2	27.4	27.9	28.6	-	-	-	-

Table 11. Herring biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2007.

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	0	0	0	0	100	0	0	0	0	0	0
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	7	0	0	0	0	100	0	0	0	0	0	0
8	14	11	11	0	0	79	6.9	0	0	6.9	6.9	51.221
9	32	96	43	44	9	72	1.2	1.6	0.1	3	2.3	28.32
10	34	128	76	45	7	50	11.7	7.7	1.1	20.4	15.8	193.075
11	9	3	0	3	0	89	0	0	0	0	0	0.178
12	16	32	9	12	11	38	0.8	1.6	0.7	3.1	2.2	31.358
13	4	0	0	0	0	100	0	0	0	0	0	0
14	16	36	20	0	16	44	19.1	0	0.6	19.7	19.2	149.357
15	13	1	0	0	1	92	0	0	0.1	0.1	0.1	0.517
16	10	0	0	0	0	100	0	0	0	0	0	0
17	6	0	0	0	0	100	0	0	0	0	0	0
18	6	0	0	0	0	100	0	0	0	0	0	0
19	12	0	0	0	0	100	0	0	0	0	0	0
Total	231	307	159	104	44	78	39.7	10.9	2.6	53.2	46.4	454.026
Cv (%)	-	-	-	-	-	-	-	-	-	23	24.9	21.6

Table 12. Celtic Sea and VIIj Herring acoustic survey time series as used in the stock assessment process. Abundance expressed as TSN (total stock numbers) and biomass SSB (spawning stock biomass). Ages in winter rings. Note: The summer 1999/2000 or autumn 2004/05 survey's not used in tuning.

Season	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Age (Rings)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	202	3	-	0	-	25	40	0	24	-	2	-
1	25	164	-	30	-	102	28	42	13	-	65	21
2	157	795	-	186	-	112	187	185	62	-	137	211
3	38	262	-	133	-	13	213	151	60	-	28	48
4	34	53	-	165	-	2	42	30	17	-	54	14
5	5	43	-	87	-	1	47	7	5	-	22	11
6	3	1	-	25	-	0	33	7	1	-	5	1
7	1	15	-	24	-	0	24	3	0	-	1	-
8	2	0	-	4	-	0	15	0	0	-	0	-
9	2	2	-	2	-	0	52	0	0	-	0	-
TSN (Millions)	469	1338	-	656	-	256	681	423	183	-	312	305
SSB ('000 t)	36	151	-	100	-	20	95	41	20	-	33	36
CV	53	26	-	36	-	100	88	49	34	-	48	35

Table 13. Sprat biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2007.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	% zeros	Def Biomass	Mix Biomass	Biomass (t)	Abundance millions
1	14	0	0	0	100	0	0	0	0
2	7	0	0	0	100	0	0	0	0
3	9	0	0	0	100	0	0	0	0
4	8	0	0	0	100	0	0	0	0
5	7	0	0	0	100	0	0	0	0
6	7	12	0	12	14	0	0.2	0.2	16.89
7	7	0	0	0	100	0	0	0	0
8	14	3	3	0	93	1.5	0	1.5	97.00
9	32	8	0	8	97	0	0.2	0.2	18.11
10	34	0	0	0	100	0	0	0	0
11	9	0	0	0	100	0	0	0	0
12	16	0	0	0	100	0	0	0	0
13	4	0	0	0	100	0	0	0	0
14	16	0	0	0	100	0	0	0	0
15	13	0	0	0	100	0	0	0	0
16	10	0	0	0	100	0	0	0	0
17	6	0	0	0	100	0	0	0	0
18	6	0	0	0	100	0	0	0	0
19	12	0	0	0	100	0	0	0	0
Total	231	23	3	20	97	1.5	0.4	1.9	132.00
Cv (%)	-	-	-	-	-	-	-	80.4	73.9

Table 14. Pilchard biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2007.

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	0	0	0	0	100	0	0	0	0	0
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	7	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	9	2	0	2	0	78	0	0.2	0	0.2	1.32
12	16	12	7	0	5	81	0.6	0	0	0.6	4.86
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	10	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
19	12	0	0	0	0	100	0	0	0	0	0
Total	231	14	7	2	5	98	0.6	0.2	0	0.8	6.179
Cv (%)	-	-	-	-	-	-	-	-	-	56.6	57.2

Table 15. Cetacean sightings, counts and group size ranges. Celtic Sea herring acoustic survey, October 2007

Species	No. Sightings	No. Individuals	Range of Group Size
Bottlenose dolphin	1	4	
Common dolphin	65	2126	300 to 350
Pilot whale	1	16	
Risso's dolphin	2	30	12 to 18
White-sided dolphin	1	70	
Harbour porpoise	3	9	2 to 5
Unidentified dolphin	20	146	2 to 30
Fin whale	3	5	1 to 3
Humpback whale	1	1	
Minke whale	13	15	1 to 2
Unidentified whale	2	2	
			1
Grey Seal	3	3	1

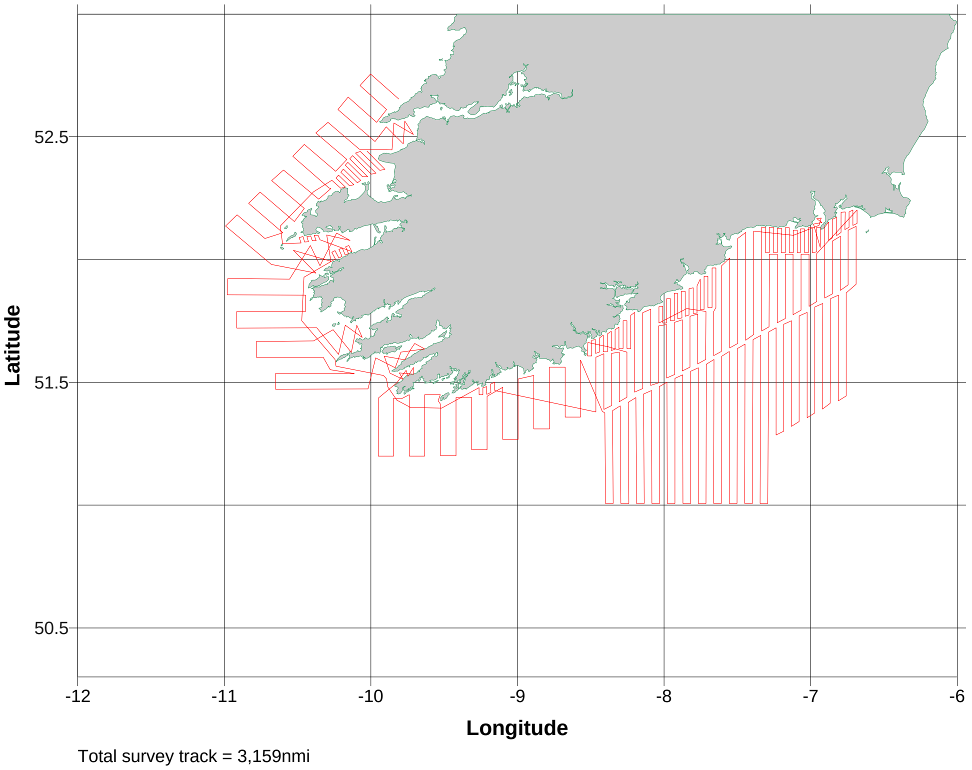


Figure 1. Cruise track (red line) and numbered survey strata. Celtic Sea herring acoustic survey, October 2007.

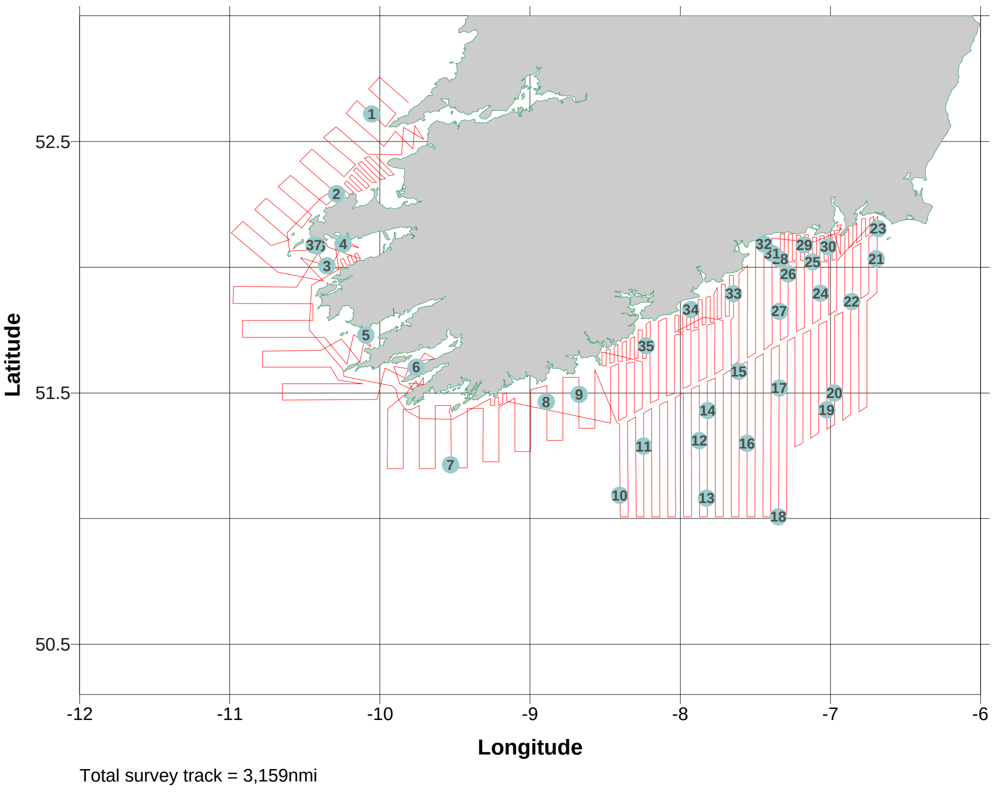


Figure 2. Haul positions. Celtic Sea herring acoustic survey, October 2007.

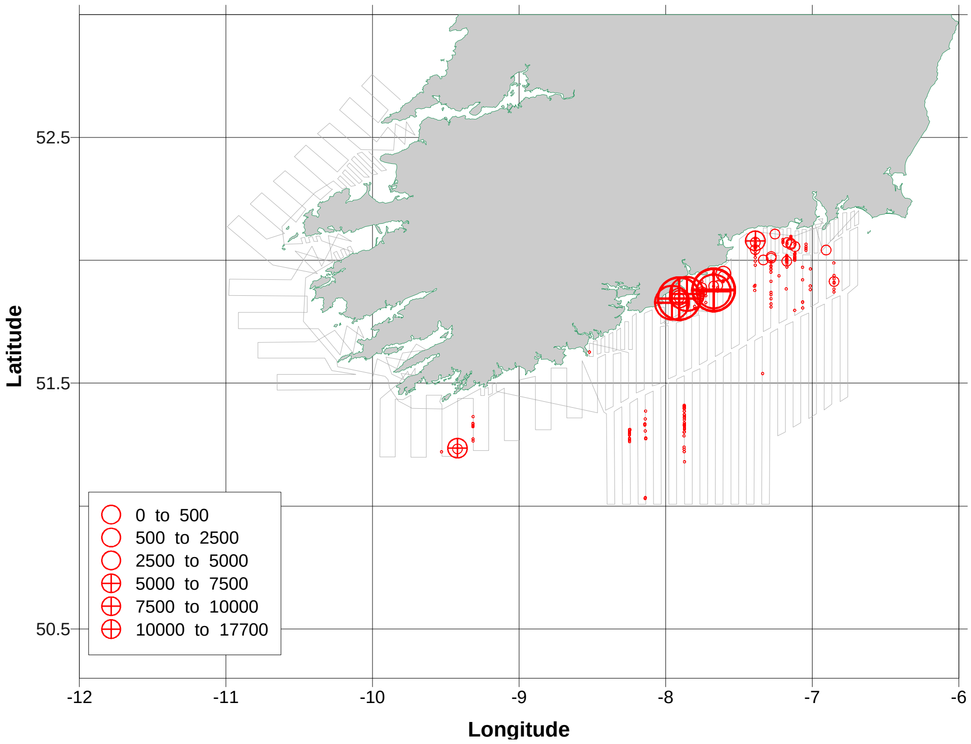


Figure 3. Weighted herring NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” herring categories. Celtic Sea herring acoustic survey, October 2007.

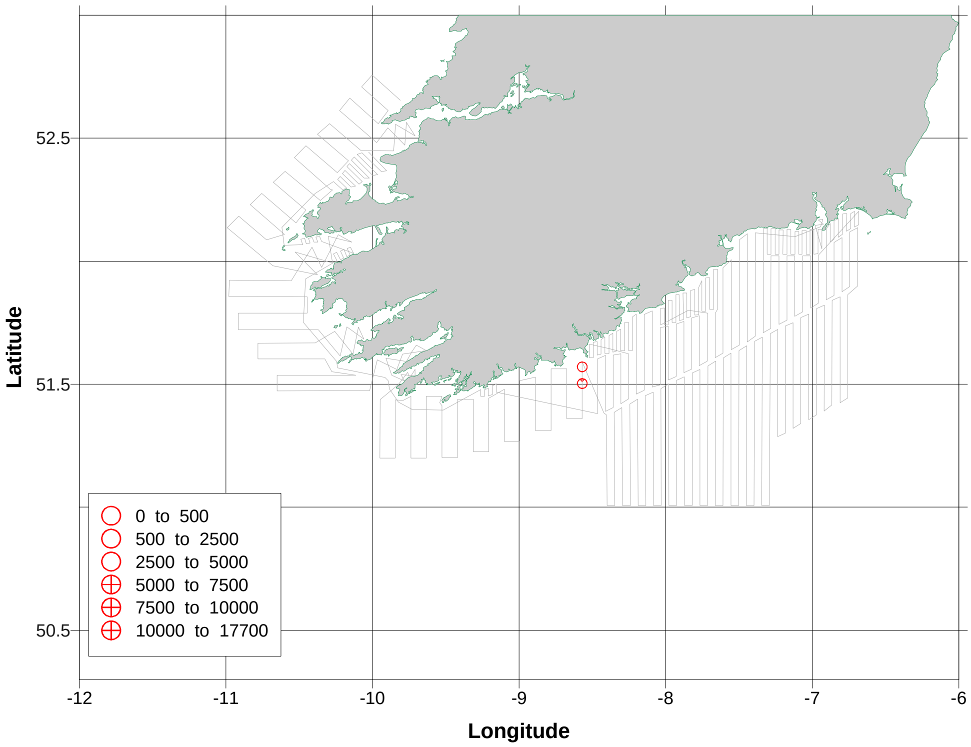


Figure 4. Weighted Sprat NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” sprat categories. Celtic Sea herring acoustic survey, October 2007.

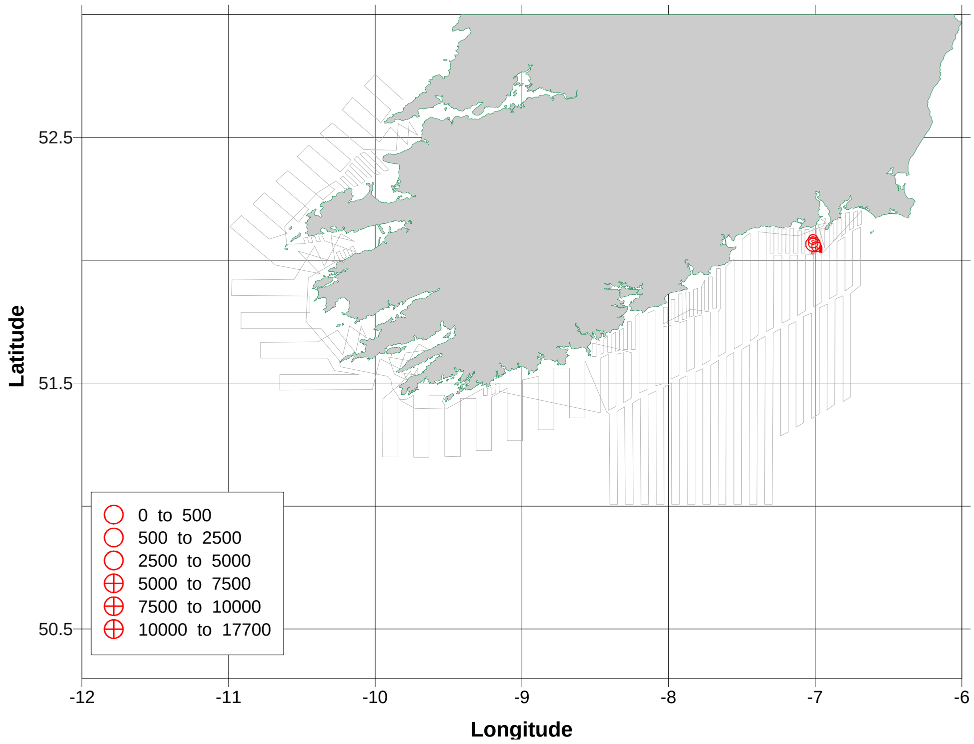


Figure 5. Weighted Pilchard NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” pilchard categories. Celtic Sea herring acoustic survey, October 2007.

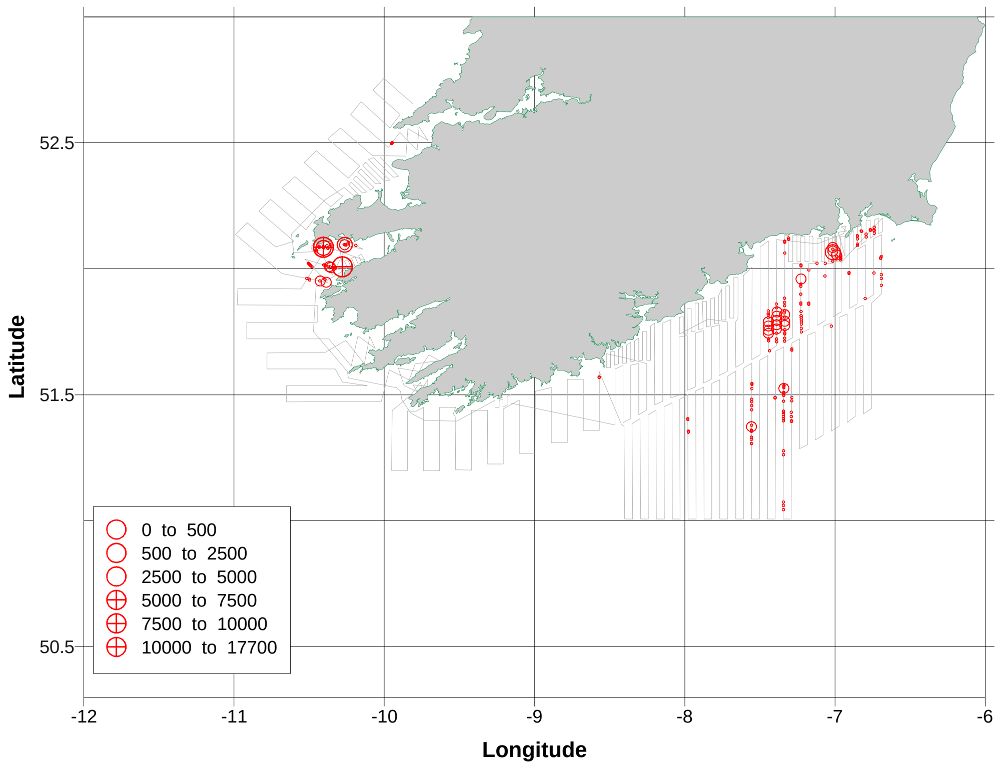


Figure 6. Weighted Mackerel NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” mackerel categories. Note: Abundance was not estimated for this species due to uncertainties in the data.

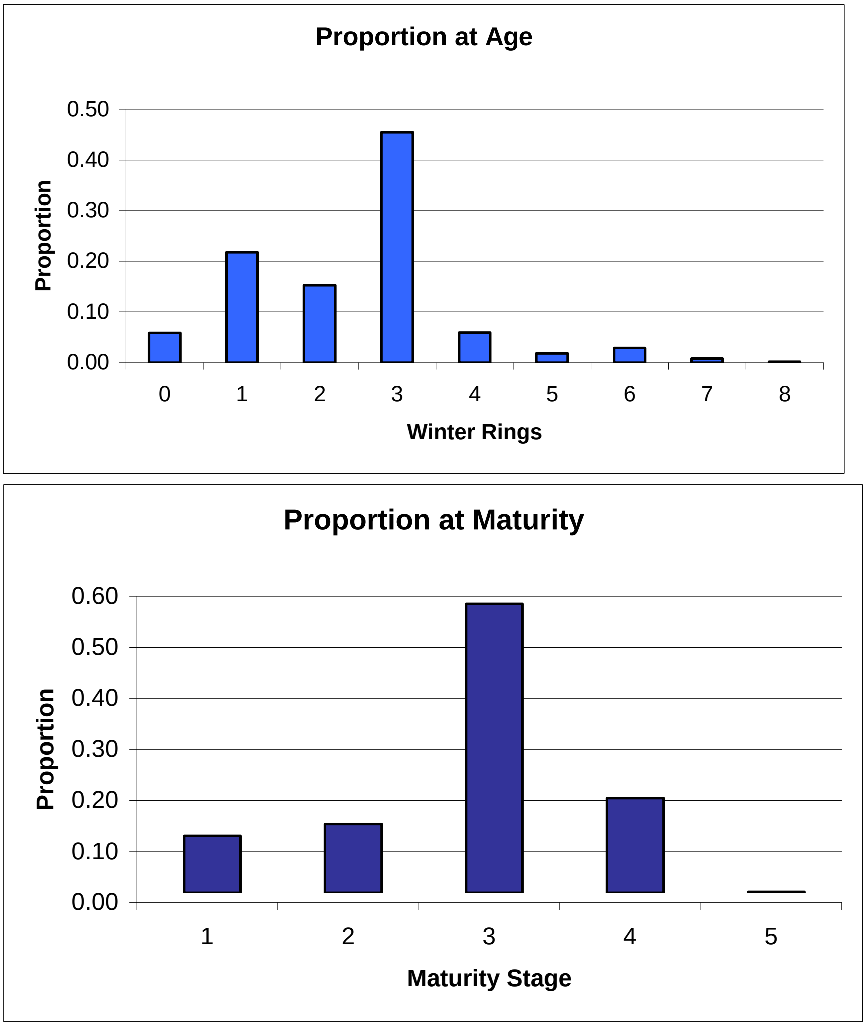
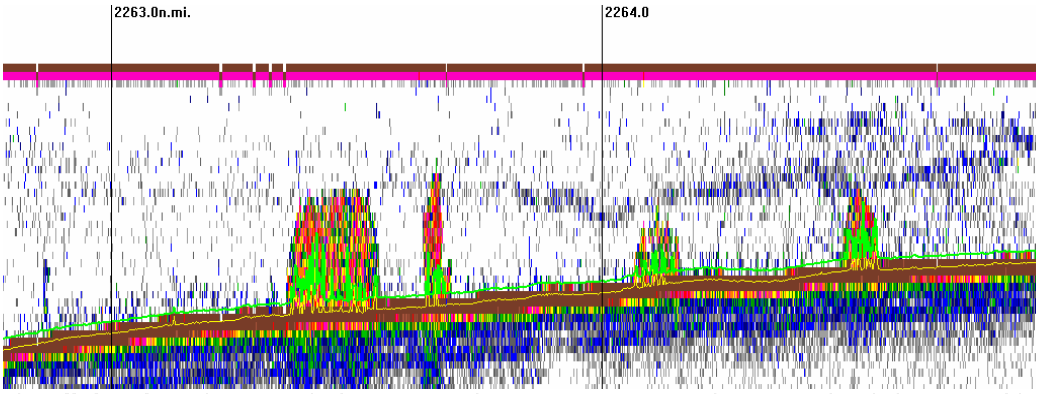
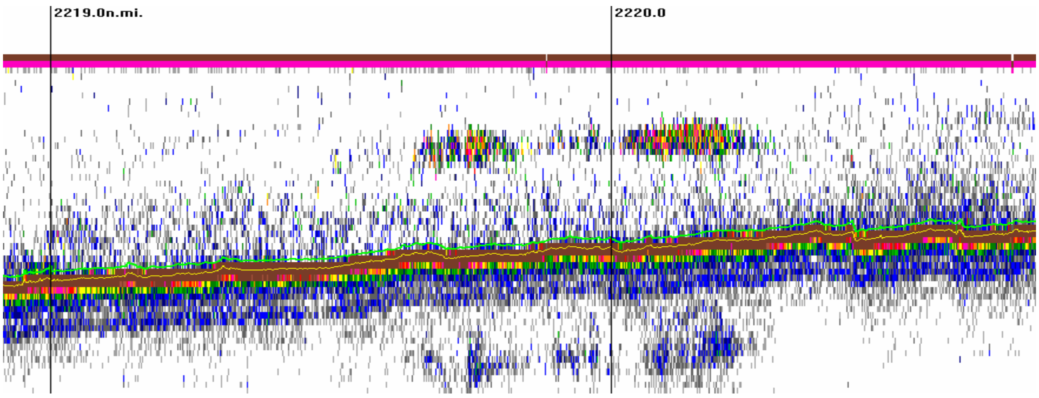


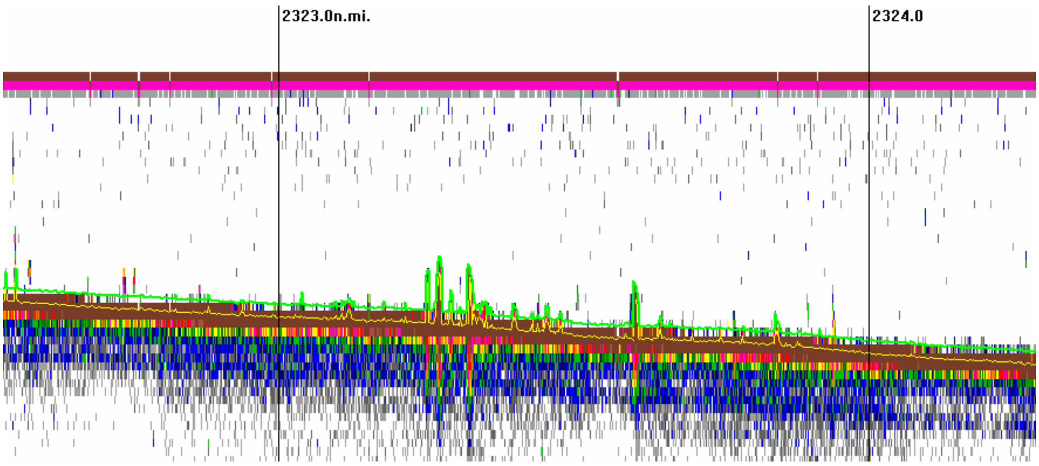
Figure 7. Breakdown of herring ages (above) and maturity (below) from combined survey trawl stations. Celtic Sea herring acoustic survey, October 2007.



a). ***Pilchard*** marks recorded at 06:50 (Haul 30 Stratum 12). Water depth is 35m with marks extending to 16m. Note: Pilchard schools exhibit very similar schooling behaviour and TS response as herring schools.

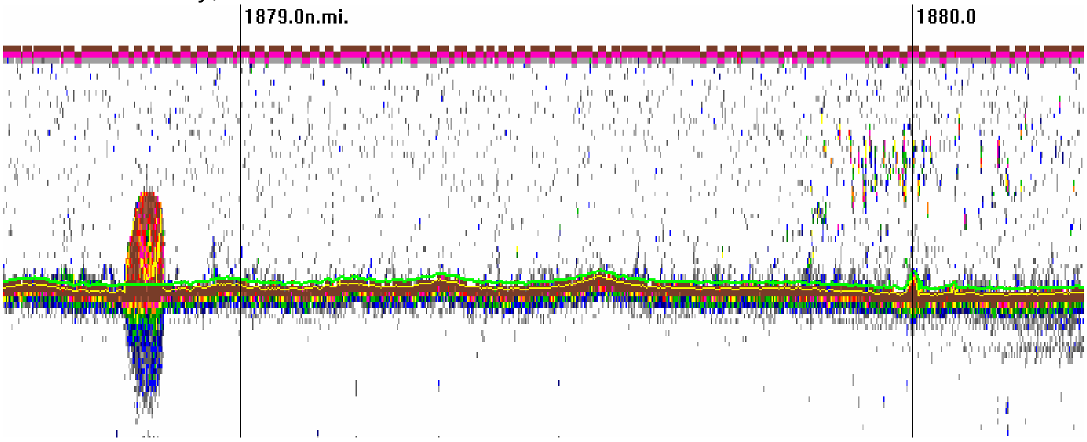


b). Midwater night time ***Herring*** mark (pre-spawning fish, stage 3) 7m tall in 24m of water (Haul 29, Stratum 12). Note day/night variation in schooling behaviour between figures b) and c). Also both above mark types were difficult to capture and highly mobile.



c). Midwater daytime time ***Herring*** mark commonly encountered during the survey (pre-spawning fish, stage 3) 4m tall in 44m of water (Haul 30, Stratum 10).

Figure 8. Echograms (a-d) of main pelagic species encountered. Celtic Sea herring acoustic survey, October 2007.



d). ***Herring & Mackerel*** mixed mark type. Target mark was the solid red mark on the left of the echogram. This mark was 14m tall in 48m of water (Haul 21, Stratum 10) and yielded 55% pre-spawning herring (stage 3) and 43% mackerel.

Figure 8. continued.

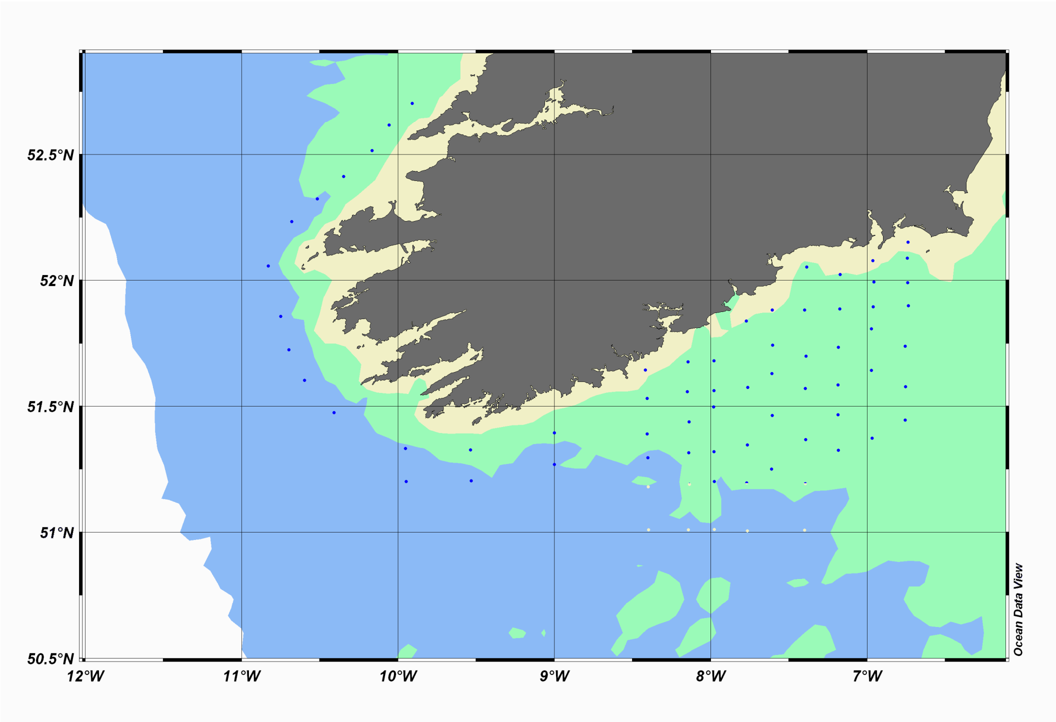


Figure 9. Position of the 64 vertical CTD casts undertaken during the survey. Celtic Sea herring acoustic survey, October 2007.

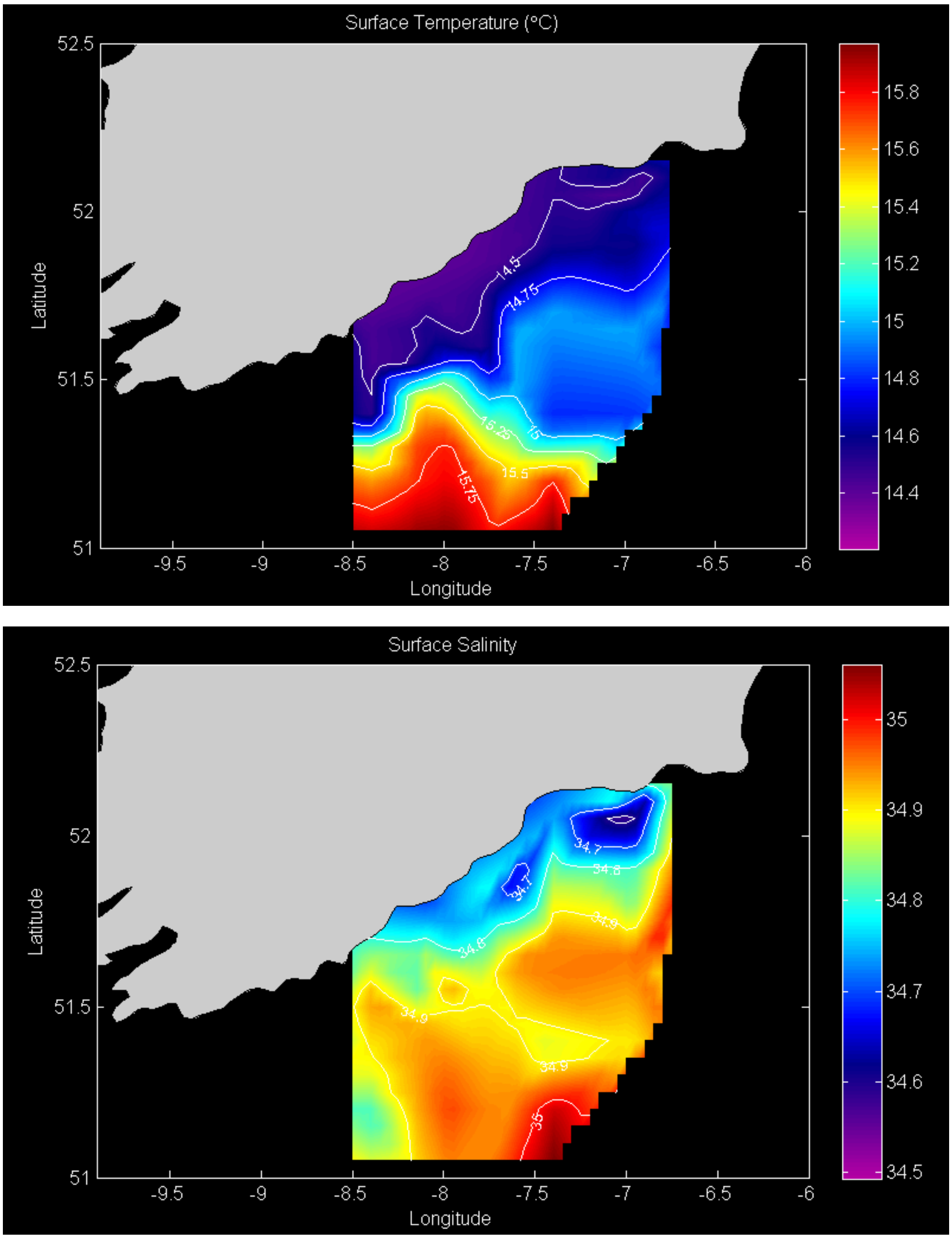


Figure 10. Horizontal temperature (above) and salinity (below) distribution taken at 3m subsurface from combined CTD cast data. Celtic Sea herring acoustic survey, October 2007.

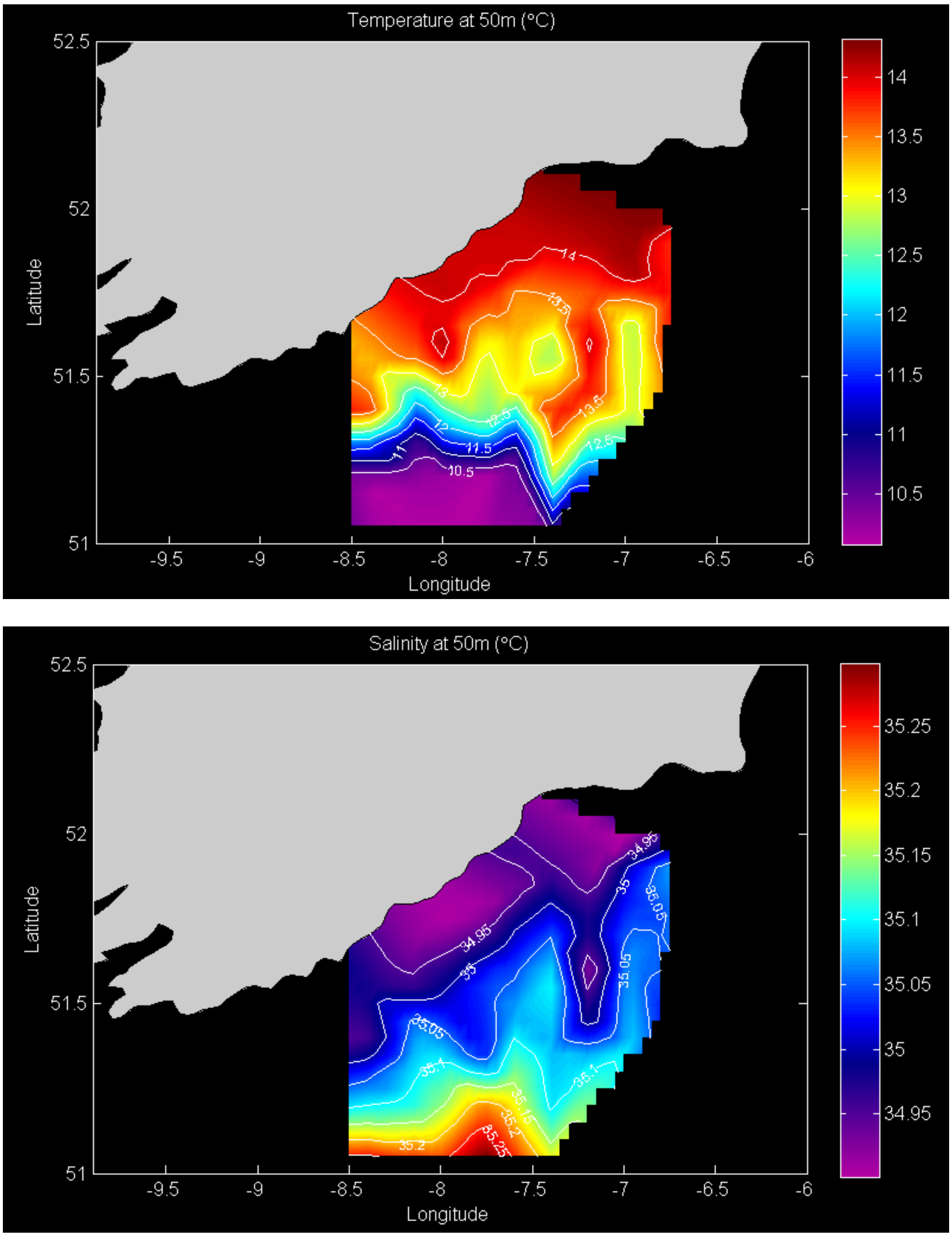


Figure 11. Horizontal salinity (above) and temperature (below) distribution taken at 50m subsurface from combined CTD cast data. Celtic Sea herring acoustic survey, October 2007.

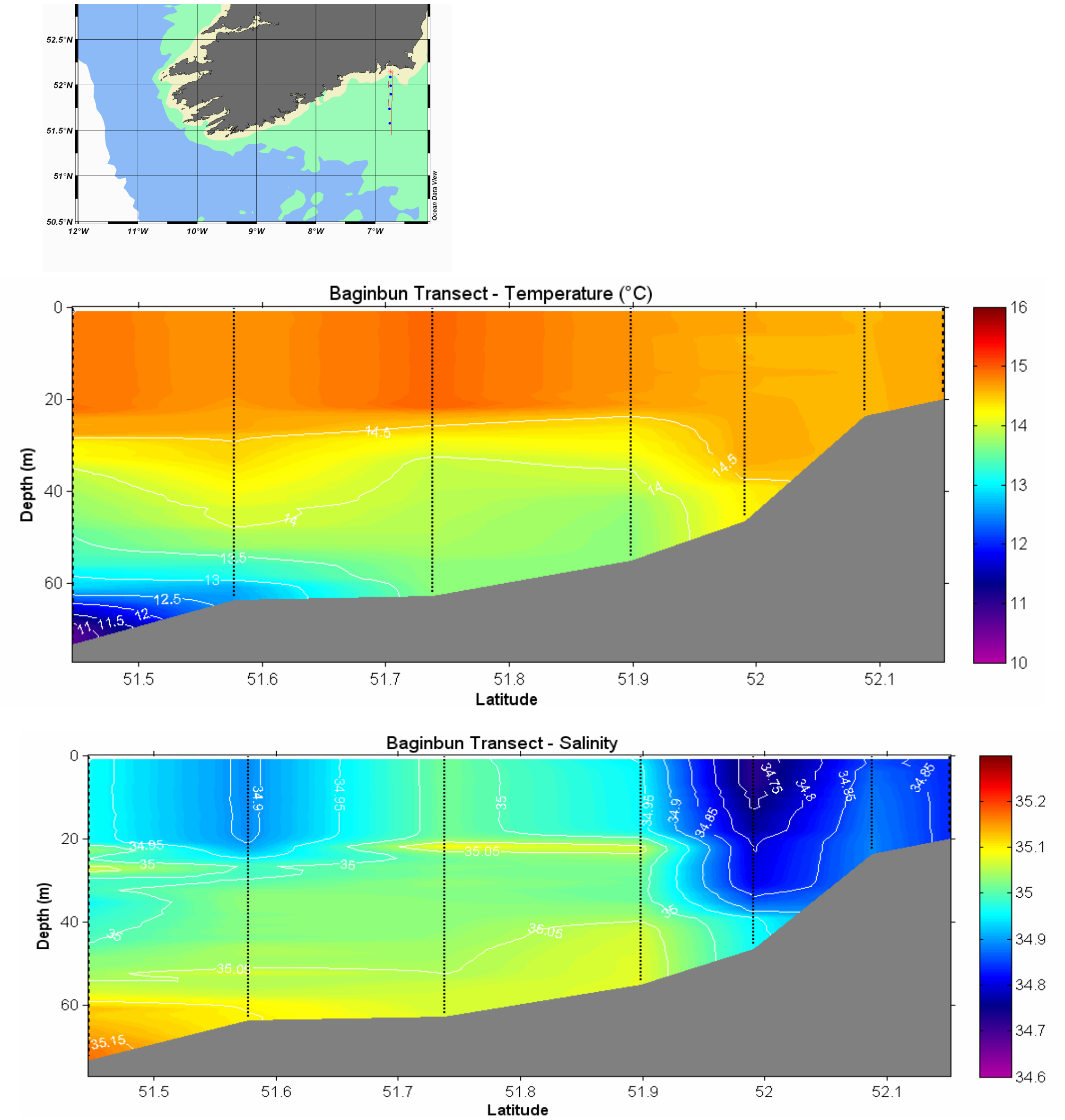


Figure 12. Vertical distribution of temperature (above) and salinity (below) along the Baginbun transect, stratum 11. Celtic Sea herring acoustic survey, October 2007.

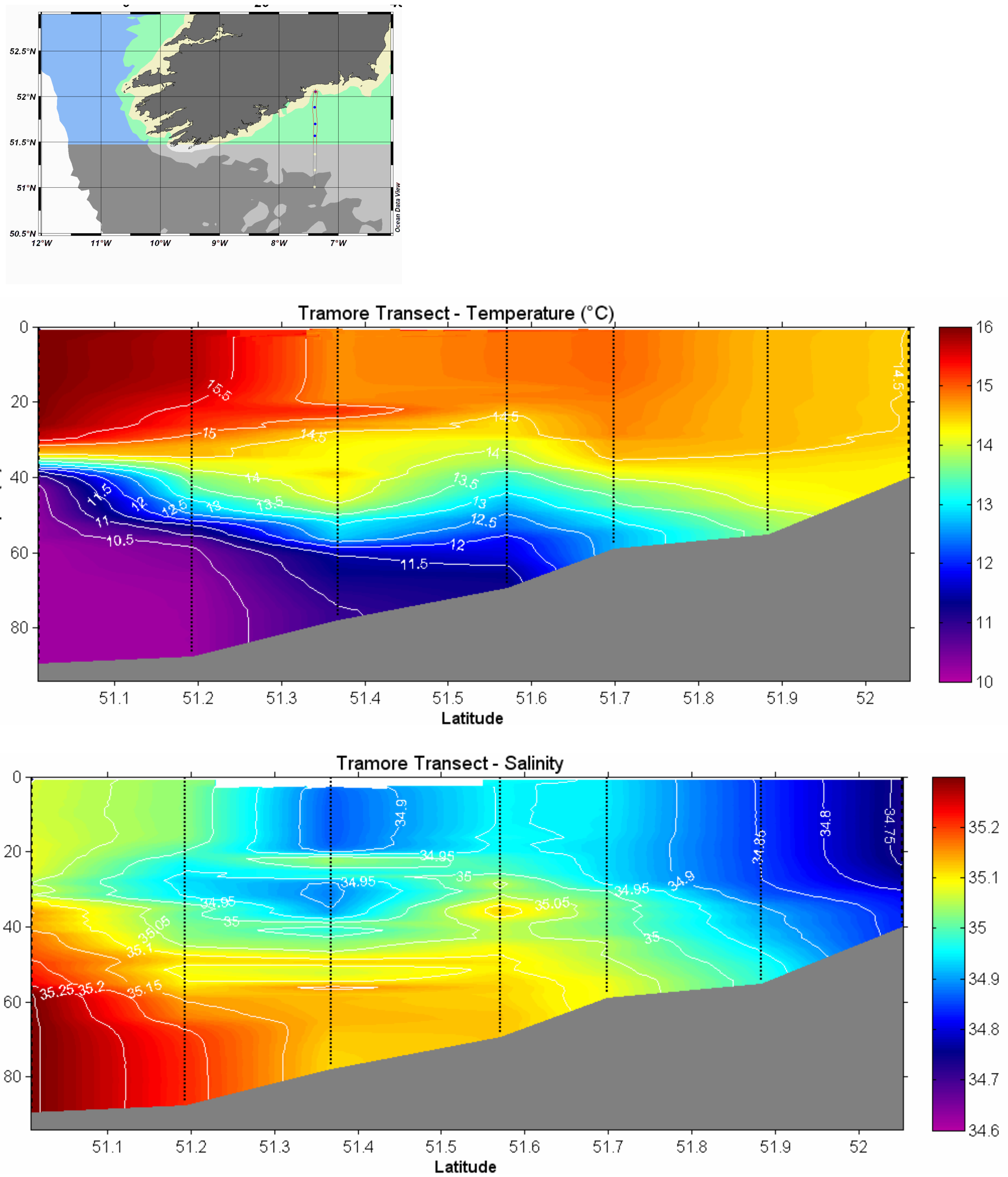


Figure 13. Vertical distribution of temperature (above) and salinity (below) along the Tramore transect, stratum 9. Celtic Sea herring acoustic survey, October 2007.

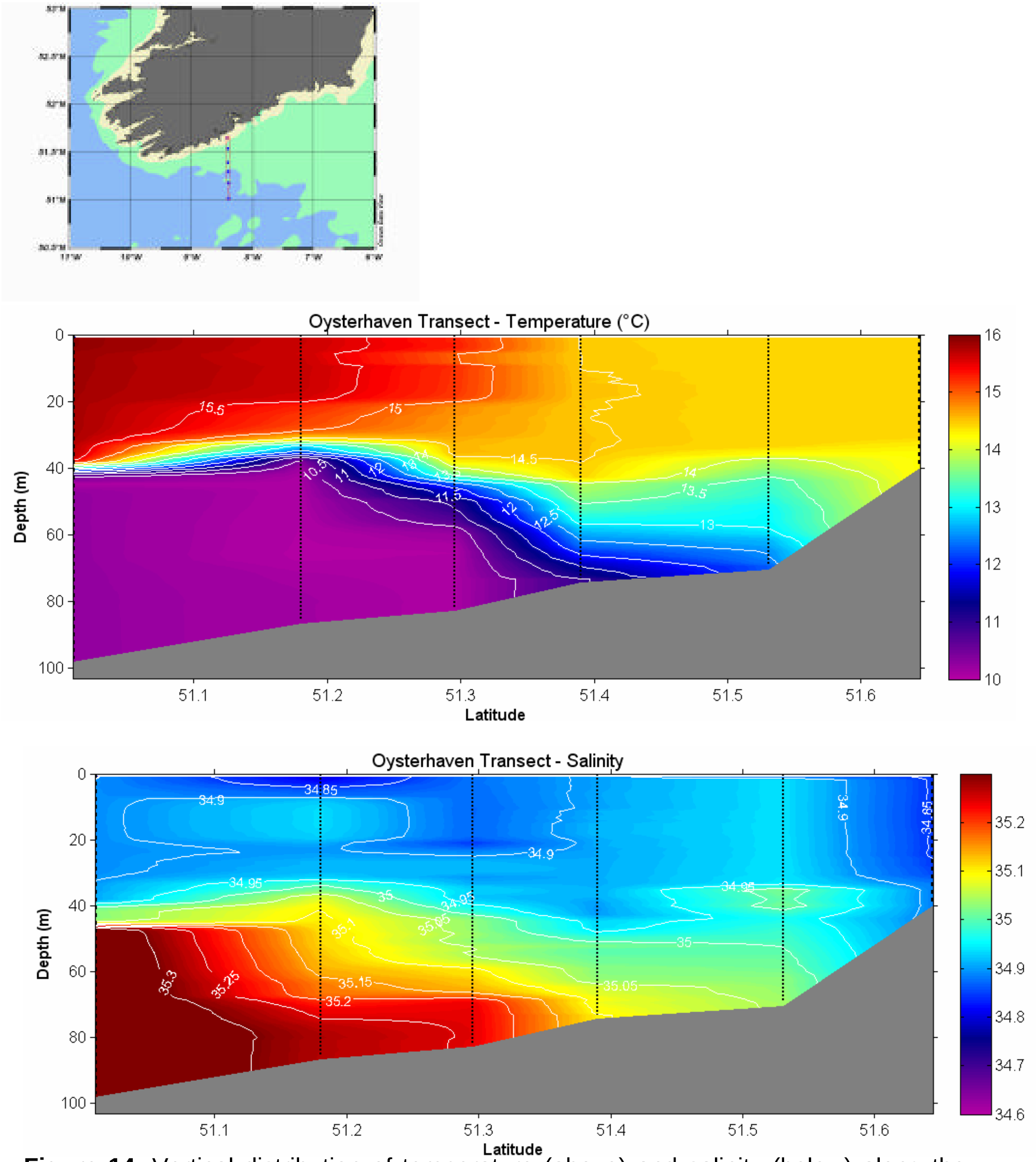


Figure 14. Vertical distribution of temperature (above) and salinity (below) along the Oysterhaven transect, strata 9, 10 & 15. Celtic Sea herring acoustic survey, October 2007.

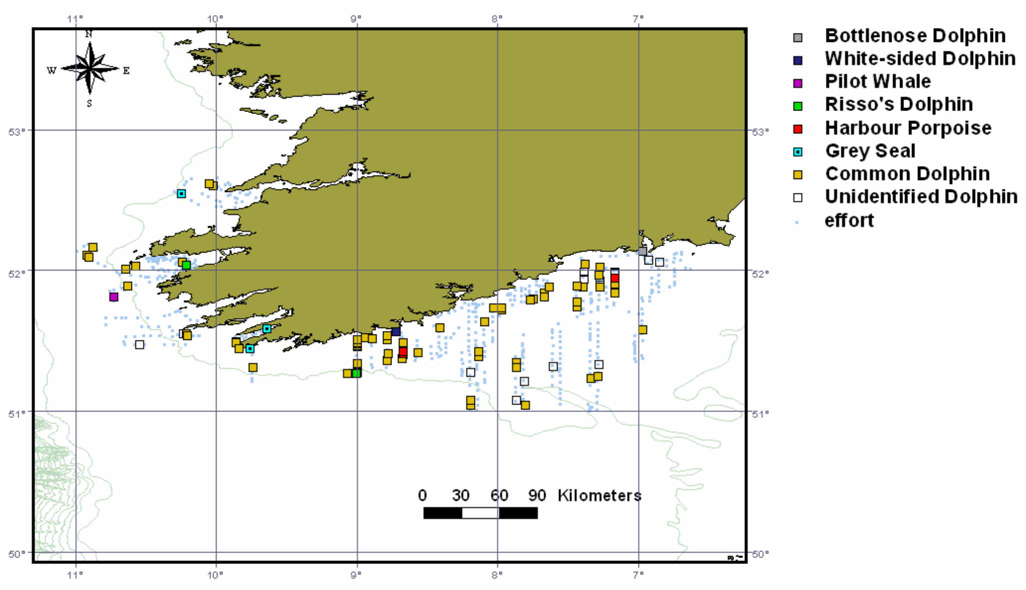


Figure 15. Distribution of dolphin and seal sightings. Celtic Sea herring acoustic survey, October 2007.

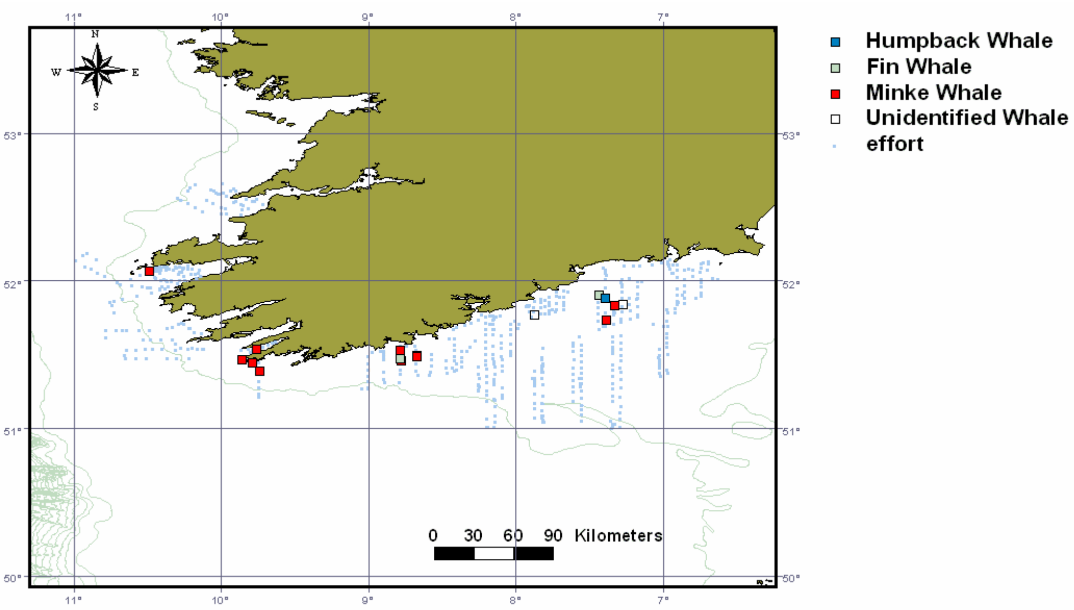


Figure 16. Distribution of whale sightings. Celtic Sea herring acoustic survey, October 2007.

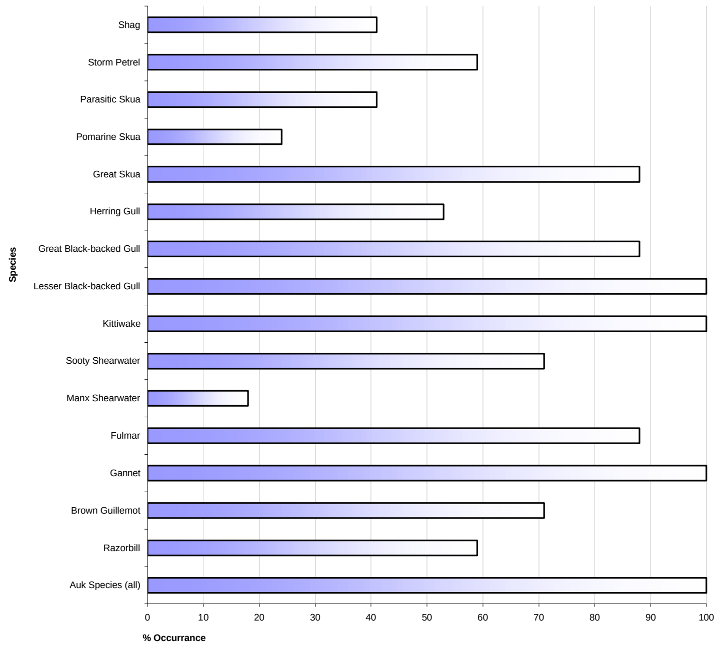


Figure 17. Percentage of days on which 15 bird species were recorded. Celtic Sea herring acoustic survey, October 2007.

HERRING MIDWATER TRAWL

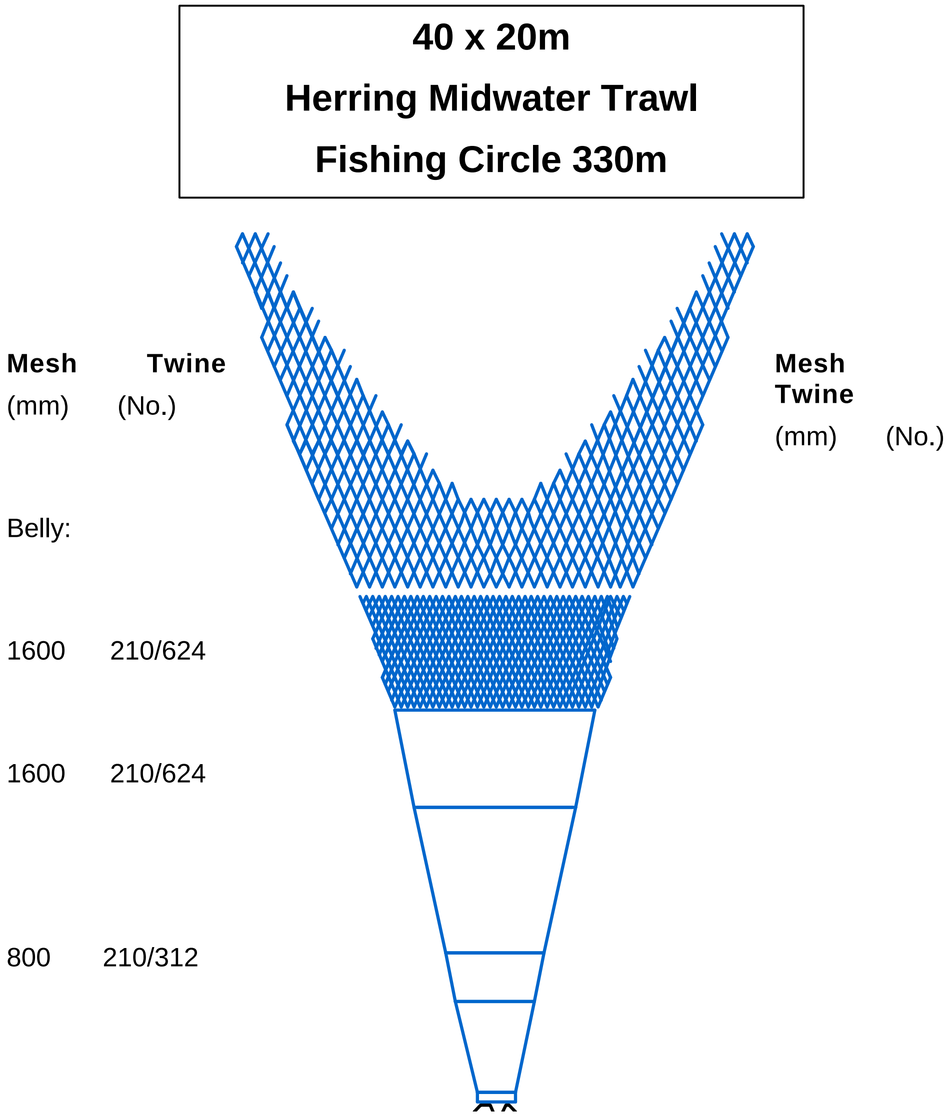


Figure 18. Single herring midwater trawl net plan and layout. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

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 used as primary data source during the survey.

Echo sounder :	ER60 PC		Locality :	Ireland		
		TSSphere:	-33.50 dB			
Type of Sphere :	WC-38,1	(Corrected for soundvelocity o		Depth(Sea floor)	25	m
Comments:						
28.03.07						
Reference Target:						
TS		-33.50 dB		Min. Distance		10.00 m
TS Deviation		9.5 dB		Max. Distance		17.00 m
Transducer: ES38B Serial No. 30227						
Frequency		38000 Hz		Beamtype		Split
Gain		25.55 dB		Two Way Beam Angle		-20.6 dB
Athw. Angle Sens.		21.90		Along. Angle Sens.		21.90
Athw. Beam Angle		6.67 deg		Along. Beam Angle		6.39 deg
Athw. Offset Angle		0.03 deg		Along. Offset Angl		0.04 deg
SaCorrection		-0.65 dB		Depth		5.00 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:						
EK60 Version 2.1.1						
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.		9.9 dB/km		Sound Velocity		1488.5 m/s
Beam Model results:						
Transducer Gain =		25.82 dB		SaCorrection =		-0.70 dB
Athw. Beam Angle =		7.18 deg		Along. Beam Angle =		7.10 deg
Athw. Offset Angle =		-0.03 deg		Along. Offset Angle=		-0.06 deg
Data deviation from beam model:						
RMS = 0.10 dB						
Max = 0.22 dB No. = 36 Athw. = 3.3 deg Along = 2.5 deg						
Min = -0.36 dB No. = 1 Athw. = 4.5 deg Along = -0.7 deg						
Data deviation from polynomial model:						
RMS = 0.06 dB						
Max = 0.18 dB No. = 136 Athw. = -2.1 deg Along = 3.4 deg						
Min = -0.18 dB No. = 159 Athw. = -2.1 deg Along = -1.4 deg						
Comments :						
Flat calm conditions						
Wind Force :	1-3 kn.	**Wind Direction :**		SW degrees		
Raw Data File:	\\Expfileclstr\ER-60_Data\CSHAS_2007\RAW ER60 Files\Calibration\BW_Mar_2007-D200					
Calibration File:	\\Expfileclstr\ER-60_Data\ER-60\Calibrations 2007\CSHAS 07\38 KHZ					
Responsible :		Ciaran O'Donnell				