Irish Blue Whiting Acoustic Survey
ICES Divisions VIa,b &VIIb,c,j,k

FSS Pelagics
March - April 2004

MRV CELTIC EXPLORER

Ciaran O'Donnell, Eugene Mullins, Terje Monstad, Gavin Macualay, Gavin Power and Jenny Ullgren.

Blue Whiting Acoustic Survey Cruise Report
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Cruise Report:	Blue Whiting Acoustic Survey Cruise Report	
Cruise Code:	CEXP BW032004	
Start Date:	22nd March, Galway.	
End Date:	6th April, Greenore	
Vessel:	MRV CELTIC EXPLORER	
Gear:	Single mid-water trawl (82 x 73m)	
ICES Areas:	VIaS,b and VIIb,c,j & k	
Personnel:	Ciaran O'Donnell	(Cruise leader)
	Eugene Mullins	(Deck Scientist)
	Gavin Macaulay	Acoustic Consultant (NIWA)
	Terje Monstad	Acoustic Consultant (Norway)
	Gavin Power:	MI Fisheries Blue Whiting PhD
	Jenny Ullgren	NUIG Oceanography PhD
	Joanne O'Brian	(IWDG)
	John Boyle	Gear Consultant/Industry Observer.

Objectives:

1. Obtain an age stratified biomass estimate of the spawning stock of blue whiting
2. Cover an acoustic track from 51^0 N to 56^0 N, with a transect spacing of 40 miles.
3. Perform intercalibration with the RV *Johan Hjort* (IMR, Bergen, Norway) and other survey vessels if possible.
4. Carry out fishing in each box (1 degree longitude * 2 degrees latitude).
5. Recover 2 ADCP moorings on the western slopes of the Porcupine Bank.
6. Collect biological and acoustic data on mesopelagic fishes and the deep scattering layers (time permitting).

1. Introduction

Acoustic surveys on northern blue whiting (*Micromesistius poutassou*) stocks have been carried out since the early 1970s by the Institute of Marine Research (IMR), Bergen. In the early 1980s a coordinated acoustic survey approach was adopted, with both Russia and Norway participating to estimate the size of the stock. The acoustic survey programme is carried out for fishery management purposes, results are presented annually at the ICES led Northern Pelagic and Blue Whiting Fisheries Working Group and from this catch advice is determined for the following year.

The highly migratory nature of this stock and its components require a large geographical area to be surveyed during a relatively short spawning window. Acoustic surveys are routinely carried out on specific spawning and pre-spawning aggregations of blue whiting. This can allow for high concentrations of fish to be surveyed in a relatively small geographical and often well defined area, if the timing is synchronised.

This survey was conducted as part of a collaborative survey coordinated by the Institute of Marine Research, Bergen, Norway, using the vessel the MRV "*Johan Hjort*". Also participating were the MRV "*Fridtjof Nansen*" (PINRO, Russia) and the MRV "*Tridens*" (RIVO, Netherlands).

The total combined area surveyed in 2004 covered from the Faroe Islands in the north (62°of longitude) to the southern coast of Ireland (50.5° N), area coverage to the west extended from 2°-18° of latitude. The Irish component of the survey was made up of transects covering some 2,080 nautical miles (Figure 1). In addition to the collection of acoustic data fishing hauls were carried out to determine the make up of fish marks recorded by the equipment and to assess the length, weight, age, sex and maturity of the stock. Oceanographic data was collected using a number of spaced hydrograhic stations where salinity and temperature of the water column was recorded at depths of up to 1200 m.

2. Materials and Methods

Calibration of ER 60 Scientific Echosounder

Calibration of the ER 60 was carried out in Killary Harbour Co. Galway on the 23rd March at the start of the survey and again in Bantry Bay, Co. Cork on the 2nd April once the survey track was complete. See Table 1 for the instrument settings. The ER 60 was last calibrated in January 2004. Calibration of the ER 60 provides a measure of the electronic drift which occurs through such systems and allows the appropriate correction factors to be applied to the data in order to calculate the most accurate biomass estimate from insonified fishes. For a more detailed description of the calibration of acoustic instruments please refer to Foote *et al*, 1987.

The operating frequency calibrated at the start of the survey was 38 kHz, during the second calibration the 38 kHz was re-calibrated in addition to the following, 18, 38, 120, 200 kHz. The Blue Whiting biomass generated from this survey and the combined surveys was solely generated from data acquired through 38 kHz.

It should be noted that the beam models were not updated during the second calibration as the survey track was not completed and this would have been inconsistent with the rest of the survey data. Beam models were updated once the survey was fully completed for future vessel work.

Intervessel Calibration

An intercalibration was carried out between the RV "*Celtic Explorer*" and the RV "*Johan Hjort*" on the 24th March on the northern slopes of the Porcupine Bank. An area was selected by the Norwegian cruise leader which was characterised by multi-depth layers of acoustic interest. The uppermost layer of interest (100-300m) was thought to compose of mesopelagic fish species and plankton mixed and a second lower layer (400-600 m) of blue whiting. Acoustic marks in this area could be traced to a point where the main layers dissipated thus providing a measure of each vessels acoustic capability in both fish density and areas of little or no fish concentrations.

The methodology employed consisted of both vessels, firstly the Johan Hjort picking a course which ran over 20 nautical miles (nmi) to the north of the starting position. The Celtic Explorer followed this course at a distance of 0.5 nmi and a bearing of 8-10° off the lead vessels starboard quarter. The idea being to avoid the lead vessels wake. To further remove such noise from estimates when analysing the data the top 15m of the water column was disregarded. The lead vessel indicated via radio the point at which the first nautical mile point began and logging commenced. After 20 nmi the roles were reversed and a further 17 nmi was covered on a course back to the south over the same ground, with the Celtic Explorer leading.

Total S_A values per 100m depth layer and S_A values allocated to blue whiting, after echogram scrutinisation, were summed per 1 nmi interval and transmitted to the Johan Hjort for comparison.

At the end of the 37 nmi run a comparative fishing tow was carried out to compare length distributions in the catches. The Johan Hjort followed the Celtic Explorer in the same direction at a distance of some 0.5 nmi with both vessels fishing between 55-70 minutes. Length distributions were transmitted to the Johan Hjort for comparison.

Survey design and Acoustic data collection

Acoustic data was collected over a 24 hr period on a predetermined cruise track (Figure 1). Area coverage extended from 56° 00N to 50° 30N and 9° 00W to 15° 30W. Effectively covering from the 200m contour off the north coast of Ireland out to deep water (>1500m) covering the Rockall Trough, Porcupine Bank, Porcupine Sea Bight and finishing off to the southwestern corner of Ireland. Transect spacing was set at 40 nmi and a total of 2080 nmi were covered. Towards the end of the survey the track had to be modified from the original due to an unforeseen port call to disembark an injured crewman. Off track steaming is represented as a thin line, while survey transects are marked as a heavy line in Figure 1. A zigzag track was adopted for the remaining survey time, crossing the 500 m to 200 m contours from the 51° 30N to the 50° 30N.

The acoustic data were collected using the vessels ER60 scientific echosounder, consisting of a 38kHz transducer, a General Purpose Transceiver (GPT) and a Processing Unit (desktop computer). The Simrad ES-38B (38 kHz) split-beam transducer mounted within the vessels drop keel and lowered to the working depth of 3m below the vessels hull or 8.8m below the sea surface. This working depth was maintained throughout the survey.

During both the intercalibration and while on the survey track the vessel was cruising using DC twin electric motor propulsion, supplied from 1 main engine, so in effect providing “silent cruising” as compared to normal operations (See ICES CRR Report 209). However, it should be noted that during fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

Acoustic data were observed and recorded onto the hard-drive of the Processing Unit using the equipment settings agreed at the pre-cruise meeting. These settings were configured into the ER-60 and maintained throughout the survey and intercalibration (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. A portable computer running Sonar Data’s Echolog Echoview 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.

The equipment was monitored over a 24 hr period by a member of the scientific crew. A 30 minute log was taken recording time, position from the vessels GPS and any comments. This log was used to monitor the time spent off track during fishing operation of hydrographic stations and any general observations.

Data Handling and Biomass estimation

Acoustic data was backed up every 24 hrs and scrutinised using Sonar data’s Echoview (V 3.1) post processing software for the previous days work. Data was partitioned into the following categories plankton (<200 m depth layer), mesopelagic species, blue whiting and bottom fish (including argentines, mackerel and horse mackerel). Partitioning of data into the above categories was largely subjective and was viewed by 3 scientists experienced in viewing echograms.

Biomass Estimation

The concept of the coordinated survey was to produce a combined estimate of the blue whiting spawning stock size. The data collected onboard was also used to create an independent, if not as accurate an estimate, of both total and SSB biomass for blue whiting. The reasoning behind this was to gain a better understanding of the data and also as a means of screening the data. It should be noted that the estimate was attained through a non-computer generated analysis and should therefore be treated with caution. Although the base data is sound variation may have been introduced as the abundance estimate and data were handled. For the purposes of abundance estimation the survey area was divided into 2 sub areas.

Sub area I (N Porcupine):	52° 30N and to the North
Sub area II (S Porcupine):	52° 30N and to the South

With following methodology employed;

The surveyed area was divided into 2 sub areas separated by the 53° 30N line of latitude, the area was then further subdivided into rectangles of 1° latitude by 2° longitude, as employed for the combined survey estimate. The 2 sub divisions were used to separate areas geographically and this also proved the best option when analysing the data.

S_A values of blue whiting were extracted from Echoview and used to produce a map of estimates of biomass and abundance per 5 nmi log interval on each transect. A zero line was of distribution was then formed. Mean S_A per area of rectangle within these lines of distribution were then allocated. Data on length distribution and individual weights of blue whiting were used to produce mean values for each trawl haul and assigned to each assessment rectangle as deemed appropriate. These data were then combined with age and maturity data from the same samples to produce an age-length key for the surveyed stock.

The target strength (TS) used was:

TS = 21.8 log L – 72.9 dB, where L is fish length in cm.

The numbers of fish per rectangle were calculated from;

N = S_A x Rectangle area (m²) x Density Coefficient ($1.488 * 10^{6} * L^{-2.18}$).

Multiplying the number generated with corresponding mean weight values from trawl samples provides the biomass of individuals in weight.

For a more detailed description of the methodology employed see Anon (Monstad *et al*), 1982.

Hydrographic data collection

A total of 18 hydrographic stations were carried out during the survey (See Figure 1). In total 4 stations were carried out in the Rockall trough (max depth 1200 m), 3 stations were carried out in the Porcupine Bank area (max depth attained 200 m). A further 5 stations were undertaken in the area to the south of the Porcupine Bank, 1 in the Porcupine Sea Bight, and 4 on the western fringes. In shallow shelf areas along the 200 m contour 7 stations were carried out. Results are displayed in horizontal temperature and salinity profiles as shown in Figures 6 & 7 respectively.

Fishing operations and biological data

Trawl hauls were carried out to determine the identity of insonified fish marks and to ground-truth the data from the ER 60 (See Figure 1 and Table 2). 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 samples were taken and as a result samples were restricted to marks occurring greater than 5 m from the seabed.

A single pelagic midwater trawl with the dimensions of 82m in length (LOA) and 73m at the wings ends and a fishing circle of 768 m was employed during the survey (Figure 8). Mesh size in the wings was 12.8 m through to 5 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 48 m, which was observed using both a cable linked Furuno netsonde (50 kHz) and a Scanmar widebeam trawleye with an acoustic link. The net was fitted with both Scanmar catch and depth sensors. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being viewed through the Scanmar Scanbas system.

Biological Sampling

Fish samples were divided into species composition by weight. Species other than the blue whiting were weighed only as a component of the catch, no further processing was carried out. Measurements of blue whiting lengths were taken to the nearest 0.5 cm. Age, length, weight, sex, maturity and stomach fullness were recorded for each individual blue whiting within a random 50 fish sample from each trawl haul. In addition to this a further random 50 fish were taken from each haul and processed for extra length and weight analysis. The appropriate raising factors were calculated to provide length frequency compositions for bulk of each haul.

3. Results

Intercalibration

Details of the intercalibration results are provided in Appendix 1 and briefly are summarised below.

Overall the data suggests that for the purposes of formulating a combined biomass estimate no correction factor need be applied to the acoustic data collected from the Celtic Explorer. As stated by the author the data can be used interchangeably without correction.

Comparative trawl hauls made by the vessels showed a similar length distribution for similar fishing time. However it should be noted that the recorded catches were small, less than 15 kg of blue whiting per vessel.

Blue whiting biomass

Fish distribution

Results indicate blue whiting to be most prevalent in the surveyed area approaching the shelf edge and in waters of a depth greater than 200m (Figure 2). Blue whiting were encountered on 21 of the 23 survey transects. The highest registrations were encountered in the area to the north of the Porcupine Bank along the shelf break (Sub area I). It is difficult to accurately estimate the distribution to the south (Sub area II) due to incomplete coverage. However, blue whiting were found to be relatively consistent along transects crossing the Porcupine Sea Bight, if at lower concentrations than to the north.

The greatest concentrations found throughout the survey were midwater between 400-600 m depth contours. Towards the shelf break fish were sometimes observed to "merge" with the bottom as depths approached 300m and continued on for sometime as a "blue dust" to an upper limit of 200m (Figure 3). As the blue whiting concentrations approached shelf break areas (300m) mixing with other species was often observed. During trawl hauls in the shelf break area at this depth mackerel (*Scromber scombrus*), horse mackerel (*Trachurus trachurus)* and greater argentine (*Argentina silus*) were most frequently found mixed in the catch.

The characteristic long "green snake" of blue whiting was somewhat elusive on this survey and maybe a consequence of timing as opposed to an indication of actual stock abundance. Contact from the Irish pelagic fleet at the time of the survey suggested that are that the bulk of blue whiting were being targeted in the northern part of the survey area and further north.

Estimation of Stock Size

The estimate for total abundance of blue whiting from the Irish survey 2004 is;

	Abundance ($N*10^6$)	Biomass (1000 tonnes)	SSB (1000 tonnes)
Sub area I: (N Porcupine)	**14,413.90**	**1,377.450**	**1,365.060**
Sub area II: (S Porcupine)	**1,615.40**	**99.283**	**95.310**
Combined:	**16,029.3**	**1,476.733**	**1,460.370**

Total biomass was estimated at around 1.5 million tonnes for the area surveyed. As this is the first time this area was surveyed by Ireland we have no time series on which to compare.

SSB of blue whiting in the area surveyed was estimated at 98.4% of the total abundance estimate, this value assumes all fish at 20cm and over are mature and spawning. Numbers are taken as relative and not absolute.

It should be noted that this estimate was attained through a non-computer generated analysis and should therefore be treated with caution. Although the base data is sound, variation may have been included as the abundance figures were worked up by hand.

Total biomass is summarised per rectangle (1° latitude by 2° longitude) and shown in Figure 4. A breakdown of the total numbers per rectangle by sub area are shown in Table 3.

Breakdown of Stock Surveyed

Overall the surveyed area was dominated by 4 year old fish (2000 year class) which made up over 30% of both weight and numbers, 3 year old fish (2001 year class) were also strongly represented at 28% The next dominant year class over the total area was made up of 2 year old fish (2002 year class). Trawl samples overall were found to contain individuals of between 1 and 10 years old.

Age variation between sub areas was well defined. In the northern Porcupine area 4 and 3 year old fish (2001 year class) were the dominant year classes respectively in both numbers and weight (Figure 5). In the southern Porcupine area 2 year old fish (2002 year class) were the most prevalent in both numbers and weight, representing over 40%. Secondary dominance was made up of 3 year old fish making up over 35% by weight and numbers, 4 year old fish represented over 15% as compared to double this in the northern Porcupine area.

Mean length and weight for blue whiting from the north and south sub areas were 26.88 cm & 95.56 g and 22.99 cm & 61.46 g respectively. This was to be expected owing to the dominance of older mature fish (3-4 yrs) from catches in the northern area. Smaller younger fish made being dominant in the southern sub area.

Hydrography

A total of 18 hydrographic stations were carried out during the survey. The CTD data was complied to produce horizontal temperature and salinity profiles for the survey area. Shallow CTD stations (under 250m) were summarised as being well mixed in terms of both temperature and salinity as would be expected in shelf areas in early spring. Results from deep stations indicate that winter mixing has penetrated to depths of 600 m. This is not unusual in the Rockall Trough area and correlates with data recorded from previous oceanographic cruises in the spring.

Surface temperature profiles (10m) show a general trend of colder water in the north (10.2°C) of the survey area with a gradual increase noted towards the south where the highest recorded temperature was 11.4°C. Surface temperatures around the Porcupine area were 10.6°C. The 100m depth profile shows the same temperature maintained at surface waters in the Porcupine area, this is also the case for the Rockall trough and Porcupine Sea Bight. The number of stations and depth layers shown do not show any significant variation or highlight any anomalies for the survey area. The same can be said for the salinity profiles.

Two moored ACDP (Acoustic Doppler Current Profilers) units have been in place since early February to the north (170 m) and the northeast (210 m) of the Porcupine Bank. However, the due to weather conditions in the area it was not deemed feasible to recover the units.

4. Discussion

Overall the survey was carried out and completed as originally planned, with the exception of some missing geographical coverage due to unforeseen circumstances (injured crewman). The missing transect was covered while steaming to port but the data was deemed unuseable and no S_A values could be assigned to blue whiting. As a result the estimate generated for the south Porcupine area could be considered a slight underestimate.

Timing of the survey indicates that the bulk of the spawning stock was not contained within the survey area. In the northern porcupine area the majority of fish encountered were spent, indicating spawning had already taken place. However, it should be noted that the bulk of the abundance estimate was generated from this area (>93%). In the southern porcupine area the estimate was made up of more young and immature blue whiting which are known to be resident along the shelf break throughout the year. This would indicate that the bulk of the adult population had migrated north or dispersed from the area. This is further substanciated by the age composition of sub areas as determined by survey trawl samples.

Maturity was assumed for fish all fish over 20 cm in length. This value was determined from trawl samples and can be regarded as a conservative estimate for the surveyed stock as a whole.

The overall biomass estimate for blue whiting should be treated as relative values and not as an absolute estimate as obtained by these acoustic methods. The estimate for abundance for the northern porcupine area was approximately 1.4 million tonnes. It should be noted that the northern Porcupine area was also surveyed by the Johan Hjort within the same time period and a total biomass of 1.4 million tonnes was estimated for an area of similar size (Heino, pers. com).

Acknowledgments

We would like to express our thanks and gratitude to Ciaran Flanagan (Captain) and crew of the Celtic Explorer for their good will and professionalism during the survey. We would also like to thank John Boyle for his help and advice on the fishing gear.

References

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

Anon. (Monstad et al), 1982. Report of the International acoustic survey on blue whiting in the Norwegian Sea, July/August 1982. ICES, Doc.CM. 1982/ H.5.

Mitsen R.B. 1999. Underwater Noise of Research Vessel: Review and Recommendations. ICES Coop. Res. Rep. 209

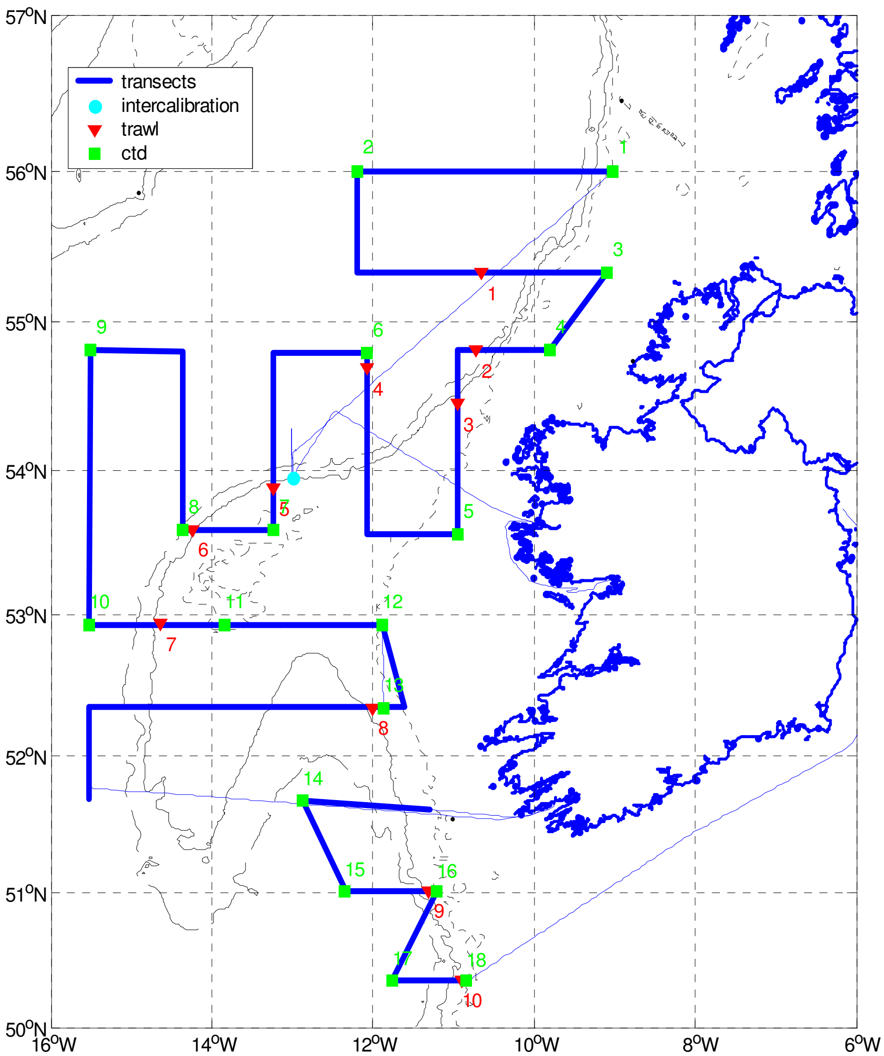


Figure 1 Cruise track for the Irish component of the International Blue Whiting Acoustic Survey showing pelagic trawl positions and hydrographic stations, March – April 2004.

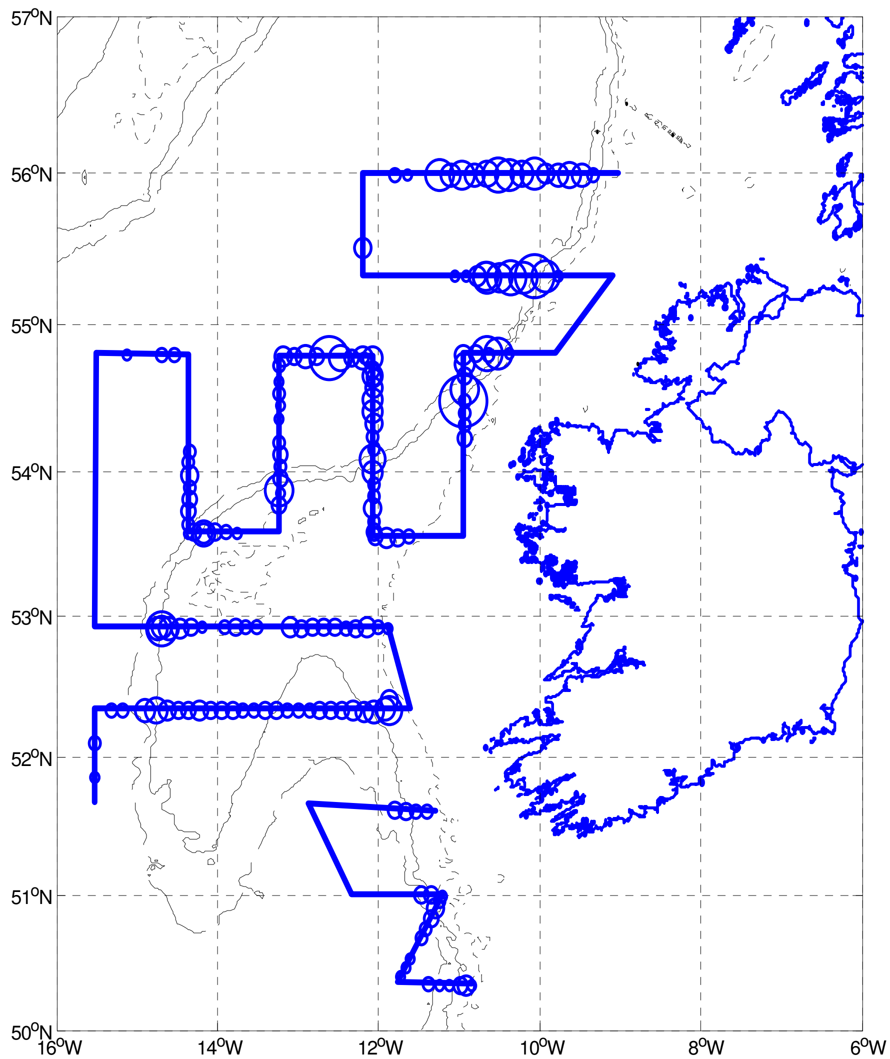


Figure 2 S_A plots per 5 nautical mile region, circle area is proportional to S_A value. Blue Whiting Acoustic Survey, March – April 2004.

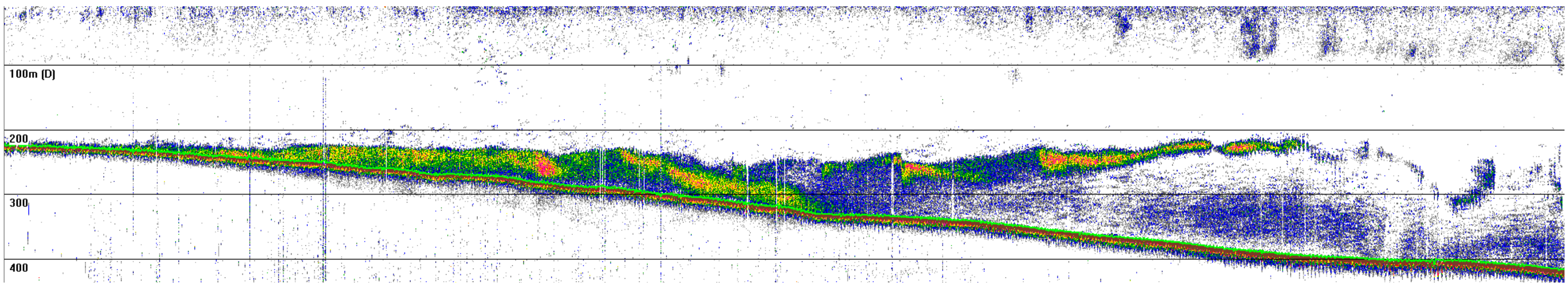


Figure 3 Echogram from survey Haul 09, sub area II -S Porcupine. Catch composed of 33% Blue Whiting, 31% Mackerel and 35% Horse mackerel. Note: High intensity red marks tight on the bottom to the left of the echogram at 230 m.

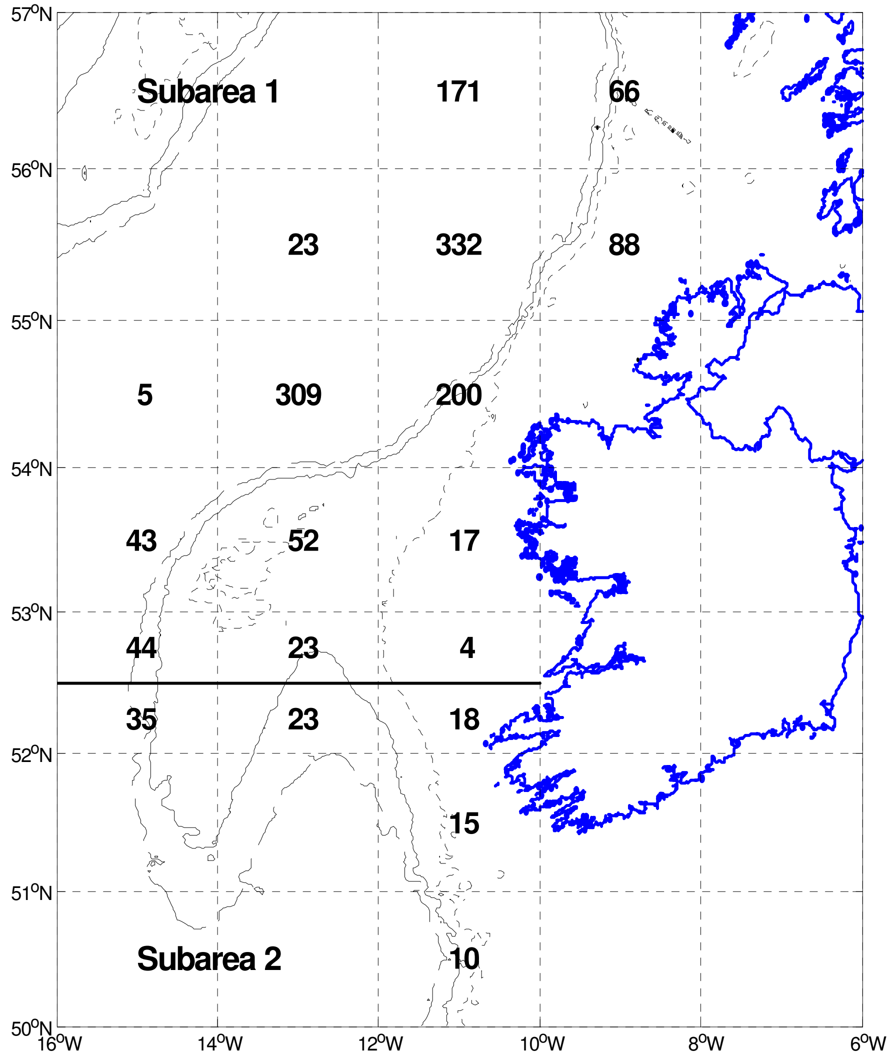


Figure 4 Thousands of tonnes per analysis rectangle by sub area of Blue Whiting. Blue Whiting Acoustic Survey, March – April 2004.

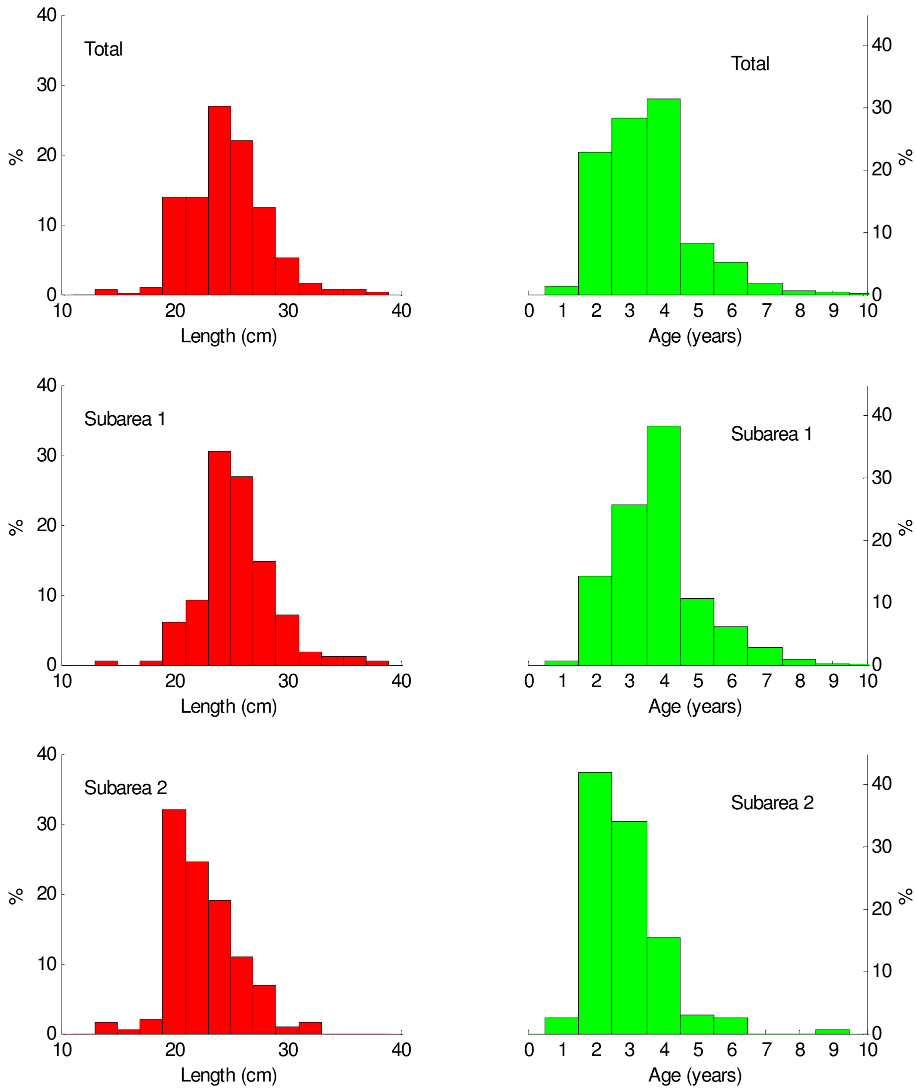


Figure 5 Total length and age breakdown of blue whiting stock and by sub area. Blue whiting survey March-April 2004.

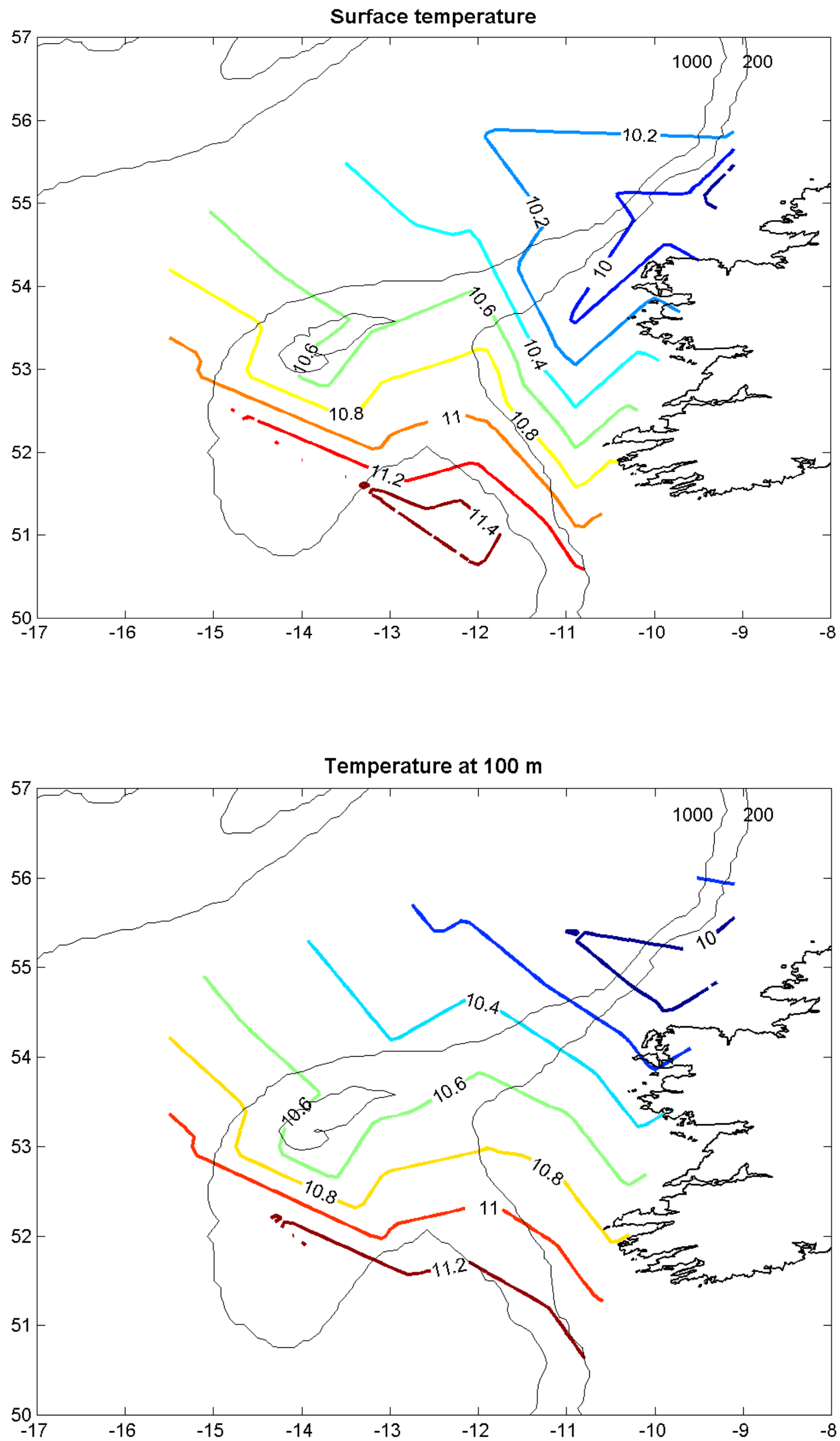


Figure 6 Horizontal temperature profiles compiled from CTD drops within the survey area. Surface plot taken at 10 m, March 2004.

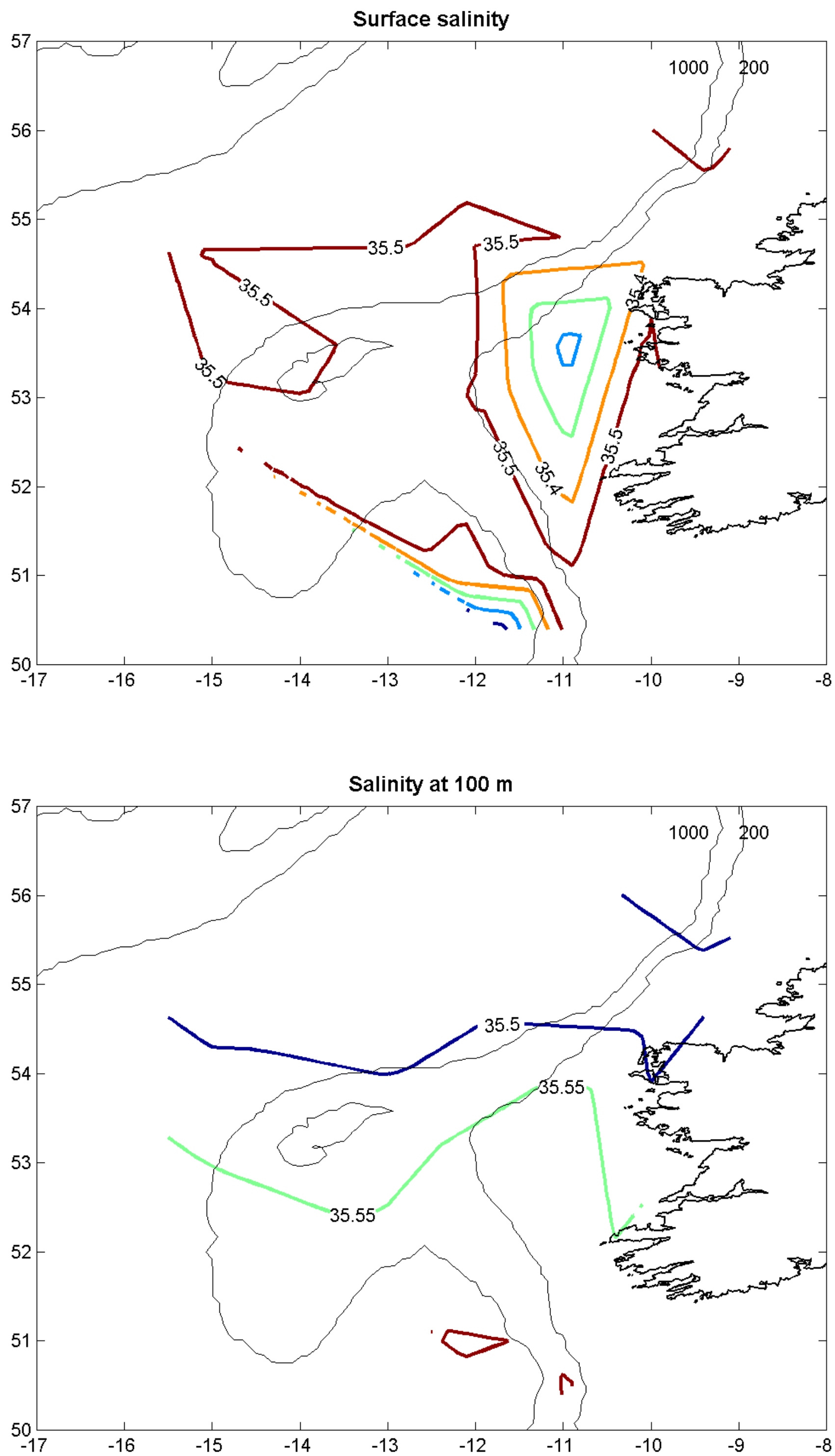
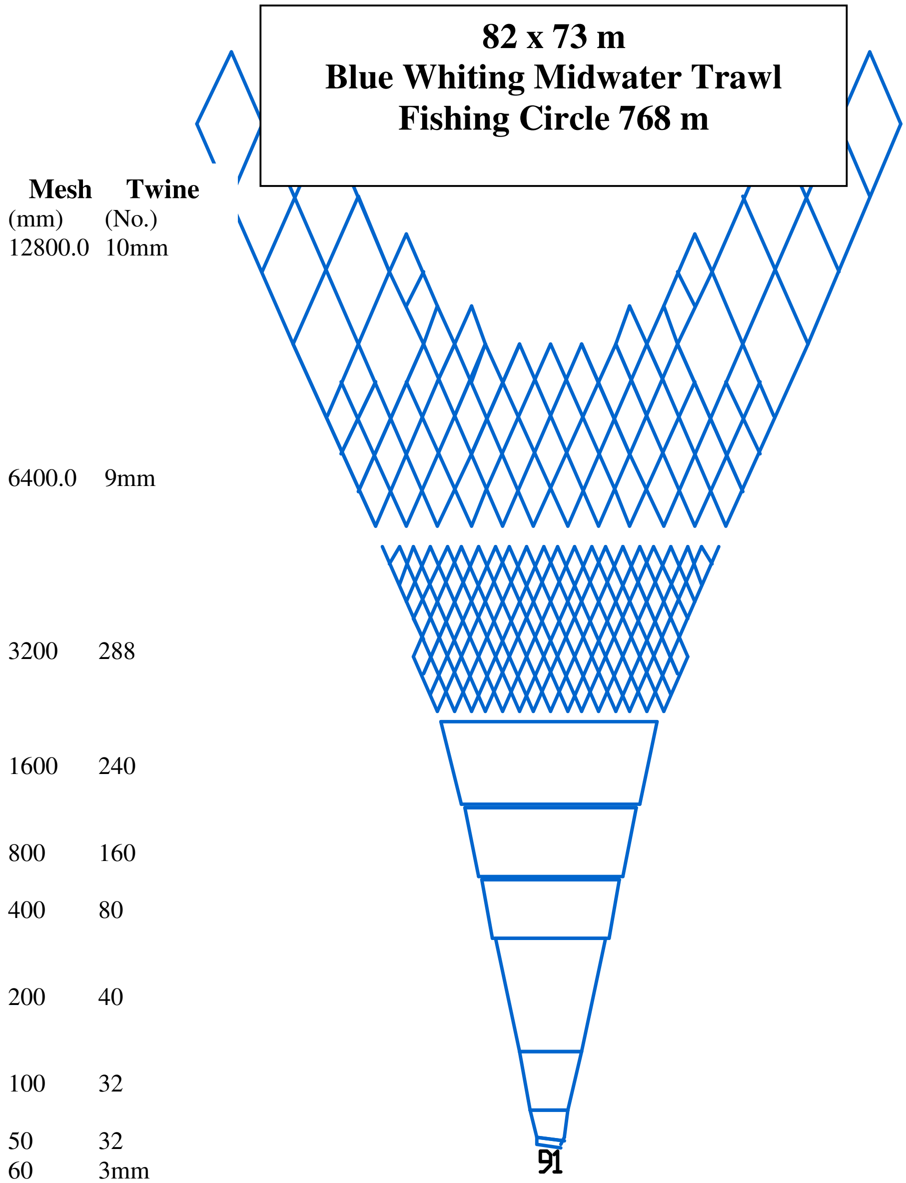


Figure 7 Horizontal salinity profiles compiled from CTD drops within the survey area. Surface plot taken at 10 m, March 2004.



Clump weights:	1000 Kg per side
Trawl doors:	Polyice pelagic 6m² (weight in air 750Kg)
Bridle length:	148m (80fm)

Figure 8 Pelagic midwater trawl employed during the Blue whiting Acoustic Survey, March 2004.

Echo sounder:	Simrad ER 60
Frequency:	38 kHz
Transducer:	ES 38B- Serial
Absorption Coefficient:	9.6 dB/Km (manual)
Pulse length:	1.024 m/s
Bandwidth:	2.425 kHz
Transmitting Power:	2000 W (Max)
Angle Sensitivity:	21.9 dB
2- way beam angle:	-20.6
Gain:	25.22
S_A Correction:	-0.53
3 dB Beam Width:	
Alongship:	7.5°
Athwartship:	7.5°
Max Range:	750m

Table 1. Settings for the Simrad ER 60 echosounder, employed both during the intercalibration and during the survey transects, March 2004.

Haul No.	Start Position	Stop Position	Depth (m)	Bulk Catch (Kg)	Species	Weight in catch (kg)	Species % of catch
1	55° 19.80N & 10° 47.48W	55° 19.79N & 10° 49.05W	450-500	350	Blue Whiting	341.76	98.03
					Mesopelagics	6.866	1.97
2	54° 48.54N & 10° 36.47W	54° 48.42N & 10° 34.14W	450-500	150	Blue Whiting	148.91	99.23
					Mesopelagics	0.58	0.77
3	54° 30.08N & 10° 56.37W	54° 32.26N & 10° 56.17W	450	2500	Blue Whiting	1671.49	66.87
					Argentine	32.31	1.29
					Mackerel	795.79	31.84
4	54° 38.15N & 12° 04.09W	54° 36.20N & 12° 04.07W	500	200	Blue Whiting	199.44	99.85
					Mesopelagics	0.56	0.15
5	53° 54.37N & 13° 13.69W	53° 55.10N & 13° 13.67W	350	200	Blue Whiting	199.30	99.75
					Mesopelagics	0.7	0.25
6	53° 35.35N & 14° 13.76W	53° 35.39N & 14° 14.35W	470-500	125	Blue Whiting	125	100
7	52° 55.64N & 14° 42.64W	52° 55.74N & 14° 44.66W	350	75	Blue Whiting	74.70	99.76
					Mesopelagics	0.30	0.24
8	52° 20.44N & 11° 56.27W	52° 20.53N & 11° 55.24W	285-320	150	Blue Whiting	149.08	99.38
					Mesopelagics	0.92	0.62
9	51° 0.69N & 11° 19.29W	51° 0.71N & 11° 20.74W	270-290	150	Blue Whiting	201.94	33.66
					Scad	211.01	35.19
					Mackerel	186.85	31.15
10	50° 20.87N & 10° 56.35W	50° 20.92N & 10° 59.01W	220-277	150	Blue Whiting	101.84	67.89
					Scad	42.05	28.03
					Mackerel	6.13	4.08

Table 2. Catch composition of trawl hauls.

Note: "Mesopelagics" was used to represented those mesopelagic species which made up less than 10% by weight of total catch.

Rectangle	S_a $m^2/n.m^2$	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
5712	908	1590	1	28.370	1012.440662	1461.68	117.140	171.221
5710	620	900	1	28.370	1012.440662	564.94	117.140	66.177
5614	388	570	4	27.045	1123.707559	248.52	91.550	22.752
5612	936	2988	1	28.370	1012.440662	2831.56	117.140	331.689
5610	1022	725	1	28.370	1012.440662	750.17	117.140	87.875
5516	80	632	6+4	25.700	1255.881672	63.50	80.485	5.111
5614	778	3948	5+4	25.990	1225.533654	3764.28	82.195	309.405
5512	664	3000	2+3+4	26.247	1199.524846	2389.45	83.837	200.325
5416	377	1120	6+7	25.443	1283.701351	542.03	79.180	42.918
5414	186	2880	5	24.935	1341.400609	718.56	72.840	52.340
5412	173	990	3	25.835	1241.61936	212.65	77.880	16.561
5316 A	466	900	7	26.530	1171.806024	491.46	88.940	43.710
5314 A	126	1800	7+7+8	25.017	1331.834108	302.06	77.443	23.392
5312 A	276	150	8	21.990	1764.21671	73.04	54.450	3.977
Porc-N	7,000	22,193		26.878		14413.90	112.970	1377.45
Total							112.970	
5316 B	350	960	7	26.530	1171.806024	393.73	88.940	35.018
5314 B	131	1790	8	21.990	1764.21671	413.69	54.450	22.525
5312 B	608	300	8	21.990	1764.21671	321.79	54.450	17.522
5212	127	1260	8+9	21.600	1834.398783	293.54	50.115	14.711
5112	68	1560	9+10	21.700	1816.020352	192.64	49.350	9.507
Porc-S	1,284	5,870		22.991		1615.40	61.460	99.283
				22.991			61.460	
Totals	**8,284**	**28,063**				**16029.30**		**1476.736**

Table 3 Breakdown of abundance for sub areas used during analysis. Blue whiting survey, March 2004. (Note: Trawl number (S) indicates the combination of data used to allocate to each rectangle for data partitioning).

		Abundance; $N *10^6$			Biomass; 1000 tonnes					
Sub-area	Area Sq.n.mile	Immature	Mature	Sum	Immature	Mature	Sum	Mean W g	Mean L cm	Density T/sq.n.m.
Porcupine North (1)	22193	129.72	14284.17	14413.9	12.4	1365.06	1377.45	95.56	26.88	62.07
Porcupine South (2)	5870	64.62	1550.774	1615.39	3.97	95.31	99.28	61.46	22.99	16.91
Total	28063	177.67	15851.62	16029.29	16.37	1460.37	1476.74	92.13	24.83	52.62

Table 4. Assessment of blue whiting maturity, by numbers and biomass, for areas surveyed 2004.

	Age												
Length Cm	1 2003	2 2002	3 2001	4 2000	5 1999	6 1998	7 1997	8 1996	9 1995	10 1994	Abundance Nx 10-6	Biomass 1000 tns	Mean Weight g
15	23.05										23.0469	0.3918	17.00
16											15.4214	0.34698	22.50
17		14									13.9537	0.3907	28.00
18	10.56	0									10.5596	0.29567	28.00
19	53.44	160									213.752	7.80196	36.50
20		453									453.006	18.1202	40.00
21		280	18.6	9.32	0						307.476	13.8272	44.97
22		164	164	14.9	14.9						357.852	18.8624	52.71
23		301	318	212	0						830.893	48.8233	58.76
24		499	932	865	99.8						2396.29	158.922	66.32
25		83	804	1165	194	27.2					2273.75	168.826	74.25
26		0	1047	1228	144	72.2					2491.94	205.859	82.61
27		0	385	1193	269	192	38.5				2077.66	194.532	93.63
28		0	330	593	297	33	33				1285.39	132.986	103.46
29		0	214	321	214	178	107		35.6		1069.04	121.978	114.10
30		42	0	255	212	255	42.5				806.86	109.136	135.26
31			46	92	138	138	138	46			597.775	89.8038	150.23
32			0	39.5	0	79	0	0			118.569	21.3816	180.33
33			49.5		49.5	0	0	24.7			123.712	21.9959	177.80
34					0	0	56.1	56.1			112.167	22.9381	204.50
35					47	94	0	0			140.959	35.0425	248.60
36					47	47	0	47			140.959	35.8036	254.00
37					0		56.1			56	112.167	31.2384	278.50
38					56.1						56.0832	15.5911	278.00
39													
40													
TSN (1000000)	102.5	1996	4308	5987	1783	1116	471	174	45.6	56	16029.29	**1474.894**	
TSB (1000 tns)													
Mean length (cm)	17.55	22	25.5	26.2	28.5	29.8	31	33.6	29	37			
Mean weight (g)	29.13	54	80.4	87.5	119	138	155	200	114	278			

Table 5. Stock estimate of blue whiting for combined sub-areas Porcupine North and Porcupine South. March-April 2004

Appendix 1

Inter-calibration between R/V Celtic Explorer and R/V Johan Hjort

Mikko Heino

Acoustic inter-calibration between R/V Johan Hjort and R/V Celtic Explorer was conducted on 24 March 2004 on the northern slopes of the Porcupine Bank (N 54^o 00' and W 13^o 00') under good weather conditions. Standard instrument settings were kept during the experiment to simulate a realistic survey situation. The main acoustic features in the area were a layer in depths of 100-300 m, probably consisting of mesopelagic fish, and a layer of blue whiting in depths around 400-600 metres. The blue whiting layer got gradually sparser further away from the shelf edge. The inter-calibration was run over 37 nautical miles between 10:30-15:35 GMT. For the first 20 nm, both vessels were cruising towards north, with Celtic Explorer following J. Hjort at a distance of 0.5 nm and 5-10º (about 1-1.5 cables) to the starboard side. The roles were then reversed, and the vessels cruised southwards for 20 nm. In the beginning the logs were synchronized. After the turn, the synchronization was not very good.

The data were stored by 100 m depth layers. However, as the main acoustic features spanned more than one such layer, we focus on combined layers from depths of 100-300 m and from 400-600 m. In addition, the data were scrutinized, and the acoustic densities allocated to blue whiting were compared.

Figure 1 shows total acoustic densities recorded by the two vessels for the first 20 nm. These display similar overall patterns but considerable differences between individual observations. Much higher values on miles 6-10 in 100-300 m layer for Celtic Explorer in comparison to J. Hjort are caused by noise involving interference and false bottom echoes. Observations for the lower depth layer (400-600 m) were little contaminated by noise, but the value from Celtic Explorer for the first mile probably includes some bottom echoes. Regression models fitted on logarithmic scale show a rather poor fit (low R^2, a large intercept and slope much less than one) for the upper depth layer, but a reasonably good fit (moderately high R^2, a non-significant intercept and slope only little less than one) for the lower depth layer (Table 1).

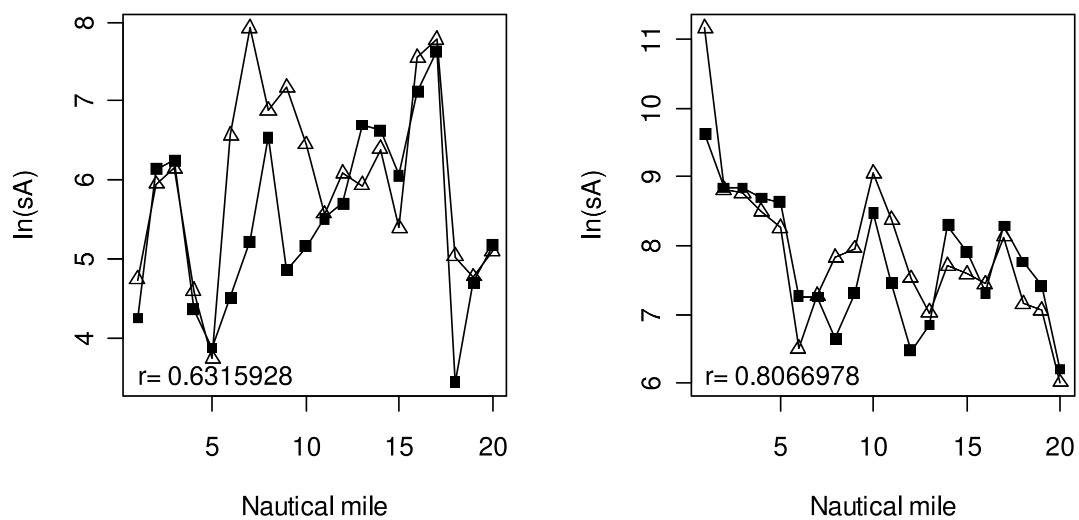


Figure 1. Acoustic densities recorded at the depth layers 100-300m (left) and 400-600 m (right) by Celtic Explorer (triangles) and J. Hjort (squares). Correlation coefficients between the time series are inserted.

Table 1. Regression models for the first 20 nm (n=20) fitted on logarithmic scale. The null hypothesis for t-tests on slope is that the slope is not different from one. Acoustic densities from Johan Hjort are taken as the independent variable and those from Celtic Explorer as the dependent variable.

Depth layer	Parameter	Estimate	Std. Error	t value	Pr(>|t|)	R^2 (%)
100-300 m	Intercept	3.855	1.030	3.74	0.001	32.2
	Slope	0.509	0.174	-2.82	0.012	
400-600 m	Intercept	0.383	1.308	0.29	0.773	65.1
	Slope	0.967	0.167	-0.198	0.386	

Scrutinized data show much better correspondence than raw data (Figure 2), probably because they are less influenced by noise and bottom echoes. The largest discrepancy occurs on miles 31-32, and is probably caused by noise that cannot be separated from blue whiting echoes in the data from Celtic Explorer. The large difference in the last mile is caused asynchrony in logs, such that the last mile of Celtic Explorer covers more of a dense shelf edge spawning aggregation than the last mile of J. Hjort.

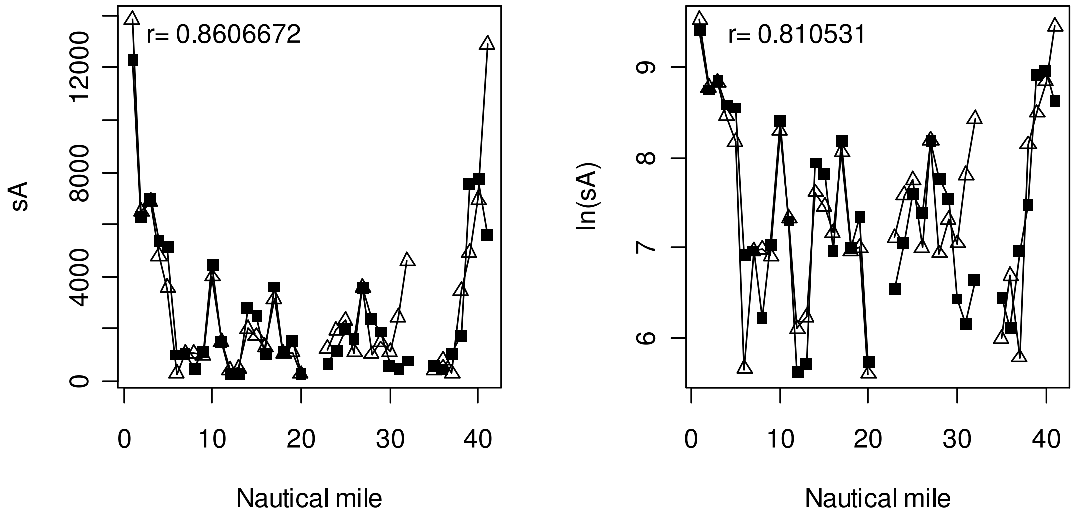


Figure 2. Comparison of blue whiting acoustic densities recorded by Celtic Explorer (triangles) and J. Hjort (squares). Miles 21-22 and 33-34 are not included because of respectively turning and steering problems of Celtic Explorer.

We established regression models to compare the acoustic observations by the two vessels (Table 2). Simple regression models fitted data well, with slope parameters being well estimated (low standard errors) and a high proportion of variability in data being explained by the models. Depending on the subset of data, estimated slope varied in the range 0.95-1.05, but was never significantly different from one. Furthermore, none of the intercepts was significantly different from zero. Regressions forced through the origin were thus considered. These had slopes between 0.95 and 1.03; again, no slope was estimated to be significantly different from one. The results thus show that the acoustic densities for blue whiting made on both vessels are very similar. We therefore conclude that, because the estimated slope varied on both sides of one (depending on the subset of data) but none of the estimates was significantly different from one, the acoustic data from Celtic Explorer and J. Hjort can be used interchangeably without any correction factors.

After the acoustic inter-calibration, pelagic trawls of the two vessels were compared. Both vessels towed to the same direction at a distance of about half nautical mile apart. Celtic Explorer towed at depth of 500 m for 55 minutes and caught 11.2 kg of blue whiting. J. Hjort towed for 70 minutes at depths of 480-500 metres and caught 16 kg of blue whiting. The length distributions in the catches were similar. Blue whiting in the catch of Johan Hjort were almost identical in average length (mean±sd: 26.1±1.9cm) with the blue whiting in the catch of Celtic Explorer (26.2±2.0cm). The difference was statistically insignificant (p=0.528). The performance of the pelagic trawls of the two vessels thus appears to be similar, at least under conditions encountered during this comparison.

Table 2. Regression models for the first 20 nm (n=20), all data (n=37), miles 31-32 excluded (n=35) and miles 31-32 and 41excluded (n=34). Intercept is estimated in the first three regressions, whereas regression through the origin is assumed for the last three. The null hypothesis for t-tests on slope is that the slope is not different from one. No logarithmic transformation was applied here in order to make the models more robust for possible predictions outside the observed ranges. Acoustic densities from Johan Hjort are taken as the independent variable and those from Celtic Explorer as the dependent variable.

Data	Parameter	Estimate	Std. Error	t value	Pr(>|t|)	R^2 (%)
First 20 nm	Intercept	-304.6	200.1	-1.522	0.145	96.4
	Slope	1.051	0.0477	1.064	0.221	
All	Intercept	228.6	377.9	0.605	0.549	74.1
	Slope	0.9912	0.0991	-0.089	0.395	
All\31-32nm	Intercept	-46.30	366.7	-0.126	0.900	78.7
	Slope	1.035	0.0936	0.370	0.369	
All\31,32,41nm	Intercept	-36.67	198.4	-0.185	0.855	91.5
	Slope	0.9537	0.0514	-0.900	0.262	
First 20 nm	Slope	0.9995	0.0349	-0.015	0.394	97.7
All	Slope	1.0334	0.0698	0.479	0.352	85.9
All\31-32nm	Slope	1.0262	0.0645	0.407	0.364	88.2
All\31,32,41nm	Slope	0.9470	0.0360	-1.474	0.134	95.5

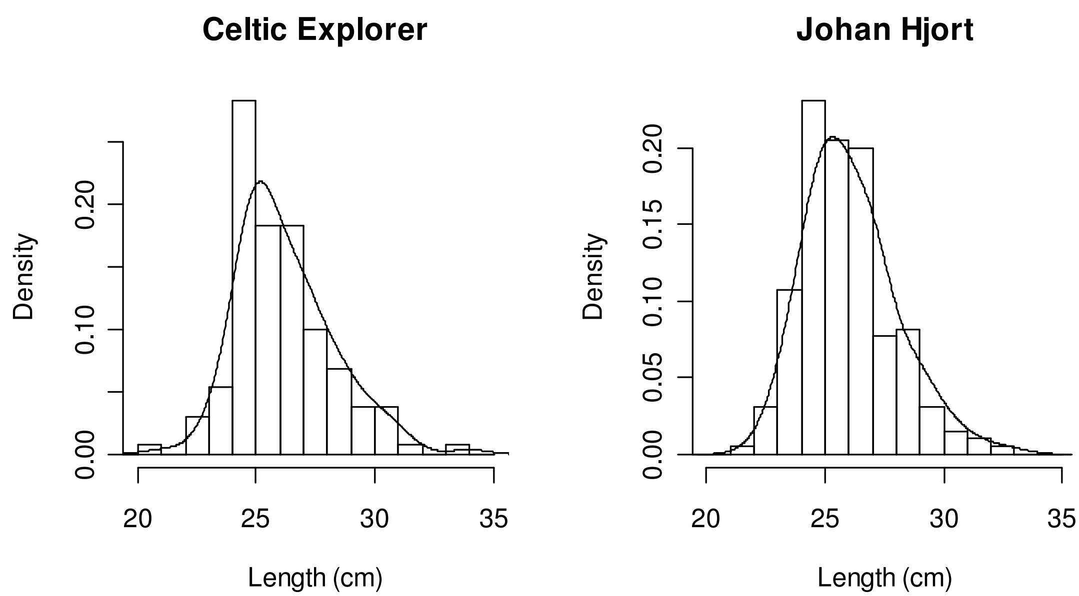


Figure 3. Length distributions from the trawls hauls of Celtic Explorer and J. Hjort. Smoothing is obtained by normal kernel density estimates. J. Hjort: n=195; Celtic Explorer: n=131.