FSS Survey Series: 2011/03

Celtic Sea Herring Acoustic Survey Cruise Report 2011

07 - 28 October, 2011

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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 of dry hold polyvalent vessels and a small number of large purpose built refrigerated seawater vessels (RSW). 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 1-20 nmi (nautical miles) of the coast. Since the mid 2000s 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 coast. 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. Since 2008 ICES division VIIaS (spawning box C) has been closed to fishing for vessels over 15m to protect first time spawners. For those vessels less than 15m 8% of the quota is allocated to this 'sentinel' fishery.

The stock structure and discrimination of herring in this area has been investigated recently. Hatfield et al. (2007) has shown the Celtic Sea stock to be fairly discrete. However, it is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea, returning to the Celtic Sea as young adults (Brophy et al. 2002; Molloy et al., 1993). The stock identity of VIIj herring is less clear, though there is evidence that they have linkages with VIIb and VIaS (ICES, 1994; Grainger, 1978). Molloy (1968) identified possible linkages between young fish in VIIj and those of the Celtic Sea herring. For the purpose of stock assessment and management divisions VIIaS, VIIg and VIIj 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 is the 20th in the overall acoustic series or the seventh in the modified time series (i.e. conducted in October).

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 since 2004 by detailed hydrographic and marine mammal and seabird surveys.

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity
FSS	Ciaran O'Donnell	Acoustics (SIC)
FSS	Graham Johnston	Acoustics
FSS	Robert Bunn	Acoustics
FSS	Cormac Nolan	Acoustics
FSS	Tobi Rapp	Biologist
FSS	Macdara O'Cuaig	Biologist
FSS	Turloch Smith	Biologist
FSS	Helen McCormick	Biologist
IWDG	Paula Ni Riogain	Marine Mammal Obs.
IWDG	Mareike Volkenandt	Marine Mammal Obs.
IS&W FPO	John Regan	Industry Rep

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
- Determine estimates of biomass and abundance for other pelagic species within the survey area
- Collect physical oceanography data from vertical profiles from a deployed sensor array.
- Survey by visual observations marine mammals and seabird abundance and distribution during the survey
- Collect zooplankton samples from vertical bongo net casts

2.2.2 Area of operation

The autumn 2011 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 in the southwest and worked in an easterly direction along the south coast to coincide with temporal alignment of movements of the stock towards the coast.

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). A broad scale survey composed of 11 strata formed the boundary component of the survey. Broad scale outer lying areas are important transit areas for herring migrating to 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 8 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 70nmi (nautical miles). Transect 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 area coverage.

Transect start points within each stratum are randomised each year within established baseline stratum bounds.

An adaptive stratum was added to the core survey 2011 to cover the 'Smalls' and 'Trench' grounds in the eastern and southern survey area respectively. The Smalls is a traditional prawn fishing ground which since 2010 has been increasingly targeted by the RSW fleet searching for offshore herring aggregations in addition to the traditional areas such as the Labadie Bank and the Rigs areas. However, in 2011 the offshore fishery was exclusive to the Smalls area. The Bank itself lies mostly inside UK waters with the southwest tip protruding into Irish waters. Geographically the distance between traditional offshore herring grounds and the Smalls area is significant (c.60nmi).

Core survey areas were covered as normal to retain the integrity of the survey time series. Survey effort was reallocated from the southwest broadscale area, which historically contributes small amounts of herring to the overall estimate.

In total the combined survey accounted for 3,402nmi; with approximately 3,100nmi of integrateable acoustic transect available.

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 EK60 scientific echosounder. The Simrad split-beam transducers are 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. Four operating frequencies were used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used to generate the abundance estimate.

While 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

Calibration of the EK60 was carried out in Dunmanus Bay on the 7th of October during hours of daylight. Good calibration results were obtained for all frequencies. Results of the 38kHz calibration and survey settings are shown in Table 2.

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 predominantly for the Celtic Sea Herring Survey are those recommended by the acoustic survey planning group based at 38 kHz (Anon, 1994):

Herring	TS =	20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS =	20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS =	20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS =	20logL – 67.5 dB per individual (L = length in cm)
Anchovy	TS =	20logL – 71.2 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 calibrated Seabird 911 sampler at 1m subsurface and 3m above the seabed. Hydrographic stations were equally spread at on each transect where possible (Figure 1).

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) = $0.0314 * L^{2.574}$ (L = length in cm)

Mackerel weight (grams) = $0.0058 * L^{3.073}$ (L = length in cm)

Sprat weight (grams) = $0.0041 * L^{3.291}$ (L = length in cm)

Anchovy weight (grams) = $0.0358 * L^{2.464}$ (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

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

,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 jth track fragment.

Hauls are assigned with their own stratification to acoustic strata, the conversion of NASC into mean density is done at the track fragment level, as 1nmi ESD units. The haul assignment, $h_{m,s,t,j}$, is related to mark type (m) and is determined by hauls geographically closest to the defined mark type. Age and maturity length-keys are applied as 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 $\sum_{spe}^{species} \sum_{i} p_{spe,i} 10^{(a+b\log10(L_{spe,i}))/10}$

, 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

$B_T = \sum_k^{track\cdot fragment} \overline{n}_k w_k$, 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 1nmi is the length of the track fragment.

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

Herring	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	1,234	136,706	95.3
Mixture	0	0	0.0
Probably	66	6,792	4.7
Total estimate	1,300	143,498	100
Possibly	0	0	
Possible estimate			
SSB Estimate			
Definelty	976	117,081	95.7
Probably	0	0	0.0
Mixture	46	5,266	4.3
SSB estimate	1022	122,347	100

Total herring biomass shown above was determined from 20 survey strata (19 historic plus 1 adaptive). The biomass from strata 20, which covered the Trench and southwest Smalls grounds is included in the tables and figures of this report. Biomass and abundance for the 19 historic survey strata that make up the survey time series are presented separately in Annex 1.

Survey biomass and abundance was derived from 226 echotraces that were identified as herring with the aid of 22 directed trawls (Figure 2). Of the total number of echotraces attributed to herring, over 77% were in the 'Definitely herring' category and over 22% occurred in the 'Probably herring' category (Table 10). The estimate of TSB itself is composed of over 95% of 'Definitely herring' and so can be regarded as being of high precision. No mixed herring schools were observed during the survey as the majority of herring echotraces occurred in relatively large and discrete homogeneous shoals.

Herring TSB (total stock biomass) and abundance (TSN) estimates were 143,498 t (CV 27.7%) and 1,300 million individuals (CV 27.7%), respectively. The overall SSB (spawning stock biomass) observed during the survey was 122, 347 t (CV 27.8%), comprising a spawning abundance (SSN) of 1,022 million individuals.

Strata 20 contributed 7% (9,900t) and 6% (72 million individuals) to the TSB and TSN respectively.

Herring stock abundance and biomass estimates are further broken down by age, maturity status, size and strata in Tables 5-10.

3.1.2 Herring distribution

A total of 22 trawl hauls were carried out during the survey (Figure 2), with 16 hauls containing herring and 9 hauls containing >50% herring by weight of bulk catch (Table 3). In general, large high density herring schools were most abundant within 20nmi of the coast from the Old Head of Kinsale to Waterford Harbour (Figure 3). The highest density of schools was centred on the 52° line latitude between Helvick Head and Waterford Harbour, similar to distribution in 2010.

No high density herring aggregations observed offshore in the Mid Celtic Sea around the Kinsale gas rigs or north of the Labadie Bank. This was unusual in that a significant proportion of biomass is often observed offshore as the shoals are moving from summer feeding areas to inshore spawning areas. Anecdotal information from the demersal fleet reported herring aggregating around the Labadie Bank area after the survey finished in late October after a notable absence all summer. The absence of herring from summer feeding grounds was also confirmed during the July 2011 boarfish acoustic survey which comprehensively covered the south Celtic Sea (O'Donnell *et al.* 2011).

This considered the survey area was extended further to the south and east to cover the 'Trench' and southwest corner of the 'Smalls' fishing grounds respectively (strata 20, Table 10, Figure 1). Real time information from the fleet was used to plan coverage in the extended area. For the first year the offshore fishery was centred exclusively on this area straddling the UK waters and away from more traditional grounds further west. Herring aggregations were reported in this area since 2009 but offshore catches were not taken exclusively from here until 2011. A total of 9 herring shoals were identified in strata 20 (Table 10, Figure 7d).

Few herring were detected around the southwest and no herring were observed in the southwest Bays with the exception of a small aggregation in Dingle Bay. A single medium/large density aggregation was observed around the Mizen area which contributed almost 6% to the TSB and 5% to TSN (Figure 3, Table 11). Most unusually in March a demersal trawler working in this area had a bycatch of actively spawning herring, something never seen before in an area associated with predominantly autumn/winter spawning fish.

Herring schools observed during the survey could be broadly categorised as discrete, dense single marks protruding from the sea-bed or very high density extensive 'layers' that extended up 3.5nmi in length (Figure 7e). In certain areas large extensive layers followed a particular depth contour and were noted on successive north-south transects indicating a continuation across transect intervals.

The large extensive herring schools described above were encountered around the 52°N line, north of which remains closed to fishing. Observations over successive years show that herring located inside the closed area and undisturbed by fishing activity will form extremely dense, extensive schools at night over large areas (Figure 7f).

3.1.3 Herring stock composition

A total of 546 herring were aged from survey samples in addition to 4,065 length measurements and 900 length-weight measurements (Tables 4). Herring age samples predominantly ranged from 0-9 winter-rings (Tables 5 & 6, Figure 6).

Of the 20 strata surveyed 11 contained no herring. Herring biomass was primarily distributed along the south coast close inshore where 92% of the TSB and 94% of the TSN of the stock was located. Strata 10 contained the greatest herring biomass contributing over 90,000t of herring which was equal to 883 million individuals (Figure 3, Table 10). The survey was adapted after 9 days at sea to cover further offshore (strata 20) as herring were notably absent from traditional offshore strata. Real time information from the fleet was used to fine tune coverage. Strata 20 contributed 7% and 6% to the TSB and TSN respectively.

Herring within the 2 winter-ring age group dominated the survey estimate representing over 35% of biomass and 37% of total abundance(Table 5 and 6). The 3 winter-ring age group were ranked second representing 39 of biomass and 23% of total abundance. During the 2010 survey the then 2 winter-ring (now 3-winter rings) was the most abundant. The third most dominate age group was the 1 winter-ring group contributing 27% to the total biomass and 26% to total abundance respectively.

As previous strong year classes grow, older age classes are becoming more evident in the standing stock with 5, 7 and 6 winter-ring groups well represented in the 2011 estimate contributing 14% of the total biomass. Age readings of commercial landings and survey samples show close correlation.

Maturity analysis indicate the majority (>85%) of the TSB as sexually mature (Tables 7 and 8, Figure 6). However, no actively spawning or spent individuals were encountered during the survey, indicating the dominance of the winter spawning component of this stock in this estimate. The mature component of the stock (stages 3 to 8) sampled during the survey was in a pre-spawning state and was predominantly comprised of stage 4 individuals (>60% of the mature component). Continuing from 2010 observations the 0 winter-ring group are poorly represented n the estimate.

3.2 Other pelagic species

3.2.1 Sprat

Sprat	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	5,404	26,096	82.6
Mixture	428	5,497	17.4
Probably	0	0	0.0
Total estimate	5,832	31,593	100

Sprat were distributed in 5 main areas during the survey and were sampled in 10 out of 22 hauls (Figure 4, Table 3). In total 1,930 length measurements and 927 length/weight measurements were recorded. Mean length overall was 10.4cm and mean weight was 11g. Individuals ranged from 6.5 to 15.5cm in length and 2 to 32g in weight. In total 230 sprat schools were identified during the survey (Table 12). In terms of number of schools and overall biomass the largest aggregations were observed in Dingle Bay with 58 schools accounting for 35% of the total biomass. Sprat schools in Dingle Bay were of mixed sized cohorts. Large high density sprat aggregations in the southwest were largely composed of small individuals, <9cm, (Figure 7b) as compared to offshore where larger individuals (>11cm) dominated. Mixed sprat containing mackerel were observed inshore around the Helvick area and were found to contain mixed length cohorts.

3.2.2 Anchovy

Anchovy	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	66	2796	71.1
Mixture	1	35	0.9
Probably	26	1104	28.1
Total estimate	93	3935	100

Anchovy were observed for the first time during this survey time series as single homogeneous medium to high density schools (Figure 7c). Schools were highly localised within a discrete area (Figure 5, Table 13). Previously anchovy have been observed in small numbers as part of the mixed trawl samples taken from bottom scattering layers. Anchovy were caught in 2 out of 22 hauls. In total 119 lengths and 117 length/weight measurements were recorded. Mean length was 17cm and mean weight was 39g. Individuals ranged from 15 to 20.5cm in length and 24 to 61g in weight.

3.3 Oceanography

A total of 63 CTD stations were carried out during the survey. Surface plots of temperature and salinity are presented for the 5, 20, 40 and the >60 m depth profiles in Figures 8-11. In general, the hydrographic conditions in the Celtic Sea were cooler than observed during the 2010 survey and the survey area was dominated by a pool of cool water.

Surface waters in the Celtic Sea in July, as determined from MI data buoy network was the lowest since buoy deployment in 2004 (Lyons *pers comm.*). This could be in part accounted for by the short warm spring and cool, stormy early summer months which may have affected the formation of a surface thermocline. A distinct feature is the finger of cold surface water tight along the south coast which is most apparent in the western inshore stations, where unseasonably low SST of 9-10℃ was observed for October (Figure 8). Temperature and salinity plots for points within Bantry and Ken-

mare Bays for all plots should be treated with a degree of caution as they are constructed from interpolated data rather than actual data points.

At increasing depths along the south coast the influence of this cold water mass extends from close inshore southwards and most prominently eastwards to the 07° line of longitude (Figures 9-11). During 2010 the influence of colder water masses was limited to deeper waters and at greater depths.

Salinity profiles appear to follow a similar pattern as in previous years with lower salinity noted in the coastal waters close to large river inputs and also in the north-eastern area influenced by the Irish Sea.

Thermocline depth in early summer was reported as increasing greatly towards the shelf edge (>30m) and was significantly deeper than unusual for this time of year (Van Der Kooij, *pers. comm.*). This may be attributed to the unseasonably windy weather in early summer which will have increased ocean mixing and these conditions have persisted straight through into autumn.

Further east SST appears to follow a similar pattern to previous years, if not moderately cooler. Distinct boundary areas between cool pool of water in the Celtic Sea and warmer waters are evident and this is most prominent at depth in the east of the Celtic Sea (Figures 10 and 11). Temperature at the seabed was compared with historic records and found to be warmer than average in the Bristol Channel and colder than average in the central Celtic Sea (Van Der Kooij, *pers. comm.*) The influence of warmer Atlantic water is evident in the southwest to the west of the pool of cooler water in the central Celtic Sea.

3.4 Marine mammal and seabird observations

A total of 129hrs of observations were logged during the 20 days of the survey. A low Beaufort Wind Force Scale (Beaufort scale) facilitated observations and 14 days with a Beaufort scale < 4 were recorded. Visibility was generally good over the cruise with a view of more than 6 km for 14 days. Observation effort was reduced for six days when Beaufort scale was >= 4 and swell height >= 2 m. On the 9th of October a high swell and stormy conditions limited observation effort to few hours. Dense fog made observations impossible on the 13th and 17th of October and on the as 22nd of October due to stormy weather conditions. Further, the cruise and the observations were stopped for half days on the 8th and 18th of October due to the EK60 calibration and while on standby before entering UK waters.

3.4.1 Marine mammal sightings

A total of 114 cetacean sightings covering 870 individuals of three species were recorded (Figure 12). The common dolphin (*Delphinus delphis*) was the most commonly encountered cetacean (73% of sightings, Table 14) and the only dolphin species. Single individuals or groups of up to 55 animals were recorded. Most groups passed the vessel while traveling, however many dolphins stayed close to the boat, bow riding on the waves.

Fin whales (*Balaenoptera physalus*) were the most abundant whale species recorded during this survey (22% of sightings, Table 14). Fin whales were observed as single individuals and also in groups of 3 to 6 animals. Generally, whales were sighted at distance from the vessel and were identified by their characteristic blow. Closest distance to the boat was 300m, which allowed the body of the animals to be seen to confirm identification. Fin whales were mainly thought to be traveling. During one occasion (16.10.2011) about 10 animals in three groups were sighted in the distance and were likely feeding on the large sprat (*Sprattus sprattus*) aggregations. Approximately 15 fishing boats were in the same region and Celtic Explorer EK60 echotraces indicated the presence of sprat. It is likely, that some animals were encountered twice during the cruise by passing the same area more often on the survey transects.

3.4.2 Seabird sightings

During the survey 17 seabird species were recorded:

Auk species: Common guillemot (*Uria aalge*) and Razorbill (*Alca torda*)

Skua species: Great Skua (*Stercorarius skua*), Pomarine skua (*Stercorarius pomarinus*) and Parasitic skua (*Stercorarius parasiticus*)

Gull species: Kittiwake (*Rissa tridactyla*), Lesser Black Backed Gull (*Larus fuscus*), Great Black Backed Gull (*Larus marinus*) and Herring Gull (*Larus argentatus*)

Shearwater species: Shooty Shearwater (*Puffinus griseus*), Manx Shearwater (*Puffinus puffinus*) and Great Shearwater (*Puffinus gravis*)

Further recorded species were: Northern Gannet (*Morus bassanus*), Northern Fulmar (*Fulmarus glacialis*), Common Shag (*Phalacrocorax aristotelis*), Storm Petrel (*Hydrobates pelagicus*) and a Tern species.

For several days, five different terrestrial bird species were resting on the boat: Blackcap (*Sylvia atricapilla),* Meadow Pipit (*Anthus pratensis*), Pied Wagtail (*Motacilla alba*), Chiff chaff and a Sparrowhawk (*Accipiter sp.*).

4 Discussion and Conclusions

4.1 Discussion

The aims and objectives of the survey were carried out as planned but not fully completed. One survey stratum at Kerry Head (19) was not surveyed due to lack of time. Over 30hrs of survey time was cut from the overall schedule due to a governmental engagement on the vessel and an unscheduled weather buoy deployment. Weather conditions were mixed throughout the survey but little time (<12hrs) was lost due to poor weather. Comprehensive trawl sampling was carried out when fish and scattering layers were encountered. All scheduled CTD casts were completed and a number of zooplankton samples were taken as part of an ancillary project.

The distribution of herring follows a similar pattern to that observed in 2009/2010, with the bulk of the stock located within 20nmi of the coast in the east. The most striking difference in 2011 and somewhat comparable to 2010 was the lack of large, high density herring aggregations offshore. Such high density aggregations normally contribute significantly to the overall survey biomass. This year has been somewhat exceptional in that herring have been absent from offshore summer feeding areas all summer as observed by the demersal fleet. Even more unusual was that in March spring spawning herring were observed south of Mizen Head in an area historically associated with autumn spawners.

Information from the fishery indicates that the quantity of herring on the ‘Smalls’ fishing grounds has increased over the last 3 years. However, this year is the first year that the entire fishery has been focused on this area and away from traditional feeding areas. However, it is important to note that it terms of the survey this is only the second year where no offshore aggregations have been encountered in the south Celtic Sea. For the survey to fully contain the stock and track changes in abundance with precision a degree of flexibility in the survey design must exist while retaining the integrity of the core time series.

Adaptive coverage (stratum 20) was based on real time positional data of where the offshore fishery was taking place and this was contained within the new survey area. Survey effort was reallocated away from the southwest corner, an area that has historically yielded little herring biomass. Herring aggregations remained within the same general geographic area for a number of weeks (pre and post survey) centred on the southwest corner of the ‘Smalls’ and ‘Trench’ grounds. However, in the final days of the survey (and the fishery) catch positions outside of the additional strata were reported as was anecdotal reports of fish on the Labadie Bank, which was not covered. It is therefore difficult to ascertain whether the fish on the smalls were indeed part of the stock surveyed or constituted additional biomass that was located further east. What is certain is that if herring did appear in later October on the Labadie Bank they were not counted during the survey.

The 2011 SSB estimate is very similar to the 2010 estimate, if the adaptive stratum (20) is included. Comparing like with like, for the survey time series and excluding strata 20 the 2011 TSB and SSB estimates are in the region of 10,000t (8%) lower. The difference was comprised almost entirely of mature fish.

The decrease in observed SSB between 2010 and 2011 would not be considered as an actual indication of the standing stock. Inter-annual variation of this order (8%) is not uncommon across acoustically derived estimates considering the current size of this stock. The data from this survey is presented as a relative and not absolute index of stock abundance and no single estimate will determine the trend.

The contribution of immature fish to the TSB remains positive and accounts for 15% of biomass and 21% of TSN (Tables 7 and 8). In 2010 a higher proportion of immature fish were observed contributing 21% and 33% to biomass and numbers respectively. Recruitment therefore remains positive for this stock in terms of 1 winter-ring fish. However, it is important to note that this survey targets pre-spawning aggregations it is generally not considered a good indicator of emerging 0-winter ring recruits.

Hydrographic conditions during the survey were dominated by a large pool of cold water in the central Celtic Sea which has persisted since early summer. The presence of such a body of unseasonably cool water will no doubt have had an effect on the productivity and distribution of prey species to forage feeders including herring, especially in frontal areas. The distribution of biomass of herring, sprat and anchovy was primarily located in areas with a surface water temperature of 12℃ or more. Interestingly the distribution of anchovy and sprat both occurred at a distinct frontal boundary region of cold/warm water at depth (>60m). As frontal areas area associated with high productivity this could account for the high abundance in this region. The presence of this cool water mass may be connected to the eastern shift distribution of herring on the Smalls and away from their normal feeding areas in the mid Celtic Sea. Comparing temperatures profiles with 2010 the influence of cool water is not visible in surface waters due to the development of the seasonal thermocline. The presence of cool water on the sea bed is visible but not to the extent observed this year.

4.2 Conclusions

- Celtic Sea herring survey estimate of biomass and abundance (Strata 1-20: adaptive) can be broken down as: TSB and TSN are 143,500 t (CV 27.7%) and 1,300 million individuals (CV 27.7%) respectively. SSB is 122, 347 t (CV 27.8%).

- Celtic Sea herring survey estimate of biomass and abundance (Strata 1-19: historic) can be broken down as: TSB and TSN are 133,564 t (CV 29.5%) and 1,228 million individuals (CV 29.5%) respectively. SSB is 112, 497 t (CV 30.6%).

- Strata 20 contributed 7% (9,900t) and 6% (72 million individuals) to the TSB and TSN respectively and was composed of over 98% mature fish.

- Positive effect of the closed area (VIIaS) north of 52°N was again evident during the survey with very large, extensive undisturbed schools of herring extending for several miles in length.

- 2 winter-ring age group dominated the survey estimate representing over 35% of TSB and 37% of TSN. The 3 winter-ring age group was ranked second representing 39% of TSB and 23% of TSN. The third most dominate age group was the 1 winter-ring group contributing 27% to TSB and 26% to TSN.

- Older fish of the 5, 7 and 6 winter-ring groups well represented in the 2011 estimate totalling 14% of the TSB.

Acknowledgements

We would like to thank Anthony Hobben (Captain) and the crew of the Celtic Explorer for their help and professionalism during the survey. We also thank John O' Regan for his expert advice on fishing operations and for liaising with the commercial fishing fleet.

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

Brophy, D., and B. S. Danilowicz. 2002. Tracing populations of Atlantic herring (*Clupea harengus* L.) in the Irish and Celtic seas using otolith microstructure. ICES Journal of Marine Science, 59:1305-1313.

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

Grainger, R. J. (1978). A study of herring stocks west of Ireland and their oceanograo-hic conditions. Oceanography. Galway, University College Galway: 262.

ICES. 1994. Report of the Study Group on Herring Assessment and Biology in the Irish Sea and Adjacent Waters. ICES CM 1994/H :5. 67pp.

Molloy, J., E. Barnwall, and J. Morrison. 1993. Herring Tagging Experiments around Ireland, 1991. Fishery Leaflet, 154: 7pp.

Molloy, J. (1968). "Herring investigations on the southwest coast of Ireland 1967." ICES CM 1968/H:14: 10 pp

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., Farrell, E., Saunders, R. and Campbell, A. (2011). Borefish Acoustic Survey Cruise Report 2011. FSS Survey Series: 2011/03.

J van der Kooij, S Warnes, F Luxford, A Plirú, R Scott and B Roel, 2011. Cruise report CEND09-11. PELTIC11: sardine and other small pelagic fish in the western Channel and Celtic Sea. (In press).

5 Tables and Figures

Table 1. Survey Strata details. Celtic Sea herring acoustic survey, October 2011. Strata 20 (adaptive) is highlighted in blue and is not included as part of the existing time series.

Strata no.	Strata name	Survey type	Transect type	Total transects	Active transects	Transect spacing	Active transect distance (nmi)	Strata area (nmi2)
1 (a,b)	SW Shannon	Broad scale	Parallel	26	14	4	179	731
2	Inside Shannon	Broad scale	Zigzag	7	5	\	16	43
3	Dingle	Broad scale	Zigzag	9	7	\	53	95
4 (a,b)	SW corner	Broad scale	Parallel	3	2	4	37	132
5	Kenmare	Broad scale	Zigzag	7	7	\	9	91
6	Bantry	Broad scale	Zigzag	8	7	\	9	53
7	Dunmanus	Broad scale	Zigzag	7	7	\	121	16
8	Mizen area	Broad scale	Parallel	27	14	4	350	980
9	Offshore CS	Broad scale	Parallel	63	32	2	930	2,102
10 (a,b,c,d,e)	Inshore CS	Broad scale	Parallel	61	34	2	323	1,265
11	Baginbun	Spawning grd	Parallel	17	9	1	81	39
12	Tramore	Spawning grd	Parallel	31	17	1	163	101
13	Waterford Hbr	Broad scale	Zigzag	4	4	\	14	3
14	Ballycotton	Spawning grd	Parallel	32	16	1	206	120
15	Daunt	Spawning grd	Parallel	25	13	1	132	80
16	Stags	Spawning grd	Parallel	9	5	1	121	11
17	Dingle_S	Spawning grd	Parallel	11	6	1	77	14
18	Dingle_N	Spawning grd	Parallel	11	6	1	24	12
19	Kerry Head	Spawning grd	Parallel	23	12	1	-	-
20	Trench/Smalls	Broad scale	Parallel	27	14	2	260	714
			Total	408	231		3,104	6,603

Table 2. Calibration report: Simrad EK60 echosounder at 38 kHz, employed during the Celtic Sea herring acoustic survey, October 2011.

Vessel : R/V Celtic Explorer		Date : 8/10/2011	
Echo sounder : ER60 PC		Locality : Dunmanus Bay	
Type of Sphere : WC-38,1	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) : 38 m	

Calibration Version 2.1.0.11

Comments:
Dunmanus Bay, Survey start

Reference Target:

TS	-33.50 dB	Min. Distance	15.00 m
TS Deviation	5.0 dB	Max. Distance	25.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	26.0 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.94 deg	Along. Beam Angle	6.91 deg
Athw. Offset Angle	- 0.04 deg	Along. Offset Angl	-0.06 deg
SaCorrection	-0.32 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

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

Sounder Type:
ER60 Version 2.2.0

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	9.3 dB/km	Sound Velocity	1503.0 m/s

Beam Model results:

Transducer Gain =	25.44 dB	SaCorrection =	-0.75 dB
Athw. Beam Angle =	6.82 deg	Along. Beam Angle =	6.81 deg
Athw. Offset Angle =	-0.06 deg	Along. Offset Angle=	-0.11 deg

Data deviation from beam model:
RMS = 0.17 dB
Max = 0.61 dB No. = 253 Athw. = 2.4 deg Along = 4.1 deg
Min = -0.83 dB No. = 311 Athw. = -0.5 deg Along = 4.7 deg

Data deviation from polynomial model:
RMS = 0.14 dB
Max = 0.52 dB No. = 305 Athw. = -2.7 deg Along = 4.1 deg
Min = -0.43 dB No. = 311 Athw. = -0.5 deg Along = -4.7 deg

Comments :

Wind Force : **Wind Direction :**

Raw Data File: \\Expfileclstr\ER-60_Data\CSHAS_2011\RAW ER60 Files\Calibration\CSHAS_2011

Calibration File: \\Expfileclstr\ER-60_Data\ER-60\Calibrations_2011\CSHAS 2011\38 KHZ

Calibration : Ciaran O'Donnell

Table 3. Catch table from directed trawl hauls during the Celtic Sea herring acoustic survey, October 2011. An additional aged commercial sample is not shown here but was applied to acoustic data in Dingle Bay, strata 18.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	11.10.11	51 18.62	009 28.85	11:25	76	0-8	30.0	0.5	60.4	0.0	37.4	0.0	1.7
2	11.10.11	51 23.68	009 15.61	17:35	53	0-20	0.0	0.0	0.0	0.0	0.0	0.0	
3	12.10.11	51 05.22	008 23.70	10:58	105	0-4	112.0	0.0	79.7	0.0	3.3	0.0	17.0
4	14.10.11	51 29.19	007 39.48	10:12	79	0-4	26.3	0.2	28.4	0.0	69.7	0.0	1.7
5	14.10.11	51 08.31	007 36.10	15:35	92	16	67.6	0.5	13.2	0.0	82.1	0.0	4.2
6	15.10.11	51 24.74	007 23.19	8:40	83	15-25	112.7	0.2	8.4	0.0	89.7	0.0	1.7
7	16.10.10	51 28.19	007 10.03	3:39	79	28-55	1500.0	0.0	45.0	0.0	0.0	0.0	55.0
8	16.10.11	51 24.87	007 06.18	12:04	80	0-18	220.0	0.6	66.1	0.0	32.4	0.0	0.9
9	16.10.11	51 18.42	007 00.16	22:42	86	0-30	1200.0	95.1	0.8	0.0	0.2	0.0	3.9
10	18.10.11	51 09.54	006 37.63	18:24	104	0-18	2000.0	86.2	1.0	0.0	0.0	0.0	12.7
11	19.10.11	51 59.30	006 50.44	11:36	46	0-25	Foul haul	0.0	0.0	0.0	0.0	0.0	0.0
12	19.10.11	51 58.89	006 56.62	20:35	56	0-28	4000.0	95.5	4	0.0	0.00	0.10	0.0
13	20.10.11	52 00.17	007 09.43	3:49	50	0-25	1400.0	67.0	33.0	0.0	0.0	0.0	0.0
14	21.10.11	52 01.20	007 22.26	4:19	45	0-15	3000.0	82.2	17.6	0.0	0.0	0.0	0.2
15	21.10.11	51 50.78	007 31.26	16:56	65	0-5	112.0	0.3	46.6	0.0	51.2	0.0	1.9
16	22.10.11	51 53.98	007 41.44	1:17	28	0-10	1200.0	88.0	4.3	0.0	0.0	7.5	0.2
17	22.10.11	51 52.62	007 46.34	9:24	25	22	2500.0	98.7	0.9	0.0	0.0	0.5	0.0
18	22.10.11	51 48.30	008 01.20	19:50	18	0-18	3000.0	99.8	0.2	0.0	0.0	0.0	0.0
19	23.10.11	51 39.57	008 04.94	12:07	74	0-15	Foul haul	0.0	0.0	0.0	0.0	0.0	0.0
20	24.10.11	51 40.17	008 27.43	15:57	25	0-25	1500.0	99.9	0.0	0.0	0.1	0.0	0.0
21	25.10.11	51 19.13	009 34.99	8:44	85	20-30	4.0	0.0	13.8	0.0	49.6	0.0	36.7
22	25.10.11	51 25.51	009 49.86	13:40	70	0-25	8.9	0.7	46.7	0.0	22.4	0.0	30.2

Table 4. Length-frequency of herring hauls used for calculating 'definitely' and 'probably' abundance categories. Haul 23 represents a commercial haul applied during the analysis**.** Celtic Sea herring acoustic survey, October 2011.

Haul	9	10	12	13	14	16	17	18	20	23*	
length (cm)											Total
12											
12.5											0
13											0
13.5											0
14											0
14.5											0
15											0
15.5											0
16											0
16.5			1								1
17											0
17.5											0
18											0
18.5				3	1	1			1		6
19				8	12	1	1		1		23
19.5	3		3	21	31	5		2	3		68
20	5		11	16	27	7	6	5	9		86
20.5	4		5	24	60	5	1	7	16		122
21	1		15	13	42	5	3	18	19		116
21.5	4	1	11	17	40	10	1	9	23		116
22	7	2	21	30	26	21	4	16	17		144
22.5	10	1	13	36	25	35	9	15	37	1	181
23	20	4	28	35	17	32	18	21	26	1	201
23.5	15	12	45	47	14	46	12	30	54	3	275
24	41	11	56	58	8	55	52	30	59	8	370
24.5	34	24	60	60	10	58	47	58	51	11	402
25	60	29	27	39	17	51	56	60	37	8	376
25.5	44	32	58	42	15	60	60	51	60	6	422
26	34	49	38	21	7	47	57	47	31	4	331
26.5	29	60	14	20	4	38	44	54	41	0	304
27	27	48	19	15	8	14	33	34	35	1	233
27.5	14	29	12	3		15	28	20	22	1	143
28	2	16	6	2		4	10	14	8	4	62
28.5	2	4	3		1	2	4	5	5	1	26
29		3	1						2	1	6
29.5											0
30											0
30.5											0
31											0
31.5											0
32											0
32.5											0
33		1									1
Total	**356**	**326**	**447**	**510**	**365**	**512**	**446**	**496**	**557**	**50**	**4,065**

Table 5. 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 2011.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0.6	2.8	2.3	0.4	0.8	0.3	0.5	0.1	0	0	7.7
9	0	0	0.1	0.1	0	0	0	0	0	0	0	0.2
10	0	24	35.9	20.4	2.9	4	1.2	1.5	0.2	0.1	0	90.2
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0.8	0.7	0.3	0	0.1	0	0	0	0	0	2
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0.8	7.7	11	2.1	3.6	1.4	1.9	0.3	0.1	0	28.9
15	0	0.3	1.3	1.1	0.2	0.4	0.1	0.2	0	0	0	3.7
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0.3	0.3	0.1	0	0	0.1	0	0	0	0.9
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0.1	1.8	3.5	0.8	1.8	0.7	1	0.1	0	0	9.9
Total	0	26.6	50.6	38.9	6.6	10.8	3.8	5.3	0.7	0.3	0	143.5
%	0	18.5	35.3	27.1	4.6	7.5	2.6	3.7	0.5	0.2	0	100

Table 6. Herring abundance (millions) at age (winter rings), by strata as derived from acoustic estimate of abundance. Celtic Sea herring acoustic survey, October 2011.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0.0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	7.3	25.5	17.3	2.9	5.5	1.9	2.9	0.4	0.2	0	63.9
9	0	0.1	0.5	0.5	0.1	0.1	0	0.1	0	0	0	1.4
10	0.1	309.7	347.6	158.9	21.1	26.9	7.8	9.6	1.1	0.3	0	883.0
11	0	0	0	0	0	0	0	0	0	0	0	0.0
12	0	10.7	7.3	2.3	0.3	0.4	0.1	0.2	0	0	0	21.4
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	9.6	67.7	82.8	14.7	23.9	8.9	11.8	1.6	0.7	0	221.7
15	0	3.4	11.9	8.3	1.4	2.6	0.9	1.4	0.2	0.1	0	30.2
16	0	0	0	0	0	0	0	0	0	0	0	0.0
17	0	0	0	0	0	0	0	0	0	0	0	0.0
18	0	0	2.6	2.7	0.4	0.2	0.3	0.5	0.1	0	0	6.8
19	0	0	0	0	0	0	0	0	0	0	0	0.0
20	0	2	16	26	6	12	4	6	1	0	0	72.2
Total	0.1	342.4	478.9	298.9	46.6	71.3	24.0	32.6	4.1	1.5	0	1300.5
%	0	26.3	36.8	23.0	3.6	5.5	1.8	2.5	0.3	0.1	0	100
Cv (%)	88	32	31.5	28.9	27	27	26.1	26.1	27.1	28	NA	NA

Table 7. Herring biomass (000's tonnes) at maturity by strata. Totals do not account for the "possibly" herring classification. Celtic Sea herring acoustic survey, October 2011.

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	0.4	7.3	0	7.7
9	0	0.2	0	0.2
10	19.2	71	0	90.2
11	0	0	0	0
12	0.7	1.3	0	2
13	0	0	0	0
14	0.5	28.4	0	28.9
15	0.2	3.5	0	3.7
16	0	0	0	0
17	0	0	0	0
18	0	0.9	0	0.9
19	0	0	0	0
20	0.1	9.9	0	9.9
Total	21.2	122.3	0	143.5
%	14.7	85.3	0	100

Table 8. Herring abundance (millions) at maturity by strata. Totals do not account for the possibly herring classification. Celtic Sea herring acoustic survey, October 2011.

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	5.5	58.3	0	63.9
9	0.1	1.4	0	1.4
10	253.3	629.7	0	883.0
11	0	0	0	0
12	8.8	12.5	0	21.4
13	0	0	0	0
14	6.9	214.8	0	221.7
15	2.6	27.7	0	30.2
16	0	0	0	0
17	0	0	0	0
18	0	6.7	0	6.8
19	0	0	0	
20	1.048	71	0	72
Total	278.2	1022.3	0	1,300.5
%	21.4	78.6	0	100

Table 9. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Celtic Sea herring acoustic survey, October 2011.

Length (cm)	Age (Rings) 0	1	2	3	4	5	6	7	8	9	10	Abund (mils)	Biomass 000's t	Mn wt (g)
12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.5	0.1	-	-	-	-	-	-	-	-	-	-	0.1	-	44.5
17	-	-	-	-	-	-	-	-	-	-	-	0	0	0
17.5	-	-	-	-	-	-	-	-	-	-	-	0	0	0
18	-	-	-	-	-	-	-	-	-	-	-	0	0	0
18.5	-	3.71	-	-	-	-	-	-	-	-	-	3.7	0.2	59.5
19	-	22.3	-	-	-	-	-	-	-	-	-	22.3	1.4	63.7
19.5	-	57.7	-	-	-	-	-	-	-	-	-	57.7	3.9	68.0
20	-	47.4	5.92	-	-	-	-	-	-	-	-	53.3	3.9	72.6
20.5	-	79.8	21.7	-	-	-	-	-	-	-	-	101.5	7.9	77.3
21	-	63.5	9.07	-	-	-	-	-	-	-	-	72.6	6.0	82.2
21.5	-	36.2	36.2	-	-	-	-	-	-	-	-	72.4	6.3	87.2
22	-	21.9	43.9	-	-	-	-	-	-	-	-	65.8	6.1	92.5
22.5	-	4.37	61.1	8.75	-	-	-	-	-	-	-	74.2	7.3	97.9
23	-	5.58	58.8	2.82	-	-	-	-	-	-	-	67.2	7.0	103.6
23.5	-	-	71.9	6.76	-	-	-	-	-	-	-	78.7	8.6	109.4
24	-	-	79.3	18.8	-	-	-	-	-	-	-	98.1	11.3	115.4
24.5	-	-	49.8	53.7	-	-	-	-	-	-	-	103.5	12.6	121.7
25	-	-	28	61.8	7.5	-	-	-	-	-	-	97.4	12.5	128.1
25.5	-	-	13.2	70	13.2	5.72	1.87	-	-	-	-	104.1	14.0	134.7
26	-	-	-	51.5	11.3	3.19	3.19	1.63	-	-	-	70.7	10.0	141.6
26.5	-	-	-	20.9	4.83	30.6	1.59	3.24	-	-	-	61.1	9.1	148.6
27	-	-	-	2.89	7.23	24.6	7.23	10.1	1.45	-	-	53.5	8.3	155.9
27.5	-	-	-	0.93	0.93	6.48	5.55	8.33	1.85	0.93	-	25.0	4.1	163.3
28	-	-	-	-	1.61	0.8	4.02	4.02	0.8	-	-	11.3	1.9	171.0
28.5	-	-	-	-	-	-	0.59	4.1	-	0.59	-	5.3	0.9	178.9
29	-	-	-	-	-	-	-	0.99	-	-	-	1.0	0.2	187.0
29.5	-	-	-	-	-	-	-	-	-	-	-	0	0	0
30	-	-	-	-	-	-	-	-	-	-	-	0	0	0
30.5	-	-	-	-	-	-	-	-	-	-	-	0	0	0
31	-	-	-	-	-	-	-	-	-	-	-	0	0	0
31.5	-	-	-	-	-	-	-	-	-	-	-	0	0	0
32	-	-	-	-	-	-	-	-	-	-	-	0	0	0
32.5	-	-	-	-	-	-	-	-	-	-	-	0	0	0
33	-	-	-	-	-	-	-	0.14	-	-	-	0.14	0.04	260.2
SSN (mil)	0.1	111	433	298	46.6	71.3	24	32.6	4.1	1.5	-	1022.3	-	-
SSB ('000s t)	0.0	9.4	46.7	38.9	6.6	10.8	3.8	5.3	0.7	0.3	-	-	122.3	-
Mn Wt (g)	44.5	77.6	106	130	142	151	157	163	162	169	-	-	-	-
Mn length (cm)	16.8	20.8	23.4	25.4	26.3	26.9	27.3	27.7	27.7	28.1	-	-	-	-

Table 10. Herring biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2011.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass ('000t)	SSB ('000t)	Abundance millions
1	14	0	0	0	0	100	0	0	0	0	0	0
2	4	0	0	0	0	100	0	0	0	0	0	0
3	7	0	0	0	0	100	0	0	0	0	0	0.0
4	2	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	2	2	0	0	93	7.7	0	0	7.7	7.3	63.9
9	32	2	2	0	0	97	0.2	0	0	0.2	0.2	1.4
10	34	119	84	0	35	62	84.4	0	5.8	90.2	71	883.0
11	9	0	0	0	0	100	0	0	0	0	0	0.0
12	17	5	4	0	1	88	2	0	0	2	1.3	21.4
13	4	0	0	0	0	100	0	0	0	0	0	0
14	16	57	57	0	0	25	28.9	0	0	28.9	28.4	221.7
15	14	26	11	0	15	64	2.7	0	1	3.7	3.5	30.2
16	5	0	0	0	0	100	0	0	0	0	0	0.0
17	5	0	0	0	0	100	0	0	0	0	0	0.0
18	6	6	6	0	0	83	0.9	0	0	0.9	0.9	6.8
19	0	0	0	0	0	0	0	0	0	0	0	0.0
20	14	9	9	0	0	79	9.9	0	0	9.9	9.8	72.2
Total	216	226	175	0	51	82	136.7	0	6.8	143.5	122.3	1300.5
Cv (%)	-	-	-	-	-	-	-	-	-	27.7	27.8	27.7

Table 11. Celtic Sea and VIIj Herring acoustic survey time series (Strata 1-19-historic). Abundance (millions), TSN and SSB (000's tonnes). Age in winter rings.

Note: 2009/2010 values are derived from 18 kHz data.

Season Age (Rings)	1995 1996	1996 1997	1997 1998	1998 1999	1999 2000	2000 2001	2001 2002	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012
0	202	3	-	0	-	25	40	0	24	-	2	-	1	2	239	5	0.1
1	25	164	-	30	-	102	28	42	13	-	65	21	106	63	381	346	341
2	157	795	-	186	-	112	187	185	62	-	137	211	70	295	112	549	463
3	38	262	-	133	-	13	213	151	60	-	28	48	220	111	210	156	273
4	34	53	-	165	-	2	42	30	17	-	54	14	31	162	57	193	41
5	5	43	-	87	-	1	47	7	5	-	22	11	9	27	125	65	60
6	3	1	-	25	-	0	33	7	1	-	5	1	13	6	12	91	20
7	1	15	-	24	-	0	24	3	0	-	1	-	4	5	4	7	26
8	2	0	-	4	-	0	15	0	0	-	0	-	1	-	6	3	3
9	2	2	-	2	-	0	52	0	0	-	0	-	0	-	1	-	1
Abundance	469	1338	-	656	-	256	681	423	183	-	312	305	454	671	1,147	1,414	1,228
SSB	36	151	-	100	-	20	95	41	20	-	33	36	46	93	91	122	112
CV	53	26	-	36	-	100	88	49	34	-	48	35	25	20	24	20	31

Table 12. Sprat biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2011.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass ('000t)	Abundance millions
1	14	0	0	0	100	0	0	0	0	0
2	4	16	16	0	0	3.3	0	0	3.3	948.0
3	7	58	58	0	0	11	0	0	11	3,127.3
4	2	0	0	0	100	0	0	0	0	0
5	7	45	45	0	14	1.4	0	0	1.4	408.6
6	7	0	0	0	100	0	0	0	0	0
7	5	0	0	0	100	0	0	0	0	0
8	14	36	36	0	79	4.4	0	0	4.4	582.3
9	32	103	45	58	72	4.6	2	0	6.6	459.5
10	34	20	0	20	94	0	3.5	0	3.5	220.2
11	9	0	0	0	100	0	0	0	0	0
12	17	0	0	0	100	0	0	0	0	0
13	4	5	5	0	75	0.5	0	0	0.5	31.7
14	16	0	0	0	100	0	0	0	0	0
15	14	0	0	0	100	0	0	0	0	0
16	5	0	0	0	100	0	0	0	0	0
17	5	0	0	0	100	0	0	0	0	0
18	6	0	0	0	100	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	14	25	25	0	0	86	0.8	0	0.8	54.6
Total	216	308	230	78	0	84	26.1	5.5	31.6	5,832
Cv (%)	-	-	-	-	-	-	-	-	18.9	15.1

Table 13. Anchovy biomass and abundance by survey strata. Celtic Sea herring acoustic survey, October 2011.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Prob Biomass	Poss Biomass	Biomass ('000t)	Abundance millions
1	14	0	0	0	0	100	0	0	0	0	0
2	4	0	0	0	0	100	0	0	0	0	0
3	7	0	0	0	0	100	0	0	0	0	0
4	2	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	56	23	4	29	78	2.8	0	1.1	3.9	93.4
10	34	0	0	0	0	100	0	0	0	0	0
11	9	0	0	0	0	100	0	0	0	0	0
12	17	0	0	0	0	100	0	0	0	0	0
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	14	0	0	0	0	100	0	0	0	0	0
16	5	0	0	0	0	100	0	0	0	0	0
17	5	0	0	0	0	100	0	0	0	0	0
18	6	0	0	0	0	100	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	14	0	0	0	0	100	0	0	0	0	0
Total	216	56	23	4	29	97	2.8	0	1.1	3.9	93.4
Cv (%)	-	-	-	-	-	-	-	-	-	62.8	62.6

Table 14. Sightings, counts and group size ranges for cetaceans sighted during current survey. Celtic Sea herring acoustic survey, October 2011.

Species	No. of sightings	Percentage of sightings (%)	No. of animals	Range of group size
Common dolphin	83	73	814	1-55
Fin whale	25	22	49	1-6
Minke whale	6	5	6	1

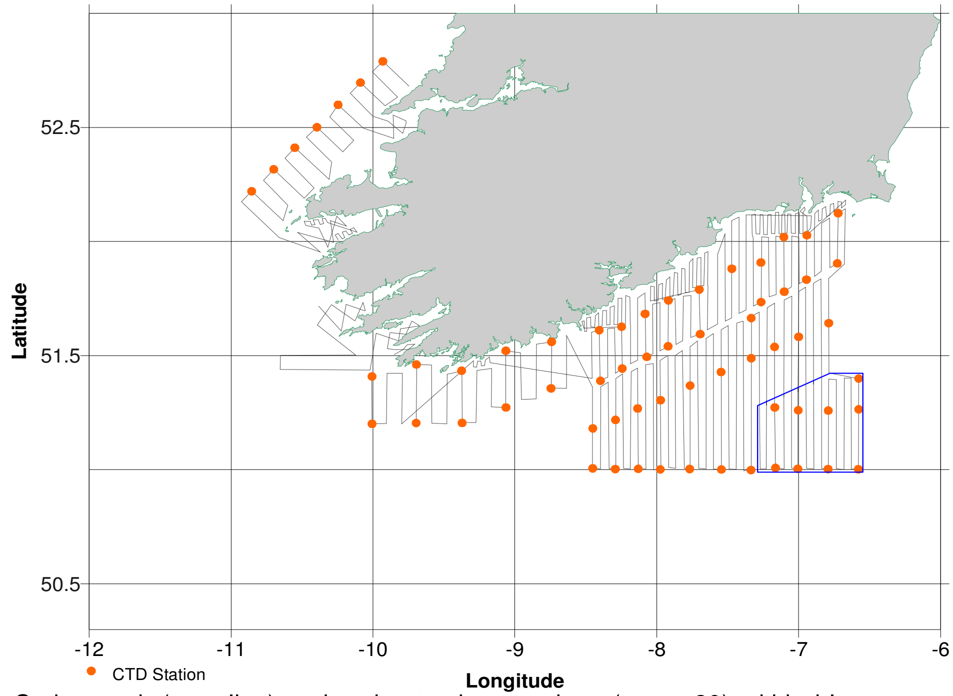


Figure 1. Cruise track (grey line) and cruise track extensions (strata 20) within blue box. CTD casts sites appear in orange. Celtic Sea herring acoustic survey, October 2011.

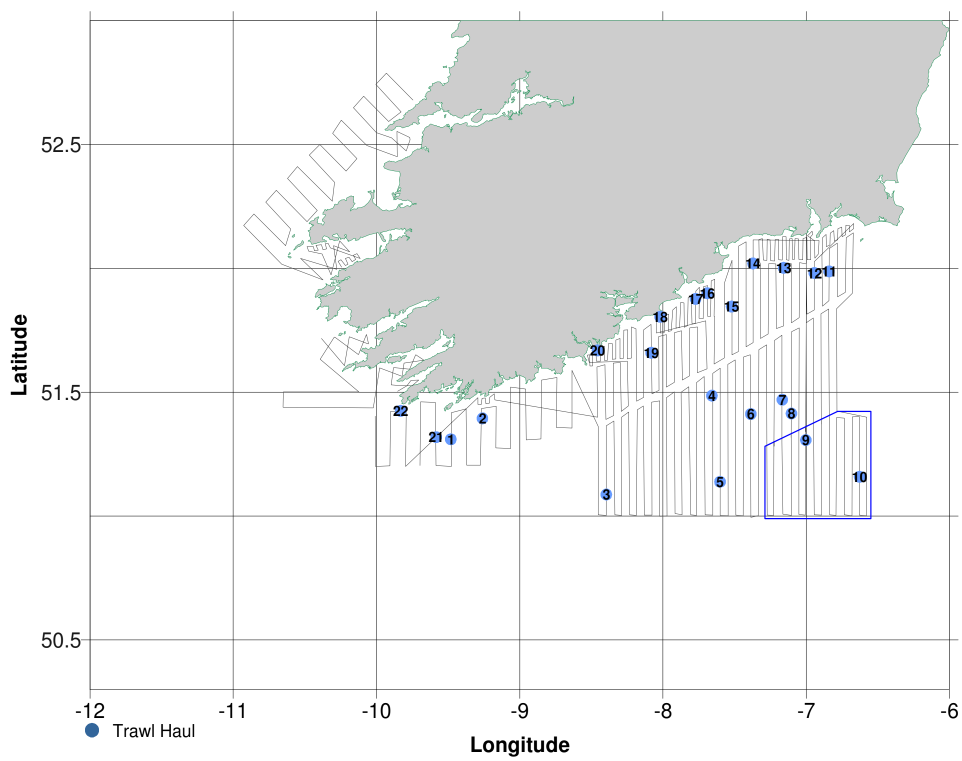


Figure 2. Haul positions. Celtic Sea herring acoustic survey, October 2011.

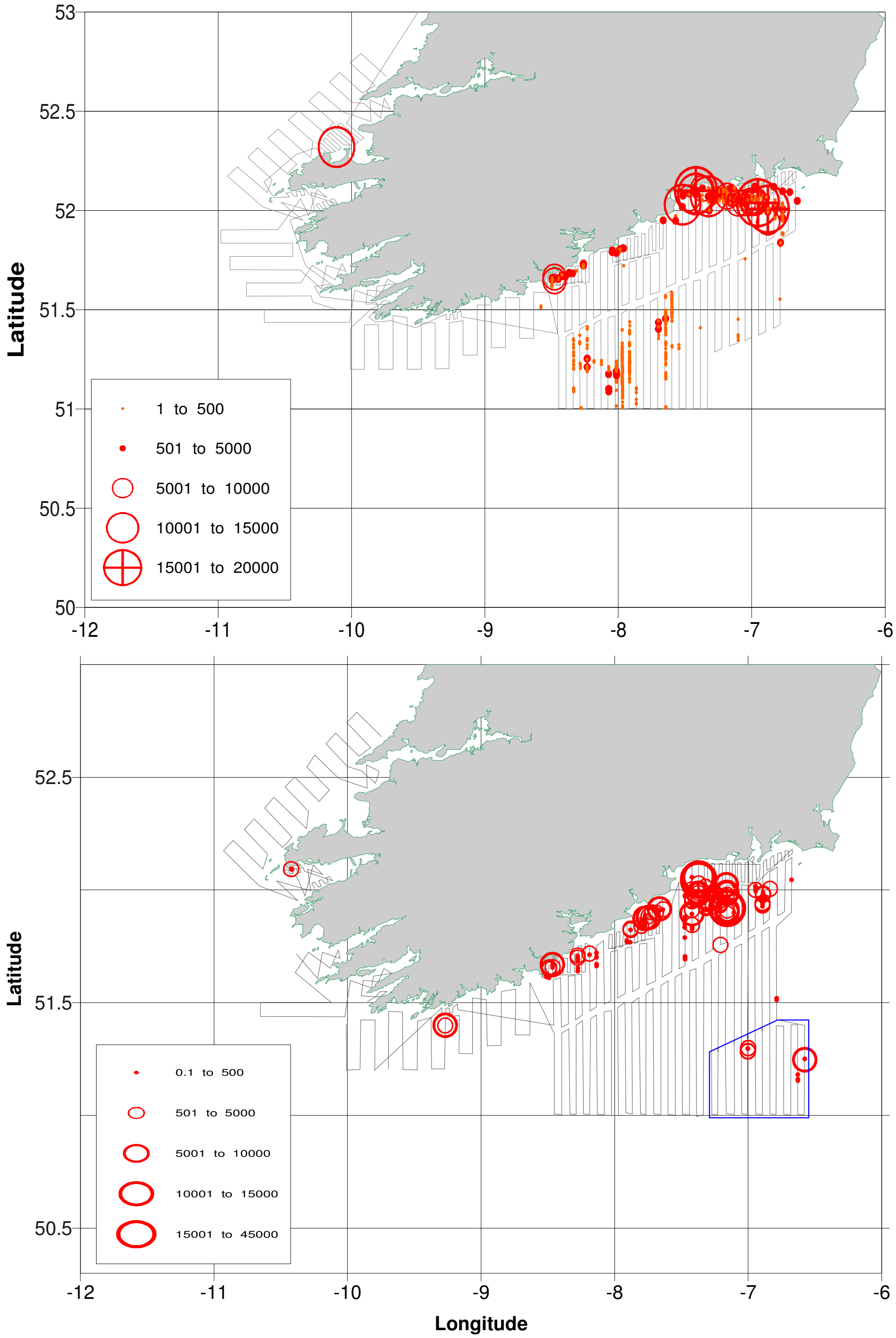


Figure 3. Weighted herring NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” categories. Top Panel 2010, bottom panel 2011. Celtic Sea herring acoustic survey, October 2011. Blue box represents Strata 20.

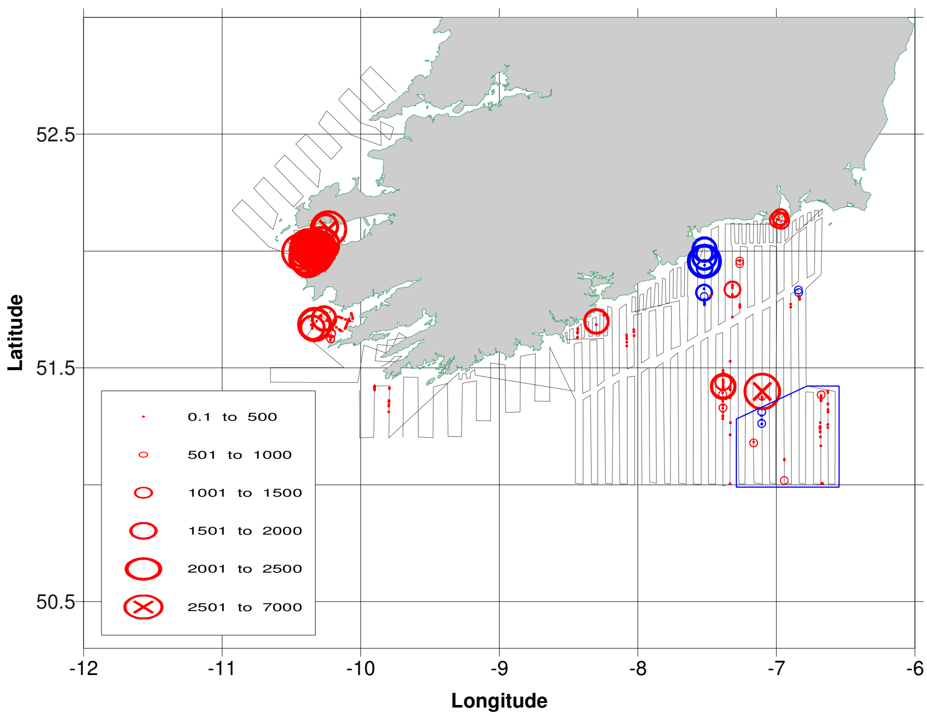


Figure 4. Weighted Sprat NASC (Nautical area scattering coefficient) plot showing the distribution of "definitely" and "probably" categories in red and "mixed" species schools containing sprat in blue. Celtic Sea herring acoustic survey, October 2011.

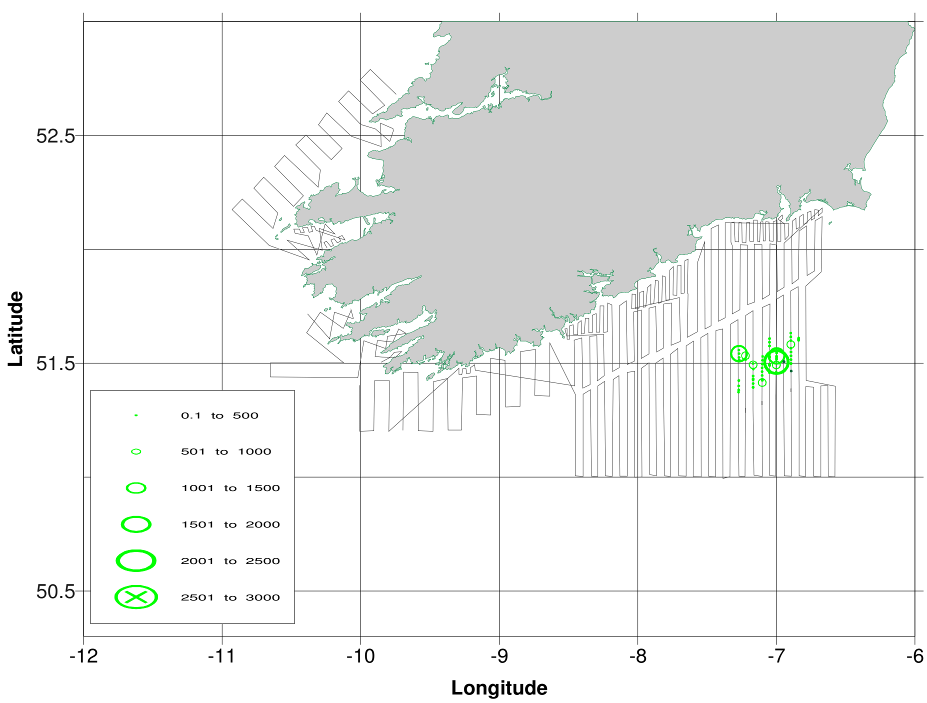


Figure 5. Weighted Anchovy NASC (Nautical area scattering coefficient) plot showing the distribution of "definitely" and "probably" categories. Celtic Sea herring acoustic survey, October 2011.

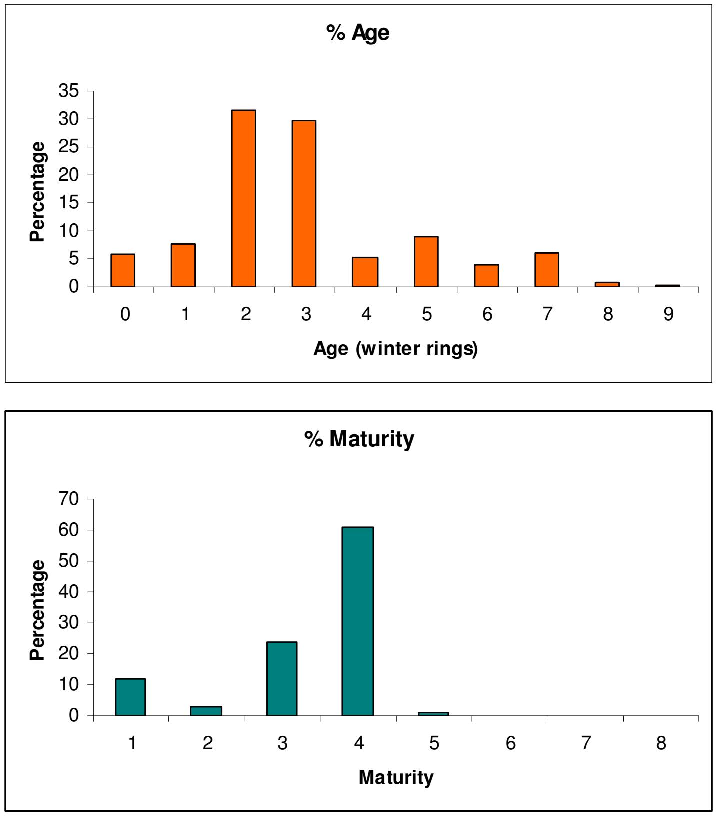
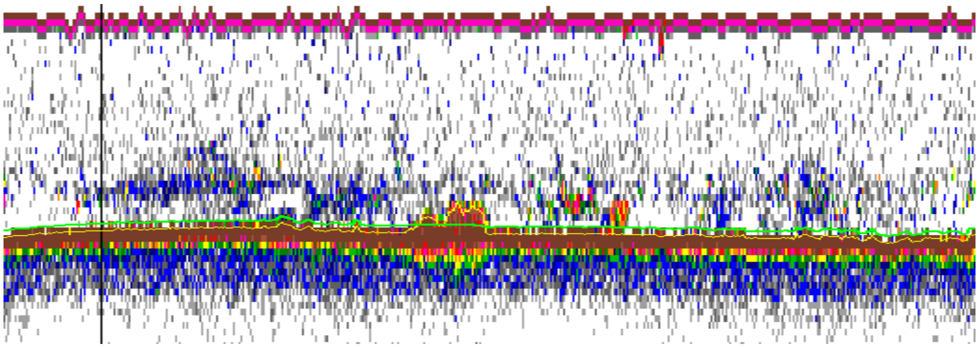
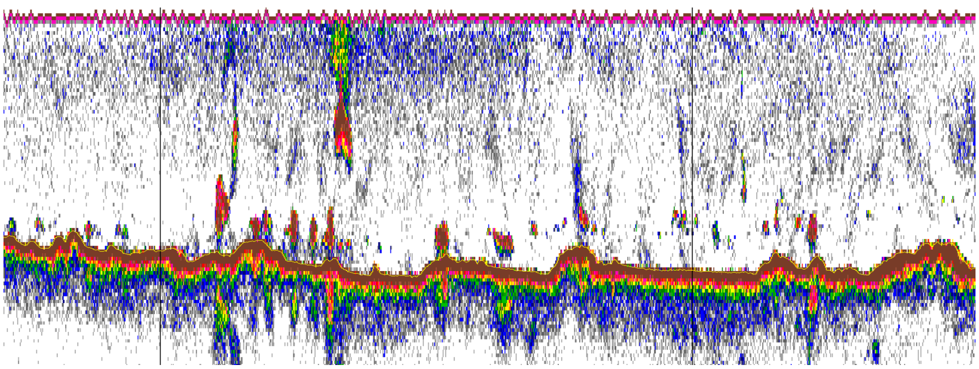


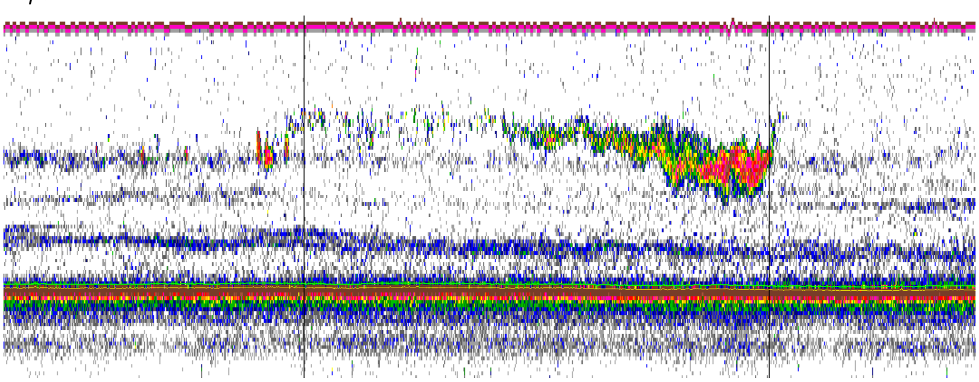
Figure 6. Percentage age and maturity of actual herring samples used in the analysis (n=546). Celtic Sea herring acoustic survey, October 2011.



a). *Small high density herring schools observed in Dingle Bay during the night, water depth 42m.*

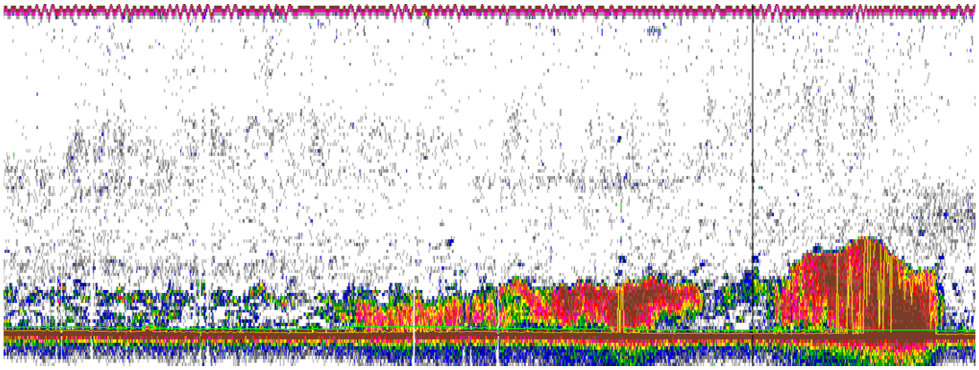


b). *High density daytime sprat schools located south of Mizen Head, prior to Haul 22. Water depth 79m.*

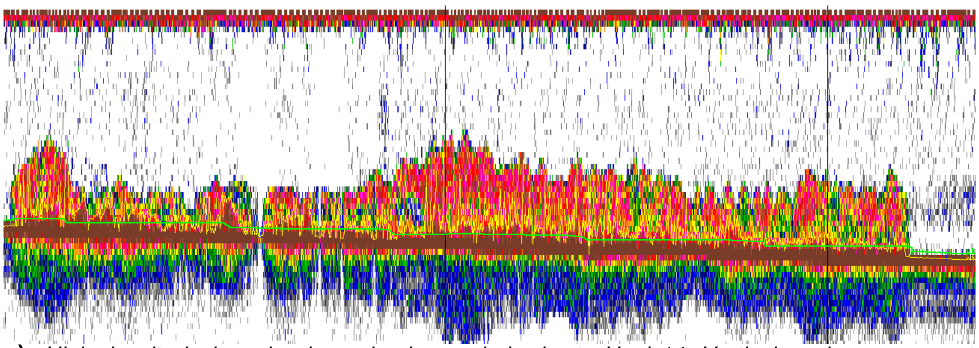


c). *High density pelagic anchovy school recorded prior to Haul 07 during the night. This school represents the highest density anchovy school observed during the survey. Water depth 70m*

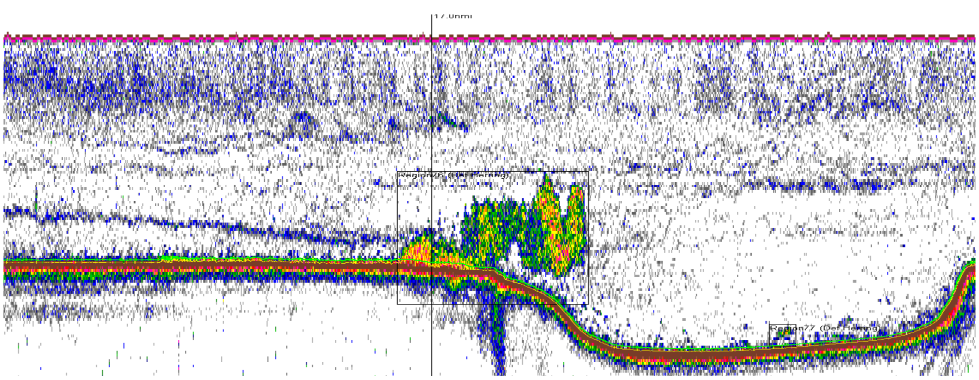
Figure 7a-f. Echograms recorded during the survey (EK60, 38 kHz). Celtic Sea herring acoustic survey, October 2011.



d). *High density offshore herring school recorded prior to Haul 10 within strata 20. Water depth 104m, school height ~20m*



e). *High density inshore herring school recorded prior to Haul 14. Vertical markers represent 1nmi. Water depth 45m, school height ~15m, represents single largest schools recorded during the survey.*



f). *High density offshore herring school recorded prior to Haul 10. The position of the school is on the edge of a gully that runs southwest-northeast for over 25nmi and is known locally as the 'Trench'. Water depth 104m, school height ~18m.*

Figure 7a-f. Continued.

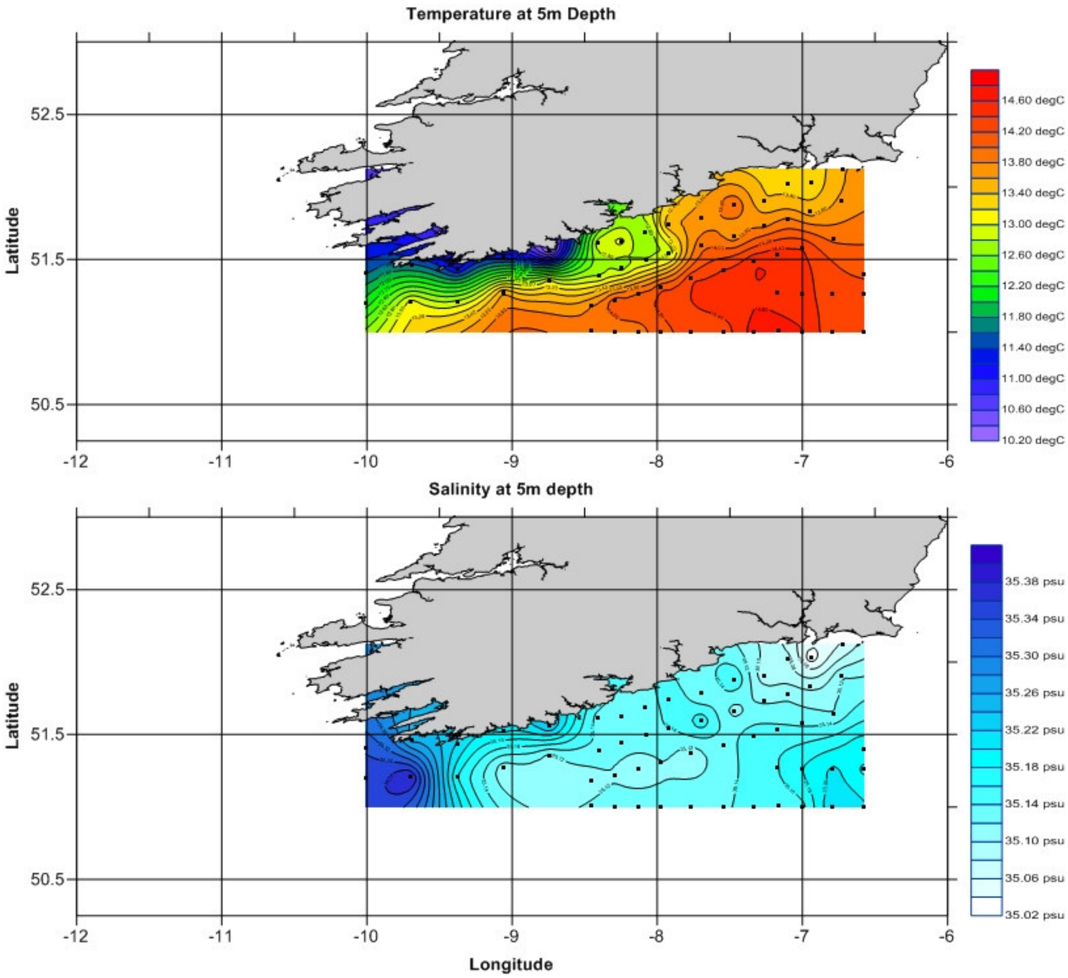


Figure 8. Surface plots of temperature (above) and salinity (below) at 5 m from combined CTD cast data. Celtic Sea herring acoustic survey, October 2011.

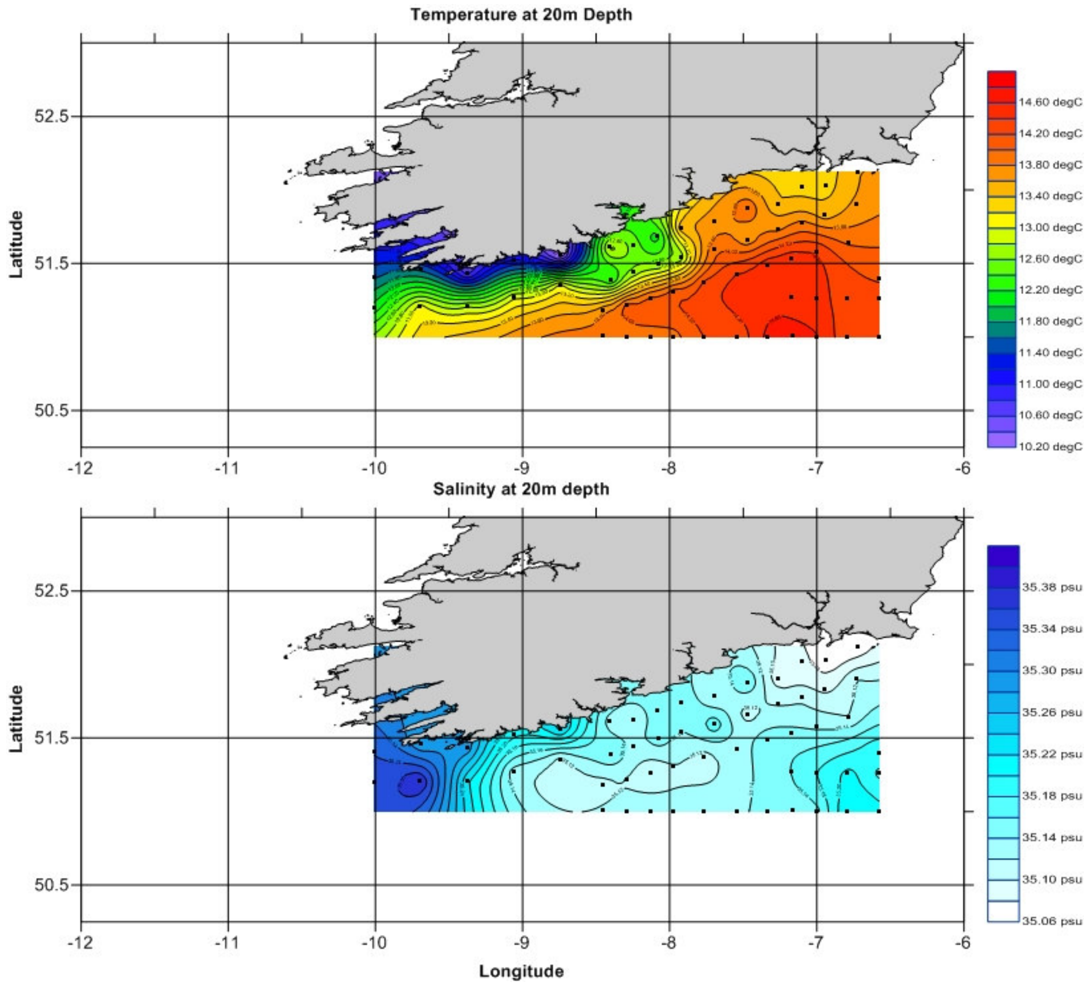


Figure 9. Surface plots of temperature (above) and salinity (below) at 20 m from combined CTD cast data. Celtic Sea herring acoustic survey, October 2011.

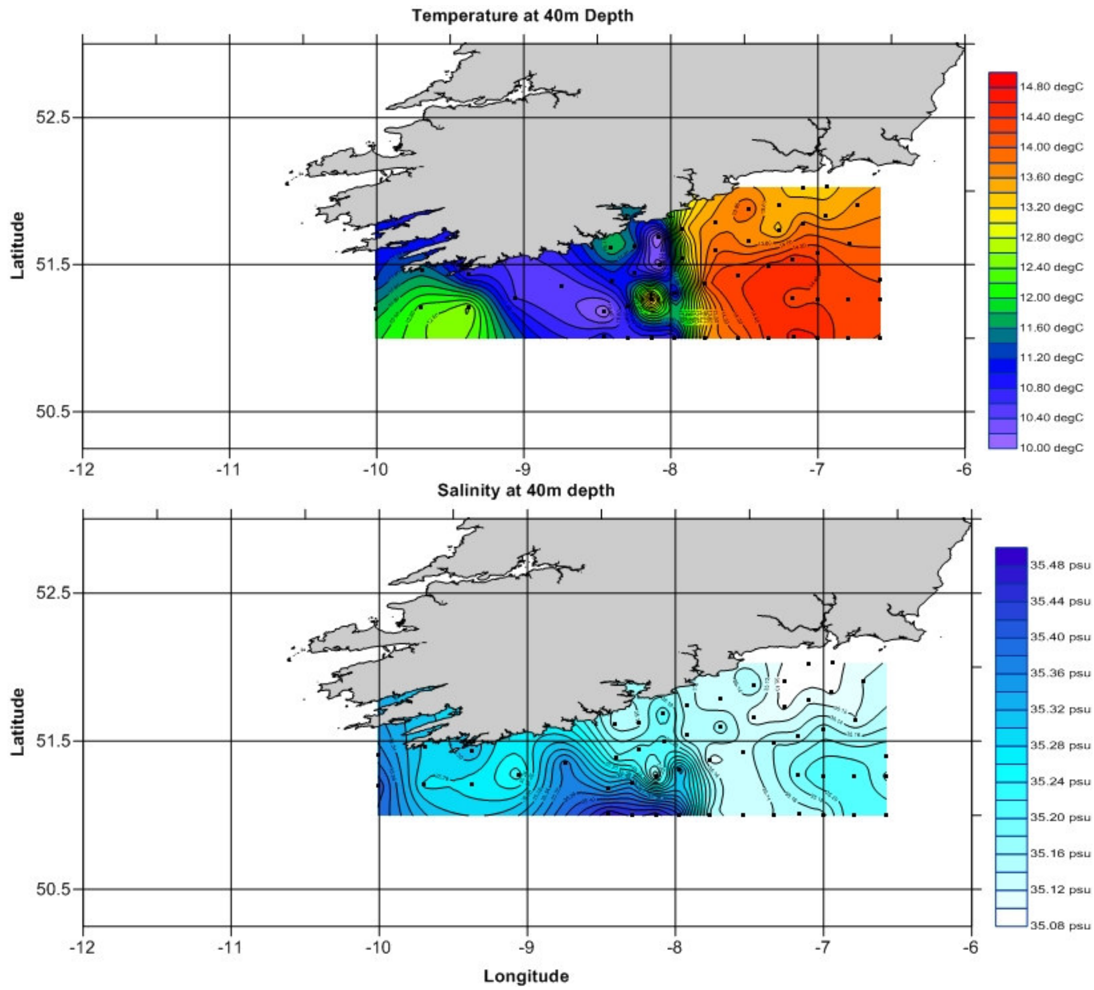


Figure 10. Surface plots of temperature (above) and salinity (below) at 40m from combined CTD cast data. Celtic Sea herring acoustic survey, October 2011.

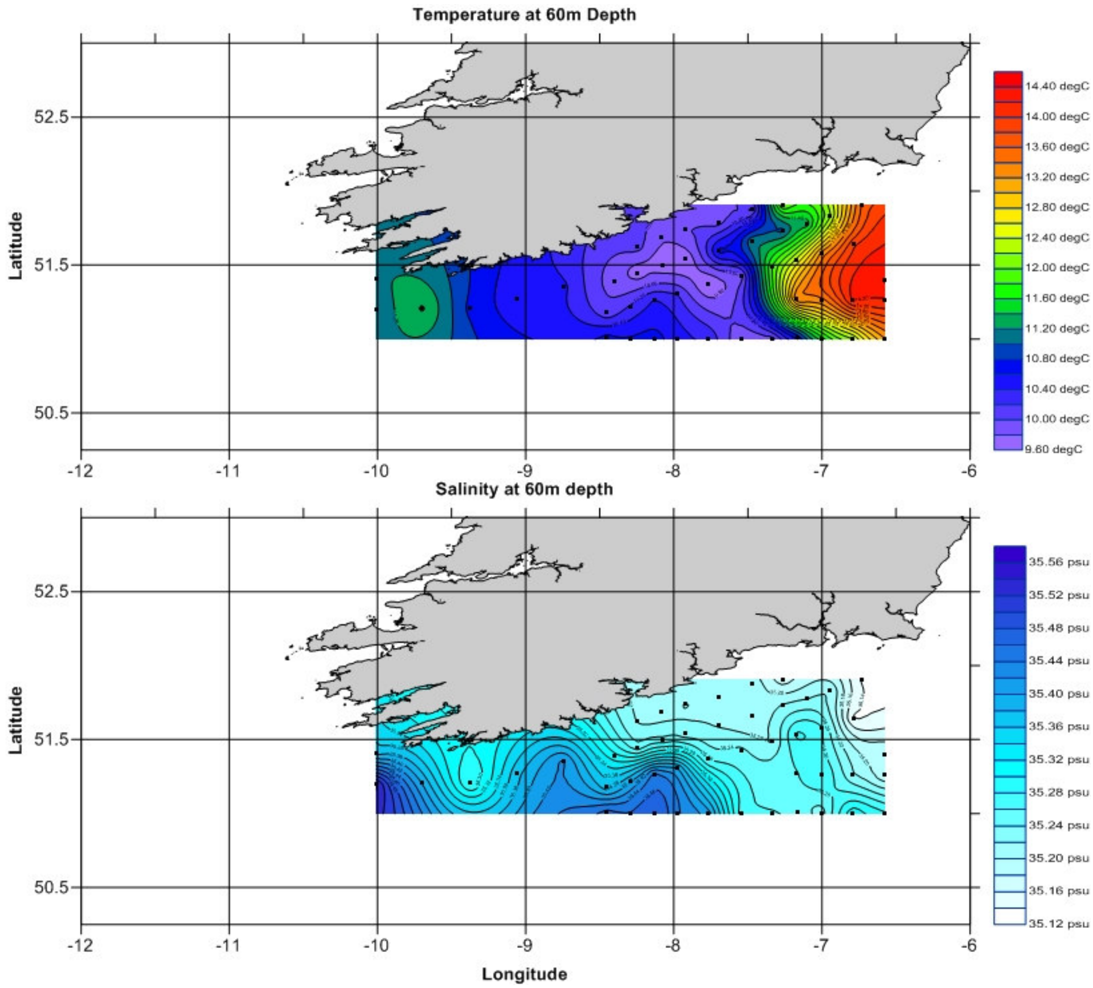


Figure 11. Surface plots of temperature (above) and salinity (below) at >60 m from combined CTD cast data. Celtic Sea herring acoustic survey, October 2011.

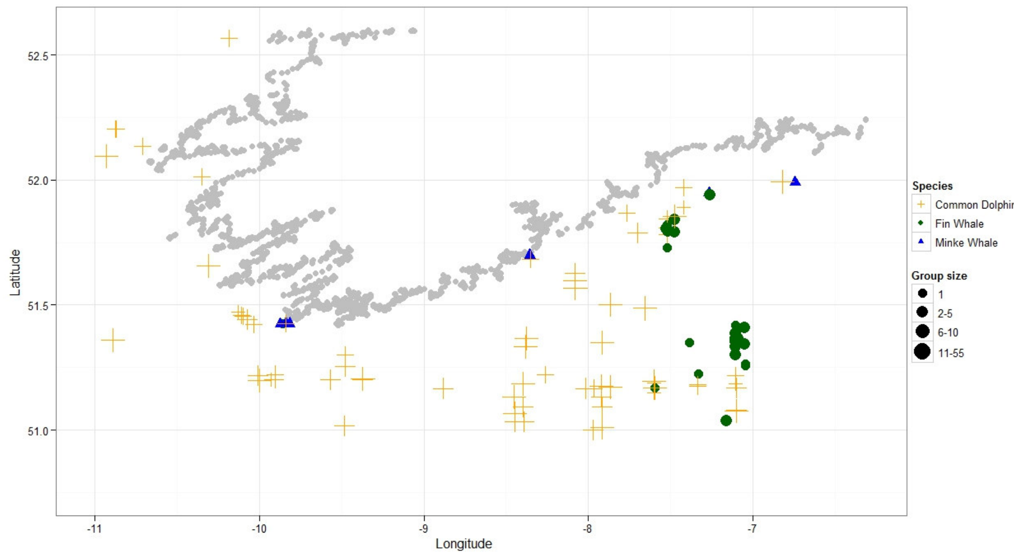


Figure 12. Distribution of cetacean sightings. Celtic Sea herring acoustic survey, October 2011.

HERRING MIDWATER TRAWL

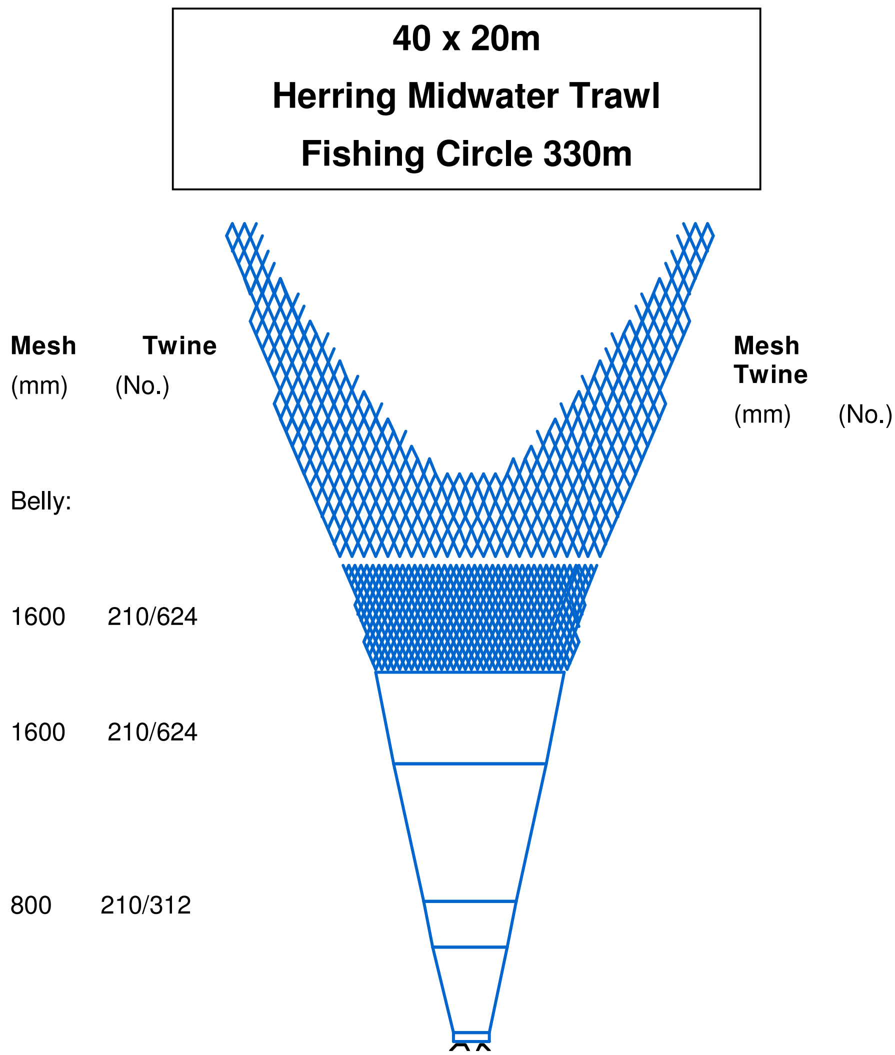


Figure 13. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey, October 2011.

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

Annex 1:

Presented here by request are the biomass and abundance tables for historic survey strata 1-19 as constitute the current survey time series.

Herring	**Millions**	**Biomass (t)**	**% contribution**
Total estimate			
Definitely	1,162	126,772	94.9
Mixture	0	0	0.0
Probably	66	6,792	5.1
Total estimate	1,228	133,564	100
Possibly	0	0	
Possible estimate			
SSB Estimate			
Definelty	905	107,231	95.3
Probably	0	0	0.0
Mixture	46	5,266	4.7
SSB estimate	951	112,497	100

Table 1. Herring biomass and abundance by survey strata (1-19). Celtic Sea herring acoustic survey, October 2011.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass ('000t)	SSB ('000t)	Abundance millions
1	14	0	0	0	0	100	0	0	0	0	0	0
2	4	0	0	0	0	100	0	0	0	0	0	0
3	7	0	0	0	0	100	0	0	0	0	0	0.0
4	2	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	2	2	0	0	93	7.7	0	0	7.7	7.3	63.9
9	32	2	2	0	0	97	0.2	0	0	0.2	0.2	1.4
10	34	119	84	0	35	62	84.4	0	5.8	90.2	71	883.0
11	9	0	0	0	0	100	0	0	0	0	0	0.0
12	17	5	4	0	1	88	2	0	0	2	1.3	21.4
13	4	0	0	0	0	100	0	0	0	0	0	0
14	16	57	57	0	0	25	28.9	0	0	28.9	28.4	221.7
15	14	26	11	0	15	64	2.7	0	1	3.7	3.5	30.2
16	5	0	0	0	0	100	0	0	0	0	0	0.0
17	5	0	0	0	0	100	0	0	0	0	0	0.0
18	6	6	6	0	0	83	0.9	0	0	0.9	0.9	6.8
19	0	0	0	0	0	0	0	0	0	0	0	0.0
Total	202	217	166	0	51	83	126.8	0	6.8	133.6	112.5	1228.3
Cv (%)	-	-	-	-	-	-	-	-	-	29.5	30.6	29.5

Table 2. Total biomass (000's tonnes) of herring at age (winter rings), by strata (1-19) as derived from acoustic estimate of abundance**.** Celtic Sea herring acoustic survey, October 2011.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0.6	2.8	2.3	0.4	0.8	0.3	0.5	0.1	0	0	7.7
9	0	0	0.1	0.1	0	0	0	0	0	0	0	0.2
10	0	24	35.9	20.4	2.9	4	1.2	1.5	0.2	0.1	0	90.2
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0.8	0.7	0.3	0	0.1	0	0	0	0	0	2
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0.8	7.7	11	2.1	3.6	1.4	1.9	0.3	0.1	0	28.9
15	0	0.3	1.3	1.1	0.2	0.4	0.1	0.2	0	0	0	3.7
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0.3	0.3	0.1	0	0	0.1	0	0	0	0.9
19	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	26.5	48.8	35.4	5.8	9	3.1	4.3	0.5	0.2	0	134
%	0	19.8	36.5	26.5	4.3	6.7	2.3	3.2	0.4	0.2	0	100

Table 3. Herring abundance (millions) at age (winter rings), by strata (1-19) as derived from acoustic estimate of abundance. Celtic Sea herring acoustic survey, October 2011

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0.0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	7.3	25.5	17.3	2.9	5.5	1.9	2.9	0.4	0.2	0	63.9
9	0	0.1	0.5	0.5	0.1	0.1	0	0.1	0	0	0	1.4
10	0.1	309.7	347.6	158.9	21.1	26.9	7.8	9.6	1.1	0.3	0	883
11	0	0	0	0	0	0	0	0	0	0	0	0.0
12	0	10.7	7.3	2.3	0.3	0.4	0.1	0.2	0	0	0	21.4
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	9.6	67.7	82.8	14.7	23.9	8.9	11.8	1.6	0.7	0	221.7
15	0	3.4	11.9	8.3	1.4	2.6	0.9	1.4	0.2	0.1	0	30.2
16	0	0	0	0	0	0	0	0	0	0	0	0.0
17	0	0	0	0	0	0	0	0	0	0	0	0.0
18	0	0	2.6	2.7	0.4	0.2	0.3	0.5	0.1	0	0	6.8
19	0	0	0	0	0	0	0	0	0	0	0	0.0
Total	0.1	340.9	463.1	272.8	40.9	59.6	19.9	26.4	3.3	1.2	0.0	1228.3
%	0.0	27.8	37.7	22.2	3.3	4.9	1.6	2.2	0.3	0.1	0.0	100
Cv (%)	88	32.9	32.4	31.6	29.7	30.7	30.7	29.7	31.8	31.6	NA	NA

Table 4. Herring biomass (000's tonnes) at maturity by strata (1-19). Totals do not account for the "possibly" herring classification. Celtic Sea herring acoustic survey, October 2011.

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	0.4	7.3	0	7.7
9	0	0.2	0	0.2
10	19.2	71	0	90.2
11	0	0	0	0
12	0.7	1.3	0	2
13	0	0	0	0
14	0.5	28.4	0	28.9
15	0.2	3.5	0	3.7
16	0	0	0	0
17	0	0	0	0
18	0	0.9	0	0.9
19	0	0	0	0
Total	21.1	112.5	0	133.6
%	15.8	84.2	0	100

Table 5. Herring abundance (millions) at maturity by strata (1-19). Totals do not account for the possibly herring classification. Celtic Sea herring acoustic survey, October 2011.

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	5.5	58.34	0	63.9
9	0.1	1.4	0	1.4
10	253.3	629.7	0	883.0
11	0	0	0	0
12	8.8	12.5	0	21.4
13	0	0	0	0
14	6.867	214.8	0	221.7
15	2.559	27.7	0	30.2
16	0	0	0	0
17	0	0	0	0
18	0.02	6.7	0	6.8
19	0	0	0	0
Total	277.1	951.1	0	1228
%	22.6	77.4	0	100

Table 6. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes) for strata 1-19. Celtic Sea herring acoustic survey, October 2011.

Length	Age (Rings)											Abund	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	10	(mils)	000's t	(g)
12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.5	0.1	-	-	-	-	-	-	-	-	-	-	0.1	-	44.5
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.5	-	3.71	-	-	-	-	-	-	-	-	-	3.7	0.2	59.5
19	-	22.3	-	-	-	-	-	-	-	-	-	22.3	1.4	63.7
19.5	-	57.5	-	-	-	-	-	-	-	-	-	57.5	3.9	68.0
20	-	47.1	5.88	-	-	-	-	-	-	-	-	52.9	3.8	72.6
20.5	-	79.6	21.7	-	-	-	-	-	-	-	-	101.2	7.8	77.3
21	-	63.4	9.06	-	-	-	-	-	-	-	-	72.5	6.0	82.2
21.5	-	36	36	-	-	-	-	-	-	-	-	71.9	6.3	87.2
22	-	21.7	43.4	-	-	-	-	-	-	-	-	65.0	6.0	92.5
22.5	-	4.32	60.4	8.65	-	-	-	-	-	-	-	73.4	7.2	97.9
23	-	5.41	57.1	2.74	-	-	-	-	-	-	-	65.2	6.8	103.6
23.5	-	-	69.3	6.52	-	-	-	-	-	-	-	75.9	8.3	109.4
24	-	-	75.6	18	-	-	-	-	-	-	-	93.6	10.8	115.4
24.5	-	-	46.9	50.6	-	-	-	-	-	-	-	97.6	11.9	121.7
25	-	-	25.6	56.4	6.84	-	-	-	-	-	-	88.9	11.4	128.1
25.5	-	-	12.2	64.8	12.2	5.3	1.73	-	-	-	-	96.3	13.0	134.7
26	-	-	-	44.6	9.76	2.76	2.76	1.41	-	-	-	61.3	8.7	141.6
26.5	-	-	-	17.3	3.99	25.3	1.31	2.68	-	-	-	50.5	7.5	148.6
27	-	-	-	2.42	6.04	20.6	6.04	8.46	1.21	-	-	44.7	7.0	155.9
27.5	-	-	-	0.73	0.73	5.14	4.41	6.61	1.47	0.73	-	19.8	3.2	163.3
28	-	-	-	-	1.27	0.63	3.16	3.16	0.63	-	-	8.8	1.5	171.0
28.5	-	-	-	-	-	-	0.51	3.54	-	0.51	-	4.6	0.8	178.9
29	-	-	-	-	-	-	-	0.57	-	-	-	0.6	0.1	187.0
29.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SSN (mil)	0.1	110	418	272	40.9	59.6	19.9	26.4	3.3	1.2	-	951.1	-	-
SSB ('000s t)	0.0	9.3	44.9	35.4	5.8	9.0	3.1	4.3	0.5	0.2	-	-	112.5	-
Mn Wt (g)	44.5	77.6	105	130	141	151	156	162	162	170	-	-	-	-
Mn length (cm)	16.8	20.8	23.3	25.4	26.2	26.9	27.3	27.6	27.7	28.2	-	-	-	-