FSS Survey Series: 2009/02

Blue Whiting Acoustic Survey Cruise Report

March 27- April 16, 2009

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1 Introduction

Acoustic surveys on the blue whiting (*Micromesistius poutassou*) stock in the north east Atlantic have been carried out by the Institute of Marine Research (IMR), Norway since the early 1970s. In the early 1980s a coordinated acoustic survey approach was adopted, with both Russia and Norway participating to estimate the size of this migratory stock within its key spawning grounds. Since 2004, the coordinated survey program has expanded and to include vessels from the EU (Ireland and the Netherlands) and the Faroes.

Due to the highly migratory nature of the stock a large geographical area has to be surveyed. Spawning takes place from January through to April along the shelf break and offshore Banks including the Rosemary, Hatton and Rockall Banks. Peak spawning occurs between mid-March and mid April and acoustic surveys are timed to occur during this phase. To facilitate a more coordinated spatio-temporal approach to the survey participating countries meet annually to discuss survey methods and define target areas at the ICES led Planning Group of Northern Pelagic Ecosystem Surveys (PGNAPES).

Data from the annual spawning stock abundance survey (March/April, western waters), juvenile surveys (May, Norwegian Sea and January-March, Barents Sea trawl survey) and commercial landings data are presented annually at the ICES Working Group of Widely Distributed Stocks (WGWDS). Ultimately, combined data inputs into the management and catch advice for this international cross boundary stock.

The 2009 survey was part of an International collaborative survey using the vessels RV *Celtic Explorer* (Ireland), RV *Fridtjof Nansen* (Russia), RV *Tridens* (Netherlands) and the RV *Magnus Heinason* (Faroes) and the FV Brennholm (Norwegian commercial charter). The total combined area coverage in 2009 extended from the Faroe Islands in the north (62°N) to south of Ireland (51.30°N), with east -west extension from 5°-18° W. Combined area coverage included shelf break areas (>250m) and large bathymetric features including the slope areas of the Porcupine, Rockall and Hatton Banks.

The Irish component of the survey was made up of transects covering 2,545nmi (nautical miles) covering the slope areas (>250m) of the Hebrides shelf, the eastern fringes of the Rockall Bank, the Rockall Trough and the southern slopes of the Hatton Bank. This survey represents the 6th survey in the Irish time series.

2 Materials and Methods

2.1 Scientific Personnel

Name	Institute	Capacity
Ciaran O'Donnell (SIC)	FSS	Acoustics
Eugene Mullins	FSS	Biologist
Graham Johnston	FSS	Acoustics
Ryan Saunders	FSS	Acoustics
Susan Beattie	FSS	Biologist
Kieran McCann	FSS	Biologist
Visiting Scientists		
Zoran Brkic	DFU	Biologist
Eavan O'Leary	UCC	Biologist

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic data on spawning and post spawning aggregations of blue whiting (*Micromesistius poutassou*) along the northern migration pathway from key spawning areas in target areas 1 and 2b (PGNAPES defined)
- Determine an age stratified estimate of relative abundance and biomass of blue whiting within the survey area
- Collect biological samples from directed trawling on 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

2.2.2 Area of operation

The survey covered the primary core spawning area of blue whiting to the west of the Ireland and the Western Isles (Figure 1). The survey track commenced off the northwest coast of Ireland and progressed northwards to the Hebrides using east-west transects up to 300nmi long. Westward extension reached the western flanks of the Rockall Bank. The survey was carried out in continuity from south to north with no scheduled or unforeseen disruptions.

2.2.3 Survey design

A parallel transect design was adopted with transects running perpendicular to the lines of bathymetry where possible. Offshore, transects extended to the 18°W. Transect spacing was set at 30nmi and maintained throughout the survey.

In total, the survey accounted for 3,195nmi, with 2,475nmi of data available for acoustic integration. Survey design and methodology adheres to the methods laid out in the PGNAPES acoustic survey manual.

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 1.

The acoustic data were collected using the Simrad ER60 scientific echosounder. A Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3m below the vessels hull or 8.8m below the sea surface. Three 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). Cruising speed is maintained at a maximum of 10Kts (knots) where possible. During fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

The ER60 was calibrated in Killary Harbour on April 15 at the end of the survey. Weather conditions were good with moderate easterly winds. The results from the calibration of the 38kHz transducer are presented in Table 1.

2.3.3 Inter-vessel calibration

During an acoustic intercalibration, firstly an area of blue whiting abundance is located. The characteristics of a focus area should include medium to high-density isolated schools and in clear and open water away from the commercial fleet, if possible. The lead vessel is chosen and runs a course over the schools, commonly in the order of 10 to 20nmi, with the trail vessel following at a distance of 0.5nmi and a bearing of 0.5° off the lead vessels port/starboard quarter, to avoid bubble attenuation from the propeller of the lead vessel. The lead vessel then communicates the start point at which the first nautical mile data logging point begins. Once the lead vessel is through the main area of interest logging is stopped. The process is then repeated with roles switched. NASC values allocated to blue whiting are partitioned per 1nmi interval and transmitted between vessels for analysis. A full description of methods involved is provided in MacLennan & Simmons (2005).

Once complete, a comparative trawl is undertaken with the aim of sampling the same schools. Data on length, weight, sex, maturity and age are then compared between samples.

2.3.4 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 1). 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 an external HDD and copied to DVD. Sonar Data's Echoview® Echolog (Version 4.2) 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 target area. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up onto the vessels server every 24 hrs and scrutinised using Echoview. Partitioning of data into the above categories was largely subjective and was viewed by a scientist experienced in viewing echograms.

The "EK5" files were imported into Echoview for post-processing. The echograms were divided into transects. Echo integration was performed on regions defined by enclosing selecting marks or scatter that belonged to one of the target species categories. The

echograms were analysed at a threshold of -70 dB and where necessary plankton were filtered out by thresholding at –65 dB.

Echograms were scrutinised into one of the following categories:

a). Blue whiting
b). Mesopelagic fish
c). Plankton
d). Plankton and mesopelagic fish
e). Pelagic fish

Selection criteria are based primarily on trawl data, known habitat preference of each category, as well as target strength (TS) information.

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 70m in length (LOA) and a fishing circle of 768m was employed during the survey (Figure 10). Mesh size in the wings was 12.5m through to 20mm in the cod-end. The net was fished with a vertical mouth opening of approximately 50m, 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 blue whiting were weighed as a component of the catch. Age, length, weight, sex, stomach fullness and maturity data were recorded for individual blue whiting within a random 50 fish sample from each trawl haul with a further 100 random length and weight measurements were also taken. All blue whiting were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density shoals. No bottom trawl gear was used during this survey.

2.3.7 Oceanographic data collection

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 from 1m subsurface to 1000m where depth allowed or to within 10m of the bottom on shelf slopes.

2.4 Analysis methods

2.4.1 Echogram partitioning and abundance estimates

The recordings of area back scattering strength (NASC) per nautical mile were averaged over one nautical mile, and the allocation of area backscattering strengths to species was made by comparison of the appearance of the echo recordings to trawl catches.

The allocation of NASC (Nautical Area Scattering Coefficient) values to blue whiting and other acoustic targets was based on the composition of the trawl catches and the appearance of the echotraces. To estimate the abundance, the allocated NASC values were averaged for ICES statistical rectangles (1° latitude by 2° longitude). For each statistical area, the unit area density of fish (ρ_A) in number per square nautical mile ($N*nm^{-2}$) was calculated using standard equations (Foote et al. 1987, Toresen *et al*. 1998).

For blue whiting a TS= 21.8 log(L) – 72.8 dB was applied.

To estimate the total abundance of fish, the unit area abundance for each statistical rectangle was multiplied by the number of square nautical miles in each statistical square and then

summed for all statistical rectangles within defined sub areas and for the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical rectangle and then sum of all squares within defined sub areas and the total area.

The scrutinized acoustic data from the participating vessels were reported to the Marine Institute, Bergen, to produce combined assessments of the blue whiting in accordance with PGNAPES agreements.

Acoustic, biological and oceanographic data are submitted to PGNAPES for inclusion into a dedicated survey database.

3 Results

3.1 Blue whiting abundance and distribution

A total of 23 directed trawls were carried out during the survey (Figure 1, Table 2). Of this, 21 contained blue whiting as the dominant species both by weight and numbers. The second most frequently encountered species was the Myctophid *Notoscopelus krokeyeri* present in 83% of hauls. Blackfish (*Centrophagus niger*) the second most commonly encountered species in 2008 was ranked seventh in 2009, appearing in only 30% of trawls. Dealfish (*Trachipterus arcticus*) were present in 17% trawls in small numbers.

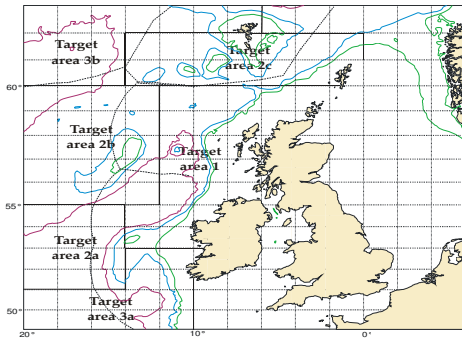
In the years 2004-08 mackerel (*Scomber scombrus*) have been infrequently encountered along the shelf slope west of the Hebrides as schools of medium to high density. In 2009, mackerel were found to be distributed widely across the combined survey area and in greater abundance than seen previously. Mackerel were taken in 8 out of 21 trawl samples from 60ºN north to as far south as 51ºN and west to 15ºW on the Hatton Bank (Table 2, Figure 3c). Ordinarily confined to the shelf slope, mackerel were encountered in open waters in depths of between 60-300m forming distinct schools occurring over large areas. Stomach contents revealed mackerel to be actively feeding on mesopelagic fish and were most frequently encountered within this layer. During daylights hours mackerel were discernable as single schools. At night mackerel schools were inclined to disperse mixing with the mesopelagic layer.

Mesopelagic species including Myctophidae were well represented in trawl catches occurring throughout the survey area and in 70% of trawl samples. Overall, some 42 species were identified from trawl samples (Table 6).

3.1.2 Blue whiting biomass and abundance

A full breakdown of the survey stock structure is presented by distribution, age, length, biomass, abundance and area in Tables 3, 4, 5 & 7 and Figures 2 & 4.

Target Area	TSN (mil)	SSN (mil)	TSB ('000s t)	SSB ('000s t)
Hebrides (1)	22,968.7	22,968.7	2,948.8	2,948.8
Rockall (2b)	5,543.6	5,463.8	702.9	699.1
Total	**28,512.2**	**28,432.5**	**3.652 mil t**	**3.648 mil t**



3.1.3 Blue whiting distribution

Blue whiting were found distributed throughout the survey area, with the bulk of the stock located along the Hebrides shelf (Figure 2). Target area 1- Hebrides shelf, contributed over 80% of the total stock biomass (TSB) with Target area 2b- Rockall, contributing the remaining 20%. The eastern Hebrides area from 57-60°N including the Rosemary Bank contained the largest concentration of high density schools observed during the survey and is consistent with the results from previous surveys. In particular the area southeast of the Rosemary Bank area produced the highest recorded biomass observed during the survey accounting for over 840,000t (Figure 3a, Tables 3 & 4). This is consistent with expected results at this time in the northern core spawning area. In 2008, the largest recorded rectangle biomass was 544,900t to the northwest of Ireland, also in Target area 1.

The area between 56-57ºN was the focus of the bulk of commercial fishing activity within the EU zone at the start of the survey and good concentrations were observed. In the western extremes, biomass within the Rockall sub area was significantly lower than observed in 2008 even with extended coverage. Fishing effort within this sub area was also notably higher than observed in previous years. Vessels were observed following actively migrating schools from 20ºW north eastwards along the western slopes of the Rockall Bank ahead of the survey. The main body of blue whiting had already migrated out of the area to the northeast when the

area was surveyed. Towards the end of the survey the bulk of commercial fishing effort was concentrated in the Faroese zone along the Wyville Thompson ridge in the northeast of the survey area that was covered by the Faroese vessel.

The eastern slopes of the Rockall Bank, Hatton and George Bligh Banks contributed a small but important component to the overall biomass estimate. Few schools were observed in the southern Rockall Trough. Some medium-high density schools were recorded in open water in the northern area (58-60ºN) often observed as a continuation of schools extending out from the shelf break and also around the Rosemary Bank.

Reports from participant survey vessels and also from contact with their respective fleets indicated that peak spawning had taken place earlier than at the same time in 2008 and migration of the stock was well underway.

3.1.4 Blue whiting stock structure

During the survey 950 fish were aged with length, weight, sex, maturity and stomach fullness index data recorded. A further 2,850 fish were measured and weighed. Age analysis, revealed survey samples were found to contain individuals of 1 to 10-years old.

The stock structure within the surveyed area revealed the stock to be dominated by 6-year old fish (2003 year class) and is consistent with commercial samples taken from the Irish fleet. This year class represented over 39% of the stock in numbers and 37% by weight (Table 5). Five and 7-year old fish (2004 and 2002 year classes) were also well represented ranking second and third and accounting for over 33% and 13% of biomass and over 30% and 15% of numbers respectively. Combined these three age classes represent over 71% of the total biomass of the stock.

In total, juvenile blue whiting of 1 and 2-years represented 0.2% and 3.2% of numbers, and 0.06% and 1.8% respectively of the total biomass. Immature blue whiting were encountered exclusively in the southwest of the Rockall Bank as 1 and 2-year olds. Maturity analysis of samples revealed that no 1-year old fish were mature but a significant proportion of 2-year old fish (2007 year class) were mature (96%). Maturity analyses Within the Hebrides sub area all 2-year old fish (100%) were found to be mature and no 1-year old blue whiting were observed. The total biomass for immature blue whiting was 38,000t (1and 2-year old) and came exclusively from the Rockall area. No 1-year old fish were observed in the Hebrides. The presence of 1-year old fish in the Rockall area can be attributed to the resident population that resides in the area year round.

Interestingly the area containing juvenile fish in Rockall was the focus of fishing effort by the Russian, Faroese and Icelandic vessels in late March/early April with up to 18 vessels fishing at any one time.

3.2 Oceanography

3.2.1 Physical oceanography

Overall 27 vertical CTD casts were carried out over the course of the survey. Open water stations were conducted to a maximum of 1,000m. The data from casts 1-10 had to be disregarded due to inconsistencies in salinity readings. The remaining 16 stations were compiled to produce horizontal profiles of temperature and salinity from 10m subsurface to 600m (Figures 6-9).

3.2 Inter-vessel calibration

One inter-calibration exercise was carried out between R/V Celtic Explorer and R/V Magnus Henson on April 9. The results are presented in Appendix 1.

4 Discussion and Conclusions

4.1 Discussion

Overall, the survey was a success and survey aims were achieved. The start of the survey saw winds speeds in excess of 30Kts for the first 6 days which slowed progress. As a result some planned CTD transects were dropped to allow more time to finish core work. The cruise track was modified midway through based on time allowances and discussion on fish distribution patterns with other participants. The ER60 calibration was carried out after the survey to reduce the time lag between cooperating vessels. Coordination and temporal progression of the participating vessels was good and synoptic coverage was achieved. Inter vessel communication was good.

Overall blue whiting distribution was similar to the 2008 survey with the main bulk of the stock distributed in the northern Hebrides core area. The more northerly distribution of the stock can be attributed to earlier migration in 2009. The TSB for 2009 was 2.5% lower than recorded in 2008 and over 17% lower in terms of abundance. However, the 2009 survey covered 30% more area and extended further west to the 18ºW than the 2008 survey, which covered only the eastern slopes of the Rockall Bank. The larger decrease in abundance between years is directly related to the growth of the 3 strong year classes that currently maintain the stock accounting for over 71% of the total survey biomass.

Over 76% of the total survey biomass was located in the Hebrides sub area. Even with the increased area coverage in the Rockall sub area the total biomass for the survey was slightly down on that observed in 2008.

The lack of juvenile fish in the core Hebrides area is a strong signal of the continued poor recruitment in the bulk of the migratory stock. Results from surveys that pick up juvenile signals in the Norwegian Sea (May survey, PGNAPES) have reported a steep decline in the number of recruiting fish over the past 3 years. The results from the 2009 survey will no doubt be monitored closely. This steep decline in recruitment is now evident in the spawning stock age structure.

The high level of early maturity of 2-year fish (96%) taken from the Rockall Bank is significantly higher than was observed for 2-year olds in 2008. Results from the international survey indicate that a proportion of 1-year old fish (15%) encountered in Rockall and Porcupine Banks were also mature. Age at first maturity for resident juveniles appears to be occurring earlier than observed before in this time series. Results from this survey found all of the 2-year fish to be mature in the Hebrides sub area. The numbers were small but nonetheless significant and could indicate a shift to earlier maturity for this age class.

The presence of pre-spawning mackerel in the Rockall Trough and the Hatton Bank has not been observed during this survey before. Mackerel are occasionally taken on the Hebrides shelf but not in open water or indeed on any of the offshore Banks. Mackerel schools were clearly visible from 60-300m depth during daylight hours and appeared to be actively feeding. All participant vessels reported a high abundance of mackerel. The presence of homogeneous schools during daylight hours can be accurately partitioned on echograms and will be carried out on future surveys should this distribution continue.

4.2 Conclusions

The absence of juveniles in the core area of the Hebrides where the bulk of the stock was located is a further signal of poor recruitment. The presence of juveniles on the south-western Rockall Bank was low but nonetheless important. Juveniles in this area can be considered as resident in the short term due to larval retention on the Bank. Overall the stock appears to be supported by older larger individuals (2002-2004 year classes) with little signs of new recruitment to the stock.

If recruitment continues to be poor in main body of the migratory stock, recruitment from resident areas such as the Rockall and Porcupine Banks will become increasingly important.

However, as little is known about how these resident fish contribute to the total stock and if at maturity what proportion, if any, do undertake seasonal feeding migrations will be difficult to quantify. Fishing pressure in areas containing resident fish and on what appear to be the only source of recruitment at present will further adversely affect the stock.

Due to the lack of immature juvenile fish within the main body of the stock it is impossible to determine whether the early maturity of the resident 1 and 2 years old fish encountered in Rockall is also the case throughout the main stock.

Acknowledgements

We would like to express our thanks and gratitude to Dennis Rowan (Captain) and crew of the Celtic Explorer for their good will and professionalism during the survey.

Our special thanks also go to our visiting scientists Zoran Brkic (Denmark) and Eavan O'Leary (UCC, Ireland). Their help and hard work was greatly appreciated and we look forward to future collaborations.

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Table 1. Survey settings and calibration report for the Simrad ER60 echosounder. Blue whiting survey, March-April 2009.

Reference Target:			
TS	-33.50 dB	Min. Distance	10.00 m
TS Deviation	9.5 dB	Max. Distance	17.00 m
Transducer: ES38B Serial No. 30227			
Frequency	38000 Hz	Beamtype	Split
Gain	25.55 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.67 deg	Along. Beam Angle	6.39 deg
Athw. Offset Angle	0.03 deg	Along. Offset Angl	0.04 deg
SaCorrection	-0.65 dB	Depth	5.00 m
Transceiver: GPT 38 kHz 1 ES38B			
Pulse Duration	1.024 ms	Sample Interval	0.191 m
Power	2000 W	Receiver Bandwidth	2.43 kHz
Sounder Type:			
EK60 Version 2.1.1			
TS Detection:			
Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %
Environment:			
Absorption Coeff.	9.9 dB/km	Sound Velocity	1488.5 m/s
Beam Model results:			
Transducer Gain =	25.82 dB	SaCorrection =	-0.70 dB
Athw. Beam Angle =	7.18 deg	Along. Beam Angle =	7.10 deg
Athw. Offset Angle =	-0.03 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:

RMS = 0.10 dB
Max = 0.22 dB No. = 36 Athw. = 3.3 deg Along = 2.5 deg
Min = -0.36 dB No. = 1 Athw. = 4.5 deg Along = -0.7 deg

Data deviation from polynomial model:

RMS = 0.06 dB
Max = 0.18 dB No. = 136 Athw. = -2.1 deg Along = 3.4 deg
Min = -0.18 dB No. = 159 Athw. = -2.1 deg Along = -1.4 deg

Table 2. Catch composition, time and location of trawl hauls. Blue whiting survey, March-April 2009.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Blue Whiting %	Mackerel %	Meso %	Herring %	Others %
1	29.03.09	56 15.39	09 10.0	08:20	500	280	2,500	100.0				
2	29.03.09	56.15.10	10.42.22	19:10	2300	250-350	9.0		75.7	4.6		19.7
3	30.03.09	56 15.08	14 29.63	17:15	400-600	400-480	57.3	66.8		0.8		32.4
4	31.03.09	56 15.3	16 51.17	08:45	500	460-500	34.3	92.9		2.7		4.4
5	01.04.09	56 43.86	15 23.75	09:18	480	440-480	110.2	95.9		0.0		4.1
6	01.04.09	56 45.29	13 36.13	18:50	800	550 & 190	14.6	5.8	20.8	41.8		31.6
7	02.04.09	56 44.31	10 37.22	10:54	>2000	440-500	4,000	100.0				
8	03.04.09	57.16.21	09.25.22	01:46	540	450-500	4,000	99.0				1.0
9	03.04.09	57 14.54	11 35.75	14:20	>2000	400-480	4500	100.0				
10	04.04.09	57.10.86	15.11.08	08:50	533	480-530	400	99.0		0.3		0.7
11	04.04.09	57.44.86	15.01.3	22:00	570-640	520-550	74.6	97.7		0.5		1.8
12	05.04.09	57.44.73	11.0.05	15:11	>2000	420 & 210	13.7	1.2		3.7		95.1
13	05.04.09	57 44.79	10 08.74	21:32	1800	450	2,500	98.5	1.0	0.1		0.4
14	06.04.09	58.14.603	09.35.98	06:23	600	340-450	8,000	99.2	0.3	0.0		0.5
15	06.04.09	58 15.16	11 09.34	14:22	1800	220	8.4		28.9			72.1
16	08.04.09	58.44.38	10.34.84	08:29	1800	400-450	4,000	100.0				
17	08.04.09	58.47.24	09.23.55	16:00	1700	300-550	1,500	99.6	0.3			0.1
18^	09.04.09	59 14.78	07 53.99	10:18	>2000	410	400	99.2	0.6	0.2		0.1
19	09.04.09	59 15.53	10 27.84	21:36	750	310-440	1,000	100.0		0.0		
20	10.04.09	59 16.08	15 30.58	21:39	500	460 & 40	123.8	75.7	0.2	0.4		23.6
21	12.04.09	59 45.22	09 35.00	08:45	1400	420 & 160	250	99.5		0.4		0.1
22	12.04.09	59 45.29	07 51.37	17:35	724	440	32.058	84.8		5.6		9.6
23	12.04.09	59 44.59	06 47.13	23:25	1800	380-480	32.1	84.8		5.6		9.6

Note: "Others" was used to represent fish and non-fish species occurring in the catch see Table 6.
^: Denotes haul carried out during intercalibration exercise with the RV *Magnus Heinason*.

Table 3. Breakdown of abundance estimate by sub area, including trawl haul allocation. Blue whiting survey, March-April 2009.

Rectangle	NASC $m^2/n.m^2$	Area $n.mile^2$	Trawl haul(s) #	length cm	Density coeff. $1.488 * 10^6 * L^{-2.18}$	Abundance $N *10^6$	weight gram	Biomass 1000 tonnes
5608	2057.6	1800	1	29.5	927.0605	3433.48	121.2	416.2406068
5610 (1)	1438.1	2400	7	29.6	922.969	3185.62	133.1	423.878
5708	1926.7	1140	8	29.3	944.397	2074.30	121.7	252.380
5710 (1)	436.2	1800	13	29.6	920.933	723.04	132.8	95.984
5808	3198.8	2250	14	29.0	968.015	6967.14	121.0	842.885
5810 (1)	1098.1	1920	16	29.4	936.711	1974.87	128.3	253.455
5906	831.2	1650	22&23	29.2	948.628	1301.02	129.3	168.249
5908	620.6	3600	18&21	30.0	893.752	1996.75	151.8	303.167
5910 (1)	1195.5	1200	19	29.7	914.864	1312.43	146.8	192.599
Target Area 1					**Sub area total**	**22968.7**		**2948.8**
5610 (2)	122.9	365	7	29.6	922.969	41.39	133.1	5.5097
5612	241.9	880	7	29.6	922.969	196.45	133.1	26.1394
5614	262.6	1039.5	5	26.4	1181.493	322.47	101.3	32.6728
5616	111.6	3000	4	26.1	1218.369	407.90	97.7	39.8641
5710 (2)	381.4	1800	13	29.6	920.933	632.21	132.8	83.9263
5712	120.1	1280	9	29.3	944.397	145.14	142.7	20.7141
5714	362.6	2220	10&11	28.8	980.519	789.31	125.1	98.7353
5810 (2)	460.4	700	16	29.4	936.711	301.91	128.3	38.7472
5812	139.0	947	16	29.4	936.711	123.27	128.3	15.8157
5814	229.9	2760	10&11	28.8	980.519	622.03	125.1	77.8102
5910 (2)	244.2	390	19	29.7	914.864	87.13	146.8	12.7868
5912	311.0	1755	19&20	29.4	940.194	513.21	139.1	71.3672
5914	391.2	3600	20	29.0	966.559	1361.12	131.4	178.8240
Target Area 2b					**Sub area total**	**5543.6**		**702.9**
					Grand total	**28512.2**		**3651.8**

Note: Target area 1: Hebrides & north Porcupine Bank; Target area 2a: western Porcupine Bank; Target area 2b: Rockall

Table 4. Breakdown of abundance and biomass by survey sub area as used during analysis. Blue whiting survey, March-April 2009.

Target area	Area nm^s	**Abundance (Mils)** Immature	Mature	Total	**Biomass ('000s t)** Immature	Mature	Total	Mean Length (cm)	Mean weight (g)	Density t/nmi2
1	17,760	0.0	22968.7	22968.7	0.0	2948.80	2948.8	29.5	128.4	166.04
2b	20,736.50	79.7	5463.8	5543.5	3.8	699.10	702.9	28.28	112.9	33.9
Total	38,496.50	79.7	28432.5	28512.2	3.8	3647.9	3651.7	28.89	120.65	99.97

Table 5. Aged stratified estimate of surveyed stock abundance and biomass. Blue whiting survey, March-April 2009.

	Age (yrs) and year class										TSN	TSB	Mn Wt
Length	1	2	3	4	5	6	7	8	9	10			
(cm)	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	(Mils)	('000t)	(g)
16.5	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
17.5	0	0	0	0	0	0	0	0	0	0	0	0	0
18	4.3	0	0	0	0	0	0	0	0	0	4.3	0.1	31.0
18.5	2.1	0	0	0	0	0	0	0	0	0	2.1	0.1	34.0
19	8.6	0	0	0	0	0	0	0	0	0	8.6	0.3	35.0
19.5	15.0	0	0	0	0	0	0	0	0	0	15.0	0.6	37.4
20	26.6	0.0	0	0	0	0	0	0	0	0	26.6	1.1	42.9
20.5	0.0	20.7	0	0	0	0	0	0	0	0	20.7	0.9	44.4
21	0.0	22.7	0	0	0	0	0	0	0	0	22.7	1.1	48.4
21.5	0.0	35.2	0	0	0	0	0	0	0	0	35.2	1.9	52.7
22	0	75.4	0	0	0	0	0	0	0	0	75.4	4.2	55.7
22.5	0	84.1	0.0	0	0	0	0	0	0	0	84.1	5.4	63.7
23	0	133.0	0	0	0	0	0	0	0	0	133.0	8.5	63.8
23.5	0	116.8	26.0	0	0	0	0	0	0	0	142.8	9.5	66.9
24	0	141.0	15.7	0.0	15.7	0	0	0	0	0	172.3	12.2	70.5
24.5	0	76.8	12.8	0.0	0	0	0	0	0	0	89.6	6.8	75.9
25	0	89.7	22.4	22.4	22.4	22.4	0	0	0	0	179.4	14.7	82.0
25.5	0	10.5	31.4	20.9	20.9	10.5	0	0	0	0	94.1	8.8	93.2
26	0	31.3	93.8	93.8	0.0	0	0	0	0	0	218.9	20.4	93.0
26.5	0	0	113.5	113.5	453.9	56.7	0	0	0	0	737.6	69.6	94.4
27	0	59.1401	59.1	354.8	887.1	236.6	0	0	0	0	1596.8	158.4	99.2
27.5	0	0	37.1	333.5	778.1	555.8	74.1	0	0	0	1778.5	185.6	104.4
28	0	36.4	109.3	437.3	1785.6	692.4	109.3	0	0	0	3170.4	351.9	111.0
28.5	0	0	0.0	231.0	1578.2	846.8	154.0	0	0	0	2810.0	323.7	115.2
29	0	0	0.0	202.5	1485.3	1957.8	405.1	0	0	0	4050.7	486.7	120.2
29.5	0	0	0	53.6	723.0	1097.9	267.8	53.6	0	0	2195.7	287.9	131.1
30	0	0	0	28.3	623.7	1672.6	510.3	56.7	28.3	0	2919.9	402.4	137.8
30.5	0	0	0	89.6	418.2	926.1	388.4	59.7	0	0	1882.1	263.5	140.0
31	0	0	0	32.6	359.1	1142.5	489.7	0	0	0	2023.9	296.3	146.4
31.5	0	0	0	0.0	134.1	558.7	245.8	22.3	0	0	960.9	148.8	154.9
32	0	0	0	53.23149	106.5	425.9	372.6	0	0	0	958.2	157.3	164.2
32.5	0	0	0	0	47.5	166.2	118.7	47.5	23.7	0	403.6	68.5	169.7
33	0	0	0	18.39751	36.8	92.0	220.8	128.8	0	0	496.7	91.3	183.7
33.5	0	0	0	0	0	125.4	125.4	62.7	12.5	0	326.1	61.4	188.3
34	0	0	0	0	0	43.5805	109.0	43.6	21.8	21.8	239.7	49.4	206.0
34.5	0	0	0	15.12732	30.3	75.6	15.1	15.1	0	0	151.3	32.1	211.9
35	0	0	0	0	0	52.9	26.5	26.5	66.2	0	172.0	37.3	216.9
35.5	0	0	0	0	0	49.8	49.8	49.8	0	0	149.4	35.8	240.0
36	0	0	0	0	0	0	22.5	22.5	0	0	45.1	11.5	255.6
36.5	0	0	0	0	0	0	11.3	22.5	0	0	33.8	9.2	273.3
37	0	0	0	0	0	0	28.8	0	0	0	28.8	7.7	268.8
37.5	0	0	0	0	0	0	0	0	0	0	0.0	0.0	308.0
38	0	0	0	0	0	0	7.2	7.2	7.2	0	21.7	6.8	314.0
38.5	0	0	0	0	0	0	0.0	4.7	0	0	4.7	1.4	307.5
39	0	0	0	0	0	0	0.0	0.0	0	0	0.0	0.0	400.0
39.5	0	0	0	0	0	0	0.0	4.7	0	0	4.7	1.9	410.0
40	0	0	0	0	0	0	0	0.0	0	1.0	1.0	0.4	369.0
40.5	0	0	0	0	0	0	0	0	0	24.0	24.0	8.1	336.0
TSN (Mils)	56.70	932.78	521.02	2100.65	9506.23	10808.17	3752.08	628.03	159.832	46.722	28512.2	3651.7	
% Mature	0	96	100	100	100	100	100	100	100	100			
TSB ('000t)	2.2	66.7	49.9	236.3	1126.8	1444.3	563.6	117.6	31.4	12.9	3651.7		
SSB ('000t)	0	65.0	49.9	236.3	1126.8	1444.3	563.6	117.6	31.4	12.897	3647.9		
Mn Wt	36.07	72.89	89.05	126.74	129.44	148.11	183.49	193.01	205.44	303.66			
Mn L	19.00	23.86	25.75	28.97	29.19	30.45	32.25	34.25	33.83	38.17			

Table 6. Species occurrence from trawl stations. Blue whiting survey, March-April 2009.

Category	Common Name	Scientific Name	Occurrence
Pelagic	Blue Whiting	*Micromesistius poutassou*	21
	Mackerel	*Scomber scombrus*	8
	Horse mackerel	*Trachurus trachurus*	1
Mesopelagics	Greater Argentine	*Argentina silus*	3
	Hatchet Fish (small)	*Argyropelecus hemigymnus*	14
	Hatchet Fish (large)	*Argyropelecus olfersi*	5
	None	*Astronethus gemmifer*	1
	Myctophidae	*Benthosema glaciale*	7
	Alfonsino	*Beryx decadactylus*	
	Ray's bream	*Brama brama*	1
	Blackfish	*Centrophagus niger*	7
	Sloanes Viper fish	*Chauliodus sloani*	8
	Myctophidae	*Diaphus raffinesqui*	3
	Myctophidae	*Diaphus metapoclampus*	1
	None	*Diretmus argentus*	1
	None	*Echiostoma barbatum*	
	Myctophidae	*Electrona rissoi*	2
	Pipefish	*Entelurus aequoreus*	1
	Balbo sabretooth	*Evermanella balbo*	1
	None	*Gonastoma elongatum*	3
	None	*Howella sherborni*	1
	None	*Lampadena speculigera*	
	Myctophidae	*Lampanyctus crocodilus*	2
	Myctophidae	*Lobianchia gemallari*	6
	Searsids	*Maulisia*	
	Pearlside	*Maurolicus muelleri*	16
	Myctophidae	*Myctophum punctatum*	7
	Greenland Argentine	*Nansenia groenlandica*	9
	Forgotten argentine	*Nansenia oblita*	
	Slender snipe-eel	*Nemichthys scolopaceous*	1
	Multipore Searside	*Normichthys operosus*	1
	None	*Notolepis rissoi*	6
	Myctophidae	*Notoscopelus krokeyeri*	19
	None	*Opisthoproctus soleatus*	1
	Shrimps	*Pandalidae*	5
	Silver Pomfret	*Pterycombus brama*	1
	Schnakenbeck's searside	*Sagamichthys schnakenbecki*	
	None	*Scopelosaurus lepidus*	
	None	*Searsia koefoedi*	
	Bean's sawtoothed eel	*Serrivomer beani*	
	None	*Sternoptyx diaphana*	1
	Scaly dragonfish	*Stomias boa*	1
	Myctophidae	*Symbolophoros veranyi*	4
	Greater Pipefish	*Syngnathus acus*	
	Dealfish	*Trachipterus arcticus*	4
	Bluntsnout smooth-head	*Xenodermichthys copei*	2
Demersal	Grey Gurnard	*Eutrigla gurnardus*	7
	Silvery Pout	*Gadiculus argentus*	4
	Norway Pout		1
Squid	Lesser flying squid	*Todaropsis elbanae*	
	Northern flying squid	*Todarodes sagittatus*	
	Short finned squid	*Omnastrephidae*	
	Unknown squid		9
Other	Jellyfish		1
	Octopus		4
		Total Number of Trawls	**23**
		Total number of Species:	**42**

Table 7. Irish survey time series. Blue whiting survey, March-April 2009.

Year	2004	2005	2006	2007	2008	2009
Target areas	2a 2b,2c	1 2a,2b	2b	1 2a,2b	1 2a,2b	1 2b
Age						
1	2.98	37.35	4.37	2.4	13.9	2.2
2	108.26	64.04	43.22	31	12.5	66.7
3	346.43	500.0	242.45	585	128.7	49.9
4	524.02	911.1	636.69	1681	1148.0	236.3
5	211.5	1010.0	342.56	1424	1445.7	1126.8
6	154.51	311.0	144.7	639.2	762.9	1444.3
7	72.76	111.0	50.41	219.3	200.0	563.6
8	34.71	69.9	18.02	126.2	33.1	117.6
9	4.06	20.5	0	14.6	0	31.4
10	15.61	0	0	5.4	0	12.9
11	0	7.87	0	0	0	0
12	0	0	0	0	0	0
TSB ('000t)	1,474.9	3,044.0	1,482.4	4,727.6	3,744.7	3,651.7
TSN (mils)	16,029.3	34,268.0	16,344.0	48,746.1	34,179.6	28,512.2
SSB ('000t)	1,471.9	3,001.0	1,478.1	4,725.2	3,726.4	3,647.9

Note: Target area 1: Hebrides & north Porcupine Bank; Target area 2a: western Porcupine Bank; Target area 2b: Rockall

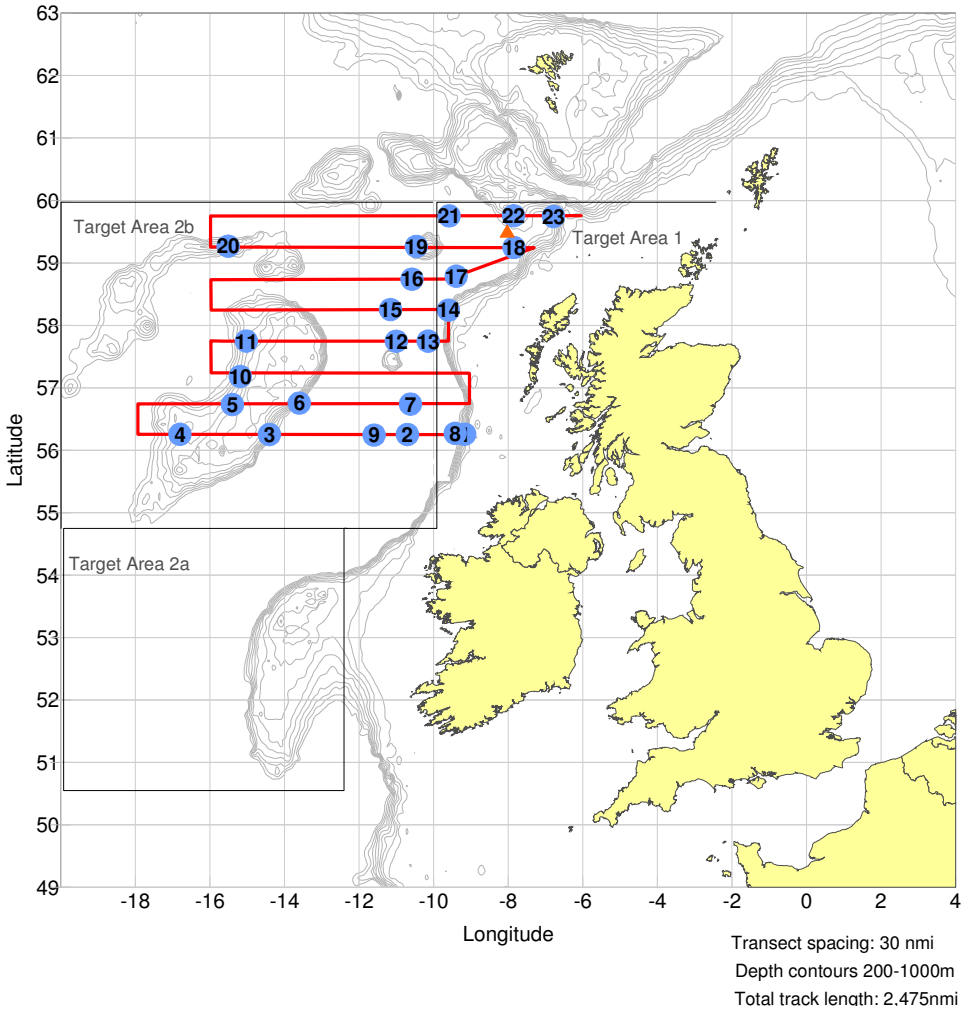


Figure 1. RV Celtic Explorer cruise track showing position of trawl stations and survey Target areas used during the analysis. Blue whiting survey, March-April 2009. Orange triangle represents intercalibration position with the RV *Magnus Henson.*

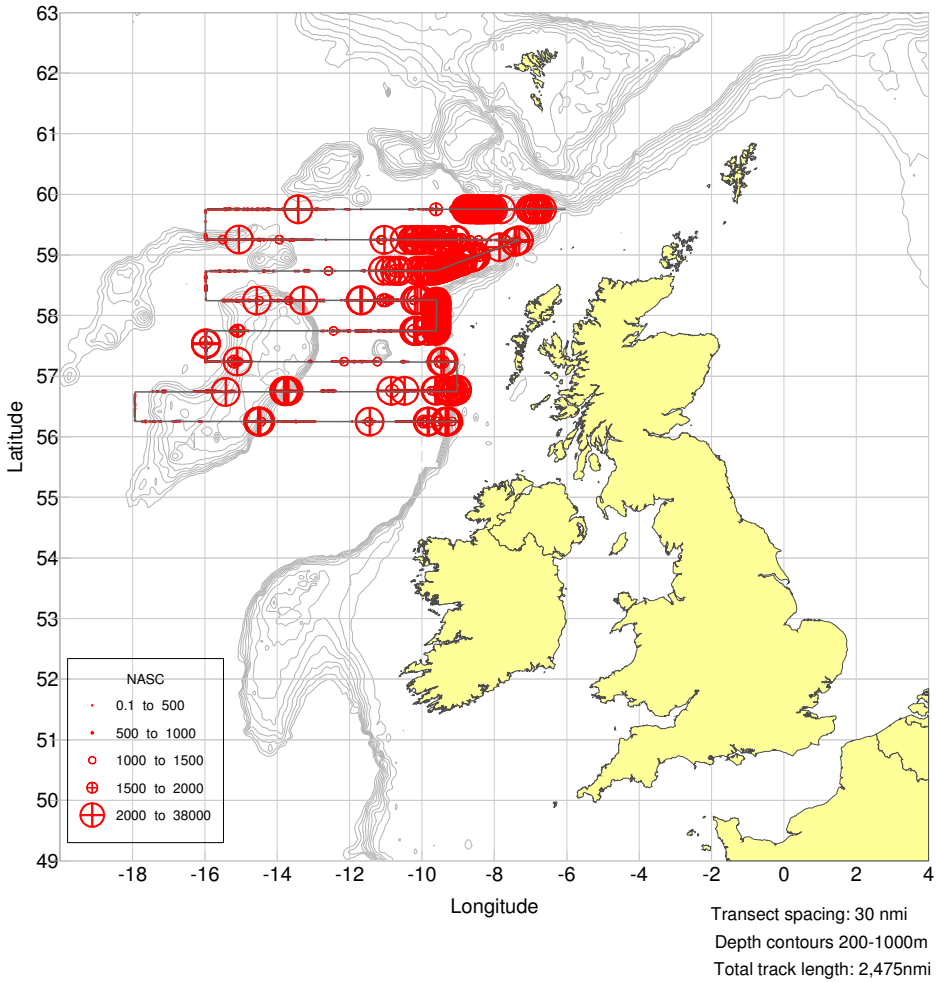
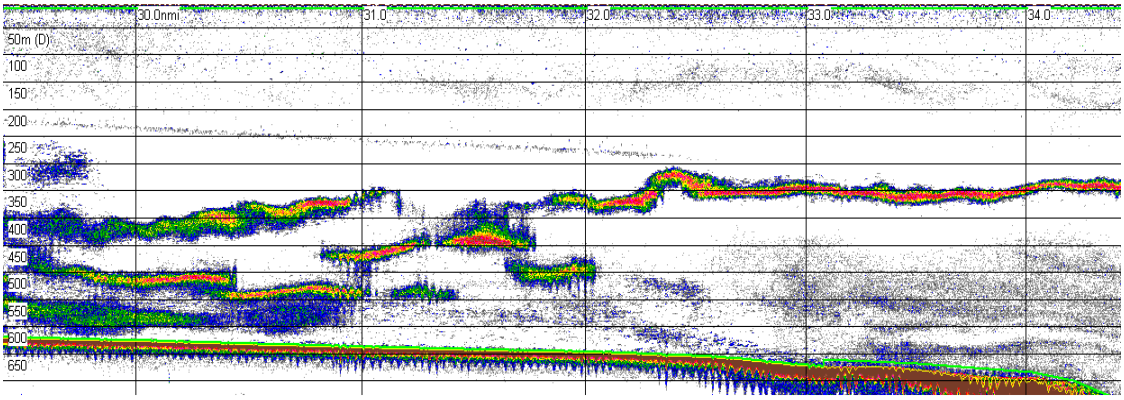
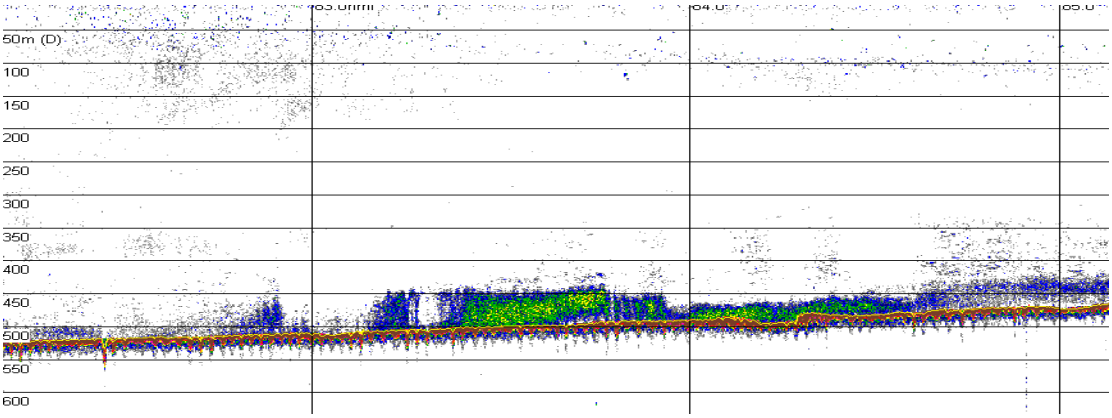


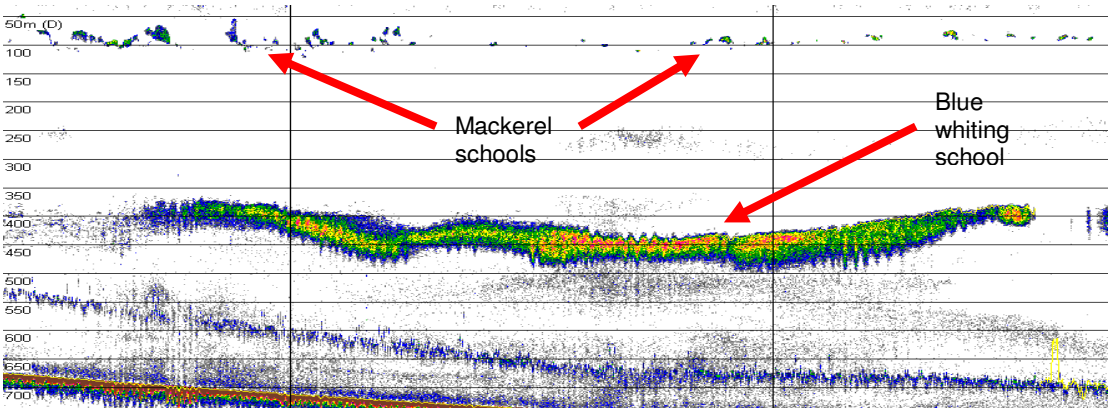
Figure 2. NASC distribution plot of blue whiting occurrence, circle size relative to NASC value. Blue whiting survey, March-April 2009.



a). *Highest density schools of blue whiting recorded during the survey (NASC value 123,771). Located on the Hebrides shelf prior to* ***Haul 14*** *(55°14N & 09°35W). Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*



b). *Low to medium density schools of blue whiting containing juveniles typical of those encountered along the south-western slopes of the Rockall Bank. Recorded prior to* ***Haul 5*** *(56°43N & 15°23W). Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*



c). *Surface schools of mackerel observed on 38kHz. Recorded prior to* ***Haul 20*** *on the north eastern slopes of the Hatton Bank. Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*

Figures 3a-c. Echotraces recorded on the ER60 echosounder with images captured from Echoview during the blue whiting survey, March-April 2009.

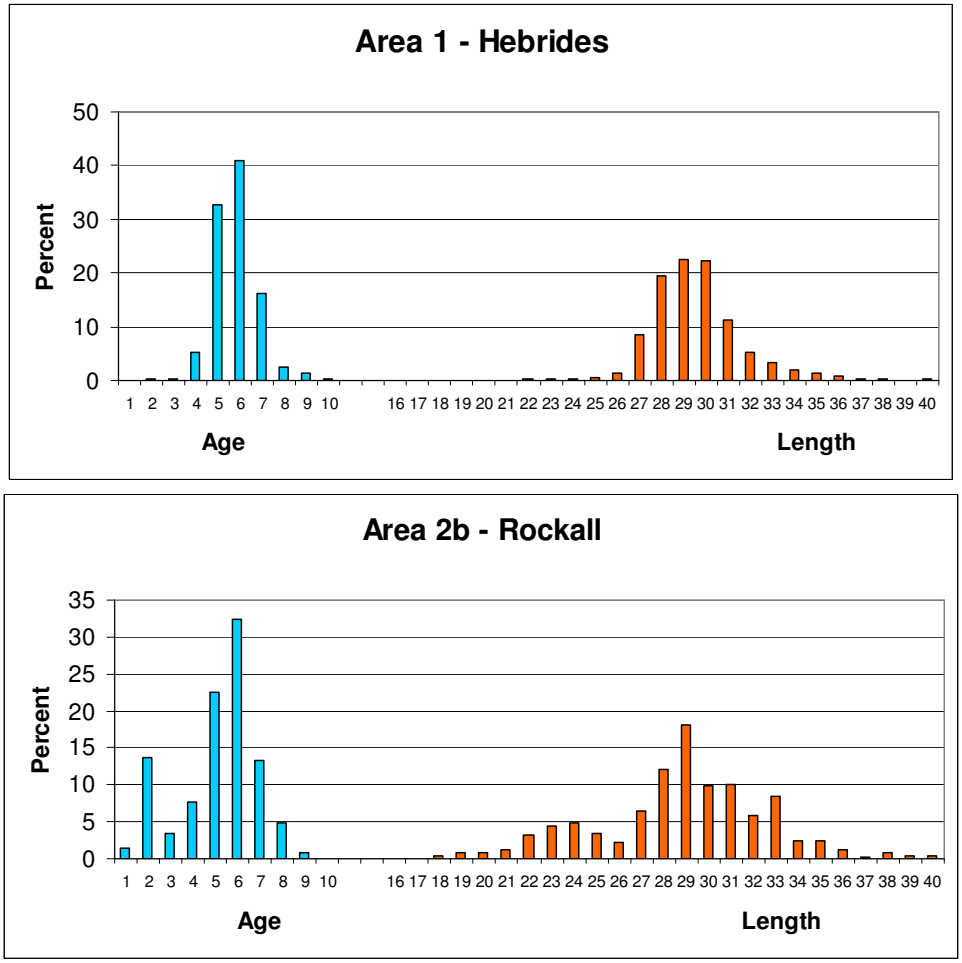


Figure 4. Age (left) and length (right) composition of blue whiting by sub area. Blue whiting survey, March-April 2009.

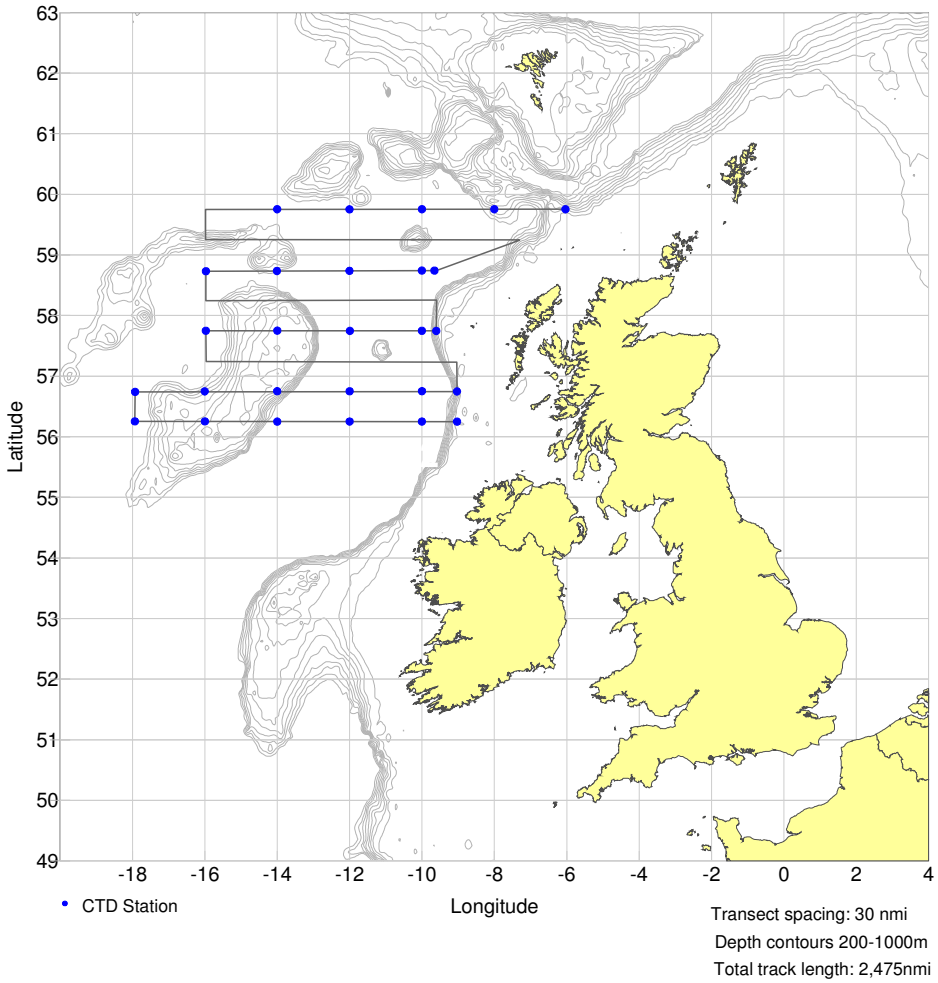


Figure 5. Oceanography stations taken as CTD casts. Open water stations were carried out to a maximum depth of 1000m. Blue whiting survey, March-April 2009.

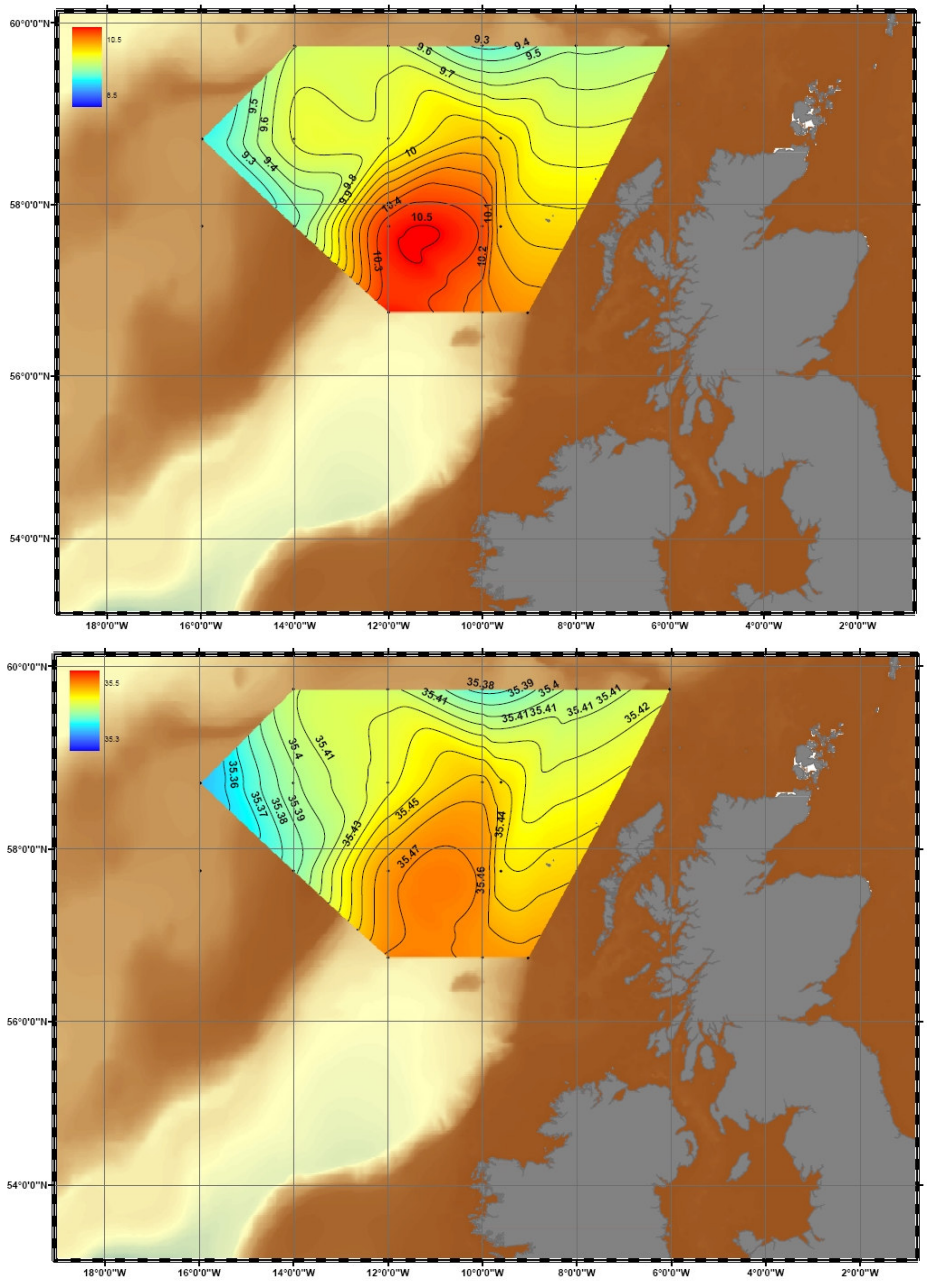


Figure 6. Horizontal temperature (top panel) and salinity (bottom panel) at 10m as derived from vertical CTD cast data. Blue whiting survey, March-April 2009.

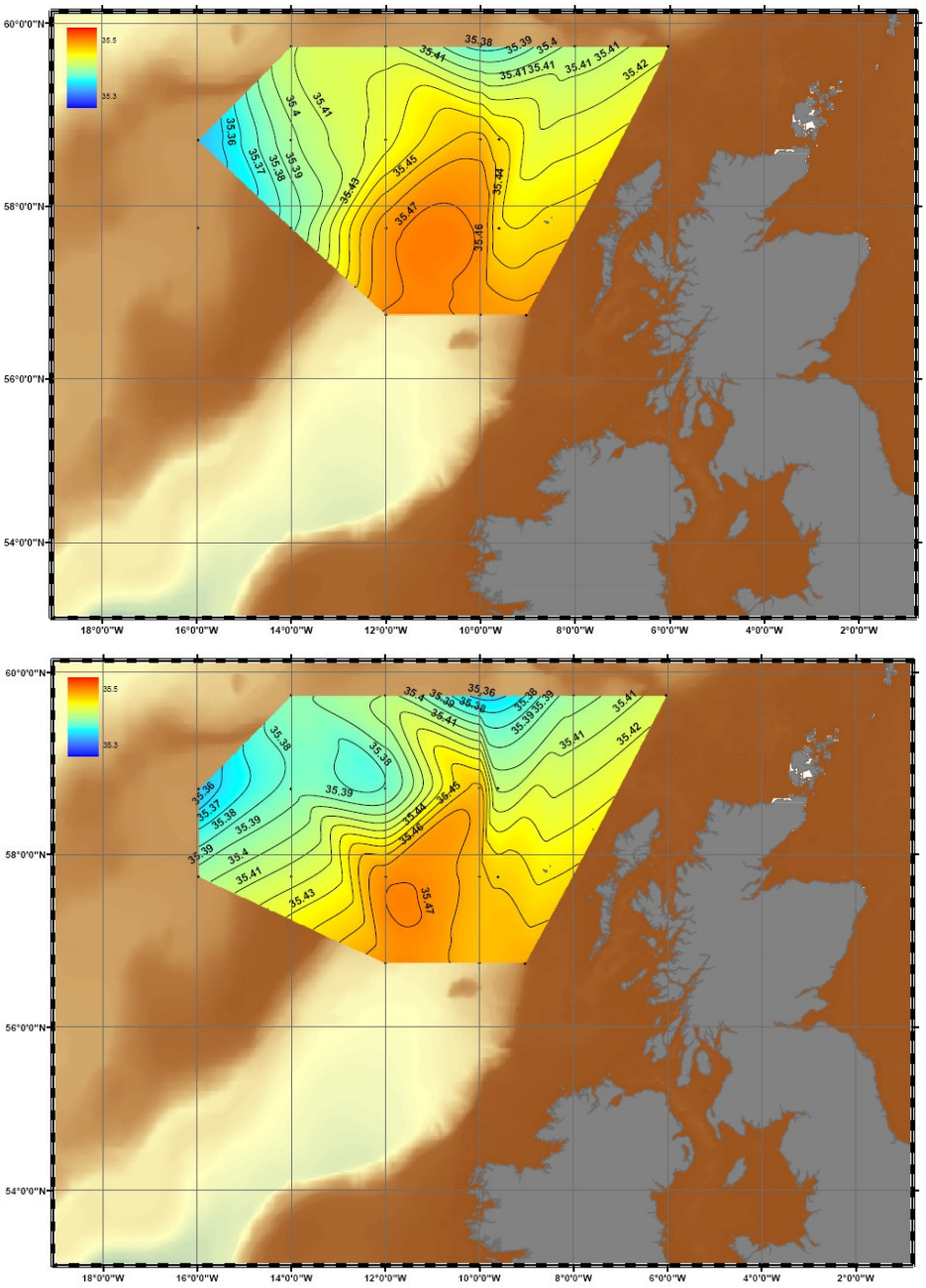


Figure 7. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD cast data. Blue whiting survey, March-April 2009.

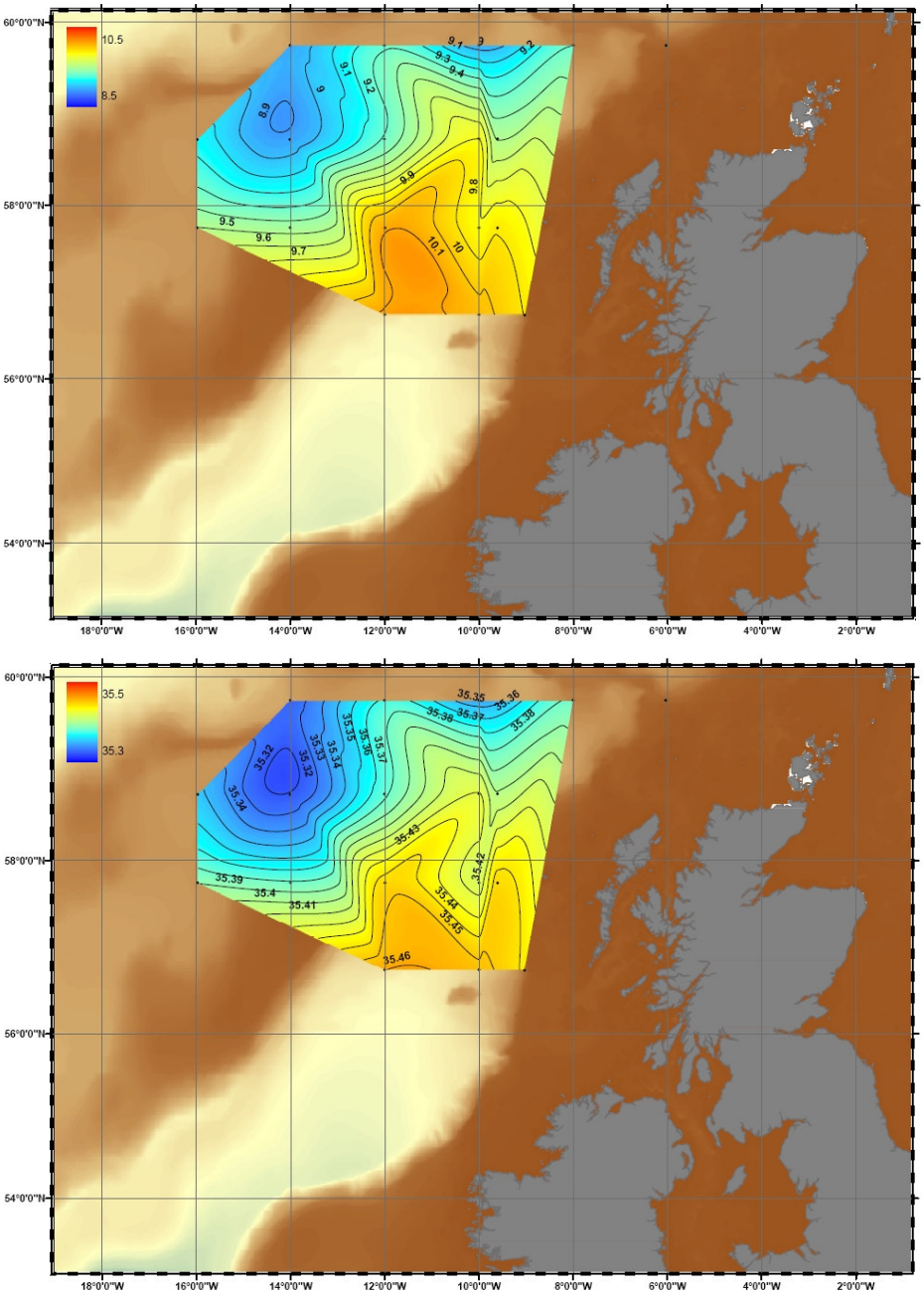


Figure 8. Horizontal distribution of temperature (top) and salinity (bottom) at 400m as derived from vertical CTD cast data. Blue whiting survey, March-April 2009.

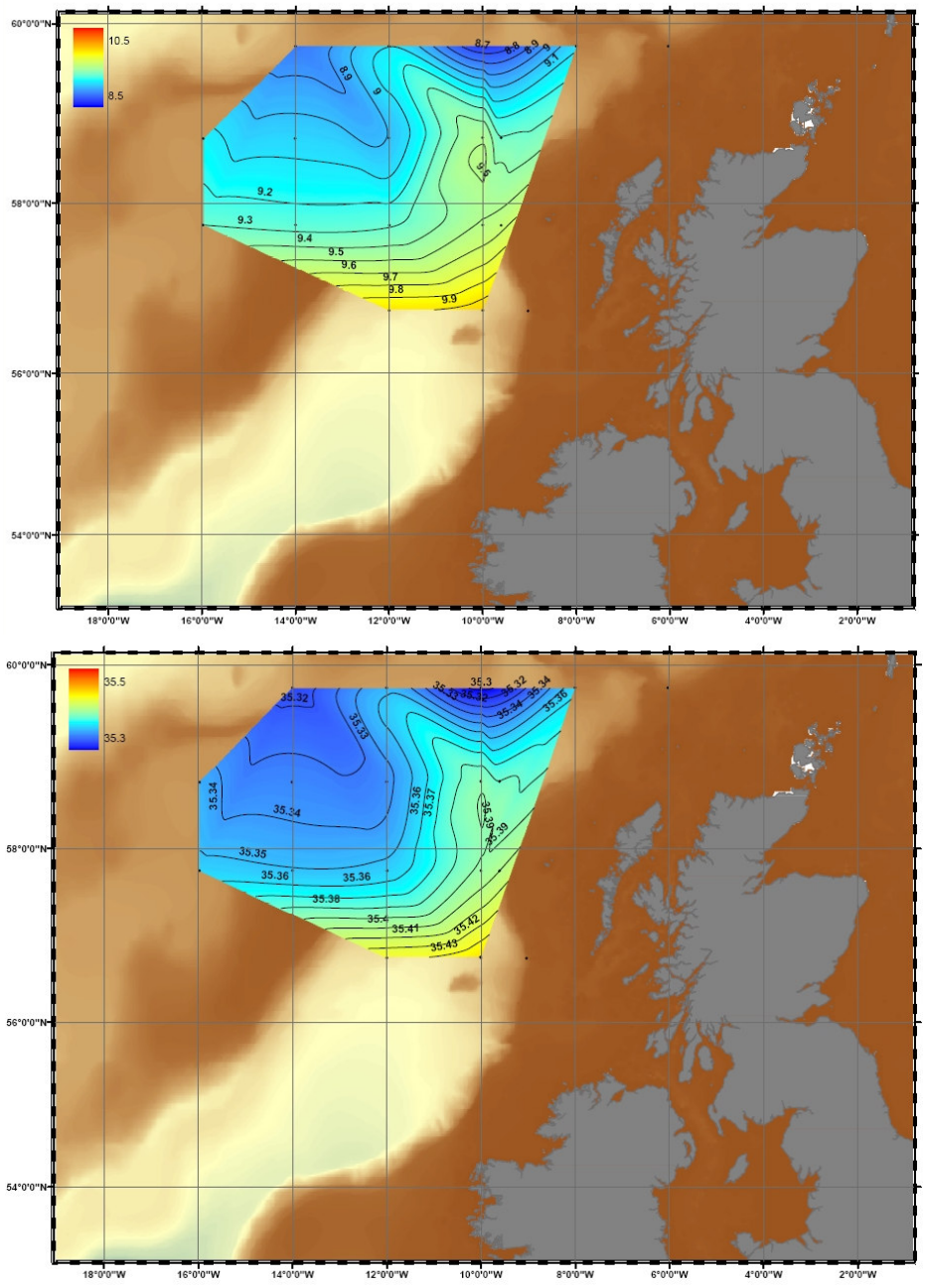
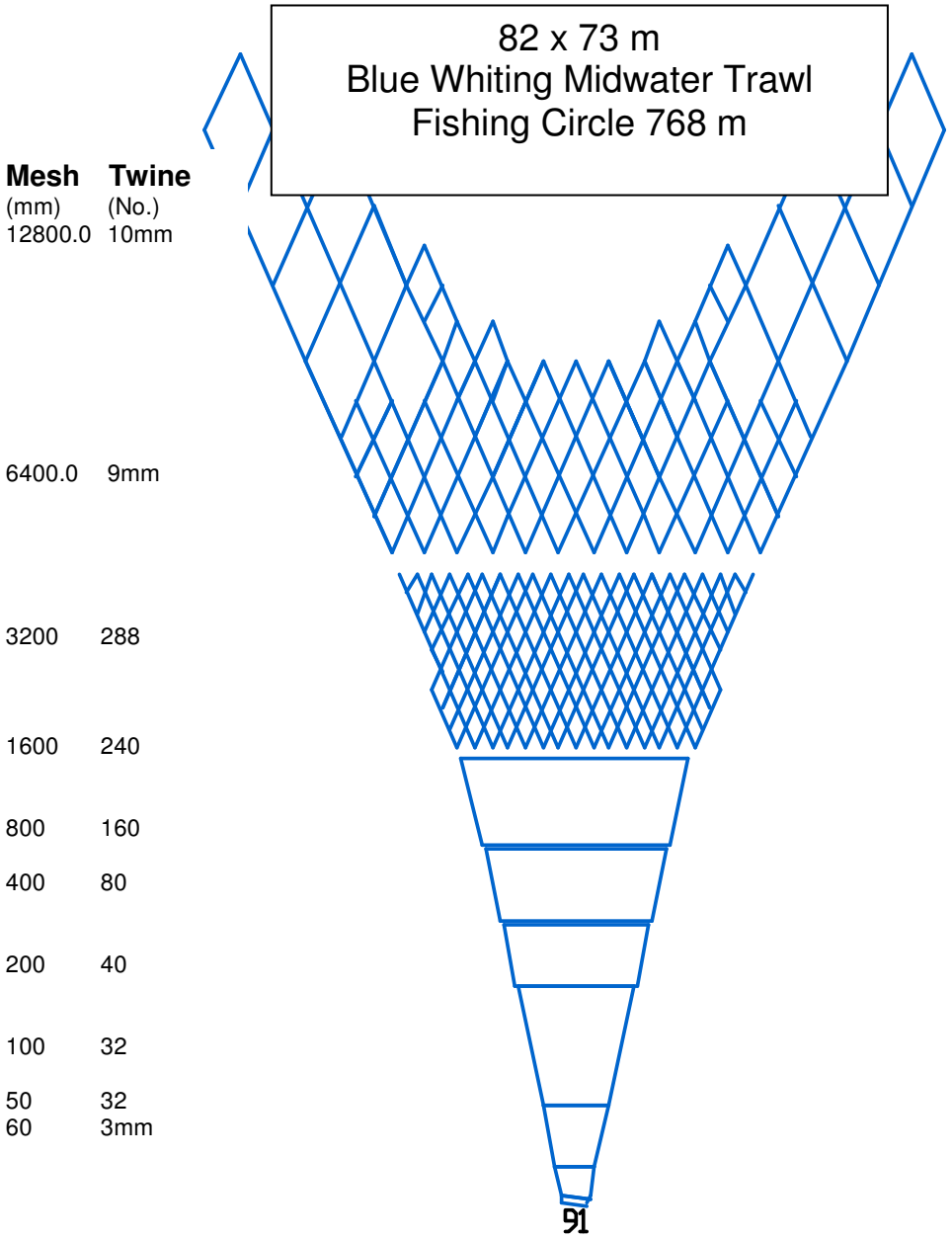


Figure 9. Horizontal distribution of temperature (top) and salinity (bottom) at 600m as derived from vertical CTD cast data. Blue whiting survey, March-April 2009.



Net specifics	
Clump weights:	1000 Kg per side
Trawl doors:	Polyice pelagic 6m² (750Kg weight in air)
Bridle length:	80m
Door spread:	170m
Vertical net opening:	50m

Figure 10. Pelagic midwater trawl employed during the Blue whiting Acoustic Survey, March-April 2009.

Appendix 1

Intercalibration exercise between the RV Celtic Explorer and the RV M. Heinason
Ciaran O'Donnell

Acoustic inter-calibration between R/V Celtic Explorer and R/V Magnus Heinason was conducted on 9 April at 06:00 to the northeast of the Rosemary Bank at position 59º 14 N & 008º 21 W. The first 10nmi transect was conducted with the M. Heinason acting as the lead vessel cruising at 8 knots in a south easterly direction. A second 10nmi transect was carried out with the Explorer as the lead vessel. Weather conditions were moderate with winds of 20-25 knots from the SE and a northerly swell of 2-2.5 m.

The main acoustic features in the area were (1) patchy schools of blue whiting in depths between 360 and 420 metres recorded intermittently throughout out the exercise, (2) a layer of presumed macro-zooplankton from depth 300 metres downward, partly mixed with the blue whiting layer, and (3) plankton and mesopelagic fish, in the uppermost 200 metres. The exercise was carried out based on the acoustic registrations of blue whiting only.

The inter-calibration was the run over 20nmi over 2 transects between 06:00-09:25 GMT. Vessels were cruising SSE at parallel courses, with the distance between the tracks being about 0.5 nm to take best advantage of the weather conditions.

Data analysis focused on acoustic densities (c, m^2/nm^2) allocated to blue whiting. On both vessels the routine procedures were followed for scrutinizing the data. Figure 1 shows acoustic densities recorded by the two vessels allocated to blue whiting. The recordings show variable agreement. Overall mean s_A values observed by both vessels were relatively low. The Magnus Heinason tended to record much higher acoustic densities during the first 1-9nmi than the Explorer on what appears to be similar registrations. At the end of the first transect the Celtic Explorer recorded its highest registration during the exercise whereas the Magnus Henson reported a zero value for the same log interval. During the first section of the second transect the Magnus Heinason recorded a single registration over 6 miles whereas the Celtic Explorer low but consistent values. Agreement was more closely aligned from 17-20nmi. Vessel cruise tracks are closely aligned for both vessels each of the 10nmi transects (Figure 2). The degree of variability between vessels over a closely aligned cruise track may be accounted for to a degree by spatial heterogeneity of the patchy schools encountered during the exercise.

At the end of the acoustic inter-calibration a comparative trawl exercise was undertaken. Both vessels turned and towed in parallel over the reciprocal course at a distance of about 0.5 nm apart. Celtic Explorer actively towed for 20 minutes at depths of 410–460 m and caught 400 kg of blue whiting. Magnus Heinason towed in the same depth for the same time and caught 7 kg of blue whiting.

The blue whiting in the catch of Celtic Explorer were larger overall as (mean length: 30.30.cm, range 22.5-37 cm) compared to the blue whiting in the catch of Magnus Heinason (mean length: 28.25cm, range 20-35cm) as shown in Figure 3. It is difficult to draw any conclusions from the trawl data due to the large difference in the weight of the catch. As described earlier the distribution of schools within the area was patchy. In this case it appears that the Explorer encountered one of these schools and the Magnus Heinason did not.

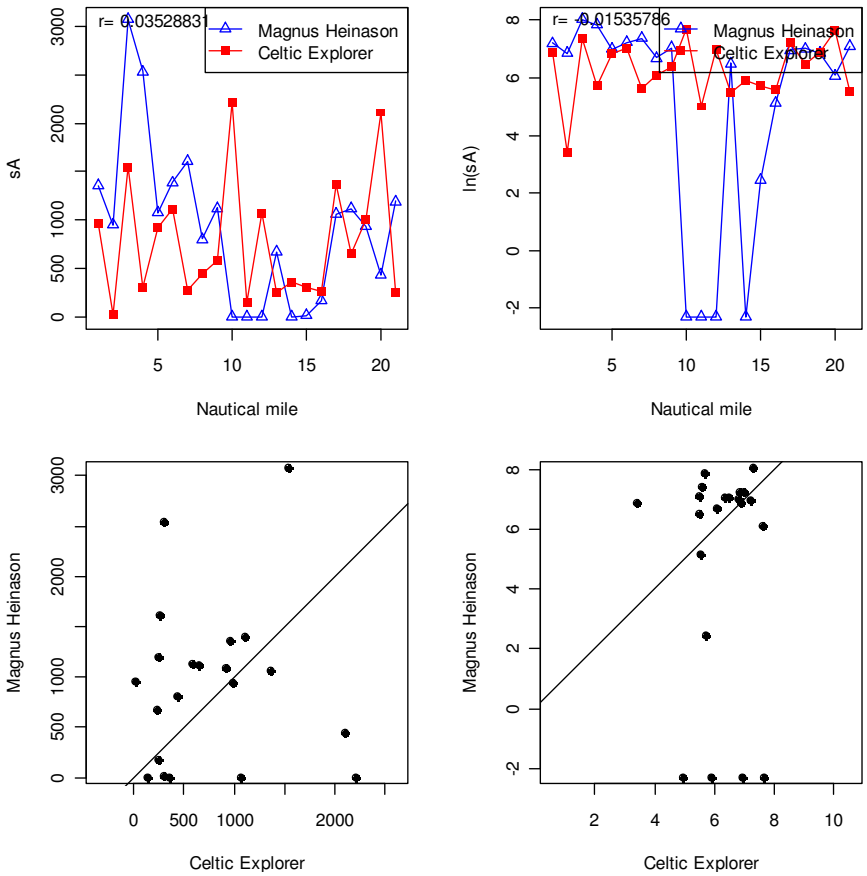


Figure 1. Comparison of blue whiting acoustic densities recorded by Magnus Heinason (open triangles) and Celtic Explorer (squares). The lower panels give same data as scatterplots. The diagonals are drawn as continuous lines.

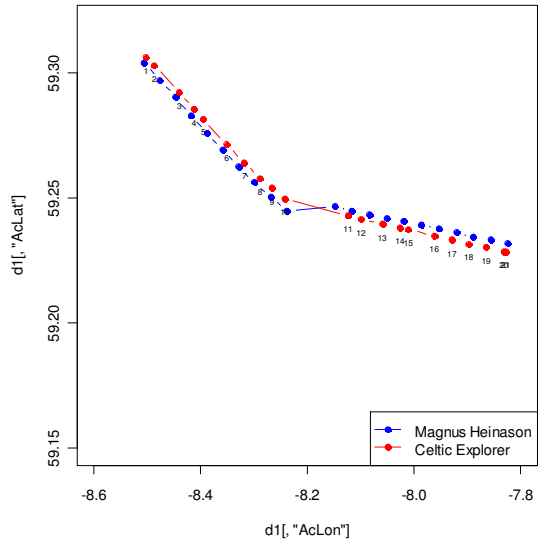


Figure 2. Intercalibration track followed by the Magnus Heinason (blue diamonds) and Celtic Explorer (red diamonds).

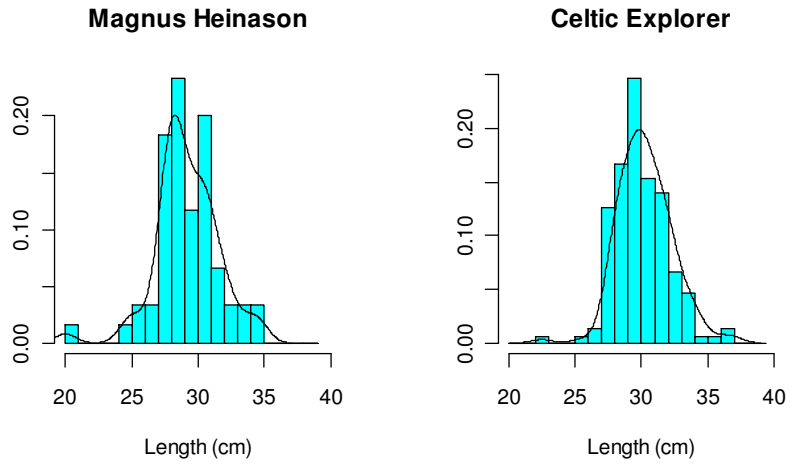


Figure 3. Length distributions from the trawls hauls by Magnus Heinason (mean length 28.25cm) and Celtic Explorer (mean 30.30cm). Smoothing is obtained by normal kernel density estimates.