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Northwest Herring Acoustic Survey Cruise Report and Abundance Estimate, 2007

by

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Abstract

The northwest and west coast herring acoustic survey programme was first implemented in 1994, with the current winter spawning survey representing the 9^{th} in the time series. The stock in this area is composed of 2 of spawning components (autumn and winter), covering a large geographical area. Spawning occurs over a protracted period of over 4-months from late September through to late March.

The age profile of the survey stock as generated from trawl samples indicated ages ranging from 1-7 years. Maturity samples indicate the largest proportion of the stock to be in a pre-spawning, spawning or spent state, with small amounts of immature fish, as would be expected at this time. The 2007 survey estimate generated a TSB (total stock biomass) of 14,200 t relating to a SSB (spawning stock biomass) of 13,974 t.

Poor weather dominated the survey with almost 25% lost in downtime. As a result the survey area and track lines had to be reduced to compensate and hydrographic stations had to be sacrificed. The poor weather experienced no doubt had an impact on herring schooling behaviour and our detection ability.

1 Introduction

The northwest and west coast (ICES Divisions VIaS & VIIb) herring acoustic survey programme was first established in 1994, with the current winter survey series beginning in 1999. A larval survey programme was carried out between 1981 and 1986. In the early 1990s, the ICES herring working group (HAWG) identified the need for a dedicated herring acoustic survey in this area (Anon, 1994). From 1994 to 1996 surveys were carried out on this stock during the summer feeding. In 1997 a two-survey spawning aggregation program was established covering both autumn and winter stock components. Acoustic surveys were originally carried out on chartered commercial vessels using a portable towed body system. Since 2004 the RV *Celtic Explorer* has been employed as the primary research platform.

The herring stock within the area is composed of 2 of spawning components (Autumn and Winter spawners), covering a large geographical area and having a protracted spawning season, which extends over a 4-month period from late September through to late March (Molloy *et al*, 2000). Traditionally fishing effort has been concentrated on spawning and pre-spawning aggregations. In VIaS, fishing begins in late November and continues until late March (Winter spawners). Further south in VIIb, peak fishing takes place from October to December (Autumn spawners). The protracted spawning period of herring and the overlap between the two spawning stocks in this area (October to February) is highly dynamic with variations between annual spawning events of up to 3 weeks.

Up to 40 vessels commonly participate in the fishery, many of which are based in the Co. Donegal port of Killybegs. The fleet is made up of 20 RSW (Refrigerated Seawater) vessels of 40-70m in length; 20 polyvalent trawlers 10 of which are vessels of 22-40m and 10 of less then 25m.

In 2006 the TAC (total allowable catch) for this area was set at 15,400 t. In 2007 the TAC was adjusted to 13,090 t, a 15% reduction from 2006.

Acoustic surveys are currently the only tuning indices available to the HAWG for stock assessment purposes[a1]. The design and execution of this survey during the current time series has evolved from variable timing in quarter one, to a fixed date occurring within the first three weeks of January. Survey coverage has also been standardised based on the results of previous surveys.

2 Materials and Methods

2.1 Scientific Personnel

Name	Organisation	Role
Ciaran O'Donnell	MI-FSS	Scientist in Charge
Afra Egan	MI-FSS	Acoustics
Deirdre Lynch	MI-FSS	Acoustics (leg 2)
Graham Johnston	MI-FSS	Acoustics (leg 1)
Turloch Smith	MI-FSS	Acoustics
John Boyd	MI-FSS	Biologist (Deck Sci)
Mairead O'Sullivan	MI-FSS	Biologist
Deirdre Hoare	MI-FSS	Biologist
Dermot Fee	MI-FSS	Biologist
Lonneke Goddjin	NUIG	Oceanography
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 VIaS and VIIb)
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of survey stock
- Collect physical oceanography data as horizontal and vertical profiles from a deployed sensor array.
- Sighting survey of marine mammals and seabirds encountered during the survey

2.2.2 Area of operation

The winter 2007 survey covered the area to the east of Malin Head (Figure 1) in Co. Donegal (ICES Division VIaS) and extended west and south along the north western seaboard covering the main bays and inlets into VIIb. The survey started in the south and worked in a northerly direction to facilitate the timing 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 surveys (O'Donnell *et al.,* 2004; 2005, 2006). The broad scale survey was composed of 6 strata and formed an integral component of the overall survey. Broad scale outer lying areas are an important transit area for inward and outward migrating herring from inshore spawning areas. The second component of the survey focused exclusively on known spawning areas (4 strata).

Strata 1, 2 and 3 covered the north Mayo coastline and east Donegal Bay (Figure 1 and Table 1). This area contains the early Autumn spawning component of the survey. Spawning can begin in October and can extend as late as mid January. Stratum 3 (Killala Bay) is an important nursery area for herring spawned outside the Bay entrance in strata 2.

Strata 4 and 5 incorporated the northern side of Donegal Bay and extended along the western fringes of Co. Donegal. Stratum 4 is an important transient area for both inward and outward migrating herring from both strata 2 and 5. Strata 5 is characterised as containing a mixture of early and mid spawning stock components and is an important spawning ground for this stock.

The north coast, containing Strata 6 to 9 as a whole may contain spawning fish from November (strata 6 & 7) through to as late as the end of February (strata 8 & 9). Strata 10 (Lough Swilly) is an important nursery area for juvenile herring.

2.2.3 Survey design

A parallel transect design was adopted with transects running perpendicular to the coastline and lines of bathymetry, where possible. Offshore extension reached up to 33 nmi (nautical miles). Transects resolution was set at 2 nmi throughout the broad scale survey and increased[a2] to 1nmi for the spawning ground surveys. Bay areas were surveyed using a zig-zag transect approach to maximise geographical coverage within confined areas.

In total the combined survey accounted for 2,883 nmi, with 2,501 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.

The acoustic data were collected using the Simrad ER60 scientific echosounder. The Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3m below the vessels hull or 8.8m below the sea surface. Three 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. However, during this survey due to an electro-mechanical fault it was impossible to maintain “silent cruising” and so normal engine operation was used throughout the survey.

2.3.2 Calibration of acoustic equipment

No system calibration was carried out during this survey due to weather induced time restrictions. The ER60 was last calibrated in Irish coastal waters some 11 weeks prior to the survey start (O’Donnell *et al,* 2006b). The beam models for all operating frequencies had not been adjusted since this time. The system is due to be calibrated again in March 2006. Should any discrepancies arise the data will be corrected as necessary.

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 3.2) 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 3.2) post processing software. Partitioning of data into the above categories 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 which had been carried out on similar echo-traces in similar water depths.

4. “Possibly herring” were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

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

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = 20logL – 67.5 dB per individual (L = length in cm)

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 13). Mesh size in the wings was 3.3 m through to 2 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 15 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 onboard and its manoeuvrability in relation to the vessel power allowed samples at or below 2m 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 strata with CTD cast undertaken on selected transects in each strata. Hydrographic stations were equally spread at 6nmi spacing on each transect where possible (Figure 6).

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. Ships 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 & wind direction. For each sighting the following data were recorded: time; location; species; distance; bearing; 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. 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) = $0.0137^{*} L^{2.785}$ (L = length in cm)

Mackerel weight (grams)= $0.002^{*} L^{3.377}$ (L = length in cm)

Sprat weight (grams) = $0.004^{*} L^{3.180}$ (L = length in cm)

2.5.2 Abundance estimate

Total abundance, N_T, is given by $\sum_{m}^{Mark-types} N_{T,m}$, the sum over the total abundance by mark-types.

$$N_{T,m} = \sum_{s}^{strata} N_{m,s}$$

Suppressing the mark-type index, m, the stratum abundance is

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

,where *l* is the transect length and $\bar{n}$ is the transect mean abundance n.mi^{-2} which is given by

$$\sum_{j}^{track\cdot fragments} n_{s,t,j} d_{s,t,j} \Big/ l_{s,t}$$

, where d is the distance of the track fragment and $n_{s,t,j}$ is the mean abundance n.mi^{-2} for the jth track fragment.

Because hauls are assigned with there own stratification that will not necessarily coincide with the acoustic strata, the conversion of NASC into mean density is done at the track fragment level, usually a 1 n.mi segment, but these could be just for the schools themselves. The haul assigned, $h_{m,s,t,j}$, depends strongly on the mark-type (m) and since more than one school can be in a track fragment it needs to be specified. Since age and maturity length-keys are to be applied, the basic estimation is mean density by length bins. The $n_{s,t,j}$ is found by summing over the $n_{s,t,j}$.

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

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

, 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 Northwest herring stock

3.1.1 Herring biomass and abundance

The overall estimate of abundance was generated from a total of 222 positively identified schools. Of which, over 54% (121 schools) were represented by the 'probably' herring category, 44% (98 schools) to the 'definitely' herring category and less than 2% (3 schools) to the herring 'mixture' category. The majority of schools encountered were relatively small in size. Many of these schools did not contribute significantly to the overall estimate. Of the total number of schools encountered, 81% (181) contributed to only 29% of the TSB.

The TSB (total stock biomass) estimate was composed of over 74% of the 'definitely' herring category. A large proportion of schools were identified as 'probably' herring but contributed less than 25% to the overall TSB. Those schools not positively identified by trawling or not in close proximity to a trawl station were classified as such following the established scrutinisation protocol. Gear evasion by herring schools, a phenomenon encountered during the 2005 survey, was again evident during this survey and thus affected overall catchability.

Of the 10 strata surveyed (4 spawning boxes and 6 back ground areas), 4 strata produced no herring at all (Table 11). In total spawning areas contributed over 68% to the TSB by weight and over 67% by weight to the SSB (spawning stock biomass). Less than 2% of the TSB was made up of juvenile herring.

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

Herring	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	78.0	10575	74.4
Mixture	1.0	157	1.1
Probably	26.0	3490	24.5
Total estimate	105	14222	100
Possibly	1.0	178	
Possible estimate	106	14400	
SSB Estimate			
Definelty	76.0	10373	74.2
Probably	26.0	3444	24.6
Mixture	1.0	157	1.1
SSB estimate	103	13974	100

The stock abundance and biomass estimate is 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 19 trawl hauls were carried out over the course of the survey (Figure 2 & Table 3). Of this, 10 contained herring and 9 contained over 50% of herring by weight of bulk catch.

Overall, poor weather dominated the survey and significant alterations had to be made to the original cruise track to make the most of weather induced downtime. As a result strata were not surveyed in continuity as originally planned. Poor weather and heavy swells are known to have an adverse affect on schooling behaviour of herring causing schools to disperse thus making detection by acoustic techniques increasingly difficult.

The north Mayo coastline (Strata 1-2) was found to contain little herring biomass overall. Herring were encountered in numbers within Killala Bay (strata 3) and contributed 10.7% to the overall SSB (Figure 3,Tables 1 & 11). Individuals were found to be recovering spents (Stage 8 on an 8 point maturity scale) indicating spawning had taken place sometime ago. This is consistent with the Autumnal peak spawning events within this area. However, a small number of individuals were still in a pre-spawning state. Poor weather conditions may have contributed to the overall lack of identifiable herring biomass encountered in the outer broad scale survey (strata 1). An area that is normally associated with outwardly migrating spent fish. Of the 4 shots carried out in stratum 1-3, only 2 yielded small amounts of herring (Table 3).

Northwest Co. Donegal (strata 4 and 5) was covered using both a broad scale survey (strata 4) and a spawning box survey (strata 5). The former produced little in the way of herring biomass and only 1 haul was carried out on a low-density mark that yielded herring (Table 3 & Figure 3). Strata 5 (spawning area) contributed the largest amount of herring biomass encountered during the survey (over 39% of the TSB and over 39% of the SSB) to the overall estimate (Figure 3, Tables 3, 6, 7 & 11). This area was also one of the main areas of commercial activity during the survey. Herring within this area were composed of spent individuals (stages 7 & 8) and a smaller number of actively spawning individuals (stage 6), (Tables 8 & 9). Overall, herring schools encountered in the area were very difficult to catch with schools breaking up and ‘going to ground’ making targeting with midwater pelagic gear near impossible over rough ground. The commercial fleet working the same grounds reported the same gear evasion response. This had a marked effect on the positive identification of schools encountered on track and thus increased the proportion of ‘probably’ herring in the estimate.

The north Donegal coast (strata 6, 7 & 9) were also areas of high commercial activity. In the Tory Island spawning box (strata 7) no herring were detected in the 155nmi of transects carried out. It should be noted that commercial catches of herring were taken from this area some 7 days prior to our arrival in this strata. Our arrival in strata 7 coincided with the end of a period of very poor weather conditions. While surveying this strata a storm front passed and the vessel had to break to take shelter. No doubt the poor weather contributed greatly to the lack of herring biomass encountered in this usually productive area. Within strata 6, only 14 schools were identified from this area contributing just over 13% to the TSB and almost 13% to the SSB (Figure 3, Table 3 & 11).

Strata 9 contained the highest concentration of schools encountered during the survey, representing over 81% of the total herring schools. Herring were distributed as very loose and numerous schools carpeted over a large proportion of the spawning box. Such loose aggregations were on occasion observed to aggregate into larger masses after dark (Figure 6). Strata 8 contributed 7% to the total TSB and was contained in one school, the bulk of herring biomass was found further offshore in the spawning area of strata 9.

Strata 10 (Lough Swilly), an area normally associated with catches of juvenile herring and sprat, yielded no herring biomass during the survey.

3.1.3 Herring stock composition

In total 345 herring were aged, 2145 length measurements and 500 length weights were taken (Table 4 & 5).

Survey timing, as revealed from biological samples and distribution patterns indicate peak spawning to be earlier than at the same time in previous years (O'Donnell *et al*, 2004; 2005; 2006). However, it should be noted that weather conditions would have had a marked impact on fish behaviour within the survey confines. The lack of herring encountered along the north Mayo coastline indicates that spawning and outward migration had already taken place in this area. Commercial samples and information from skippers revealed that spawning occurred earlier than at the same time period in 2006. Further north the Limeburner area (strata 9), an area associated with the later Winter-spawners, produced a significant amount of both spent and pre-spawning fish indicating that spawning was ongoing in the area.

Herring samples from trawls indicated ages ranging from 1-7 winter rings (Figure 4, Tables 8 & 9). The dominant year classes, as determined from survey data, were 3 and 4-year old fish respectively. Three-year-old fish represented 51.8% by weight and 56.7% by numbers of the TSB. The 4-year old fish ranked the next most abundant with 22.5% by weight and 20.8% by numbers of the TSB. The 5 and 6-year old fish made up 13.2% and 7.7% by weight and 11% and 6% of the TSB estimate by numbers (Tables 6 & 7). Strata 5 contained not only the greatest herring biomass (by weight and numbers) encountered but also the broadest range of year classes (2-7).

Herring maturity, as determined from trawl samples, showed a significant proportion of the stock to be in a spawning state (Figure 4, Tables 8 & 9). Spawning state was dominated by individuals recovering from spawning or in pre-spawning states, with the latter accounting for the highest number. Less than 2% of the TSB was made up of juvenile herring and less than 3% of the TSN (total stock numbers). Juvenile herring are commonly found with sprat during this survey, the lack of juvenile herring may therefore be related to the lack of sprat encountered and is most probably related to both ambient weather conditions and timing.

3.2 Oceanography

3.2.1 Physical oceanography

A total of 20 hydrographic stations were carried out during the survey (Figure 6). At each station a vertical profile of temperature and salinity was obtained. Not all planned stations were carried out because of rough weather conditions and resultant time constraints. The weather conditions during the survey were thought to have contributed to the vertical mixing of the water layers, which was most evident north easterly, and least sheltered, stations (Figures 9 & 10). Surface data were interpolated, resulting in horizontal profiles of temperature and salinity (Figure 6). Surface temperatures ranged from 9.4 to 10.4 ^{o}C, while surface salinity values ranged from 20 to 35ppt (parts per thousand). Temperature and salinity generally increased with increasing depth. The influence of freshwater could be seen as cooler, fresher water intruding into the North Atlantic from coastal inputs. The depth of the thermocline of the intrusion was about 40 m, while the depth of the surface layer of fresher water was less pronounced at 2 to 10 m (Figures 7-10).

In Figure 6, freshwater influence from the river Moy can be seen around 9.13^{o}W, the plume was approximately 2m deep and extended to 54.5^{o}N (Figure 7). Further north along this longitude to Glenhead (54.7^{o}N), a cool freshwater wedge was visible (Figure 9). This was thought to be intrusion of Gweebarra river water. A surface layer of about 20 m deep of cooler water, associated with this fresh water, extended to 54.5^{o}N and 9.6 ^{o}W (Figures 8-10). In the section including 8.7-8.8^{o}W, a warm and saline water cell located on the bottom could be recognized, enclosed by the two cooler fresher water bodies (Figure 9). On top of this cell, at 54.4 ^{o}N, an input of fresher water was seen at around 20 m depth. At the most easterly section at 7.8 ^{o}W, the cool fresh water effluent from Mulroy Bay was measured, extending to about 55.5 ^{o}N (Figure 10).

3.2.2 Biological oceanography

Vertical NASC values were superimposed onto the temperature plots to examine whether there were any spatial links between the distribution of the different fish species and their environment. Most established herring spawning grounds are situated in the inshore bays, which are characterised by lower temperatures and salinities due to freshwater dilution.

Along transects at 9.13^{o}W and 7.8 ^{o}W acoustic data was overlaid with CTD data (Figures 8 & 10 respectively). For 9.13^{o}W this amounted to a small amount of sprat biomass (Figure 8); for 7.8 ^{o}W a higher density of herring biomass was encountered (Figure 10). The distribution of fish biomass didn't appear to be correlated with temperature or salinity levels. Herring were mainly encountered within 10 m of the bottom, where temperature was ranged from 9.6 to 10 ^{o}C and salinity from 35.1 to 34.7ppt.

With the amount of biological data available it is impossible to identify any spatial trends associated with ambient hydrographic conditions within the localised area studied.

3.3 Marine mammal and seabird observations

Environmental data was collected at 231 stations during the survey. Overall, sighting-survey conditions were very difficult as a series of gales and storm force winds struck the survey area over the entire survey period. Maximum daily wind speeds exceeded 50knots on 12 of the 18 days of the survey (66.7%). Sea state was ≤ 3 at only 21.2% of environmental stations (46.3% sea state 4-6; 32.5% sea state 6-8). Six full days and two half days were lost for cetacean observations due to bad weather (where it was unsafe to ascend to the crow's nest), days spent sheltering within bays and harbours or port calls. Visibility was good (>5km) at 74.5% of stations, moderate (1–5km) at

23.4% of stations and poor (<1km) at 2.1% of stations -discounting periods during which survey was suspended due to dense fog or heavy rain (visibility <500m). A heavy swell (2m+) persisted throughout most of the survey period and was recorded at 74% of stations. Rainfall was recorded at 29.9% of stations and fog/mist was recorded at 0.9% of stations.

3.3.1 Marine mammal sightings

Overall, 48 hours of survey time were logged with 20.1% (9.6hrs) of this at ≤ Beaufort sea state three. No cetaceans were sighted during the survey. A single grey seal was sighted c15 miles north of Fanad Head, Co. Donegal (Figure11). This was the only marine mammal sighted during the survey.

The lack of cetacean sightings during the survey is notable but not unexpected. During a summer survey in the same area in 2004, a very low relative abundance of cetaceans was recorded (Wall *et al.*, 2006) and a low relative abundance was also recorded in a cetacean survey conducted during the 2004 northwest Herring Acoustic Survey (IWDG 2004b). Although the weather conditions were undoubtedly a factor in the zero sightings rate, common dolphins generally approach the vessel and would have been sighted despite the sea state, as would the blow of any large whales. During the 2004 NW Herring Acoustic Survey only 3 sightings of cetaceans were made and these were all of groups of common dolphin that approached the ship.

The reasons for the low incidence of cetaceans off the northwest coast, as compared to the same period off the south coast are not yet understood. Small schooling pelagics, namely herring spawn on both north and south coasts at this time. A possible factor may be that the northwest of Ireland offers marginal habitat to species such as common dolphin which prefer warmer waters to the south and species such as white beaked and Atlantic white sided dolphin which prefer colder waters to the north. However this does not explain the absence of fin and humpback whales that are relatively common off the south coast and in waters further north.

Further research is required into this area, with a review of the historical data for both cetaceans and their food sources as well as an examination of oceanographic factors which might also explain the low relative abundance of cetaceans off the northwest coast.

3.3.2 Seabird sightings

Seabird species and occurrence was recorded during the same observation period and with the same effort as for marine mammals.

In total, 12 bird species were encountered during the survey (Figure 12). Six of these were seen on a regular basis: Kittiwake (*Rissa tridactyla*), herring gull (*Larus argentatus*), lesser black-backed gull (*Larus fuscus*), great black-backed gull (*Larus marinus*), fulmar (*Fulmarus glacialis*) and gannet (*Morus bassanus*).

Auk species were seen on 70% of days with guillemot (*Uria aalge*) being identified on 20% of days and razorbill (*Alca torda*) identified on 50% of days. A glaucous gull (*Larus hyperboreus*) was seen on two days and may have been the same individual. Cormorant (*Phalacrocorax carbo*) and shag (*Phalacrocorax aristotelis*) were noted in Donegal Bay as was a pair of eider duck (*Somateria mollissima*).

4 Discussion and Conclusions

Overall, poor weather dominated the survey and significant alterations had to be made to the original cruise track to make the most of weather induced downtime. As a result strata were not surveyed in continuity as planned. Poor weather and heavy swells are known to have an affect on schooling behaviour causing schools to break up and disperse. In areas of greatest abundance, once the weather cleared it may take several days for fish to reappear in numbers on the grounds In previous years the Irish mackerel fishery is normally drawing to a close towards the end of January with the full TAC taken in quarter one. However, this year the pelagic licenses had not been issued before the survey end and as a result some fishing effort was displaced to the herring fishery. Restrictions are in place to limit larger vessels to within 12nmi of the coast line to areas such as the northern areas of strata 6 and 8.

4.1 Discussion

Overall the aims of the survey were carried out to a lesser extent than originally planned. Survey coverage had to be significantly reduced to account for almost 5 days of weather-induced downtime. The cruise track was not run in continuity and strata were broken during periods of poor weather where the vessel had to seek shelter.

Hydrographic coverage was sacrificed to an extent to ensure adequate coverage of core areas. In certain instances stations were cancelled on site as weather conditions prevented the safe deployment of gear. Marine mammal observations were also hampered by poor sea state, making sightings near impossible on many days.

Poor weather not only affected our ability to carry out the survey but also had an impact on the behaviour of herring schools. Poor weather conditions are known to dissipate schools and drive fish close to the bottom. Prolonged periods of poor weather, as experienced here, had a significant impact on fish behaviour and as a result the detection of "grounded" fish becomes difficult using acoustic methods.

Catchability and gear evasion by herring schools was also an important point. Poor weather has a noted affect on catchability reflected through school size. Fishing induced changes in schooling behaviour should not be ruled out in this fishery. Behavioural changes due to prolonged fishing pressure have been noted in other heavily fished stocks, namely horse mackerel stocks targeted by the Dutch industrial fleet in the Bay of Biscay (Jacques Masse, *pers comm*.)

Peak spawning appears to be slightly earlier when compared with previous years results. This was indicated by the absence of fish along the north Mayo coastline and the occurrence of fish in the Limeburner area. The latter being associated with the later winter spawning areas and the former being the early Autumnal spawners.

4.2 Conclusions

The relative abundance of herring biomass recorded during the survey was no doubt affected by the poor weather conditions and this should be taken into consideration when comparing estimates across years.

An important time series has been established for this stock in recent years and it is vital to the accurate assessment process for this particular stock that this annual acoustic survey be continued. The current acoustic survey time series represents the only fishery independent tuning indices available to ICES for stock assessment purposes.

The health of this stock is of utmost importance to the northwest pelagic and polyvalent fleets, both now and historically. Thus a continued dedicated acoustic spawning survey is required to assess stock health and dynamics, which will no doubt be lost in a survey covering a larger geographical area during a different time period.

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5 Appendices

5.1 Tables and Figures

Table 1. Survey Strata details. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Strata	Name	Type	# Transects	Survey	Spacing	Strata Area (nmi2)	Total transect length (nmi)
1	North Shore	Parallel	30	Broad scale	2	751.58	360.5
2	Downpatrick	Parallel	21	Spawning Box	1	142.66	117.6
3	Killala	Zigzag	6	Broad scale	na	11.17	7.2
4	Offshore Glen Hd	Parallel	19	Broad scale	2	454.02	373.4
5	Glen Head	Parallel	22	Spawning Box	1	379.02	395.0
6	Offshore Tory	Parallel	23	Broad scale	2	479.41	608.5
7	Tory	Parallel	17	Spawning Box	1	183.57	155.3
8	Inshore LB	Parallel	15	Broad scale	2	76.07	198.4
9	Limeburner	Parallel	13	Spawning Box	1	290.49	257.9
10	Swilly	Zigzag	11	Broad scale	na	12.89	26.9
		Total	**177**		**Total**	**2780.88**	**2501**

Table 2. Settings for the Simrad ER60 echosounder, employed during the Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Echo sounder:		Simrad ER 60
Frequency:		38 kHz
Transducer:		ES 38B- Serial
Coefficient:		0.067 dB/Km (manual)
Pulse length:		1.024 m/s
Bandwidth:		2.425 KHz
Power:		2000 W (Max)
Angle Sensitivity:		13.9 dB
angle:		-21.69°
Gain:		25.55
S_A Correction:		-0.65
3 dB Beam Width:	Alongship:	6.39°
	Athwartship:	6.67°
Max Range:		500m

Table 3. Catch table from directed trawl hauls. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Others* %
1	05.01.07	54 20.47	09 37.71	12:02	45	0	<1		44.0		66.0	
2	06.01.07	54 15.80	09 09.85	09:01	23	0	60	100.0				
3	07.01.07	54 29.72	08 41.83	09:49	69	10	<1				100.0	
4	07.01.07	54 32.79	08 24.29	15:41	39	10	<1					100.0
5	08.01.07	54 47.86	08 18.50	14:21	98	0	<1	55.0	43.0		2.0	
6	08.01.07	54 38.54	08 47.53	21:50	55	30	<1	97.0	3.0			
7	08.01.07	54 39.48	08 53.91	23:41	92	0	2,500	100.0				
8	09.01.07	54 42.77	09 03.78	06:03	68	20-50	750	100.0				
9	10.01.07	54 46.81	09 04.87	13:43	85	0-15	0					100.0
10	14.01.07	54 52.92	08 41.76	12:09	51	6.1	0					
11	15.01.07	55 10.90	08 13.60	22:55	31	0	2.8	14.3			9.9	77.0
12	16.01.07	55 32.60	07 54.34	09:54	75	0	6	100.0				
13	16.01.07	55 22.20	07 52.52	12:35	59	0-20	0					
14	16.01.07	55 34.51	07 50.65	16:40	74	10	87	99.7	0.2		0.1	
15	17.01.07	55 29.76	07 43.37	08:24	65	0-20	40	98.5			0.1	1.2
16	17.01.07	55 22.42	07 40.98	11:04	55	0-23	0					
17	17.01.07	55 17.24	07 57.74	20:29	52	11	1,500	100.0				
18	19.01.07	55 21.58	08 33.38	19:23	94	0-10	<5					100.0
19	21.01.07	55 22.01	08 09.98	16:58	56	0-10	0					

Table 4. Length frequency (%) of herring hauls used for calculating 'definitely' and 'probably' abundance. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Length (cm)	Haul 2	Haul 5,6,7	Haul 8	Haul 12	Haul 14	Haul 15	Haul 17	Totals
21.5	3		2		3			**8**
22	4	2	1		2		1	**10**
22.5	5	6	10	1	2		1	**25**
23	13	5	10		3		6	**37**
23.5	24	8	13	1	7	1	9	**63**
24	23	17	25	8	5	3	15	**96**
24.5	24	17	24	6	13	3	26	**113**
25	30	45	39	9	32	12	56	**223**
25.5	37	47	60	10	42	10	47	**253**
26	31	63	50	10	60	29	60	**303**
26.5	48	41	42	13	47	30	35	**256**
27	60	38	35	14	46	48	31	**272**
27.5	38	19	33	14	26	32	17	**179**
28	24	22	22	13	24	44	9	**158**
28.5	8	7	9	6	10	40	1	**81**
29	2	3	3	4	6	28	3	**49**
29.5		1	2		1	7		**11**
30		1			1	2		**4**
30.5						2		**2**
31				1				**1**
31.5								
32						1		**1**
Totals	**374**	**342**	**380**	**110**	**330**	**292**	**317**	**2145**

Table 5. Herring Age length key from combined trawl samples. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Age (rings) Length (cm)	0	1	2	3	4	5	6	7	8	9	Total
21.5			2								**2**
22			1								**1**
22.5		1	2								**3**
23				4							**4**
23.5			3	3							**6**
24			1	7							**8**
24.5				19							**19**
25			1	31							**32**
25.5				34	6						**40**
26				33	10		1				**44**
26.5				32	20	6					**58**
27				15	25	9	4				**53**
27.5				4	13	12	2	1			**32**
28					3	8	5	2			**18**
28.5					4	9	5	1			**19**
29.5							3	1			**4**
30											**0**
30.5						1					**1**
31								1			**1**
31.5											**0**
32											**0**
Total	**0**	**1**	**10**	**182**	**81**	**45**	**20**	**6**	**0**	**0**	**345**
%	**0.00**	**0.29**	**2.90**	**52.75**	**23.48**	**13.04**	**5.80**	**1.74**	**0.00**	**0.00**	**100**

Table 6. Total biomass (000's tonnes) of herring at age (winter rings), by strata as derived from acoustic estimate of abundance**.** Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Strata	0	1	2	3	4	5	6	7	8	9	Total
1	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	**-**
3	-	-	0.1	0.8	0.4	0.2	0.1	-	-	-	**1.6**
4	-	-	-	0.1	-	-	-	-	-	-	**0.2**
5	-	-	0.1	3.2	1.3	0.6	0.3	0.1	-	-	**5.6**
6	-	-	-	1.2	0.4	0.1	0.1	-	-	-	**1.9**
7	-	-	-	-	-	-	-	-	-	-	**-**
8	-	-	-	0.6	0.2	0.1	-	-	-	-	**1**
9	-	-	-	1.5	0.9	0.8	0.6	0.2	-	-	**4.1**
10	-	-	-	-	-	-	-	-	-	-	**-**
Total	-	-	**0.3**	**7.4**	**3.2**	**1.9**	**1.1**	**0.3**	-	-	**14.2**
%	-	**0.2**	**2.3**	**51.8**	**22.5**	**13.2**	**7.7**	**2.4**	-	-	**100**

Table 7. Herring abundance (millions) at age (winter rings), by strata as derived from acoustic estimate of abundance. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Strata	0	1	2	3	4	5	6	7	8	9	Total
1	-	-	-	-	-	-	-	-	-	-	**-**
2	-	-	-	-	-	-	-	-	-	-	**-**
3	-	0.054	0.842	6.48	2.532	1.413	0.575	0.154	-	-	**12.049**
4	-	-	-	0.606	0.335	0.133	0.03	0.009	-	-	**1.113**
5	-	0.189	1.473	26.19	8.87	3.994	1.603	0.415	-	-	**42.734**
6	-	0.015	0.446	9.989	2.557	0.902	0.447	0.107	-	-	**14.464**
7	-	-	-	-	-	-	-	-	-	-	**-**
8	-	0.008	0.229	5.133	1.312	0.462	0.229	0.055	-	-	**7.428**
9	-	0.033	0.507	11.43	6.319	4.756	3.469	1.12	-	-	**27.633**
10	-	-	-	-	-	-	-	-	-	-	**-**
Total	**-**	**0.299**	**3.497**	**59.83**	**21.93**	**11.66**	**6.354**	**1.859**	**-**	**-**	**105.42**
%	**-**	**0.284**	**3.317**	**56.75**	**20.8**	**11.06**	**6.027**	**1.763**	**-**	**-**	**100**
Cv (%)	**-**	**41.6**	**41.9**	**49.1**	**42.5**	**37.1**	**38.6**	**39.8**	**-**	**-**	**-**

Table 8. Herring biomass (000's tonnes) at maturity by strata. Totals do not account for the "possibly" herring classification. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Strata	Imm	Mature	Spent	Total
1	-	-	-	-
2	-	-	-	-
3	0.1	0.7	0.8	1.6
4	-	0.1	0.1	0.2
5	0.1	2.6	2.9	5.6
6	-	0.8	1	1.9
7	-	-	-	-
8	-	0.4	0.5	1
9	-	2.1	1.9	4.1
10	-	-	-	-
Total	**0.2**	**6.8**	**7.2**	**14.2**
%	**1.7**	**47.5**	**50.7**	**100**

Table 9. Herring abundance (millions) at maturity by strata. Totals do not account for the possibly herring classification. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Strata	Imm	Mature	Spent	Total
1	-	-	-	-
2	-	-	-	-
3	0.749	5.456	5.844	12.049
4	-	0.543	0.571	1.113
5	1.362	18.957	22.415	42.734
6	0.297	6.316	7.851	14.464
7	-	-	-	-
8	0.152	3.243	4.032	7.428
9	0.37	13.802	13.46	27.633
10	-	-	-	-
Total	2.93	48.318	54.173	105.42
%	2.78	45.833	51.387	100

Table 10. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

Length	Age (Rings)										Abundance	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	(millions)	000's t	(g)
21.5	-	-	0.3	-	-	-	-	-	-	-	0.25	0.02	70
22	-	-	0.4	-	-	-	-	-	-	-	0.36	0.03	75.6
22.5	-	0.3	0.6	-	-	-	-	-	-	-	0.9	0.07	81.5
23	-	-	-	2.4	-	-	-	-	-	-	2.41	0.21	87.7
23.5	-	-	1.2	1.2	-	-	-	-	-	-	2.45	0.23	94.2
24	-	-	0.7	5.1	-	-	-	-	-	-	5.81	0.59	101.1
24.5	-	-	-	5.8	-	-	-	-	-	-	5.8	0.63	108.3
25	-	-	0.3	10	-	-	-	-	-	-	10.76	1.25	115.8
25.5	-	-	-	9.7	1.7	-	-	-	-	-	11.37	1.41	123.8
26	-	-	-	13	3.9	-	0.4	-	-	-	17.1	2.26	132.1
26.5	-	-	-	7.6	4.8	1.4	-	-	-	-	13.79	1.94	140.8
27	-	-	-	3.6	6	2.2	1	-	-	-	12.63	1.89	149.8
27.5	-	-	-	1.2	3.9	3.6	0.6	0.3	-	-	9.66	1.54	159.3
28	-	-	-	-	1	2.7	1.7	0.7	-	-	6.13	1.04	169.2
28.5	-	-	-	-	0.7	1.5	0.8	0.2	-	-	3.18	0.57	179.6
29	-	-	-	-	-	-	1.5	0.5	-	-	2.06	0.39	190.3
29.5	-	-	-	-	-	-	0.3	0.1	-	-	0.44	0.09	201.5
30	-	-	-	-	-	0.2	-	-	-	-	0.15	0.03	213.2
30.5	-	-	-	-	-	0.1	-	-	-	-	0.09	0.02	225.4
31	-	-	-	-	-	-	-	0	-	-	0.04	0.01	238
31.5	-	-	-	-	-	-	-	0	-	-	0.04	0.01	264.7
SSN	**-**	**-**	**1.9**	**59**	**22**	**12**	**6.4**	**1.9**	**-**	**-**	**102.49**	**-**	**-**
SSB	**-**	**-**	**0.2**	**7.3**	**3.2**	**1.9**	**1.1**	**0.3**	**-**	**-**	**-**	**13.974**	**-**
Mn wt (g)	**-**	**82**	**92**	**123**	**146**	**161**	**171**	**180**	**-**	**-**	**-**	**-**	**-**
Mn L (cm)	**-**	**23**	**24**	**26**	**27**	**28**	**28**	**29**	**-**	**-**	**-**	**-**	**-**

Table 11. Herring biomass and abundance by survey strata. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 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	30	-	-	-	-	100	-	-	-	-	-	-
2	21	-	-	-	-	100	-	-	-	-	-	-
3	6	4	4	-	-	83	1.6	-	-	1.6	1.5	12.049
4	15	3	-	3	-	87	-	0.2	-	0.2	0.2	1.113
5	23	19	11	-	8	70	5	-	0.6	5.6	5.5	42.734
6	19	14	7	-	7	84	0.2	-	1.7	1.9	1.8	14.464
7	17	-	-	-	-	100	-	-	-	-	-	-
8	8	1	1	-	-	88	1	-	-	1	0.9	7.428
9	14	181	75	-	106	21	2.8	-	1.2	4.1	4	27.633
10	11	-	-	-	-	100	-	-	-	-	-	-
Total	164	222	98	3	121	85	10.6	0.2	3.5	14.2	14	105.421
Cv (%)	-	-	-	-	-	-	-	-	-	42.8	42.9	43.8

Table 12. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007. time series. Abundance (millions), TSB and SSB (000's tonnes). Age in winter rings.

Winter rings	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
0	-	-	5	19.36	-	0.09	1.28	-	-
1	18.99	10.71	22.69	51.65	10.28	-	7.83	1.6	0.3
2	104.77	60.88	52.33	102.93	26.26	3.9	56.91	6.9	3.5
3	32.53	48.96	6.41	48.15	30.02	62.35	93.51	86.7	59.8
4	11.34	25.57	6.47	10.87	11.08	54.93	109.87	57.5	21.9
5	1.65	9.43	2.63	9.17	2.94	80.07	100.8	27.9	11.7
6	0.94	2.35	1.94	5.54	0.64	47.14	56.54	16	6.35
7	0.3	1.28	0.12	3.95	0.94	13.81	21.16	4.8	1.86
8	0.17	0.43	0.24	1.68	0.3	11.77	24.64	4.8	-
9+	0.11	0.75	0.07	2.06	0.14	-	12.74	1.3	-
Abundance (millions)	170.8	160.36	97.9	111.33	82.6	274.06	485.29	202.9	105.41
Total Biomass (t)	23,762	21,048	11,062	8,867	10,300	41,700	71,253	27,770	14,222
SSB (t)	22,788	20,500	9,800	6,978	9,500	41,300	66,138	27,200	13,974

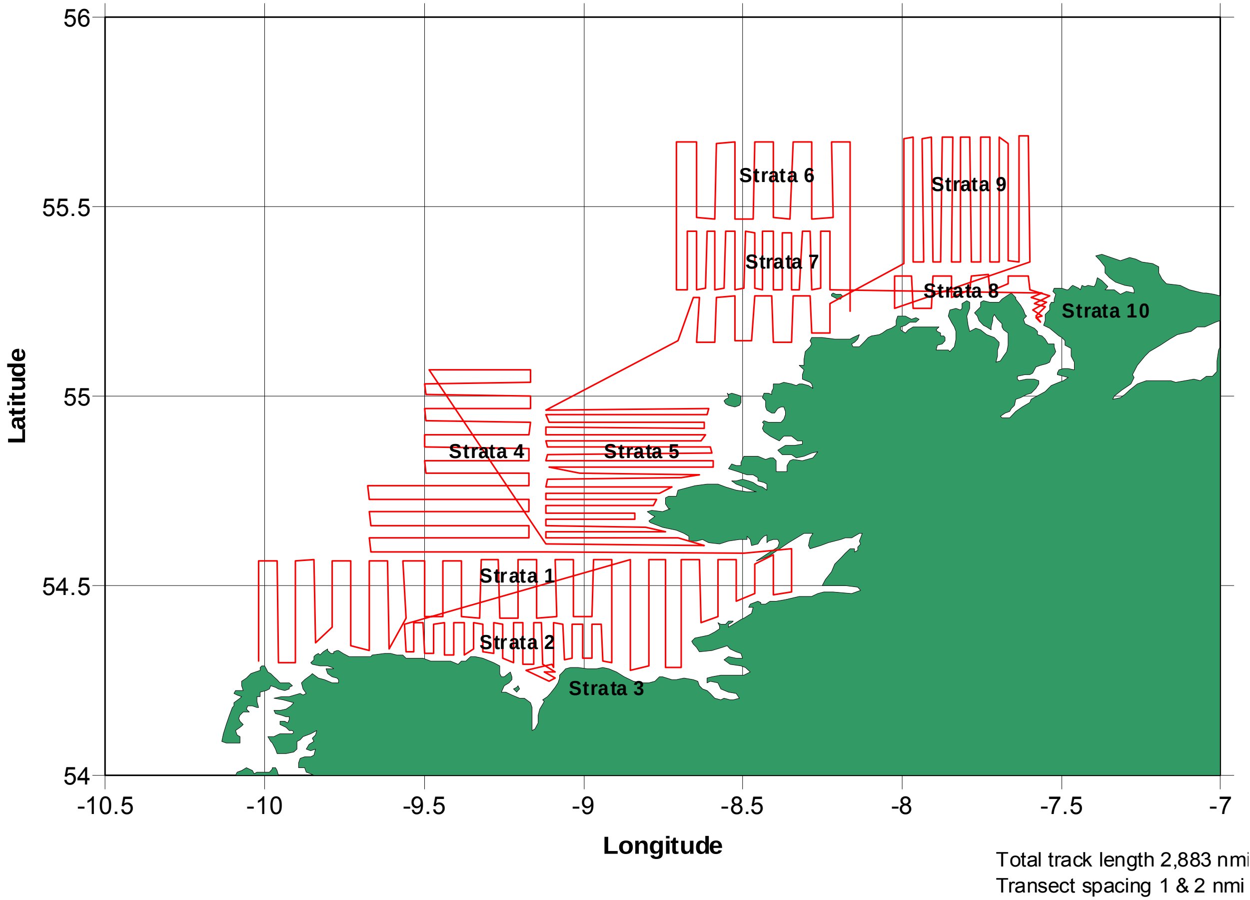


Figure 1. Cruise track (red line) and numbered survey strata. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

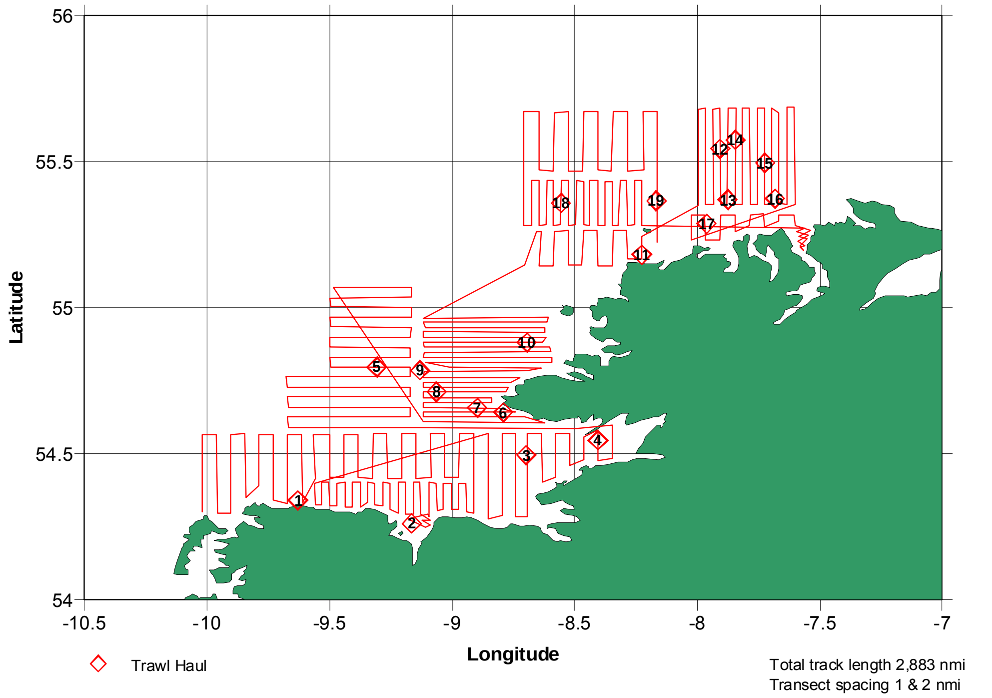


Figure 2. Cruise track haul positions and hydrographic stations. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

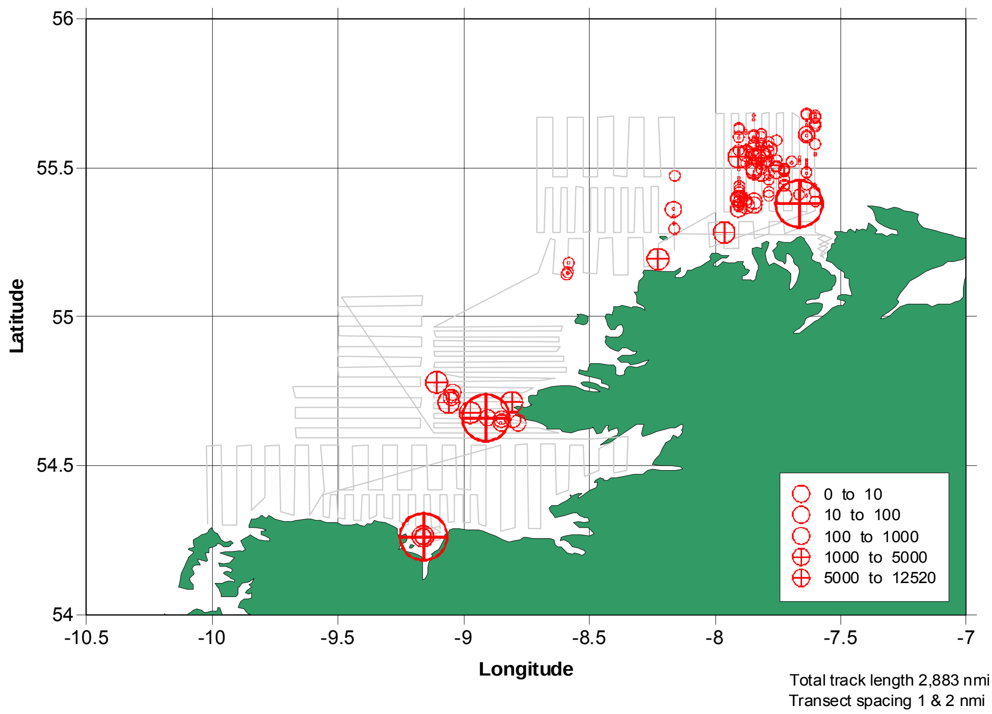


Figure 3. Weighted herring NASC (Nautical area scattering coefficient) plot showing the distribution of “definitely” and “probably” herring categories. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

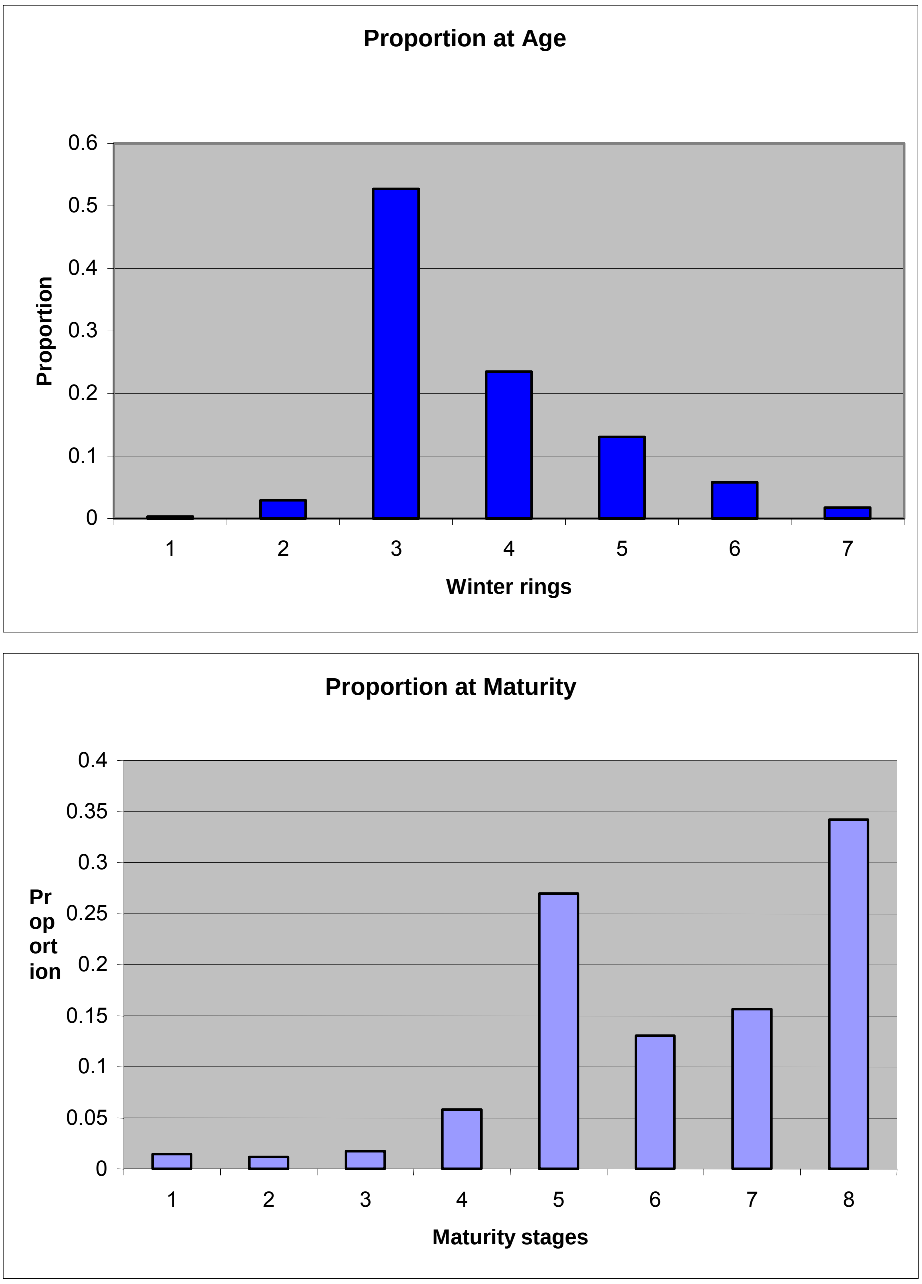
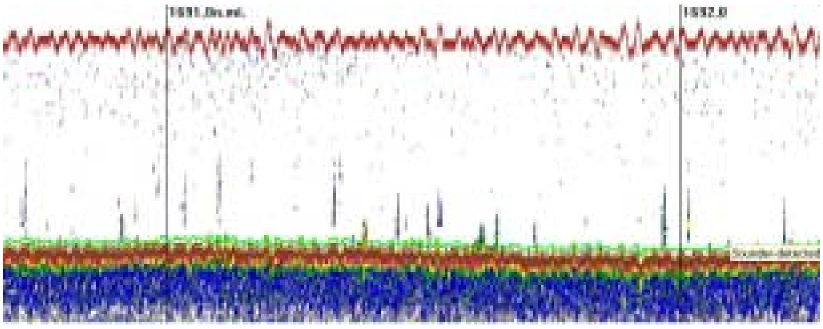
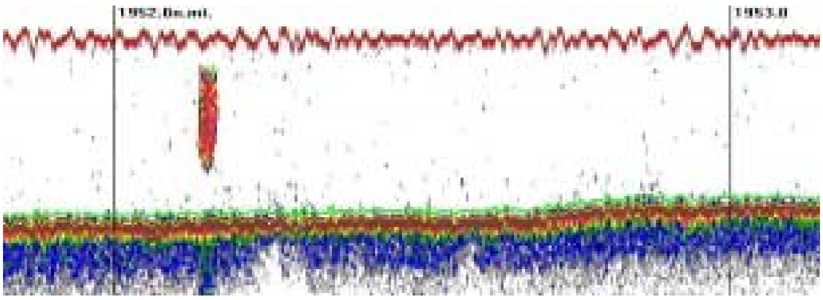


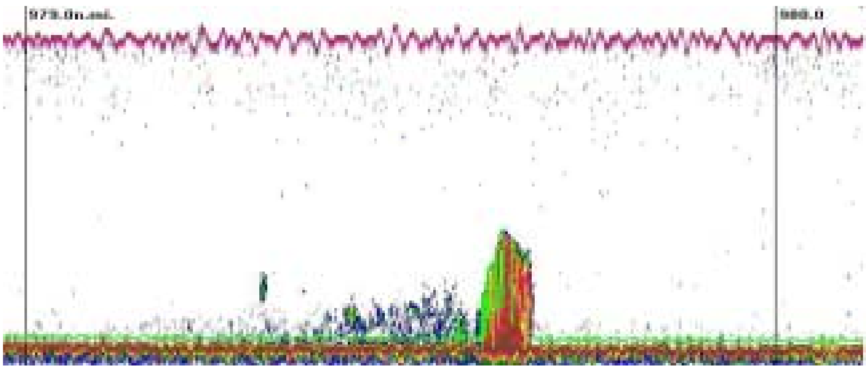
Figure 4. Breakdown of herring ages (above) and maturity (below) from combined survey trawl stations. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.



a). Bottom daytime ***Herring*** marks (spent & pre-spawning fish) recorded at 11:35. Herring schooling in vertical striations Strata 9 spawning box, Haul 13. This daytime mark type was commonly observed in both main spawning boxes along the northwest and north coast (Strata 9 & 5 respectively).

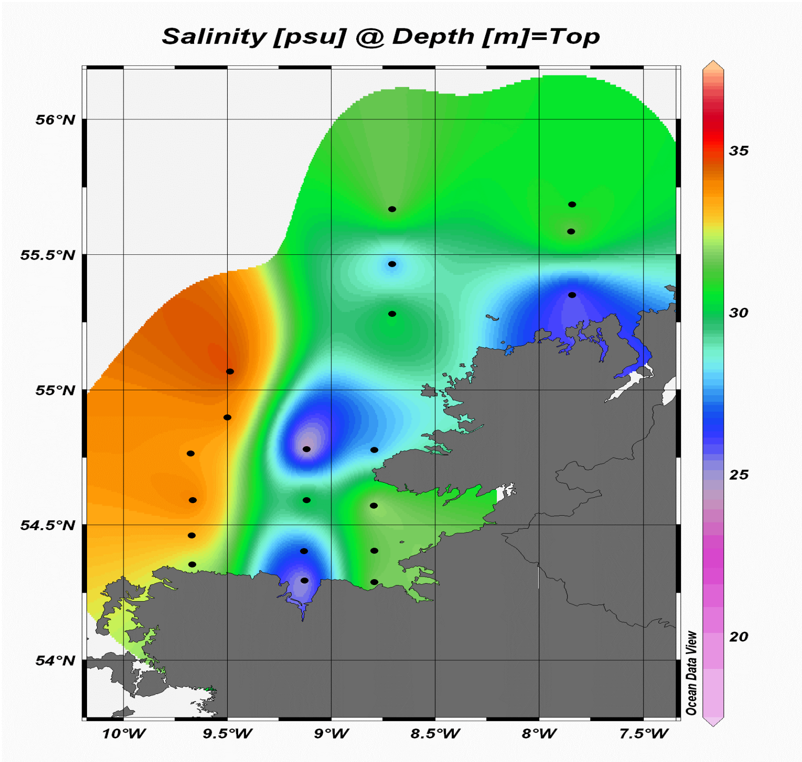


b). Midwater night time ***Herring*** mark (spent & pre-spawning fish) 24m tall in 52m of water (Haul 17, strata 8). Note day/night variation in schooling behaviour between figures a) and b). Also both above mark types were very difficult to capture and highly mobile.



c). Spawning ***Herring*** mark tight on the bottom and relatively stationary. Recorded at 23:41, Haul 07, strata 5 (spawning box).

Figure 5. Echograms (a-c) of main pelagic species encountered. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.



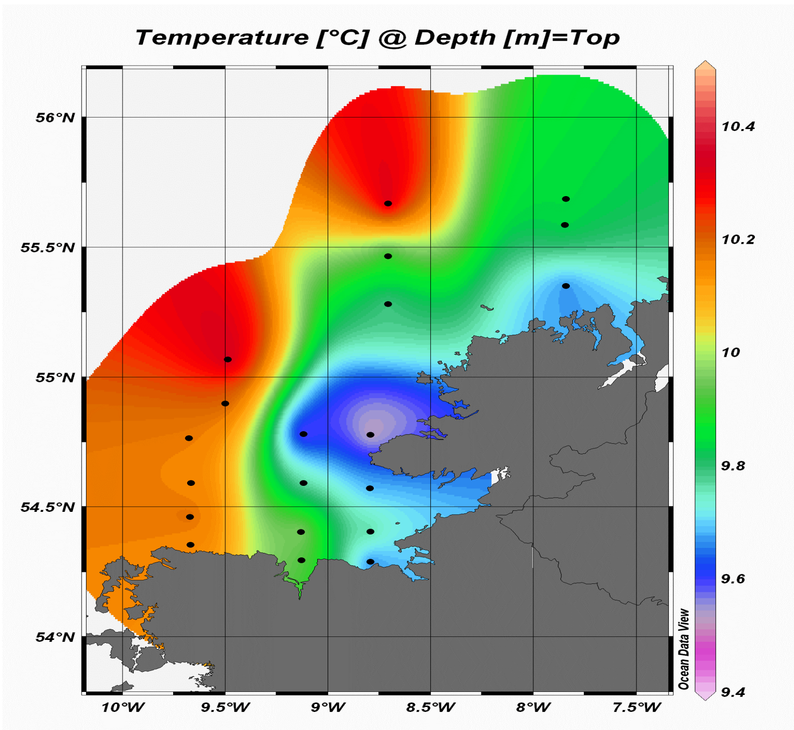


Figure 6. Horizontal salinity (above) and temperature (below) distribution taken at 3m subsurface from combined CTD cast data. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

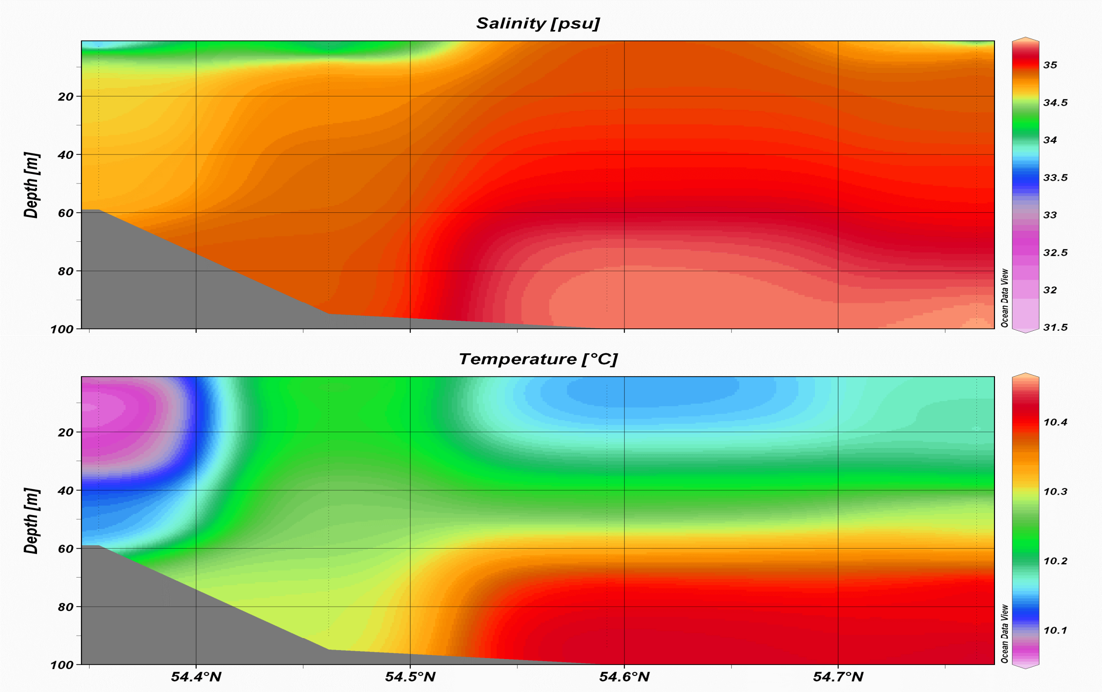


Figure 7. Vertical distribution of salinity (above) and temperature (below) along the Benwee transect, strata 1. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

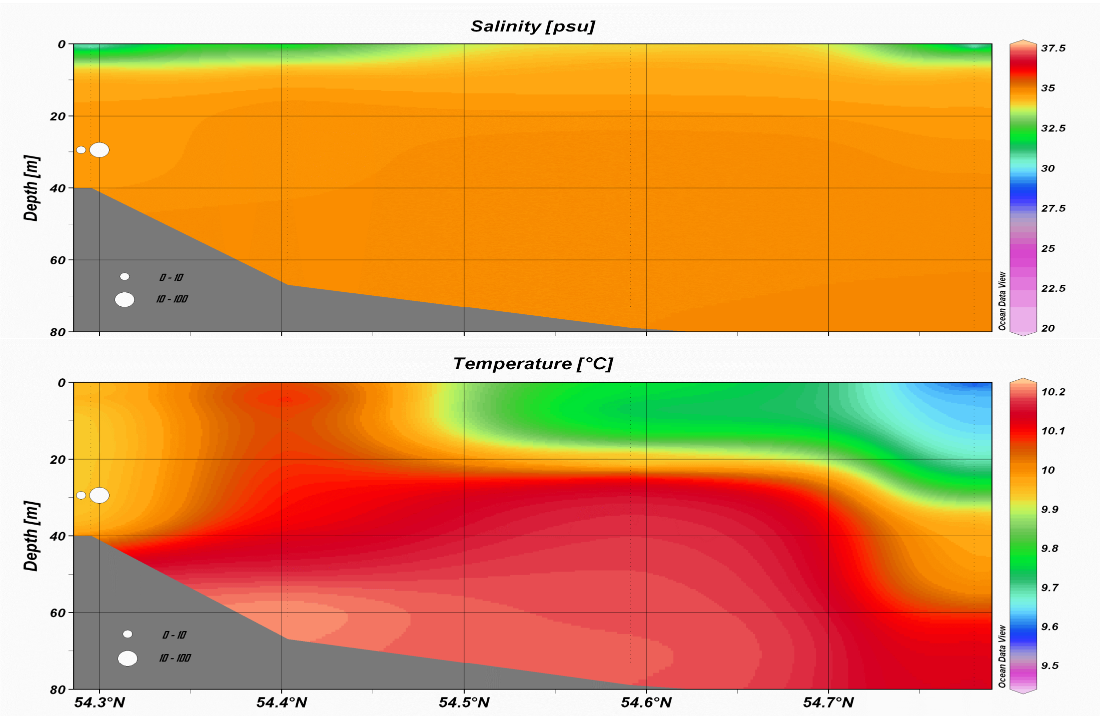


Figure 8. Vertical distribution of sprat NASC (Nautical area scattering coefficient) in relation to salinity (above) and temperature (below) for the Killala transect, strata 1 & 2. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

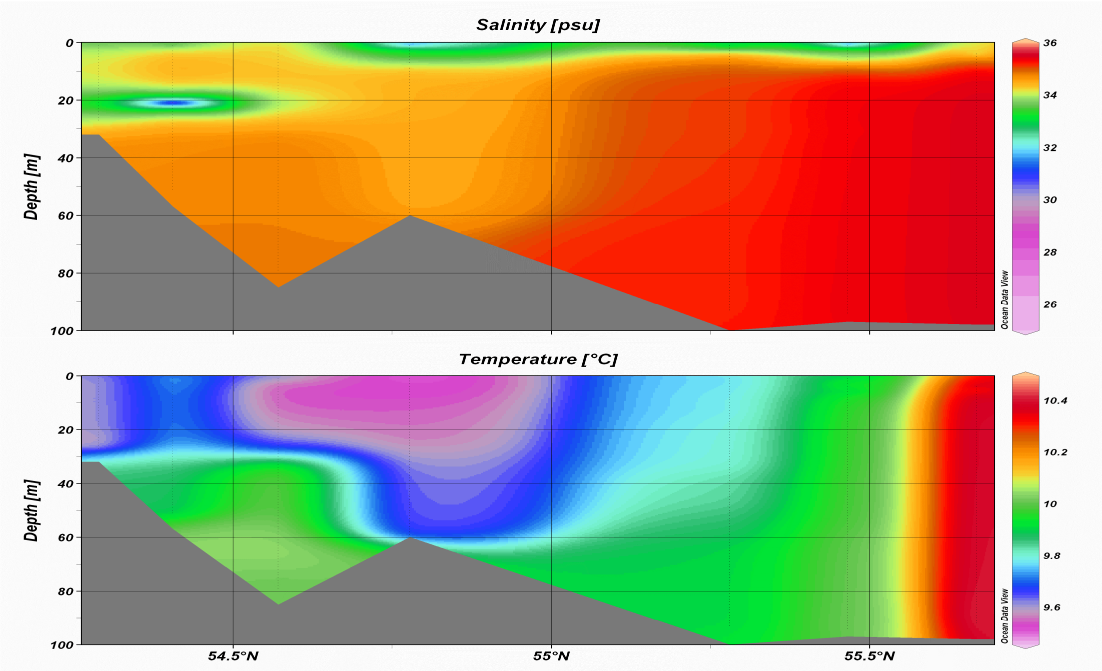


Figure 9. Vertical distribution of salinity (above) and temperature (below) along the Glen Head transect, strata 1 & 4. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

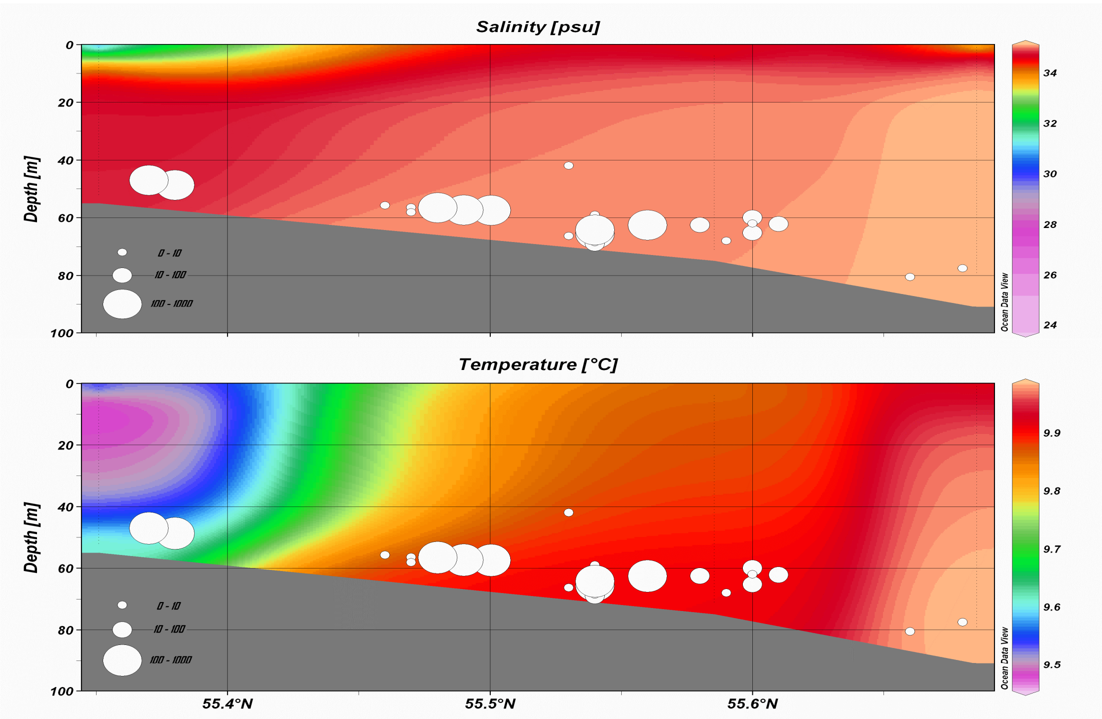


Figure 10. Vertical distribution of herring NASC (Nautical area scattering coefficient) in relation to salinity (above) and temperature (below) for the Fanad Head transect, strata 8 & 9. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

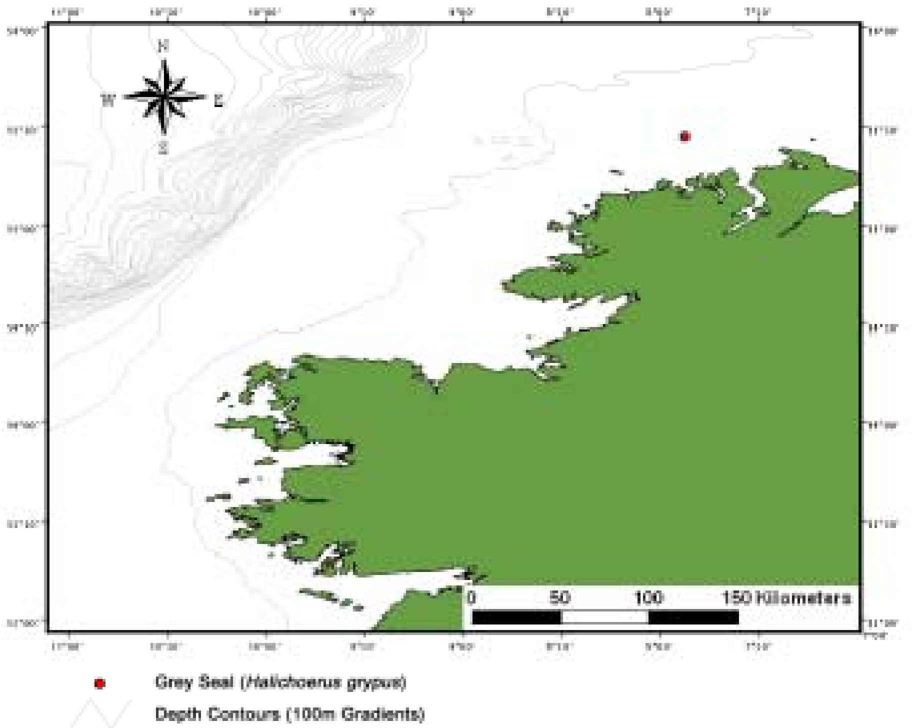


Figure 11. Distribution and size of cetacean sightings. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

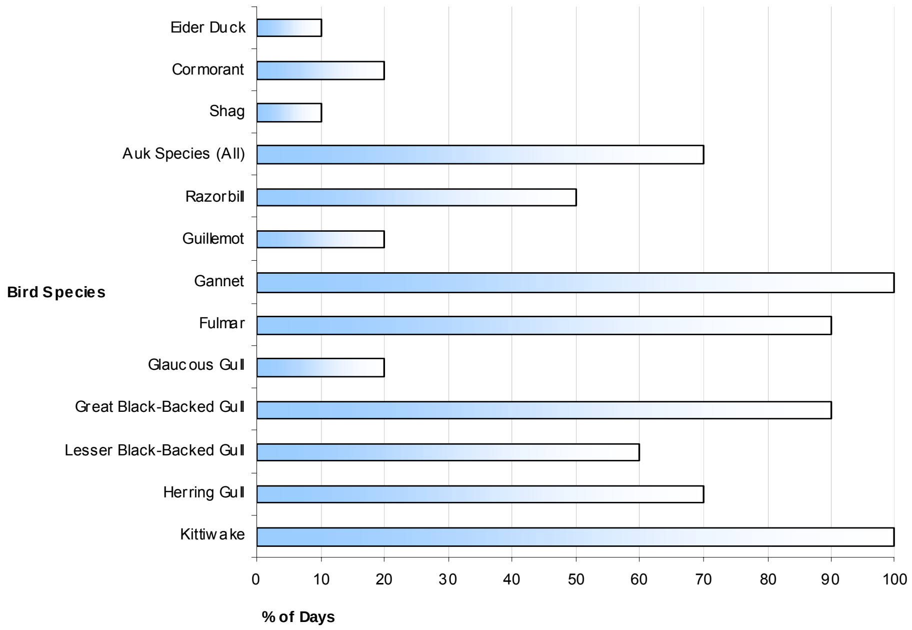


Figure 12. Percentage of days on which 12 bird species were recorded. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

HERRING MIDWATER TRAWL

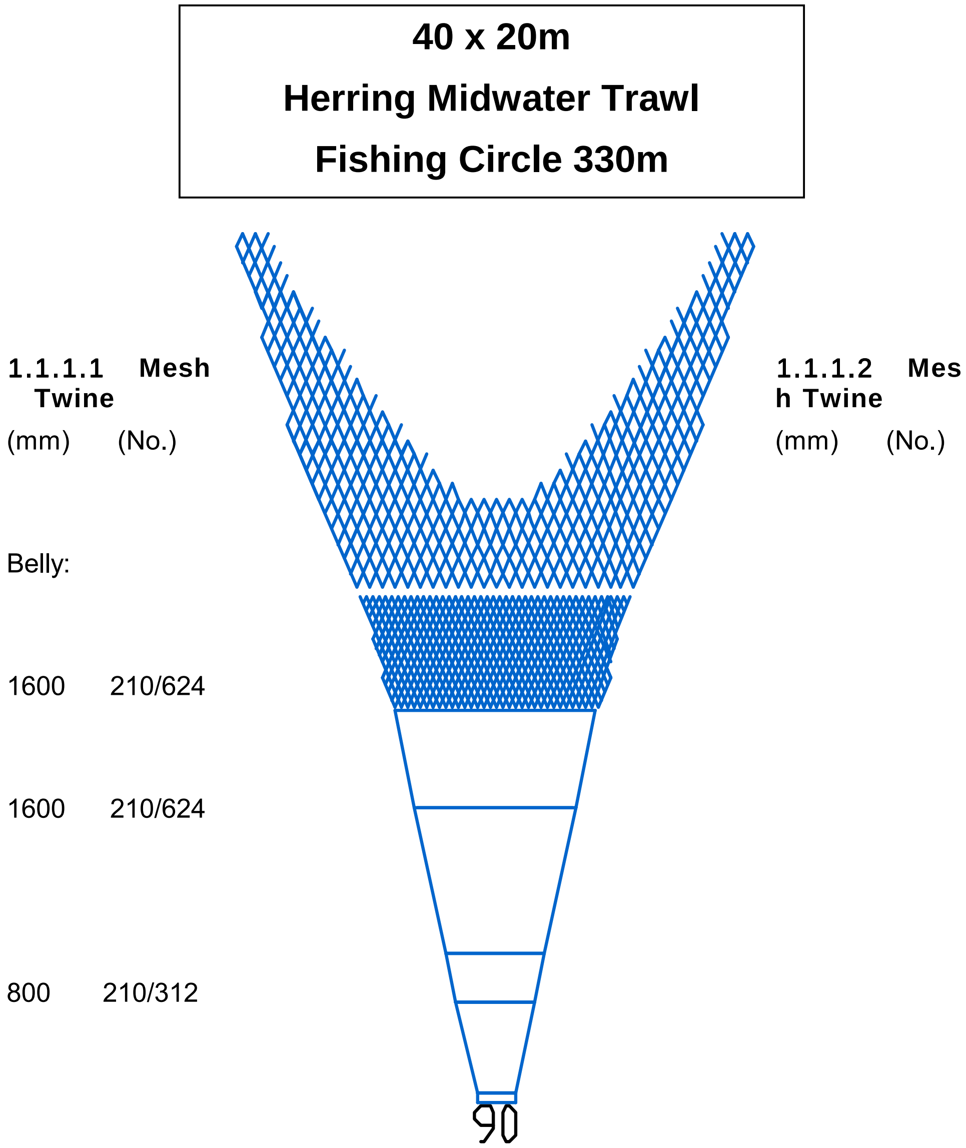


Figure 13. Single herring midwater trawl net plan and layout. Northwest herring acoustic survey (ICES Divisions VIaS & VIIb), January 2007.

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