FSS Survey Series: 2010/01

Blue Whiting Acoustic Survey Cruise Report

March 19- April 7, 2010

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1 Introduction

Acoustic surveys on blue whiting (*Micromesistius poutassou*) spawning aggregations 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 the main spawning grounds to the west of Ireland and Britain. Since 2004, an International coordinated survey program has expanded 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 from the southern Porcupine Bank area northwards to the Faroe Shetland Ridge including offshore areas as 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 Working Group of Northern Pelagic Ecosystem Surveys (WGNAPES).

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 2010 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 RV G.O. Sars (Norway). The total combined area coverage extended from the Faroe Islands in the north (60.30°N) to south of Ireland (52°N), with east -west extension from 6°-18°W.

International survey participants meet shortly after the survey to present data and produce a combined relative abundance and biomass index the blue whiting spawning stock in western waters. The combined survey report is presented annually at the WGNAPES meeting held in August and made available to the WGWDS assessment group.

2 Materials and Methods

2.1 Scientific Personnel

Name	Institute	Capacity
Ciaran O'Donnell (SIC)	FSS	Acoustics
Eugene Mullins	FSS	Biologist
Ryan Saunders	FSS	Acoustics
Susan Beattie	FSS	Biologist
Kieran McCann	FSS	Biologist
Graham Johnston	FSS	Acoustics
Niels Jorgen Pihl	DFU	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 Survey design and area coverage

The survey covered the primary core spawning area of blue whiting to the west of Scotland and the Western Isles (Figure 1). Coverage extended from the shelf slopes (250m) westward to the western flanks of the Rockall Bank. The survey was carried out in continuity from south to north.

Transect design and effort allocation was pre- agreed for each vessel at the last WGNAPES. It was agreed that survey timing should be compressed into a 21 day window beginning as close as possible to the March 17 to allow for close spatiotemporal alignment of vessels to reduce the effects of double counting. A parallel transect design was used to allow transect interlacing in co-surveyed target areas (east-west orientation). Offshore, transects extended to the 18°W. Transect spacing was set at 30nmi for individual vessels and maintained throughout the survey.

In total, the Irish survey covered 54,000nmi² using 2,260nmi of transects. Survey design and methodology adheres to the methods laid out in the WGNAPES acoustic survey manual.

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the acoustic equipment are based on established settings employed on previous surveys (O'Donnell *et al.,* 2004) and are shown in Table 1.

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 March 19 at the start of the survey. Weather conditions were calm with moderate easterly winds. The results of the 38kHz transducer are shown in Table 1.

2.3.3 Inter-vessel calibration

Inter-vessel acoustic calibrations are carried out when participant vessels are working within the same general area and time and weather conditions allow for an exercise to be carried out. The procedure follows the methods described by Simmonds & MacLennan 2007.

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 4.8) 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.

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 or lower.

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 but also on known habitat preference and 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 and 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 (Figure 5). 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, biological data and oceanographic measurements from the participating vessels were uploaded to the WGNAPES online database and used to produce combined assessments of the blue whiting after the survey via correspondence.

3 Results

3.1 Blue whiting abundance and distribution

A total of 13 directed trawls were carried out during the survey (Figure 1, Table 2). Of this 10 contained blue whiting as the dominant species both by weight and numbers. The second most frequently encountered species was the Myctophid *Symbolophoros veranyi* present in 69% of hauls (Table 6). Mesopelagic species are often taken as a bycatch when targeting blue whiting at depth usually as the net is being shot/hauled through the 50-200m surface layers.

Expansive daytime layers of mesopelagic species were encountered during the survey with some schools extending to over 120m in vertical depth. The highest abundance was observed in the north and northwest survey area around the Hatton and Rosemary Banks (Figure 3b). During the 2009 survey this area contained a high abundance of surface mackerel schools that were noticeably absent in 2010. Mackerel schools had been actively feeding in this mesopelagic layer and in particular on Pearlsides (*Maurolicus muelleri*) as observed from stomach contents analysis.

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)	3,946.3	3,866.5	658.5	654.8
Rockall (2b)	822.0	817.2	130.6	130.3
Total	**4,768.4**	**4,683.7**	**789.2**	**785.1**

The Hebrides area was found to contain 84% of the total stock biomass (TSB) and 83% of the total abundance (TSN). The Rockall sub area contained the remaining 16% of biomass and 17% of abundance. During the 2009 survey a similar distribution of biomass between target areas was observed; Hebrides 81% and Rockall 19% respectively.

However, the observed TSB during 2010 was 78% lower than observed in 2009 down from 3.652 million tonnes in 2009 to 0.79 million tonnes in 2010 (Tables 3, 4 & 7). In total the survey covered 56,000nmi² which was just over 6% lower than in 2009. Area coverage in the core Hebrides area which contained the largest proportion of stock biomass remained unchanged. The reduction in area coverage occurred in the Rockall sub area and was a conscious decision after consultation with co-surveying vessels due to the absence of blue whiting registrations.

Biomass (TSB) in the Hebrides area was down 78% from 2.9 million tonnes in 2009 to 658,530t in 2010. The Rockall sub area contained the remaining 22% of the 2010 TSB down by 68% from 703,000t in 2009 to 130,640t in 2010. However, it is important to note that within the Rockall sub area 74% (96,400t) of the total biomass was observed in the Rockall Trough (rectangle 5612, Table 3) as an extension from the registrations from the shelf break within the Hebrides core area (Figure 2). The remaining 34,240t was attributed to registrations observed on the slopes of the Rockall Bank. Trawl allocations for the Rockall sub area were based on 2 samples from the Rockall Trough and not from the Rockall Plateau itself and so are not regarded as representative of the true composition. Previous surveys have yielded immature blue whiting on Plateau and slope areas which are thought to be resident residual population.

Overall the 2010 estimate is significantly lower than in 2009 and represents the lowest in the current time series (Table 7).

3.1.3 Blue whiting distribution

Blue whiting registrations were mainly distributed along the eastern shelf slopes of the Hebrides and in the Rockall Trough (Figure 2). Very few schools were observed on the slopes of the Rockall Bank.

Distribution of schools appeared to be centred further south than at the same time in 2009 and compressed longitudinally along the shelf break. Overall, the region from 56º30-57º30N along the shelf break and westwards contained the highest number of schools and was the focus of commercial fishing by Dutch and Norwegian vessels during the survey. Individual school density was the highest observed in this area during the survey (Figure 3a). Further northwards schools were distributed much closer to the shelf edge within 10nmi in most cases. The usual hotspot of distribution from the shelf edge west to the Rosemary Bank contained significantly less blue whiting than in previous years.

In the Rockall sub area blue whiting registrations were almost exclusively found in the Rockall Trough, those occurring around the Bank itself were of very low density (Figure 3c). The fishery which normally develops in March on aggregations along the southwest and western slopes of the Rockall Bank was not evident in 2010. Some Icelandic and Russian vessels were observed searching in the area but as compared to 2009 fishing effort was much reduced.

The G.O. Sars co-surveyed the same target areas as covered by the Explorer during the same time window. A good temporal alignment of approximately 36hrs time lag was achieved between vessels and both vessels report a similar pattern of blue whiting distribution.

3.1.4 Blue whiting stock structure

During the survey 450 fish were aged with length, weight, sex, maturity and stomach fullness index data recorded. A further 1,350 fish were measured and weighed. Analyses of age samples were found to contain individuals of 1 to 13-years old.

The stock structure within the surveyed area revealed the stock to be dominated by 7-year old fish (2003 year class) and is consistent with commercial landings sampled in Killybegs. This dominant year class represented 37% of the stock in numbers and 38% by weight (Table 5). Eight and 6-year old fish (2002 and 2004 year classes) were also well represented ranking second and third and accounting for 27% and 21% of biomass and 25% and 22% of numbers respectively. Combined these three age classes represent 86% of the total biomass and 83% total abundance of the stock. The three strong year classes continue to form the backbone of the stock during the continued period of very poor recruitment.

Maturity analysis of samples revealed that no 1-year old fish were mature but 100% of 2-year old (2008 year class) fish sampled were mature an increase from 96% in 2009. Of the mature fish sampled a high proportion were spawning or in a pre-spawning state as compared to the same time period in 2009 where most individuals sampled were spent.

Immature 1-year old (2009 year class) blue whiting accounted for 1.8% of numbers and 0.5% of the total biomass and were distributed north of 58ºN along the shelf edge in the Hebrides core area (Figure 4, Tables 5). The contribution of 1-year old fish to the TSB is slightly higher than observed in recent years, with the exception of 2008, and could be an indication of an emerging stronger year class (Table 7). The total biomass and abundance for immature blue whiting was 4,085t (1-year old) and 84.65 million individuals respectively. Similar observations of juvenile fish were reported further north by the Faroese vessel working in the Faroe/Shetland sub area.

As only a single sample containing no immature fish was used to determine the Rockall abundance estimate all fish were regarded as mature and so the resident immature biomass on the Rockall Bank is not represented.

3.2 Oceanography

Overall 42 CTD casts were carried out during the survey. Open water stations were conducted to a maximum of 1,000m. Horizontal profiles of temperature and salinity from 10m subsurface to 600m are shown in Figures 6-9.

As compared to 2009 the most obvious change is in the western Rockall area where water temperature was 0.5ºC cooler and salinity was reduced (Figure 9). The presence of colder less saline water may indicate the increased influence of the subpolar gyre in this area. Work carried out by Hatun *et al.* (2009) showed a positive correlation between blue whiting distribution and gyre strength. In years of strong or increased gyre influence colder less saline water is found over the Rockall Plateau. Concurrent with this, spawning aggregations are found east and further south along the shelf edge and away from the areas of fluctuating temperature and salinity. As no spawning blue whiting were observed around the Rockall Bank and distribution was centred further east and southwards than in 2009 this may be an indicator of the influence of an increase in subpolar gyre strength in 2010.

3.2 Inter-vessel calibration

No inter vessel calibration was carried out due to time constraints brought on by prolonged poor weather conditions at the end of the survey.

4 Discussion and Conclusions

4.1 Discussion

Overall, the survey was a success. Planned cruise tracks were modified during the survey based on the distribution of blue whiting and available time remaining. Weather conditions slowed progress for 5 days towards the end of the survey and almost 24hrs was lost mid way though due to an unforeseen RAF training exercise.

Communication between vessels and temporal progression for most participating vessels was good ensuring synoptic coverage was achieved in part. However, the 15 day late start of the Russian vessel did not allow for all survey data to be combined into a single estimate.

In 2010 abundance was significantly lower than in 2009 and was the lowest in the current comparable time series. Peak spawning in 2009 was considered early as the bulk of spawning stock biomass was located in the northeast of the survey area and was actively migrating after spawning. In 2010 peak spawning was considered to be later by around 2-3 weeks as much of the stock was located further south and still actively spawning. However, this alone cannot account for the significant reduction in biomass observed this year.

No samples were taken in the vicinity of the Rockall Bank and as a result no biological information was available to validate low density registrations observed on the shelf slopes. The application of biological data from the Rockall Trough although representative of registrations in that particular locale were not considered representative of those of the Bank area itself due to the lack of juvenile fish. As a result the estimate for the Rockall Bank should be treated with caution in terms of biomass and age structure.

Juvenile 1-year old blue whiting were observed north of 58ºN only. Juveniles were also observed by the Faroes vessel further north in the Shetland/Faroes sub area. The presence of juveniles in this area is consistent with previous surveys. However, in 2010 1-year old fish were better represented than in the recent comparable time series and should be monitored for continued signs of a strong emerging year class in quarter one surveys in the Norwegian Sea.

4.2 Conclusions

This survey provides a snapshot of abundance on the grounds at the time of surveying and is regarded as a relative and not absolute index of abundance estimate. As the survey is fixed in time and geographical location from year to year changes in peak spawning can introduce noise in survey abundance index as a match/mis-match of survey timing and peak abundance within the survey area. Due to the geographical range of the stock during spawning it is impossible for a single survey vessel to contain the stock within its boundaries. Overall it is agreed that the combined survey contains the stock well ensuring a good degree of confidence in the abundance indices.

In 2010 blue whiting were noticeably absent to the west of the Rockall Bank but did appear in the mid Rockall Trough. Information from Norwegian commercial vessels suggests that spawning aggregations of older/larger blue whiting appeared to the west of St. Kilda in early March and earlier than previously observed. Distribution was noticeably compressed longitudinally along the eastern shelf break in a more eastward migration pathway. Oceanographic conditions in the area show a colder and less saline body of water present to the west of the Rockall plateau that may suggest increased influence of the subpolar gyre. The strength of the gyre is known to affect the spawning dynamic of blue whiting and may be the casual link to the more eastward orientation of the stock and the later than average peak spawning in 2010.

The stock structure is still dominated by 3 strong year classes. Recruitment remains poor at present but with the possibility of an emerging year class to replace the older larger fish now leaving the stock.

Acknowledgements

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

Our special thanks also go to our visiting scientist Neils Jorgen Pihl (Denmark) for his help and hard work during the survey.

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Table 1. Survey settings and calibration report for the Simrad ER60 echosounder. Blue whiting survey, March-April 2010.

Vessel :	R/V Celtic Explorer	Date :	19/03/2010
Echo sounder :	ER60 PC	Locality :	Killary Harbour
Type of Sphere :	WC-38,1	TS_{Sphere}: (Corrected for soundvelocity or t,S)	-33.50 dB
		Depth(Sea floor) :	32 m

Calibration Version 2.1.0.11

Comments:
19.03.10

Reference Target:

TS	-33.50 dB	Min. Distance	10.00 m
TS Deviation	5 dB	Max. Distance	20.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.71 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.01 deg	Along. Beam Angle	6.97 deg
Athw. Offset Angle	- 0.02 deg	Along. Offset Angl	-0.06 deg
SaCorrection	-0.63 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

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

Sounder Type:
ER60 Version 2.2.0

TS Detection:

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

Environment:

Absorption Coeff.	10.0 dB/km	Sound Velocity	1484.9 m/s

Beam Model results:

Transducer Gain =	25.84 dB	SaCorrection =	-0.69 dB
Athw. Beam Angle =	7.04 deg	Along. Beam Angle =	6.99 deg
Athw. Offset Angle =	-0.03 deg	Along. Offset Angle=	-0.07 deg

Data deviation from beam model:
RMS = 0.11 dB
Max = 0.29 dB No. = 74 Athw. = 3.4 deg Along = -3.2 deg
Min = -0.62 dB No. = 103 Athw. = 3.6 deg Along = -3.5 deg

Data deviation from polynomial model:
RMS = 0.07 dB
Max = 0.29 dB No. = 104 Athw. = 3.8 deg Along = -3.5 deg
Min = -0.42 dB No. = 103 Athw. = 3.6 deg Along = -3.5 deg

Comments :
Flat calm conditions
Wind Force : 16 kn. **Wind Direction :** S (180 degrees)
Raw Data File: \\Expfileclstr\ER-60_Data\BWAS_2010\RAW ER60 Files\Calibration\BWAS_Mar_2010-D20070328-T135915.raw
Calibration File: \\Expfileclstr\ER-60_Data\ER-60\Calibrations_2010\CBWAS 2010\38 KHZ

Table 2. Catch composition, time and location of trawl hauls. Blue whiting survey, March-April 2010.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Sampled (Kg)	Blue Whiting %	Mackerel %	Meso %	Herring %	Others %
1	20.03.10	56 24.10	009 57.67	21:06	>1500	420	200	141.7	99.8		0.2		
2	21.03.10	56.24.32	014.17.44	20:35	750	640	6.3	6.3	25.6	0.1	10.9		57.1
3	23.03.10	56 54.44	011 45.25	23:50	>2200	380	850.0	134.3	99.9		0.1		
4	24.03.10	57 23.15	010 00.02	22:38	>1850	400	1000.0	130.0	99.9		0.1		
5	25.03.10	57 24.10	010.36.29	07:31	>1800	400	1000.0	131.4	99.9		0.1		
6	27.03.10	57 53.27	009 37.83	20:41	540	420	154.6	154.6	99.7		0.2		0.1
7	28.03.10	58 23.86	009 16.47	10:45	550	390	200	122.5	96.7		0.4		2.9
8	29.03.10	58.23.80	015.57.65	14:00	1180	410	83	83.0			2.0		98.0
9	31.03.10	58 52.91	008 53.30	18:47	>1500	100	8.6	8.6					100.0
10	31.03.10	58 53.90	008 30.92	22:01	>1500	475	2000	126.8	100.0				
11	01.04.10	58 56.08	007 56.03	04:16	>2000	430	1500.0	120.3	99.8		0.2		
12	03.04.10	59 54.07	006 30.51	11:45	500	480	233.9	233.9					100.0
13	03.04.10	59 54.12	006 34.76	14:41	520	500	800	124.5	98.4		0.0		1.5

Note: “Others” was used to represent fish and non-fish species occurring in the catch see Table 6.

Table 3. Breakdown of abundance estimate by sub area and rectangle. Blue whiting survey, March-April 2010. **(**Note: Target area 1: Hebrides & north Porcupine Bank; Target area 2a: western Porcupine Bank; Target area 2b: Rockall)

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	179.2	1500	1	30.30	877.12	312.25	148.6	46.40
5610	450.0	2160	3	29.80	909.52	1626.53	155.4	252.76
5708	134.2	1620	4 & 6	30.10	889.87	220.91	167.4	36.98
5710	199.6	480	5	30.60	858.48	662.93	184.1	122.05
5808	152.3	2100	7 & 10	29.20	950.75	363.09	145.9	52.97
5810	14.7	300	7 & 10	29.20	950.75	52.65	145.9	7.68
5906	206.9	1980	13	30.20	883.46	445.29	197.3	87.86
5908	81.4	220	13	30.20	883.46	262.68	197.3	51.83
5910	-	-	-	-	0.00	0.00	0.0	0.000
Target Area 1					**Sub area total**	**3946.3**		**658.5**
5612	171.6	1230	3	29.80	909.52	620.31	155.4	96.40
5614	44.1	845	3	29.80	909.52	53.06	155.4	8.25
5616	26.6	264	3	29.80	909.52	47.88	155.4	7.44
5712	-	-	-	-	0.00	0.00	0.0	0.00
5714	45.5	1320	5	30.60	858.48	100.79	184.1	18.56
5716	-	-	-	-	0.00	0.00	0.0	0.00
5812	-	-	-	-	0.00	0.00	0.0	0.00
5814	-	-	-	-	0.00	0.00	0.0	0.00
5912	-	-	-	-	0.00	0.00	0.0	0.00
5914	-	-	-	-	0.00	0.00	0.0	0.00
Target Area 2b					**Sub area total**	**822.0**		**130.6**
					Grand total	**4768.4**		**789.2**

Table 4. Breakdown of abundance and biomass by survey sub area as used during analysis. Blue whiting survey, March-April 2010.

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	25,200	79.8	3866.5	3946.3	3.8	654.75	658.5	29.96	164.00	26.1
2b	28,800	4.8	817.2	822.0	0.3	130.33	130.6	30.21	169.78	4.5
Total	54,000	84.6	4683.71	4768.4	4.1	785.1	789.2	28.89	120.65	14.6

Table 5. Aged stratified estimate of surveyed stock abundance and biomass. Blue whiting survey, March-April 2010.

	Age (yrs) and year class										TSN	TSB	Mn Wt
Length	1	2	3	4	5	6	7	8	9	10+			
(cm)	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	(Mils)	('000t)	(g)
13.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.39	0.02	15
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
15	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.39	0.03	23
15.5	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.77	0.06	21.5
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
16.5	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.77	0.08	27.5
17	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.39	0.04	28
17.5	6.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.88	0.28	31.5
18	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.31	0.30	36.3
18.5	4.6	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.93	0.26	37.8
19	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.74	0.47	39.9
19.5	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.89	0.21	43.2
20	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.54	0.26	46.5
20.5	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.49	0.37	49.6
21	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.39	0.07	52.0
21.5	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.83	0.70	65.0
22	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.39	0.09	62.0
22.5	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.83	1.67	64.8
23	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.72	0.35	75.0
23.5	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.08	0.17	82.0
24	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.19	0.53	85.3
24.5	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.08	0.17	80.0
25	0.0	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.46	0.55	100.0
25.5	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.74	0.07	100.0
26	0.0	0.0	0.0	8.9	8.9	0.0	0.0	0.0	0.0	0.0	17.86	1.89	106.0
26.5	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	22.02	2.37	107.8
27	0.0	0.0	0.0	21.5	43.0	0.0	0.0	0.0	0.0	0.0	64.47	7.89	122.4
27.5	0.0	0.0	33.5	16.7	33.5	50.2	16.7	0.0	0.0	0.0	150.65	19.25	127.8
28	0.0	0.0	0.0	0.0	12.6	63.1	100.9	12.6	0.0	0.0	189.15	25.59	135.3
28.5	0.0	0.0	12.4	12.4	37.2	86.8	86.8	12.4	0.0	0.0	247.95	33.45	134.9
29	0.0	0.0	0.0	14.3	14.3	186.5	200.8	71.7	28.7	14.3	530.78	79.25	149.3
29.5	0.0	0.0	0.0	23.7	23.7	82.9	284.4	106.6	35.5	11.8	568.72	88.66	155.9
30	0.0	0.0	0.0	11.5	11.5	196.3	334.9	150.1	11.5	11.5	727.61	118.38	162.7
30.5	0.0	0.0	0.0	0.0	0.0	93.5	175.2	140.2	35.0	0.0	443.89	73.51	165.6
31	0.0	0.0	0.0	0.0	7.8	109.3	218.6	148.3	0.0	0.0	484.03	86.54	178.8
31.5	0.0	0.0	0.0	0.0	16.1	64.3	88.4	96.4	0.0	0.0	265.22	48.28	182.0
32	0.0	0.0	0.0	0.0	7.2	28.7	86.2	143.7	7.2	0.0	273.11	52.90	193.7
32.5	0.0	0.0	0.0	0.0	0.0	45.1	90.1	123.9	11.3	0.0	270.31	52.41	193.9
33	0.0	0.0	0.0	0.0	0.0	26.3	8.8	105.4	8.8	0.0	149.31	30.89	206.9
33.5	0.0	0.0	0.0	0.0	0.0	7.8	31.1	38.9	23.4	0.0	101.20	21.94	216.8
34	0.0	0.0	0.0	0.0	0.0	0.0	6.0	18.0	12.0	0.0	36.06	8.80	244.1
34.5	0.0	0.0	0.0	0.0	0.0	0.0	2.4	4.8	0.0	0.0	7.21	1.80	249.7
35	0.0	0.0	0.0	0.0	0.0	0.0	18.5	0.0	0.0	0.0	18.47	4.76	257.5
35.5	0.0	0.0	0.0	0.0	0.0	0.0	7.9	7.9	15.7	0.0	31.46	8.25	262.1
36	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0	0.0	13.04	3.94	302.0
36.5	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8	1.8	0.0	5.46	2.01	369.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	20.74	6.79	327.5
37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.74	0.23	307.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
38.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
39.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
40.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
41.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
42.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	-
44.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	4.72	2.62	555.0
TSN (Mils)	84.7	35.4	50.0	131.2	215.9	1040.8	1772.6	1182.9	201.7	53.2	4768.4	789.2	
% Mature	0	100	100	100	100	100	100	100	100	100			
TSB ('000t)	4.1	2.3	6.3	17.5	30.6	167.5	296.7	212.9	39.2	12.0	789.2		
SSB ('000t)	0	2.3	6.3	17.5	30.6	167.5	296.7	212.9	39.2	12.0	785.1		
Mn Wt	39.1	68.2	108.4	131.8	148.3	168.1	203.8	199.0	226.3	274.3	166		
Mn L	18.4	22.2	26.2	28.0	29.1	30.5	32.0	31.8	33.1	34.6	29.9		

Table 6. Species occurrence from trawl stations. Blue whiting survey, March-April 2010.

Category	Common Name	Scientific Name	Occurrence
Pelagic	Blue Whiting	*Micromesistius poutassou*	10
	Mackerel	*Scomber scombrus*	1
	Horse mackerel	*Trachurus trachurus*	
Mesopelagics	Greater Argentine	*Argentina silus*	2
	Hatchet Fish (small)	*Argyropelecus hemigymnus*	1
	Hatchet Fish (large)	*Argyropelecus olfersi*	
	None	*Astronethus gemmifer*	
	Myctophidae	*Benthosema glaciale*	
	Alfonsino	*Beryx decadactylus*	
	Ray's bream	*Brama brama*	
	Blackfish	*Centrophagus niger*	1
	Sloanes Viper fish	*Chauliodus sloani*	
	Myctophidae	*Diaphus raffinesqui*	
	Myctophidae	*Diaphus metapoclampus*	
	None	*Diretmus argentus*	
	None	*Echiostoma barbatum*	
	Myctophidae	*Electrona rissoi*	
	Pipefish	*Entelurus aequoreus*	
	Balbo sabretooth	*Evermanella balbo*	
	None	*Gonastoma elongatum*	1
	None	*Howella sherborni*	
	None	*Lampadena speculigera*	
	Myctophidae	*Lampanyctus crocodilus*	
	Myctophidae	*Lobianchia gemallari*	
	Searsids	*Maulisia*	
	Pearlside	*Maurolicus muelleri*	1
	Myctophidae	*Myctophum punctatum*	
	Greenland Argentine	*Nansenia groenlandica*	1
	Forgotten argentine	*Nansenia oblita*	
	Slender snipe-eel	*Nemichthys scolopaceous*	
	Multipore Searside	*Normichthys operosus*	
	None	*Notolepis rissoi*	1
	Myctophidae	*Notoscopelus krokeyeri*	
	None	*Opisthoproctus soleatus*	
	Shrimps	*Pandalidae*	2
	Silver Pomfret	*Pterycombus brama*	
	Schnakenbeck's searside	*Sagamichthys schnakenbecki*	
	None	*Scopelosaurus lepidus*	
	None	*Searsia koefoedi*	
	Bean's sawtoothed eel	*Serrivomer beani*	
	None	*Sternoptyx diaphana*	
	Scaly dragonfish	*Stomias boa*	
	Myctophidae	*Symbolophoros veranyi*	9
	Greater Pipefish	*Syngnathus acus*	
	Dealfish	*Trachipterus arcticus*	2
	Bluntsnout smooth-head	*Xenodermichthys copei*	1
Demersal	Grey Gurnard	*Eutrigla gurnardus*	1
	Silvery Pout	*Gadiculus argentus*	2
	Norway Pout		
	Hake	*Merluccius merluccius*	1
	Anglerfish	*Lophius piscatorius*	1
	Saithe	*Pollachius virens*	1
Squid	Lesser flying squid	*Todaropsis elbanae*	
	Northern flying squid	*Todarodes sagittatus*	
	Short finned squid	*Omnastrephidae*	
	European flying squid	Todorodes sagittatus	3
Other	Jellyfish		
	Octopus		
		Total Number of Trawls	**13**
		Total number of Species:	**19**

Table 7. Irish survey time series. Blue whiting survey, March-April 2010.

Year	2004	2005	2006	2007	2008	2009	2010
Target areas	2a 2b,2c	1 2a,2b	2b	1 2a,2b	1 2a,2b	1 2b	1 2b
Age							
1	2.98	37.35	4.37	2.4	13.9	2.2	4.1
2	108.26	64.04	43.22	31	12.5	66.7	2.3
3	346.43	500.0	242.45	585	128.7	49.9	6.3
4	524.02	911.1	636.69	1681	1148.0	236.3	17.5
5	211.5	1010.0	342.56	1424	1445.7	1126.8	30.6
6	154.51	311.0	144.7	639.2	762.9	1444.3	167.5
7	72.76	111.0	50.41	219.3	200.0	563.6	296.7
8	34.71	69.9	18.02	126.2	33.1	117.6	212.9
9	4.06	20.5	0	14.6	0	31.4	39.2
10+	15.61	7.87	0	5.4	0	12.9	12.0
TSB ('000t)	1,474.9	3,044.0	1,482.4	4,727.6	3,744.7	3,651.7	789.2
TSN (mils)	16,029.3	34,268.0	16,344.0	48,746.1	34,179.6	28,512.2	4,768.4
SSB ('000t)	1,471.9	3,001.0	1,478.1	4,725.2	3,726.4	3,647.9	785.1

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

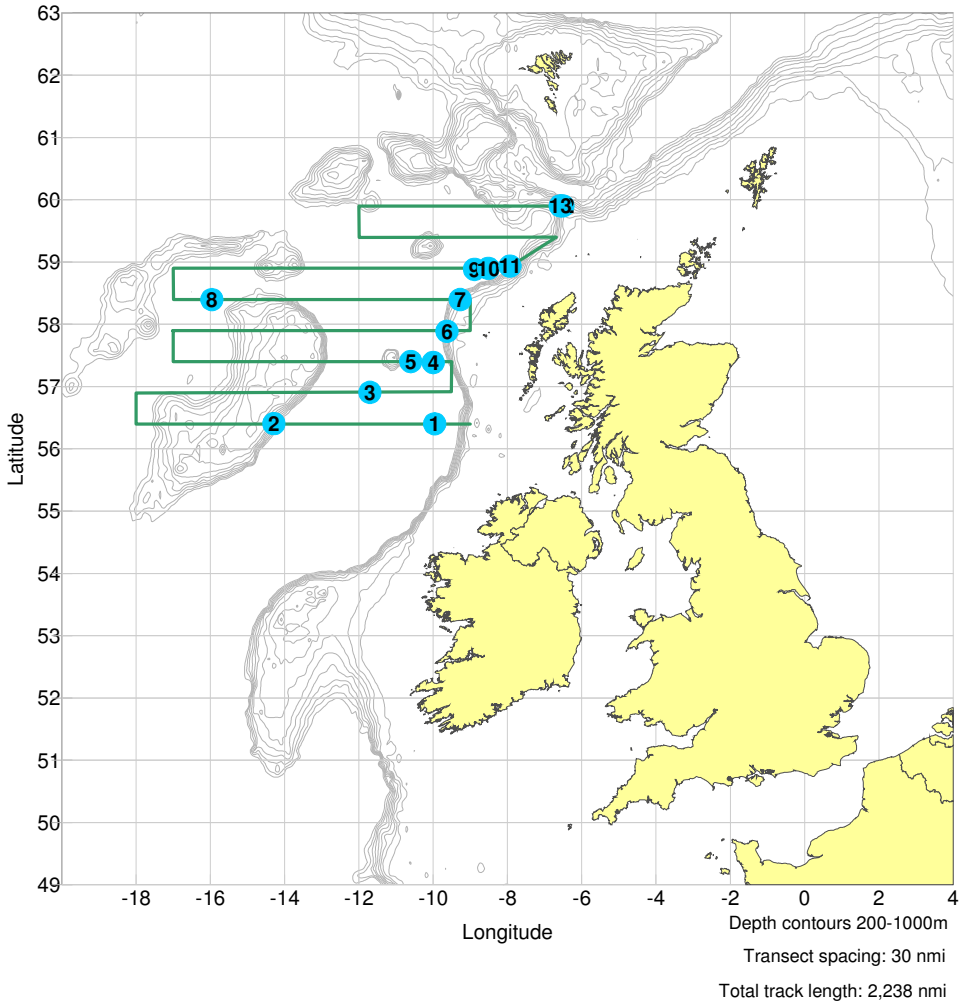


Figure 1. RV Celtic Explorer cruise track showing position of trawl stations and survey Target areas used during the analysis. Blue whiting survey, March-April 2010.

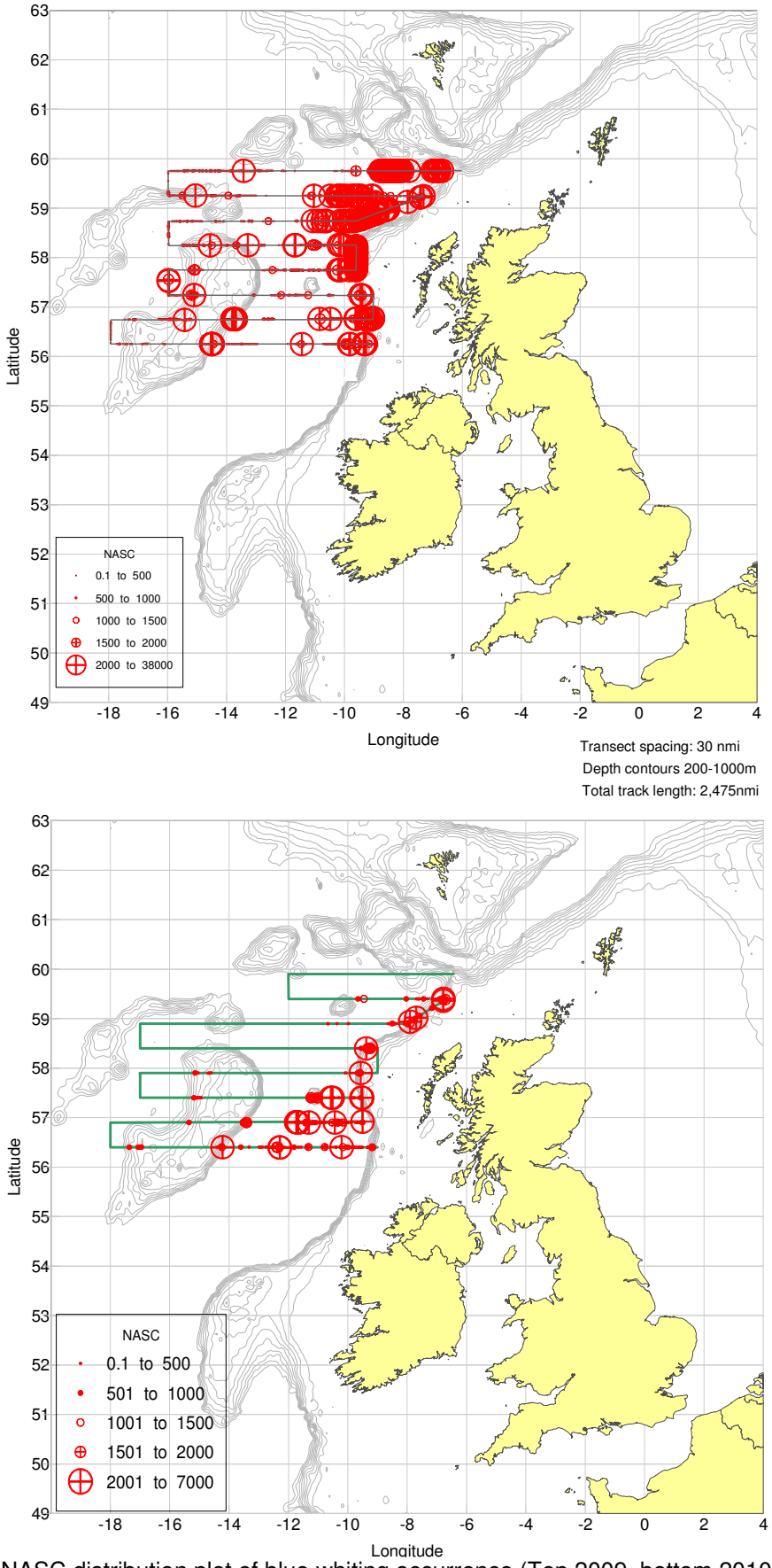
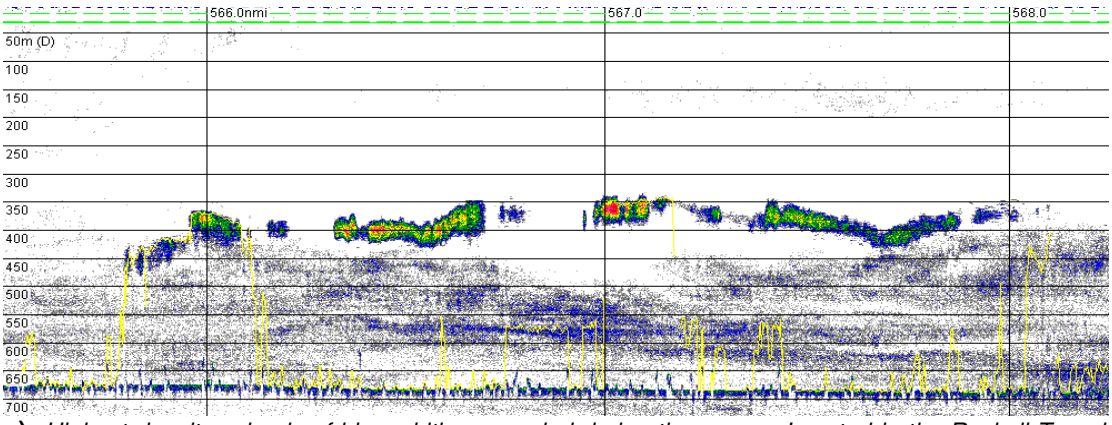
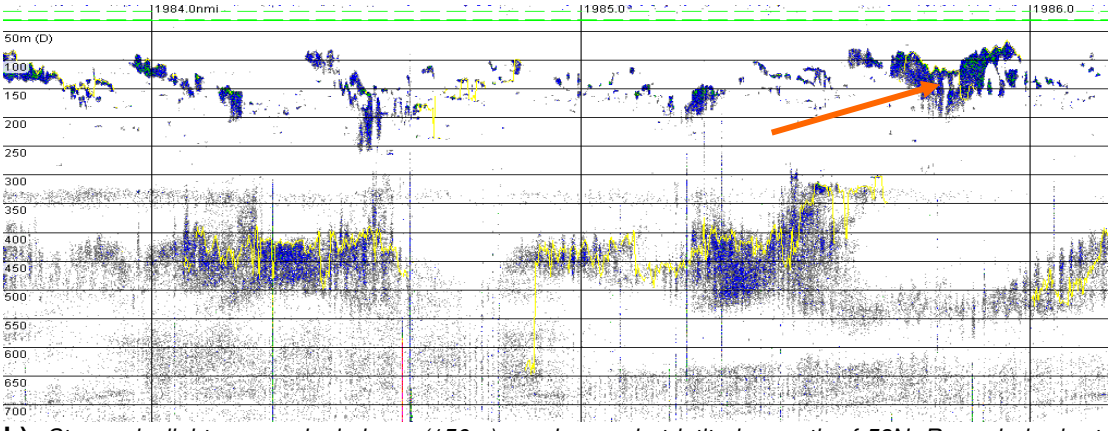


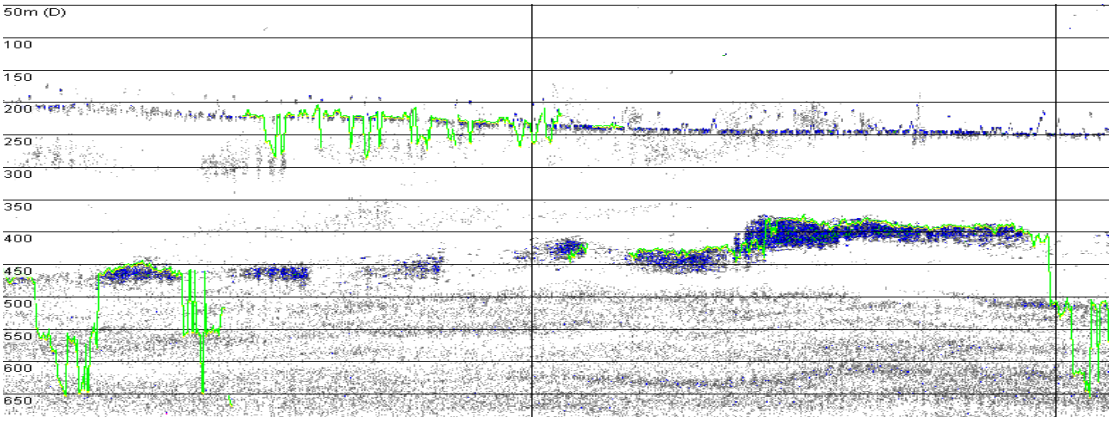
Figure 2. NASC distribution plot of blue whiting occurrence (Top 2009, bottom 2010), circle size relative to NASC value. Blue whiting survey, March-April 2010.



a). *Highest density schools of blue whiting recorded during the survey. Located in the Rockall Trough within the Hebrides sub area prior to* ***Haul 03***



b). *Strong daylight mesopelagic layer (150m) as observed at latitudes north of 58N. Recorded prior to* ***Haul 09****. Trawl targeted this layer and large school indicated by the orange arrow which was 120m tall. Catch for the trawl: a single fish- L. piscatorius.*



c). *Low density weak scattering layer of blue whiting as observed on the eastern slopes of the Rockall Bank. Recorded prior to* ***Haul 02****. Catch yielded less than 2Kg of blue whiting.*

Figures 3a-c. Echotraces recorded on the ER60 echosounder with images captured from Echoview during the blue whiting survey, March-April 2010. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.

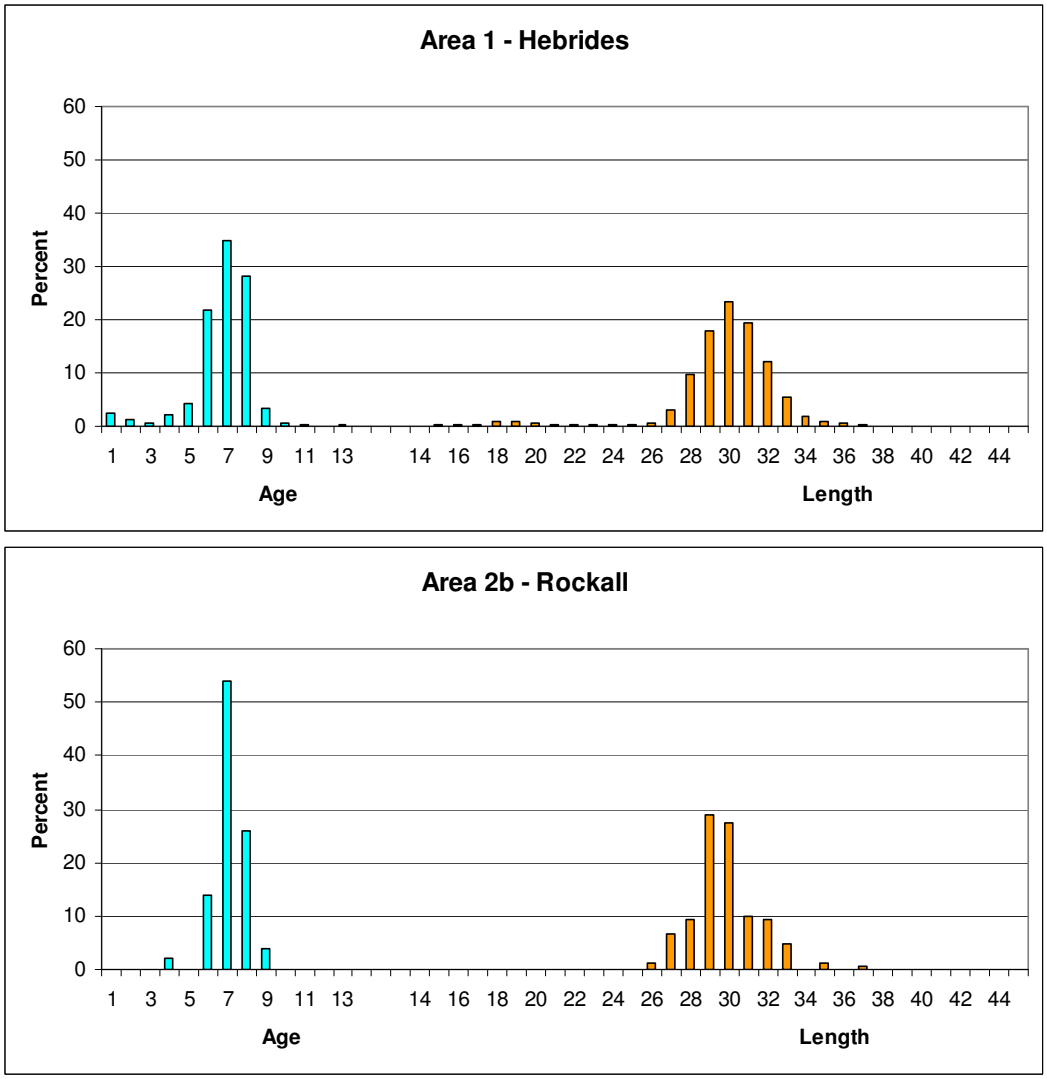


Figure 4. Age (left) and length (right) composition of blue whiting by sub area. Blue whiting survey, March-April 2010.

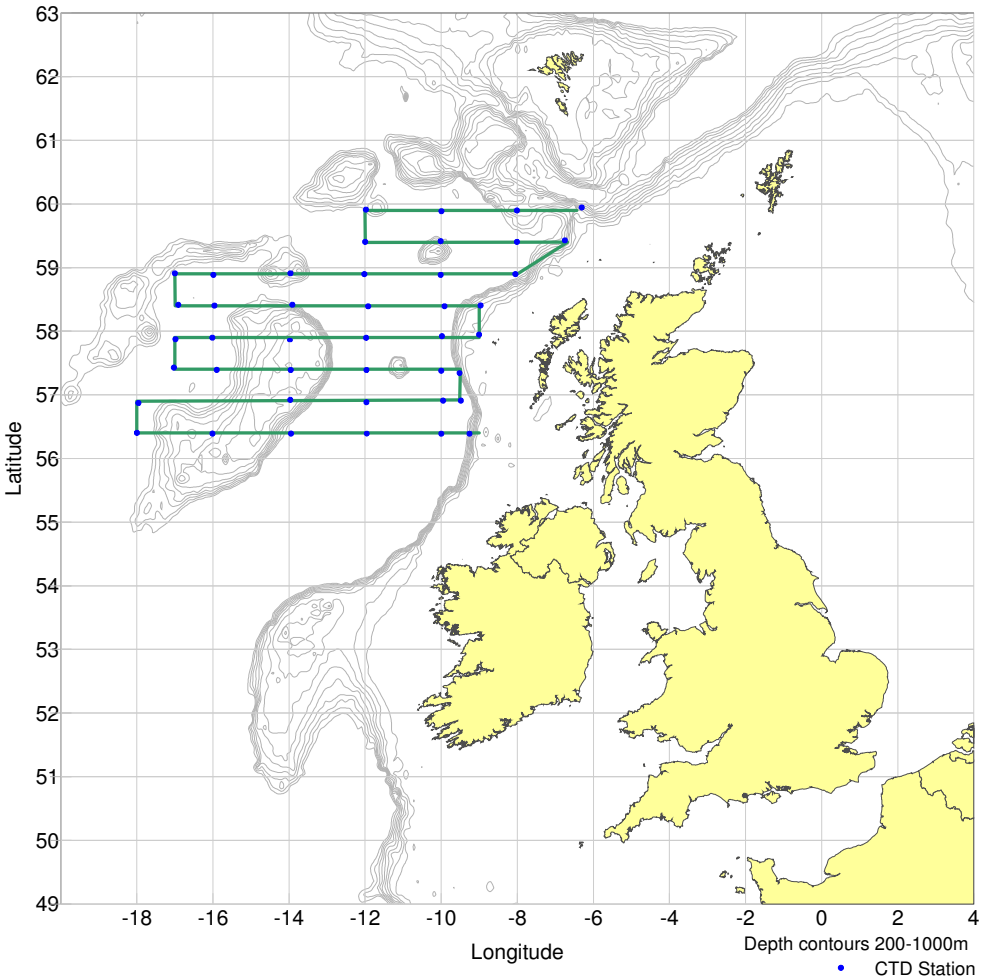


Figure 5. Oceanography stations taken as CTD casts. Open water stations were carried out to a maximum depth of 1000m. Blue whiting survey, March-April 2010.

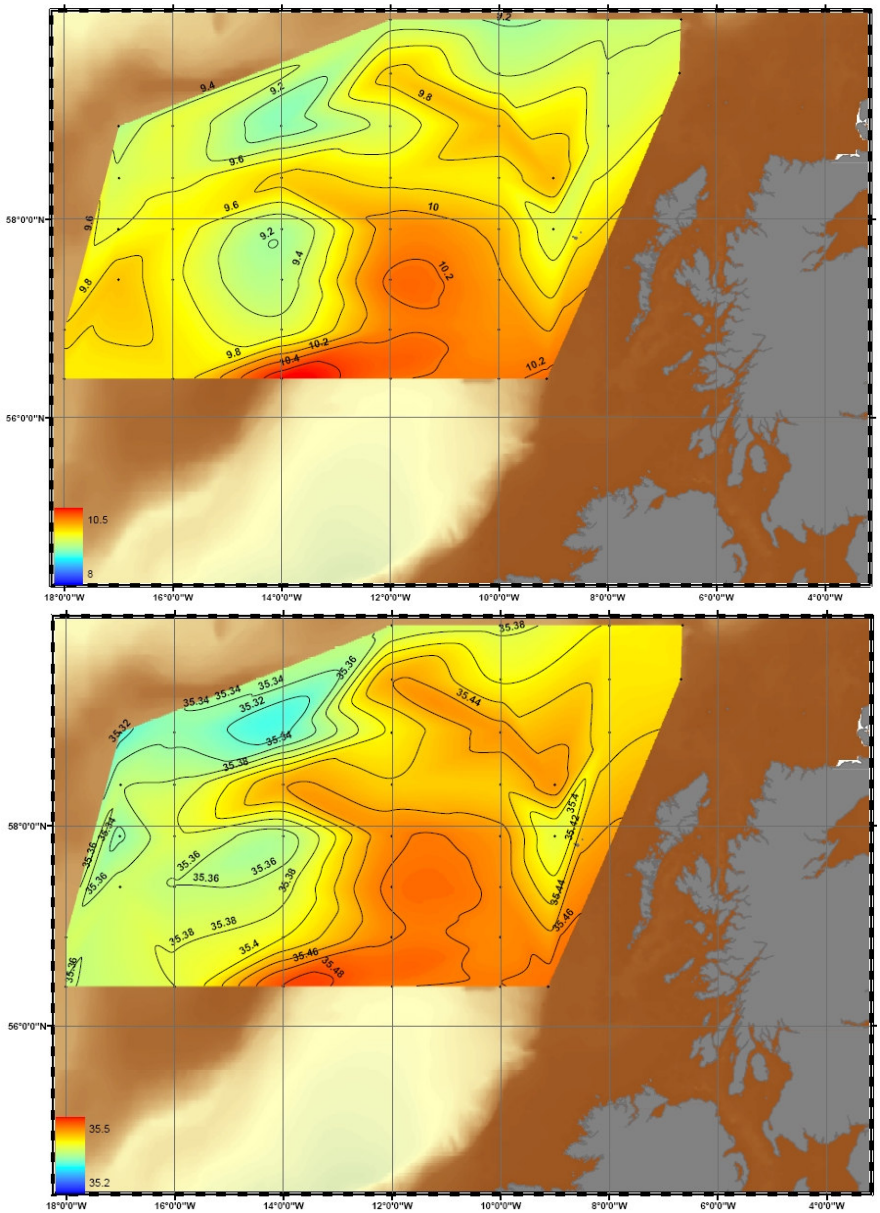


Figure 6. Horizontal temperature (top panel) and salinity (bottom panel) at 10m as derived from vertical CTD cast data. Blue whiting survey, March-April 2010.

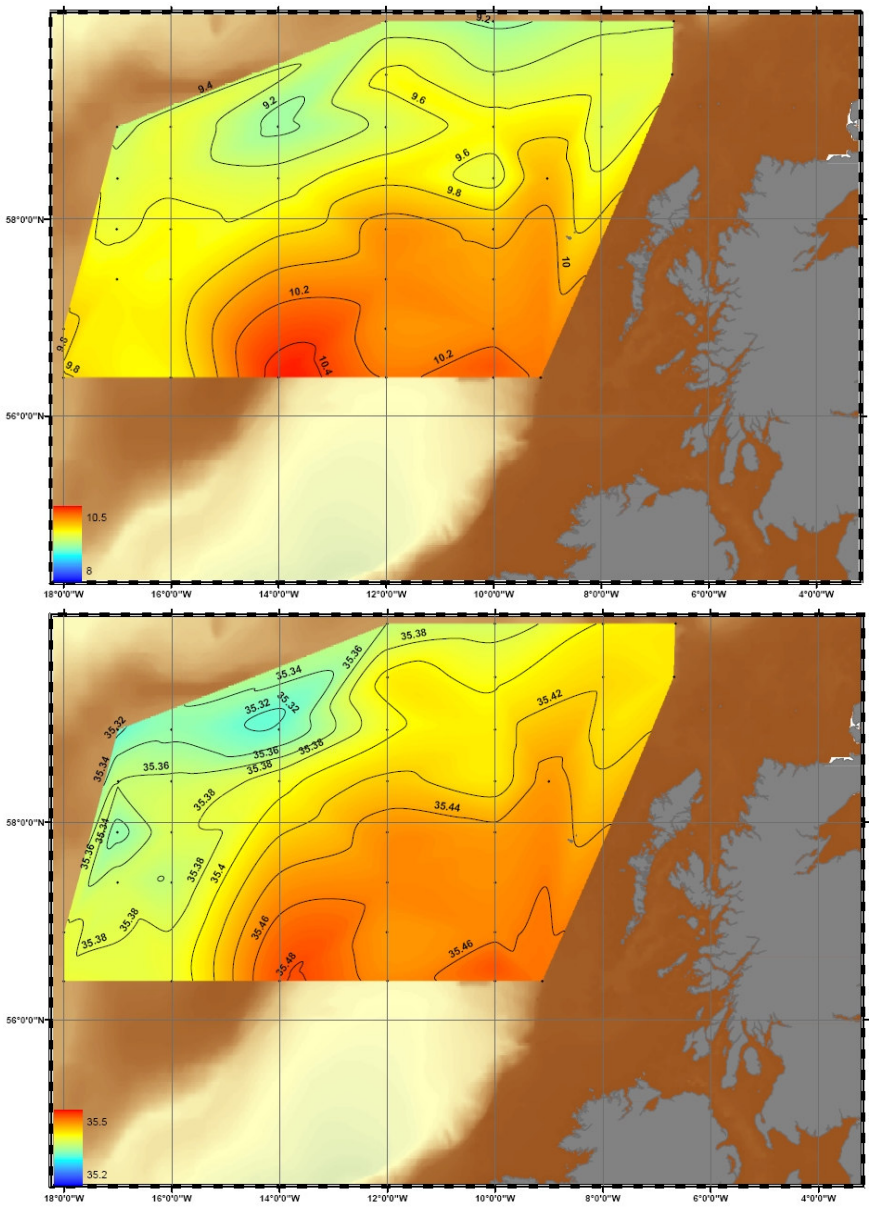


Figure 7. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD cast data. Blue whiting survey, March-April 2010.

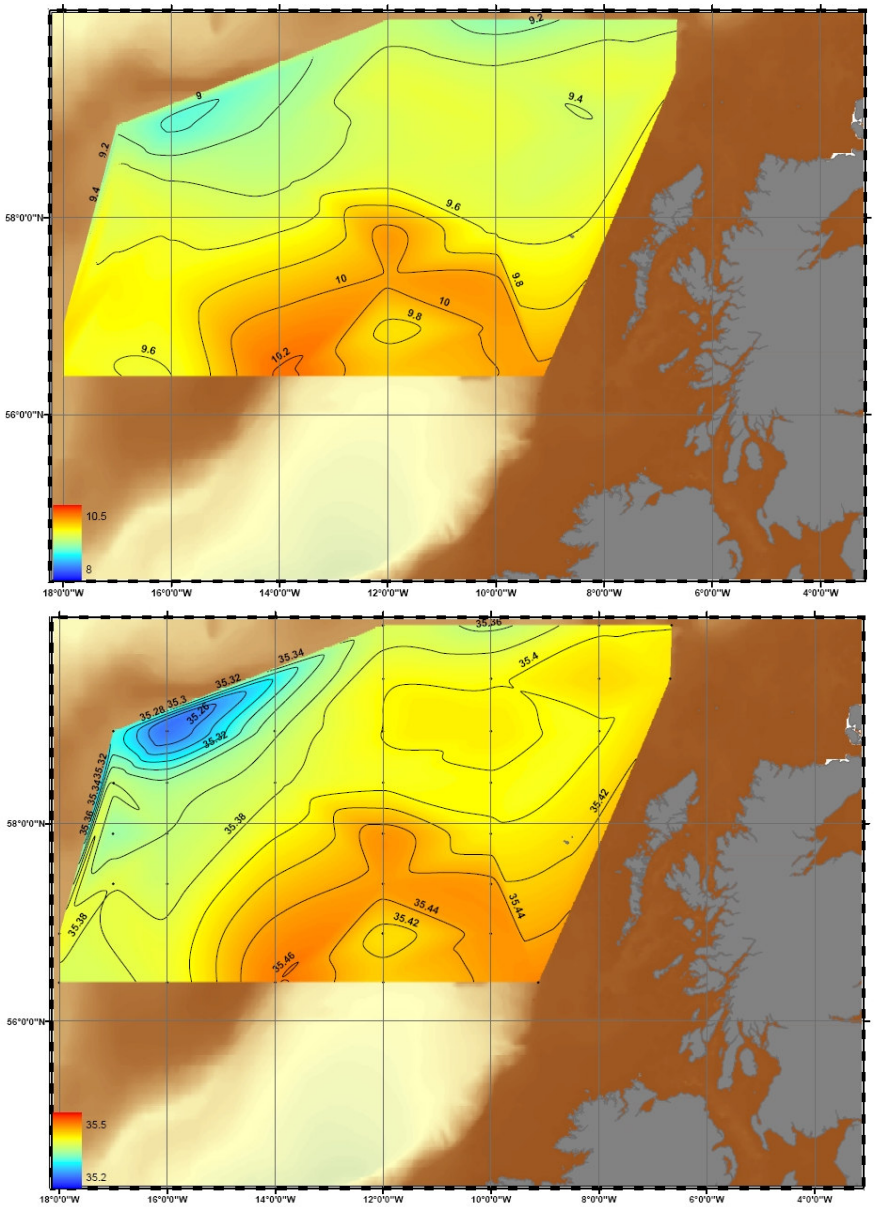


Figure 8. Horizontal distribution of temperature (top) and salinity (bottom) at 400m as derived from vertical CTD cast data. Blue whiting survey, March-April 2010.

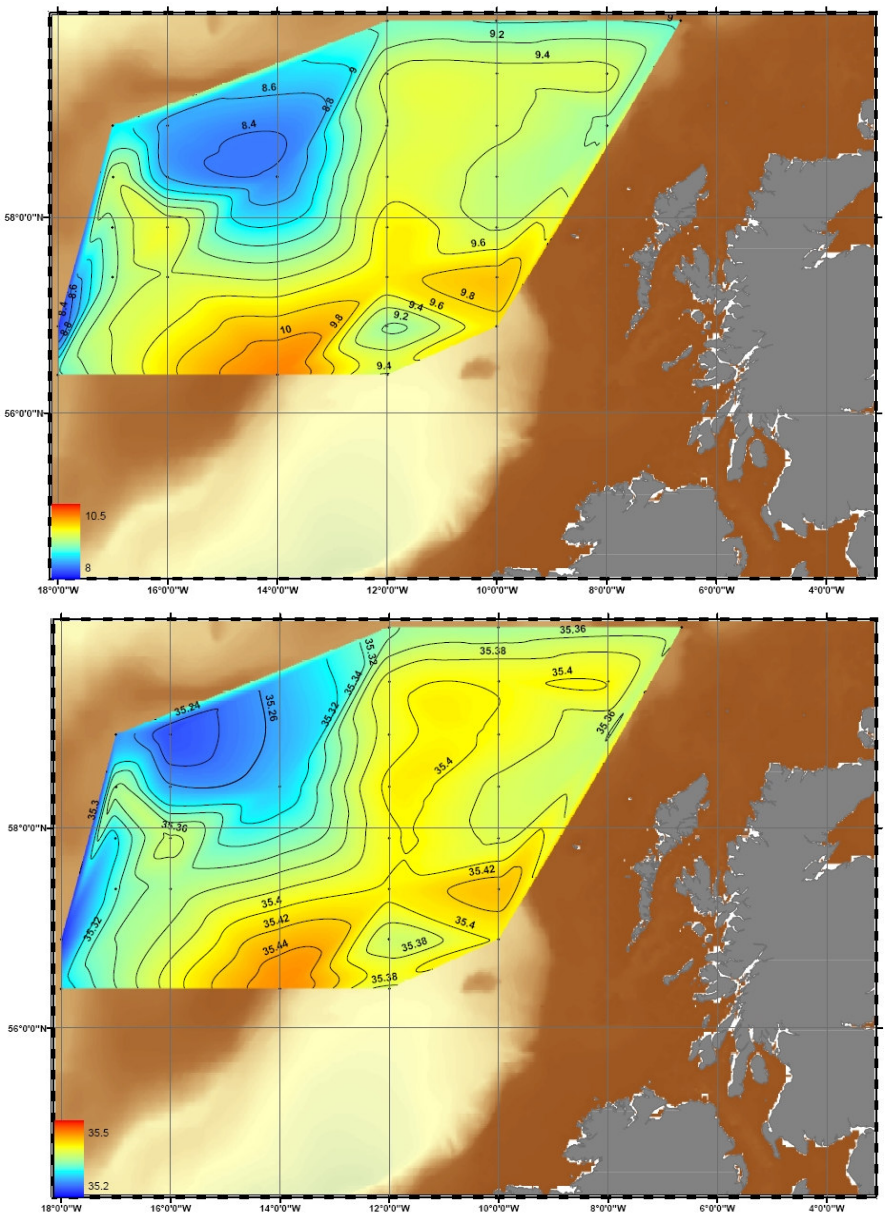
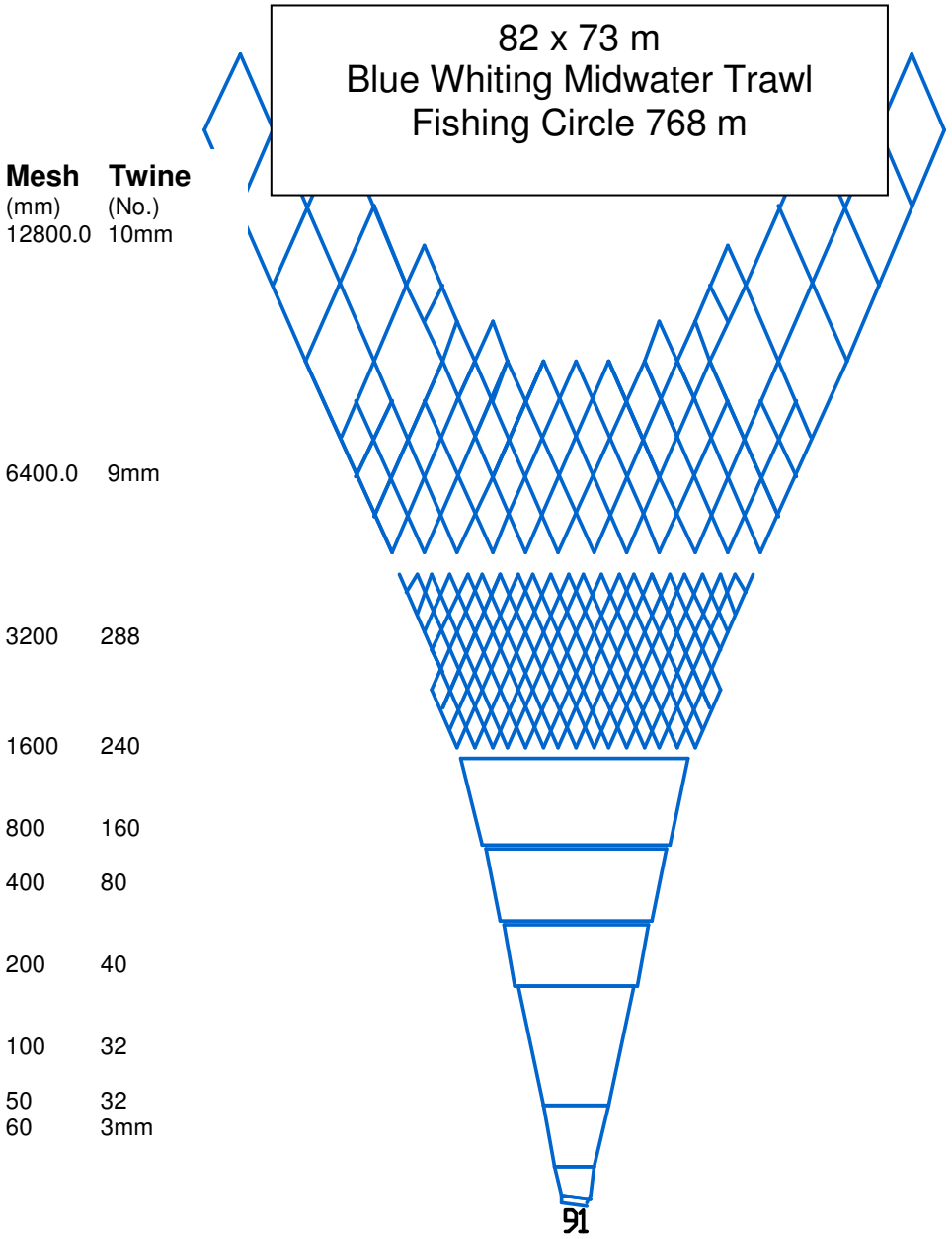


Figure 9. Horizontal distribution of temperature (top) and salinity (bottom) at 600m as derived from vertical CTD cast data. Blue whiting survey, March-April 2010.



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 2010.