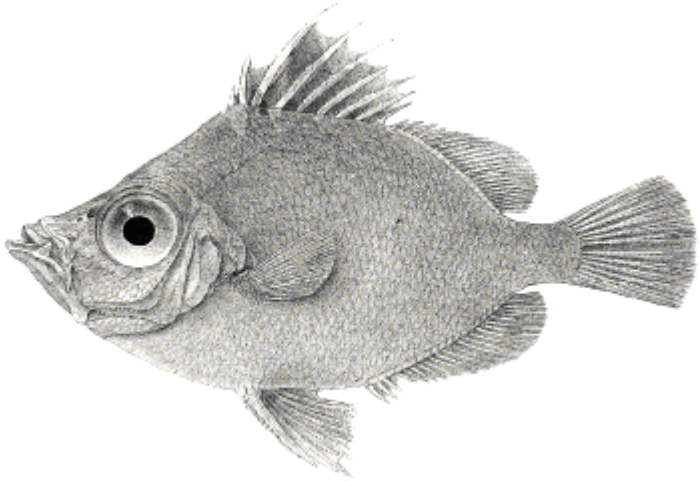
Annex 5d: Boarfish

FEAS Survey Series: 2015/03

Boarfish Acoustic Survey Cruise Report

10 July – 31 July, 2015



Day (1966)

MFV Felucca

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1 Introduction

From the early 1970s the abundance of boarfish (*Capros aper*) was seen to increase exponentially and distribution spread increasingly northwards along the western seaboard and Bay of Biscay (Blanchard and Vandermeirsch, 2005). At the same time, boarfish were caught in increasing quantities in both pelagic and demersal fisheries. This in turn resulted in damage to more commercially valuable target species. Exploratory fishing for boarfish by Irish vessels began in the later 1980s when commercial quantities were encountered during the spring horse mackerel (*Trachurus* trachurus) and mackerel (*Scrombrus scomber*) fisheries in northern Biscay. Several landings were made into Ireland for fishmeal during this time but due to logistical problems related to handling this species was not favoured by processors. Interest increased again temporarily in the mid-1990s when Dutch pelagic vessels landed frozen samples to determine if a market could be developed for human consumption.

During the early 2000s Irish landings were relatively small (<700t per year) and it was not until 2006 that a directed fishery developed. Fishing was undertaken primarily by vessels from the Castletownbere and Killybegs RSW fleets (refrigerated seawater vessels) that targeted boarfish from northern Biscay to the southern Celtic Sea. In 2007-08 vessels from Scotland and Denmark also began targeting boarfish in quantity. Irish landings are primarily landed into fishmeal plants in Denmark and the Faroe Islands with increasing amounts being landed in Killybegs in recent years. The boarfish fishery bridged an important gap between the short season fisheries for horse mackerel, mackerel and blue whiting (*Micromesistius poutassou*). As the fishery develops new markets and uses are being explored including human consumption and bio marine ingredients.

A precautionary interim management plan was adopted in November 2010 covering ICES Divisions VI, VII and VIII and an EU TAC of 33,000 t was set. Of this the Irish allocation for 2011 was 22,000 t. This precautionary TAC was based on 50-75% of total landings from the period 2007-2009 which peaked at over 83,400 t (2009). Landings in 2010 reached over 137,000t prior to the introduction of TAC control. In addition to the TAC, seasonal closures were implemented; from September 1- October 31 (Division VIIg) to protect herring feeding and pre spawning aggregations and from March 15–August 31 where mackerel are frequently encountered as a large bycatch. A catch rule ceiling of 5% bycatch was also implemented within the fishery where boarfish are taken with other TAC controlled species. In 2015 the EU TAC was set at 53,296 t with an Irish allocation of 36,830 t.

This survey represents the fifth dedicated research survey for boarfish in the time series. The commercial fishing vessel MFV *Felucca* was employed for the survey and the vessels hull mounted transducer was calibrated for scientific output.

Data from this survey will be presented to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2015 and as part of the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2016 (WGIPS).

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity
FEAS	Ciaran O'Donnell	Acoustics (SIC)
FEAS	Macdara O 'Cuaig	Analyst
FEAS	Michael McAuliffe	Analyst
Contractor	John Cunningham	Contractor

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives of the survey are listed below:

- Collect integrated and calibrated acoustic data on boarfish (*Capros aper*) aggregations within the pre-determined survey area
- Determine the biomass and abundance of boarfish by age within the survey area
- Collect biological samples from directed trawling on insonified echotraces to determine age structure and maturity state of survey stock as well as to identify echotrace to species.
- Determine the extent and behaviour of boarfish aggregations within the survey area to aid the design of future surveys
- Dovetail with the RV Celtic Explorer in the northern area to ensure close spatio-temporal alignment and synoptic coverage

2.2.2 Area of operation and survey design

The survey started on the Porcupine Bank before moving to survey the shelf sea between 53°40'N and 47°30'N from north to south (Figure 1). Area coverage was based on the distribution of catches from the previous surveys (O'Donnell *et al.* 2011).Timing was planned to coincide with the arrival of the RV *Celtic Explorer* in the northern survey area to ensure a continuous, quasi-synoptic coverage of the combined area.

In total 3,999 nmi (nautical miles) of cruise track was completed by both vessels using 133 transects and related to a total area coverage of 58,292 nmi². Transect spacing was set at 15 nmi for the *Felucca* and 15 and 7.5 nmi for the *C. Explorer* component. For the area covered by the *C. Explorer* only strata (ICES rectangles) bordering the shelf edge were considered during the analysis.

Coverage extended in coastal areas from the c.50 m contour to the shelf slope (250 m). An elementary distance sampling unit (EDSU) of 1 nmi was used during the analysis of combined survey data.

The survey was carried out from 04:00–00:00 each day for both surveys to coincide with the hours of daylight when boarfish are most often observed in homogenous schools. During the hours of darkness boarfish schools tend to disperse into mixed species scattering layers.

2.3 Sampling protocols and equipment specifications

2.3.1 Acoustic equipment

Equipment settings were determined before the start of the survey and are based on established settings employed on previous surveys (O'Donnell *et al.,* 2004 & 2011).

Acoustic data were collected using a Simrad EK 60 scientific echosounder topside unit. A Simrad ES-38B (38 KHz) split-beam transducer mounted on the vessels hull was calibrated and used throughout the survey. Vessel details and set up are provided in Appendix 1.

Cruising speed was largely determined by the weather and the effects on the quality of acoustic data. Where possible cruising speed was maintained at 10kts.

2.3.2 Calibration of acoustic equipment

The EK 60 was calibrated in Donegal Bay prior to the start of the survey in calm conditions. The calibration was carried out using standard methodology as described by Foote *et al.* (1987). Results of the calibration are presented in Table 1.

2.3.4 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The “RAW files” were logged via a continuous Ethernet connection as “EK5” files to a laptop and a HDD hard drive as a backup. Sonar Data’s Myriax Echoview® Live viewer (V6.1) was used to display echograms in real time and to allow the scientists to scroll through noting the locations and depths of target schools to a log file. A member of the scientific crew monitored the equipment continually. Time and location were recorded for each transect start/end position within each stratum. This log was also used to monitor “off track events” such as fishing operations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® post processing software (V6.1). The scrutiny process involved the allocation of echotraces (schools) to particular species or species mix categories, based on the information from the directed trawl hauls.

The NASC (Nautical Area Scattering Coefficient) values from each boarfish echotrace were allocated to one of 4 categories after scrutiny of the echograms. Categories identified on the basis of echotrace scrutiny were as follows:

1. “Definitely boarfish” echotraces were identified on the basis of captures of boarfish from the fishing trawls which were sampled directly. Based on the directly sampled schools we also characterised echotrace as definitely boarfish which appeared very similar on the echogram i.e. , large marks which showed as very high intensity (red), located high in the water column (day) and as strong circular schools.

2. “Probably boarfish” were attributed to smaller echotraces that had not been fished but which had similar characteristics to “definite” boarfish traces.

3. “Boarfish in a mixture” were attributed to NASC values arising from all fish traces in which boarfish were contained, based on the presence of a proportion of boarfish in the catch or within the nearest trawl haul. Boarfish were often taken during trawling in mixed species layers during the hours of darkness.

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

This set of categories allowed us to present the biomass estimates in terms of the best estimate (Cats 1-3), the minimum estimate (Cat 1 + 3), and the maximum estimate (Cats 1-4).

Echograms were divided into transects. Off track events, such as trawl hauls and hydrographic stations were excluded from further analysis. Echo integration was performed on regions which were defined by enclosing selected parts of the echogram that corresponded to one of the four categories above. The echograms were generally analysed and echo-integrals calculated, at a threshold of -70 dB, where necessary heavy backscatter from plankton was filtered out by thresholding at –65 dB.

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 296 m in total length with a 78 m brailer (codend) was used during the survey. The horizontal net spread averaged 90m from wing to wing Mesh size in the wings was 12.8 m through to 2 cm in the cod-end liner. The net was fished with a vertical mouth opening averaging 50m observed using a cable linked Simrad FS 900 netsonde (200 kHz). The net was fitted with Marport catch and tunnel sensors to monitor the amount catch entering the trawl.

An independent light and video/stills camera system was located in the end section of the net and positioned close to the brailer to record fish behaviour in the trawl and to verify trawl catches composition with echotrace identification. Details of camera rig and positioning within the trawl are provided in Appendix 2.

All components of the catch were sorted to species level and weight by species was recorded. For species other than boarfish, length and weight measurements were taken for 100 individuals per trawl in addition to a c.300 fish length frequency sample. Length, weight, sex and maturity data were recorded for individual boarfish in a random 50 fish sample from each trawl haul. In addition a further 100 length/weight and 300 fish length frequency measurements were taken from each haul. Due to the complexity of aging boarfish, no aging was carried out onboard and samples were analysed back in the lab. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

The decision to fish on particular echotraces was based on both the distance from other fishing operations on similar schools, and on the difference between recently observed echotraces and others previously sampled.

2.4 Analysis methods

2.4.1 Abundance estimates

The recordings of area back scattering strength (NASC) per nautical mile were averaged over a one nautical mile EDSU (Elementary sampling distance unit), and the allocation of NASC value to boarfish 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 (S_A) in number per square nautical mile ($N*nmi^{-2}$) was calculated using standard equations (Foote et al. 1987, Toresen *et al*. 1998).

NASC values assigned according to scrutinisation methods (section 2.3.5) were used to estimate the boarfish numbers according to the method of Dalen and Nakken (1983).

The following TS-length relationships used were those recommended by the acoustic survey planning group (ICES, 1994):

Herring	TS = $20\log_{10}L$ – 71.2 dB per individual (L = length in cm)
Sprat	TS = $20\log_{10}L$ – 71.2 dB per individual (L = length in cm)
Mackerel	TS = $20\log_{10}L$ – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = $20\log_{10}L$ – 67.5 dB per individual (L = length in cm)

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

Gadoids	TS = $20\log_{10}L$ – 67.4 dB per individual (L = length in cm)

For boarfish (*Capros aper*) a species specific TS length relationship was applied based on theoretical swimbladder modelling (Fässler *et al.* 2013).

Boarfish TS = $20\log_{10}L - 66.2$ dB per individual (L = length in cm)

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 rectangle and then summed for all statistical rectangles 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 by rectangle and summed for the total area.

3 Results

3.1 Boarfish abundance and distribution

The results presented here are a composite of data collected during this survey and the Malin Shelf herring acoustic survey (RV *Celtic Explorer*). Surveys were timed to ensure a continuous quasi-synoptic coverage over 42 days without interruption from north (59°30'N) to south (47°30'N).

Twenty hauls were carried out by the *Felucca* during the survey, 14 of which contained boarfish (Figure 1, Table 2). An additional 4 carried out by the *C. Explorer* were used in the analysis. In total, 4,168 lengths and 1,500 length/weight measurements were taken in addition to 695 individual boarfish otoliths collected for aging.

3.1.2 Boarfish biomass and abundance

A full breakdown of the stock estimate is presented by strata, age, length, maturity, biomass, and abundance in Tables 4-8 and Figures 3 & 4.

Boarfish	Abund (mils)	Biomass (t)	% contribution
Total estimate			
Definitely	3,742	215,337	92.6
Probably	206	13,990	6.0
Mixture	48	3,307	1.4
Total estimate	**3,996**	**232,634**	**100**
Possibly	-	-	
SSB Estimate			
Definelty	3,211	209,363	92.4
Probably	206	13,990	6.2
Mixture	48	3,306	1.5
SSB estimate	**3,465**	**226,659**	**100**
Possibly	-	-	

3.1.3 Boarfish distribution

Overall, total stock biomass was 19% higher than during the same time in 2014 and measured using comparable survey effort. Geographical distribution of boarfish followed a similar pattern to previous years with core spawning areas containing the largest abundance. In 2015 as in 2014, northern and western areas contained more biomass than observed pre-2014. Combined, the Northern, Porcupine Bank and Western areas contained almost 50% of total biomass (61% in 2014) for 41% of the geographical area covered.

A total of 681 boarfish echotraces were identified during the survey. Of this 92.6% were categorised as 'definitely' boarfish (603 echotraces), 6% as 'probably' (49) and 1.4% of 'boarfish in a mixture' (29 echotraces). A full breakdown of school categorisation, abundance and biomass by ICES statistical rectangle is provided in Table 9. A total of 70 ICES rectangles were covered by the survey representing combined area coverage of 58,292 nmi², an increase of 4% from 2014.

Of the biomass observed in 2015 the southern area contained the largest proportion of stock (over 50.5%), ranking second was the western area where 21.6% of biomass was recorded. The northern area and Porcupine Bank contributed 17.2% and 10.7% respectively.

On the Porcupine Bank, boarfish were observed in a cluster of medium to high density echotraces located close to the shelf edge (Figure 2 & Figure 5a). This pattern of distribution is typical for this area. The total number of boarfish echotraces (n=52) was lower than in 2014 but of higher overall acoustic density resulting in a biomass of c.25,000 t or 10.7% of total and greater than 2014 (c.14,000 t).

The northern area contributed 17.2% (39,900 t) to the total biomass and 14.9% (595.6 million) to total abundance and is comparable to 2014 (32,000 t). The number and acoustic density of echotraces were similar to last year (Figures 2 & 5b).

The western area contributed 21.6% (50,300 t) to total biomass and 18.5% (738.9 million) to total abundance. This area was characterised by clusters of medium and high density echotraces predominantly located below the thermocline and west of 11ºW. This east/west distribution pattern is most likely influenced by the Irish Shelf Front with boarfish preferring the oceanic side (Figures 2 & 5c).

The southern area contributed 50.5% (117,400t) to total biomass and 61% (2902.7 million) to total abundance. Distribution was comparable to previous years with boarfish observed mid-shelf on the banks such as the Jones's Bank and in greater number in 2 areas along the shelf edge (Figures 2, 5d-e & 8).

3.1.4 Boarfish stock structure

An age length key (ALK) compiled from survey and commercial samples collected from 2011-2014 was used during the analysis of survey data (Figure 3). This ALK was used in place of a survey specific key due to the unavailability of aged samples during the analysis.

Age distribution as determined from the survey indicates the stock is dominated by the following age classes in terms of biomass: 15+, 10, 7 and 9 year old fish representing over 69% of the total biomass and 15+, 7, 10 and 9 years in terms of abundance (Figure 3, Tables 5 & 6).

Immature fish (< 9.7 cm TL) were observed predominantly in the southern area mid-shelf and in much smaller numbers in the western area (Tables 7 & 8). Immature boarfish were generally observed in low numbers in catches containing mature individuals. A single high density surface layer targeted during Haul 14 (Table 2, Figure 5f) exclusively contained juvenile boarfish. In total the biomass of immature boarfish was estimated at 6,000 t (2.6%) representing 13.3% of total abundance most of which can be attributed to this juvenile aggregation.

3.2 Other pelagics

3.2.1 Horse mackerel

Horse mackerel (*Trachurus trachurus*) were encountered in 45% of survey hauls often occurring in catches with boarfish (Table 2, Figures 5g & 10).

A total of 289 echotraces were assigned to horse mackerel and 884 length measurements and 489 length and weights were recorded. The modal length of horse mackerel was 31.25 cm (range 13-39 cm) and mean weight was 276 g.

Horse mackerel were widely distributed throughout the survey area from the Porcupine Bank to the southern Celtic Sea occurring mainly as low and medium density echotraces spaced over a wide area. Maturity sampling indicated that spawning was well underway throughout the survey range. The number of echotraces and size range of individuals were comparable with 2014. Horse mackerel were observed during daytime not only as single species echotraces on the bottom but also as surface scattering layers mixed with mackerel and to a lesser extent boarfish. This behaviour would have implications for the precision of future acoustic abundance estimates for horse mackerel due to the availability of horse mackerel to acoustic sampling techniques.

3.2.2 Blue whiting

Blue whiting (*Micromesistius poutassou*) were widespread throughout the survey occurring in 20% of trawl catches. Acoustically, juvenile blue whiting were the most abundant species observed in 2015 and almost consistently throughout the survey time series to date. High

density clusters of juvenile 0-group fish dominated the mid the Celtic Sea from 48°N - 51°N (Figure 5h).

A total of 346 blue whiting were measured and 300 length and weights were recorded. The modal length occurred at 14.4 cm (range 11-18 cm) and mean weight was 19g.

3.3 Trawl mounted camera

A camera system was installed in the trawl close to the joining section of the brailer (codend) and the main body of the net. The system was used as a means to help groundtruth acoustic observations and catch composition against the corresponding trawled echotrace. Camera and lighting specification are detailed in Appendix 2.

Positioning within the trawl was determined and marked out prior to the survey. The camera was installed in the top section of the net on the 120mm mesh line (full mesh) along the central line. The lights (x2) were positioned 50cm behind the camera and 50cm to the side to prevent glare. The camera and lights were positioned looking backwards at the mouth of the brailer. In this position the diameter of the net was in the region of 4.5m tapering to a brailer diameter of 3.7m.

The system was deployed in a total of 10 hauls (Table 2, Figures 7-10) and proved very useful not only for groundtruthing but also as a means of recording behaviour of target species and gear performance. The positioning of the system close to the coded was used as a visual means of determining the composition of the catch that was committed to the brailer and thus would appear in the end sample.

4 Discussion and conclusions

4.1 Discussion

Overall, the survey can be considered a success with all components of the work program completed as planned with no downtime. Survey design, timing and geographical coverage were maintained in 2015 using baselines established in 2012. Weather conditions were average and as the acoustic calibration was undertaken pre-survey this allowed time to increase geographical coverage (4%) and transect mileage (16%) from 2014 levels.

The total number of boarfish echotraces was higher than in 2014 (401 'definitely' boarfish in 2014 vs 603 in 2015). The largest single echotrace in observed in 2015 was one third of the maximum observed in 2014. Echotrace identification was considered accurate with over 92% of the total biomass attributed to the 'definitely' category and supported by comprehensive trawling over the survey area (a 10% increase from 2014).

Overall, the total stock biomass was almost 20% higher than at the same time in 2014 and measured using comparable survey effort. Biomass was higher for all areas compared with 2014 with the exception of the western area (-34%). Over 50% of total biomass was observed in the southern region (Celtic Sea) while the remainder was split across the northern (17.2%), western (21.6%) and Porcupine (10.7%) areas. Historically the southern area has contained upwards of 60% of the total biomass.

The stock is considered to be well contained within the survey area but some doubts still exist regarding the southern limit. Information from the IFREMER PELGAS acoustic survey in the Bay of Biscay (May-June) confirms that for the first time in several years boarfish were observed in number in the northern Biscay (Pierre Pettitgas *pers comm.*). As boarfish were observed at the southern limit of this survey area it is likely that the stock was not fully contained and thus a portion of the stock remains unquantified. In previous years southern containment was considered adequate. Northward distribution was bounded by the surveys northern limits (*C. Explorer*) and eastward transects were discontinued only when detections of boarfish were not observed for several clear miles following established protocols.

4.2 Conclusions

Acoustically derived estimates of abundance are used as a relative index of the stock present within the survey area at the time of surveying. The survey therefore acts as a 'snapshot' of the stock and should not be considered as a measure of absolute stock abundance. The use of an abundance index allows for the percentage change between successive estimates to be tracked over time to reveal trends in stock abundance as the time series develops.

Stock containment in the south remains and issue for the survey. Unquantified biomass from further south is not considered to be substantial this year or in previous years but will affect the overall estimate to a degree.

The age profile of the stock as determined from trawl samples is comparable to previous years with the bulk of the stock dominated by the oldest fish (15+ years). The 7-10 year old fish remain the next dominate group of cohorts within the time series thus validating the ability of the survey to capture the age structure of the spawning population.

Overall the 2015 estimate is considered as an accurate reflection of the biomass on the ground during the time of the survey for equal and comparable survey effort (CV 17%). The overall trend of stock decline perceived within the survey time series was somewhat alleviated this year by a small increase in biomass. However, a single point estimate cannot be considered in isolation and several successive points are required to validate any trend.

4.3 Recommendations

The following recommendations are based on observations made during the survey and are provided as a means of improving future surveys.

- All efforts should be made to ensure good containment of the stock in the southern region of the survey.
- Continued participation in the annual ICES WGACEGG meeting to facilitate acoustic data and knowledge exchange between participant countries surveying in the Celtic Sea and Bay of Biscay. Namely, Ireland, UK and France.
- It is recommended that the use of optics within the trawl for groundtruthing of echotrace composition be continued and developed where possible for future use.
- The survey is due to continue onboard the RV *Celtic Explorer* from 2016 onwards and it is recommended that multi frequency analysis be used to help identify echotraces in problematic areas in the Celtic Sea.
- Hydrographic and oceanographic sampling will help to determine the thermal preference of boarfish and thus distribution during spawning.
- It is recommended that this survey from 2016 starts producing age stratified abundance estimates horse mackerel given the multi frequency suite available onboard the *Explorer*.

Acknowledgements

We would like to express our thanks and gratitude to Denis Carberry (Skipper) and crew of the FV *Felucca* for their good will and professionalism during the survey. The help and knowledge imparted during the survey was invaluable in helping to understand the behaviour of this species.

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Table 1. Survey settings and calibration report (38 kHz) for the tow body system (Simrad EK 60 echosounder).

Echo Sounder System Calibration Report

Vessel :	F/V Felucca		Date :	06.07.15	
Echo sounder :	Hull mounted		Locality :	Donegal Bay	
Type of Sphere :	CU 64	TS_{Sphere}:	-33.50 dB	Depth (Sea floor) :	38 m

Calibration Version 2.1.0.12

Comments:
Offshore drift calibration. Weather conditions good

Reference Target:

TS	-33.52 dB	Min. Distance	10.0m
TS Deviation	5 dB	Max. Distance	12.5m

Transducer: ES38B Serial No.

Frequency	38000 Hz	Beam type	Split
Gain	26.21 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.10 deg	Along. Beam Angle	7.06 deg
Athw. Offset Angle	0.12 deg	Along. Offset Angle	-0.05 deg
Sa Correction	-0.61 dB	Depth	3.50 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.192 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 Version 2.2.1

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.	9.3 dB/km	Sound Velocity	1501.9 m/s

Beam Model results:

Transducer Gain =	26.21 dB	Sa Correction =	-0.61 dB
Athw. Beam Angle =	7.10 deg	Along. Beam Angle	7.06 deg
Athw. Offset Angle =	0.12 deg	Along. Offset Angle	-0.05 deg

Data deviation from beam model:
RMS = 0.12 dB
Max = 0.41 dB No. = 204 Athw. = -2.9 deg Along = -2.8 deg
Min = -0.60 dB No. = 156 Athw. = 4.4 deg Along = 0.8 deg

Data deviation from polynomial model:
RMS = 0.10 dB
Max = 0.30 dB No. = 204 Athw. = -2.9 deg Along = -2.8 deg
Min = -0.44 dB No. = 156 Athw. = 4.4 deg Along = 0.8 deg

Comments :
Flat calm conditions
Wind Force : 2-5 kn. **Wind Direction :** SW
Raw Data File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\BFAS 2015\Hull mounted
Calibration File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\BFAS 2015\Hull mounted

Calibration : Ciaran O'Donnell

Table 2. Catch composition and position of hauls undertaken by the MFV *Felucca* and for the Celtic Explorer.

Felucca

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
1	12.07.15	52.66	-14.00	14:38	267	50-100	3,500	99.5	0.5			
2	13.07.15	53.65	-11.40	10:25	214	65	2,500	94.2	0.2		5.6	
3	14.07.15	53.14	-11.54	07:53	140	65	500	72.0	25.0		3.0	
4	14.07.15	53.14	-10.51	13:15	100	13-25	300					100.0
5*	15.07.15	52.40	-11.03	13:32	122	0-35	500	1.0	53.0		41.6	4.4
6*	15.07.15	52.40	-11.56	16:58	165	65	8,000	73.7	3.0		23.4	
7*	17.07.15	50.89	-9.34	13:48	116	0-35	200	16.5	40.1		8.4	35.0
8*	17.07.15	50.88	-10.15	18:30	123	0-50	8,000	92.6	1.1		6.4	
9	18.07.15	50.63	-9.21	11:22	110	0-25	2,000	81.4	15.4		2.2	1.0
10*	18.07.15	50.66	-8.43	16:03	106	13-45	100		34.2		65.7	0.1
11*	19.07.15	50.38	-10.21	13:44	142	70-110	10,000		1.4			98.6
12*	20.07.15	50.13	-9.42	06:52	140	0-17	3,000					100.0
13*	20.07.15	49.88	-7.94	19:37	109	0-15	1,000		55.2		38.3	6.5
14	21.07.15	49.89	-9.62	10:01	120	20-70	5,000	100.0				
15*	22.07.15	49.38	-8.11	15:34	136	0-20	5,000	12.0				88.0
16	24.07.15	49.87	-9.59	12:42	170	0-25	1,500	100.0				
17*	25.07.15	48.63	-8.60	10:00	170	35-55	5,000	100.0				
18	26.07.15	48.38	-8.60	12:25	177	0-35	2,000	100.0				
19	27.07.15	47.89	-6.97	17:43	170	65-140	8,000					100.0
20*	28.07.15	47.40	-6.05	12:21	157	0-20	3,000	100.0				

^ Includes non-target pelagic/demersal species and other taxa
*Camera installed in trawl

Table 2. Continued

Celtic Explorer

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
7	03.07.15	58.42	-8.97	20:07			7	0.2	83.3			16.5
16	09.07.15	2.84	-9.05	05:44			62	17.4	48.2	31.9	1.4	1.0
19	11.07.15	12.28	-10.20	09:12			4,000	100.0				
22	13.07.15	45.95	-10.77	05:09			97	98.6	0.7			0.7

^ Includes non-target pelagic/demersal species and other taxa

Table 3. Normalised age/length key compiled from commercial catch and survey samples collected during 2011-2014.

	Age (yrs)														
Length (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
6	1.00														
6.5	1.00														
7	0.50	0.50													
7.5	0.50	0.50													
8		1.00													
8.5		0.50	0.50												
9		0.50	0.50												
9.5			1.00												
10			1.00												
10.5			0.13	0.67	0.20										
11			0.02	0.60	0.29	0.04	0.04								
11.5				0.12	0.28	0.28	0.24	0.03	0.03	0.01					
12				0.04	0.17	0.22	0.37	0.12	0.08						0.01
12.5					0.04	0.08	0.36	0.31	0.12	0.05	0.02		0.01	0.01	0.01
13					0.02	0.03	0.26	0.24	0.20	0.10	0.05	0.02	0.03	0.01	0.04
13.5					0.01	0.03	0.22	0.19	0.18	0.12	0.05	0.04	0.04	0.02	0.10
14							0.06	0.09	0.19	0.24	0.09	0.03	0.08	0.01	0.22
14.5						0.02	0.02	0.03	0.05	0.13	0.02	0.09	0.09	0.09	0.47
15							0.03	0.03		0.06	0.06	0.06	0.15	0.06	0.56
15.5										0.09	0.00	0.00	0.00	0.09	0.83
16															1.00
16.5															1.00
17															1.00
17.5															1.00
18															1.00
18.5															1.00

Table 4. Boarfish length at age (years) as abundance (millions) and biomass (000's tonnes).

Length	Age (years)															Abundance	Biomass	Mn wt
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	(millions)	(000s t)	(g)
4.5																		
5																		
5.5																		
6	3.51															3.51	0.02	6
6.5	38.6															38.58	0.29	7.4
7	51.2	51.2														102.36	0.93	9.1
7.5	105	105														210.5	2.3	11.0
8		151														151.5	2.0	13.2
8.5		9.6	9.6													19.2	0.3	15.6
9		1.75	1.75													3.5	0.1	18.3
9.5			2.34													2.3	0.1	21.3
10			1.8													1.8	0.0	24.6
10.5			0.69	3.5	1.0											5.2	0.2	28.2
11			0.51	14.8	7.2	1.0	1.0									24.6	0.8	32.1
11.5				9.16	21.4	21.4	18.3	2.0	2.0	1.0						75.4	2.7	36.3
12				6.89	29.3	37.9	65.5	20.7	13.8						1.7	175.7	7.2	41.0
12.5					10.4	18.8	87.7	77.3	29.2	12.5	4.2		2.1	2.1	2.1	246.5	11.3	45.9
13					6.5	13	101	91	78.0	39.0	19.5	6.5	9.7	3.3	16.2	383.3	19.7	51.3
13.5					4.24	12.7	106	93.2	89	59.3	25.4	21.2	17.0	8.5	46.6	483.0	27.5	57.0
14							40	53.3	120	147	53.3	20.0	46.7	6.7	133	619.9	39.2	63.2
14.5						7.19	7.19	14.4	21.6	57.5	7.19	43.2	43.2	43.2	216	460.3	32.1	69.7
15							11.1	11.1		22.1	22.1	22.1	55.3	22.1	210	376.1	28.9	76.7
15.5										22				22	209	253.3	21.3	84.2
16															174	174.3	16.1	92.1
16.5															92.1	92.1	9.3	100.4
17															68.7	68.7	7.5	109.2
17.5															17	17.0	2.0	118.6
18															5.91	5.91	0.76	128.4
18.5															1.55	1.55	0.22	138.7
19																		
19.5																		
20																		
SSN			3.48	34	79.9	112	437	363	354	360	132	113	174	108	1195	3,464.5		
SSB			0.089	1.18	3.29	5.12	22.5	19.7	20.1	22.8	8.21	7.51	11.8	7.73	96.7		226.7	
Mn wt (g)	9.7	11.9	18.7	34.6	41.1	45.7	51.4	54.2	57	63.4	62.3	66.5	67.6	71.7	80.9			
Mn L (cm)	7.4	7.9	9.3	11.5	12.2	12.7	13.2	13.5	13.7	14.2	14.2	14.5	14.6	14.9	15.5			

Table 5. Boarfish total biomass (000's tonnes) at age (years) by ICES statistical rectangle.

Region	Strata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
North	45E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2
	44E0	0	0	0	0	0	0.1	0.5	0.5	0.6	0.8	0.3	0.3	0.4	0.3	2.9	6.6
	44E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	43E0	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.5	1.1
	43E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42E1	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.2	0.4
	41E0	0	0	0	0	0	0	0.2	0.2	0.3	0.3	0.1	0.1	0.2	0.1	1.3	2.9
	41E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40E0	0	0	0	0	0	0.1	0.4	0.4	0.5	0.6	0.2	0.2	0.3	0.2	2	5
	39E0	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.5	1.1
	38D9	0	0	0	0	0	0.1	0.5	0.5	0.7	0.9	0.3	0.3	0.5	0.4	3.4	7.6
	37D9	0	0	0	0	0.1	0.2	1.3	1.3	1.6	1.9	0.7	0.6	1	0.6	5.6	14.8
	39D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Porc	36D6	0	0	0	0	0	0	0.2	0.2	0.3	0.3	0.1	0.1	0.2	0.1	1.1	2.6
	35D5	0	0	0	0	0	0.1	0.7	0.7	0.8	1.4	0.5	0.6	1	0.7	8.5	15
	35D6	0	0	0	0	0	0	0.2	0.2	0.2	0.4	0.2	0.2	0.3	0.2	2.5	4.4
	34D5	0	0	0	0	0	0	0.1	0.1	0.2	0.3	0.1	0.1	0.2	0.1	1.7	3
	34D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West	36D8	0	0	0	0	0.1	0.2	1.4	1.3	1.5	1.8	0.7	0.6	1	0.6	6.1	15.3
	36D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35D7	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0	0.3	0.8
	35D8	0	0	0	0	0.1	0.1	0.7	0.7	0.8	1	0.4	0.4	0.6	0.4	3.5	8.6
	35D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34D7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34D8	0	0	0	0	0	0.1	0.5	0.5	0.6	1	0.4	0.4	0.6	0.5	5.3	9.9
	34D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D8	0	0	0	0	0.1	0.1	0.9	0.9	1	1.3	0.5	0.5	0.8	0.5	5.7	12.3
	33D9	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.7	1.5
	32D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2
	32D9	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.8	1.7
South	31D8	0	0	0	0	0	0	0.2	0.2	0.2	0.3	0.1	0.1	0.2	0.1	2.2	3.8
	31D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	31E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30D9	0	0	0	0	0	0	0.2	0.2	0.2	0.3	0.1	0.1	0.2	0.1	1.7	3
	30E0	0	0	0	0	0	0.1	0.3	0.2	0.3	0.4	0.1	0.1	0.2	0.2	5.4	7.3
	30E1	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	1.7	2.2
	30E2	0	0	0	0.1	0.1	0.2	0.8	0.6	0.7	1	0.3	0.3	0.5	0.5	17	22.1
	29D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D9	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.4	0.7
	29E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.4
	29E1	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0	1.7	2.2
	29E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E0	1.9	3.7	0.2	0	0	0	0	0	0	0	0	0	0	0	0	5.8
	28E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27D9	0	0	0	0	0.1	0.2	0.5	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.5	2.7
	27E0	0	0	0	0	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0	0.1	0	0.3	1.7
	27E1	0	0	0	0.1	0.2	0.3	0.8	0.6	0.5	0.4	0.2	0.1	0.2	0.1	1	4.7
	27E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26D9	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1	0.4
	26E0	0	0	0	0.1	0.4	0.5	1.5	1.1	0.9	0.7	0.3	0.2	0.3	0.2	1.4	7.8
	26E1	0	0	0	0.2	0.5	0.6	2.1	1.5	1.2	0.9	0.3	0.2	0.3	0.2	1.7	9.8
	26E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25E0	0	0	0	0	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0	0.1	0	0.3	1.6
	25E1	0	0	0	0.2	0.6	0.9	3.3	2.7	2.3	1.8	0.7	0.5	0.7	0.4	3.3	17.4
	25E2	0	0	0	0	0.1	0.1	0.6	0.5	0.4	0.3	0.1	0.1	0.1	0.1	0.6	3
	25E3	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.4
	24E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24E4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23E3	0	0	0	0.1	0.3	0.4	1.7	1.5	1.6	1.6	0.6	0.4	0.6	0.3	2.4	11.5
	23E4	0	0	0	0.1	0.2	0.3	1.4	1.2	1.3	1.2	0.4	0.3	0.5	0.2	1.9	8.9
	Total	1.9	3.8	0.3	1.2	3.3	5.1	22.5	19.7	20.1	22.8	8.2	7.5	11.8	7.7	96.7	232.6
	%	0.8	1.6	0.1	0.5	1.4	2.2	9.7	8.5	8.7	9.8	3.5	3.2	5.1	3.3	41.5	100

Table 6. Boarfish total abundance (millions) at age (years) by ICES statistical rectangle.

Region	Strata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
North	45E1	0	0	0	1.0	13.0	37.0	0.2	0.2	0.3	0.4	0.1	0.1	0.2	0.1	1.1	2.9
	44E0	0	0	0	47.0	0.4	1.2	8.0	8.1	9.7	12.2	4.1	4.4	6.3	4.4	38.3	97.2
	44E1	0	0	0	1.0	5.0	14.0	93.0	94.0	0.1	0.1	48.0	51.0	74.0	51.0	0.4	1.1
	43E0	0	0	0	8.0	72.0	0.2	1.4	1.4	1.7	2.1	0.7	0.8	1.1	0.7	6.5	16.6
	43E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42E1	0	0	0	3.0	27.0	8.0	0.5	0.5	0.6	0.8	0.3	0.3	0.4	0.3	2.5	6.3
	41E0	0	0	0	2.0	0.2	0.5	3.5	3.5	4.2	5.3	1.8	1.9	2.7	1.9	16.7	42.3
	41E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40E0	0	0	0.1	29.0	0.4	1.0	6.8	6.8	8.2	9.7	3.4	3.2	4.7	3.0	26.9	74.0
	39E0	0	0	22.0	7.0	8.0	0.2	1.5	1.5	1.8	2.2	0.8	0.7	1.1	0.7	6.3	17.0
	38D9	0	0	0	54.0	0.5	1.4	9.2	9.3	11.1	14.1	4.7	5.1	7.3	5.0	44.1	111.9
	37D9	0	0	0	37.0	1.1	3.1	23.0	22.7	26.6	29.7	10.9	9.7	14.4	8.5	75.1	224.8
	39D9	0	0	0	1.0	6.0	18.0	0.1	0.1	0.1	0.2	62.0	66.0	95.0	65.0	0.6	1.5
Porc	36D6	0	0	0	46.0	0.4	0.7	4.3	4.0	4.3	4.8	1.8	1.6	2.6	1.5	13.8	39.8
	35D5	0	0	0	0.0	0.4	1.4	11.0	11.6	13.9	21.0	7.7	8.0	13.5	9.1	105.0	202.5
	35D6	0	0	0	0.0	0.1	0.4	3.3	3.4	4.1	6.2	2.3	2.4	4.0	2.7	31.0	59.8
	34D5	0	0	0	0.0	73.0	0.3	2.2	2.3	2.8	4.2	1.5	1.6	2.7	1.8	20.9	40.3
	34D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West	36D8	0	0	0.0	0.3	2.1	4.2	24.9	23.2	25.0	28.1	10.6	9.4	14.9	8.8	80.1	231.6
	36D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35D7	0	0	44.0	4.0	0.1	0.2	1.1	1.0	1.1	1.4	0.5	0.5	0.8	0.5	4.1	11.4
	35D8	0	0	0.4	0.4	1.2	2.3	12.5	11.8	13.1	15.8	5.8	5.9	9.0	5.6	46.4	130.1
	35D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34D7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34D8	0	0	0.1	0.1	0.5	1.3	9.0	9.1	10.6	14.8	5.4	5.6	9.2	6.1	65.6	137.5
	34D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D8	0	0	12.0	0.4	1.2	2.5	16.3	15.7	17.1	20.2	7.6	7.1	11.3	7.1	71.8	178.3
	33D9	0	0	1.0	51.0	0.1	0.3	2.0	1.9	2.1	2.5	0.9	0.9	1.4	0.9	8.9	22.1
	32D8	0	0	0	7.0	21.0	44.0	0.3	0.3	0.3	0.4	0.1	0.1	0.2	0.1	1.3	3.2
	32D9	0	0	2.0	57.0	0.2	0.3	2.2	2.2	2.4	2.8	1.1	1.0	1.6	1.0	9.9	24.6
South	31D8	0	0	41.0	0.3	0.5	0.7	3.9	3.7	4.0	5.0	1.8	1.7	2.8	1.8	25.5	51.8
	31D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	31E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30D9	0	0	33.0	0.3	0.4	0.6	3.1	2.9	3.2	4.0	1.5	1.4	2.2	1.4	20.3	41.2
	30E0	0	0	0.4	0.6	1.1	1.5	5.5	4.5	4.4	5.5	1.8	1.8	2.9	2.3	57.4	89.6
	30E1	0	0	0.2	0.2	0.3	0.4	1.5	1.2	1.1	1.4	0.5	0.5	0.7	0.6	17.5	26.1
	30E2	0	0	1.6	2.4	3.6	4.4	14.9	12.0	11.5	14.8	4.7	4.7	7.4	6.3	178.4	266.5
	29D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D9	0	0	7.0	6.0	83.0	0.1	0.7	0.6	0.7	0.9	0.3	0.3	0.5	0.3	4.5	9.1
	29E0	0	0	26.0	4.0	59.0	73.0	0.2	0.2	0.2	0.2	78.0	78.0	0.1	0.1	3.0	4.4
	29E1	0	0	0.2	0.2	0.4	0.4	1.5	1.2	1.1	1.5	0.5	0.5	0.7	0.6	17.7	26.5
	29E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E0	196.5	314.8	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	521.7
	28E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27D9	74.0	0.2	21.0	1.4	3.3	4.0	11.2	7.7	6.2	4.4	1.6	1.1	1.6	0.9	7.0	50.7
	27E0	1.7	2.8	0.1	0.9	2.1	2.5	7.0	4.9	3.9	2.8	1.0	0.7	1.0	0.5	4.4	36.3
	27E1	0	0	0.2	4.0	6.0	6.6	17.9	12.2	9.9	7.3	2.8	1.9	3.0	1.5	13.4	86.7
	27E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26D9	11.0	33.0	3.0	0.2	0.5	0.6	1.7	1.2	0.9	0.7	0.2	0.2	0.2	0.1	1.0	7.6
	26E0	0.2	0.6	61.0	4.0	9.5	11.7	32.6	22.5	17.9	12.6	4.8	3.2	4.6	2.4	2025.0	146.7
	26E1	0	0	67.0	4.8	12.2	15.3	43.9	30.6	23.0	15.0	6.0	3.5	5.5	2.8	23.6	186.3
	26E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25E0	0	0	0.1	0.6	1.4	1.8	6.4	4.9	3.9	2.9	1.1	0.7	1.0	0.6	4.4	29.6
	25E1	0	0	1.4	6.8	15.1	19.8	68.7	52.7	41.8	30.9	11.6	7.6	10.8	6.3	47.2	320.6
	25E2	0	0	0.2	1.1	2.6	3.4	11.7	8.9	7.1	5.2	2.0	1.3	1.8	1.1	8.0	54.4
	25E3	0	16.0	17.0	9.0	0.2	0.3	1.2	1.0	1.0	0.9	0.3	0.2	0.3	0.2	1.2	6.9
	24E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24E3	0	0	0.0	1.0	3.0	4.0	14.0	12.0	12.0	11.0	4.0	3.0	4.0	2.0	15.0	84.0
	24E4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23E3	0	0.5	0.5	2.6	6.6	8.9	33.9	27.8	28.5	25.5	9.5	6.5	9.6	4.5	35.1	199.9
	23E4	0	0.4	0.4	2.0	5.1	6.9	26.5	21.6	22.2	19.9	7.4	5.1	7.5	3.5	27.4	155.9
	Total	198.5	319.2	16.65	34.35	8043	112	437.4	362.9	353.5	360.2	131.7	113	173.9	107.8	1195	3995.8
	%	5.0	8.0	0.4	0.9	2.0	2.8	10.9	9.1	8.8	9.0	3.3	2.8	4.4	2.7	29.9	100
	CV	99	99	63.4	22.9	21.6	19.4	17.1	16.1	14.1	12.2	12.2	11.3	11.3	11.3	10.5	NA

Table 7. Boarfish biomass (000's tonnes) by maturity by ICES statistical rectangle.

Region	Strata	Imm	Mature	Spent	Total
North	45E1	0	0.2	0	0.2
	44E0	0	6.6	0	6.6
	44E1	0	0.1	0	0.1
	43E0	0	1.1	0	1.1
	43E1	0	0	0	0
	42E0	0	0	0	0
	42E1	0	0.4	0	0.4
	41E0	0	2.9	0	2.9
	41E1	0	0	0	0
	40E0	0	5	0	5
	39E0	0	1.1	0	1.1
	38D9	0	7.6	0	7.6
	37D9	0	14.8	0	14.8
	39D9	0	0.1	0	0.1
Porc	36D6	0	2.6	0	2.6
	35D5	0	15	0	15
	35D6	0	4.4	0	4.4
	34D5	0	3	0	3
	34D6	0	0	0	0
	33D5	0	0	0	0
	33D6	0	0	0	0
West	36D8	0	15.3	0	15.3
	36D9	0	0	0	0
	35D7	0	0.8	0	0.8
	35D8	0	8.6	0	8.6
	35D9	0	0	0	0
	34D7	0	0	0	0
	34D8	0	9.9	0	9.9
	34D9	0	0	0	0
	33D8	0	12.3	0	12.3
	33D9	0	1.5	0	1.5
	32D8	0	0.2	0	0.2
	32D9	0	1.7	0	1.7
South	31D8	0	3.8	0	3.8
	31D9	0	0	0	0
	31E0	0	0	0	0
	30D8	0	0	0	0
	30D9	0	3	0	3
	30E0	0	7.3	0	7.3
	30E1	0	2.2	0	2.2
	30E2	0	22.1	0	22.1
	29D8	0	0	0	0
	29D9	0	0.7	0	0.7
	29E0	0	0.4	0	0.4
	29E1	0	2.2	0	2.2
	29E2	0	0	0	0
	28D8	0	0	0	0
	28D9	0	0	0	0
	28E0	5.8	0	0	5.8
	28E1	0	0	0	0
	28E2	0	0	0	0
	27D8	0	0	0	0
	27D9	0	2.7	0	2.7
	27E0	0.1	1.7	0	1.7
	27E1	0	4.7	0	4.7
	27E2	0	0	0	0
	26D9	0	0.4	0	0.4
	26E0	0	7.7	0	7.8
	26E1	0	9.8	0	9.8
	26E2	0	0	0	0
	26E3	0	0	0	0
	25E0	0	1.6	0	1.6
	25E1	0	17.4	0	17.4
	25E2	0	3	0	3
	25E3	0	0.4	0	0.4
	24E2	0	0	0	0
	24E3	0	0	0	0
	24E4	0	0	0	0
	23E3	0	11.5	0	11.5
	23E4	0	8.9	0	8.9
	Total	6	226.7	0	232.6
	%	2.6	97.4	0	100

Table 8. Boarfish abundance (millions) by maturity by ICES statistical rectangle.

Region	Strata	Imm	Mature	Spent	Total
North	45E1	0	2.9	0	2.9
	44E0	0	97.2	0	97.2
	44E1	0	1.1	0	1.1
	43E0	0	16.6	0	16.6
	43E1	0	0	0	0
	42E0	0	0	0	0
	42E1	0	6.3	0	6.3
	41E0	0	42.3	0	42.3
	41E1	0	0	0	0
	40E0	0	74.0	0	74.0
	39E0	0	17.0	0	17.0
	38D9	0	111.9	0	111.9
	37D9	0	224.8	0	224.8
	39D9	0	1.5	0	1.5
Porc	36D6	0	39.8	0	39.8
	35D5	0	202.5	0	202.5
	35D6	0	59.8	0	59.8
	34D5	0	40.3	0	40.3
	34D6	0	0	0	0
	33D5	0	0	0	0
	33D6	0	0	0	0
West	36D8	0	231.6	0	231.6
	36D9	0	0.0	0	0.0
	35D7	0	11.4	0	11.4
	35D8	0.1	130.1	0	130.1
	35D9	0	0	0	0
	34D7	0	0	0	0
	34D8	0	137.5	0	137.5
	34D9	0	0	0	0
	33D8	0	178.3	0	178.3
	33D9	0	22.1	0	22.1
	32D8	0	3.2	0	3.2
	32D9	0	24.6	0	24.6
South	31D8	0	51.7	0	51.8
	31D9	0	0	0	0
	31E0	0	0	0	0
	30D8	0	0	0	0
	30D9	0	41.2	0	41.2
	30E0	0.2	89.5	0	89.6
	30E1	0.1	26.0	0	26.1
	30E2	0.7	265.9	0	266.5
	29D8	0	0	0	0
	29D9	0	9.1	0	9.1
	29E0	0	4.4	0	4.4
	29E1	0.1	26.4	0	26.5
	29E2	0	0	0	0
	28D8	0	0	0	0
	28D9	0	0	0	0
	28E0	521.7	0.0	0	521.7
	28E1	0	0	0	0
	28E2	0	0	0	0
	27D8	0	0	0	0
	27D9	0.3	50.4	0	50.7
	27E0	4.6	31.8	0	36.3
	27E1	0.1	86.6	0	86.7
	27E2	0	0	0	0
	26D9	0	7.6	0	7.6
	26E0	0.8	145.9	0	146.7
	26E1	0	186.3	0	186.3
	26E2	0	0	0	0
	26E3	0	0.0	0	0
	25E0	0.1	29.5	0	29.6
	25E1	0.8	319.8	0	320.6
	25E2	0.1	54.3	0	54.4
	25E3	0	6.9	0	6.9
	24E2	0	0	0	0
	24E3	0	0.1	0	0.1
	24E4	0	0	0	0
	23E3	0.9	199.0	0	199.9
	23E4	0.7	155.2	0	155.9
	Total	531.3	3464.5	0	3995.8
	%	13.3	86.7	0	100

Table 9. Boarfish biomass and abundance by ICES statistical rectangle.

Region	Strata	No. transects	No. schools	Def schools	Prob schools	Mix schools	% zeros	Def Biomass	Prob Biomass	Mix Biomass	Biomass (000't)	SSB (000't)	Abundance millions
North	45E1	2	3	0	3	0	50	0	0.2	0	0.2	0.2	2.9
	44E0	2	5	0	5	0	50	0	6.6	0	6.6	6.6	97.2
	44E1	2	1	0	1	0	50	0	0.1	0	0.1	0.1	1.1
	43E0	2	8	0	8	0	50	0	1.1	0	1.1	1.1	16.6
	43E1	2	0	0	0	0	100	0	0	0	0	0	0
	42E0	2	0	0	0	0	100	0	0	0	0	0	0
	42E1	4	3	0	3	0	75	0	0.4	0	0.4	0.4	6.3
	41E0	4	8	0	8	0	0	0	2.9	0	2.9	2.9	42.3
	41E1	4	0	0	0	0	100	0	0	0	0	0	0
	40E0	2	23	9	0	14	0	3.3	0	1.6	5	5	74.0
	39E0	4	28	23	0	5	25	0.9	0	0.3	1.1	1.1	17.0
	38D9	2	25	25	0	0	0	7.6	0	0	7.6	7.6	111.9
	37D9	2	26	26	0	0	0	14.8	0	0	14.8	14.8	224.8
	39D9	1	3	3	0	0	0	0.1	0	0	0.1	0.1	1.5
Porc	36D6	1	11	0	11	0	0	0	2.6	0	2.6	2.6	39.8
	35D5	2	21	21	0	0	0	15	0	0	15	15	202.5
	35D6	2	16	16	0	0	0	4.4	0	0	4.4	4.4	59.8
	34D5	2	15	15	0	0	0	3	0	0	3	3	40.3
	34D6	1	0	0	0	0	100	0	0	0	0	0	0
	33D5	1	0	0	0	0	100	0	0	0	0	0	0
	33D6	2	0	0	0	0	100	0	0	0	0	0	0
West	36D8	1	25	25	0	0	0	15.3	0	0	15.3	15.3	231.6
	36D9	1	0	0	0	0	100	0	0	0	0	0	0
	35D7	2	1	1	0	0	50	0.8	0	0	0.8	0.8	11.4
	35D8	2	31	31	0	0	0	8.6	0	0	8.6	8.6	130.1
	35D9	2	0	0	0	0	100	0	0	0	0	0	0
	34D7	2	0	0	0	0	100	0	0	0	0	0	0
	34D8	2	25	25	0	0	0	9.9	0	0	9.9	9.9	137.5
	34D9	2	0	0	0	0	100	0	0	0	0	0	0
	33D8	2	16	16	0	0	0	12.3	0	0	12.3	12.3	178.3
	33D9	2	12	12	0	0	50	1.5	0	0	1.5	1.5	22.1
	32D8	2	3	3	0	0	50	0.2	0	0	0.2	0.2	3.2
	32D9	2	3	3	0	0	50	1.7	0	0	1.7	1.7	24.6
South	31D8	2	6	6	0	0	50	3.8	0	0	3.8	3.8	51.8
	31D9	2	0	0	0	0	100	0	0	0	0	0	0
	31E0	1	0	0	0	0	100	0	0	0	0	0	0
	30D8	1	0	0	0	0	100	0	0	0	0	0	0
	30D9	2	6	6	0	0	50	3	0	0	3	3	41.2
	30E0	2	26	16	0	10	0	5.9	0	1.4	7.3	7.3	89.6
	30E1	1	6	6	0	0	0	2.2	0	0	2.2	2.2	26.1
	30E2	1	27	27	0	0	0	22.1	0	0	22.1	22.1	266.5
	29D8	2	0	0	0	0	100	0	0	0	0	0	0
	29D9	2	2	2	0	0	50	0.7	0	0	0.7	0.7	9.1
	29E0	2	1	1	0	0	50	0.4	0	0	0.4	0.4	4.4
	29E1	2	10	10	0	0	50	2.2	0	0	2.2	2.2	26.5
	29E2	2	0	0	0	0	100	0	0	0	0	0	0
	28D8	2	0	0	0	0	100	0	0	0	0	0	0
	28D9	2	0	0	0	0	100	0	0	0	0	0	0
	28E0	2	8	8	0	0	50	5.8	0	0	5.8	0	521.7
	28E1	2	0	0	0	0	100	0	0	0	0	0	0
	28E2	2	0	0	0	0	100	0	0	0	0	0	0
	27D8	2	0	0	0	0	100	0	0	0	0	0	0
	27D9	2	13	13	0	0	50	2.7	0	0	2.7	2.7	50.7
	27E0	2	9	9	0	0	0	1.7	0	0	1.7	1.7	36.3
	27E1	2	13	13	0	0	50	4.7	0	0	4.7	4.7	86.7
	27E2	1	0	0	0	0	100	0	0	0	0	0	0
	26D9	2	2	2	0	0	50	0.4	0	0	0.4	0.4	7.6
	26E0	2	40	40	0	0	0	7.8	0	0	7.8	7.7	146.7
	26E1	2	37	37	0	0	0	9.8	0	0	9.8	9.8	186.3
	26E2	2	0	0	0	0	100	0	0	0	0	0	0
	26E3	1	0	0	0	0	100	0	0	0	0	0	0
	25E0	1	5	5	0	0	0	1.6	0	0	1.6	1.6	29.6
	25E1	2	45	45	0	0	50	17.4	0	0	17.4	17.4	320.6
	25E2	2	16	16	0	0	50	3	0	0	3	3	54.4
	25E3	2	2	2	0	0	50	0.4	0	0	0.4	0.4	6.9
	24E2	2	0	0	0	0	100	0	0	0	0	0	0
	24E3	2	1	1	0	0	50	0	0	0	0	0	0.1
	24E4	1	0	0	0	0	100	0	0	0	0	0	0
	23E3	1	40	40	0	0	0	11.5	0	0	11.5	11.5	199.9
	23E4	1	21	21	0	0	0	8.9	0	0	8.9	8.9	155.9
	Total	132	648	580	39	29	-	215.3	14	3.3	232.6	226.7	3995.8
	CV (%)	-	-	-	-	-	-	-	-	-	11.4	NA	17

Table 10. Boarfish survey time series.
Note: 2011 estimate has been revised for daylight hours only in line with current methods.

Age (Yrs)	2011	2012	2013	2014	2015
0	-	-	-	-	-
1	5.0	21.5	-	-	198.5
2	11.6	10.8	78.0	-	319.2
3	57.8	174.1	1,842.9	15.0	16.6
4	187.4	64.8	696.4	98.2	34.3
5	436.7	95.0	381.6	102.3	80.0
6	1,165.9	736.1	253.8	104.9	112.0
7	1,184.2	973.8	1,056.6	414.6	437.4
8	703.6	758.9	879.4	343.8	362.9
9	1,094.5	848.6	800.9	341.9	353.5
10	1,031.5	955.9	703.8	332.3	360.0
11	332.9	650.9	263.7	129.9	131.7
12	653.3	1,099.7	202.9	104.9	113.0
13	336.0	857.2	296.6	166.4	174.0
14	385.0	655.8	169.8	88.5	108.0
15+	3,519.0	6,353.7	1,464.3	855.1	1195.0
TSN (mil)	11,104	14,257	9,091	3,098	3,996
TSB ('000t)	670,176	863,446	439,890	187,779	232,634
SSB ('000t)	669,392	861,544	423,158	187,654	226,659
CV	21.2	10.6	17.5	15.1	17.0

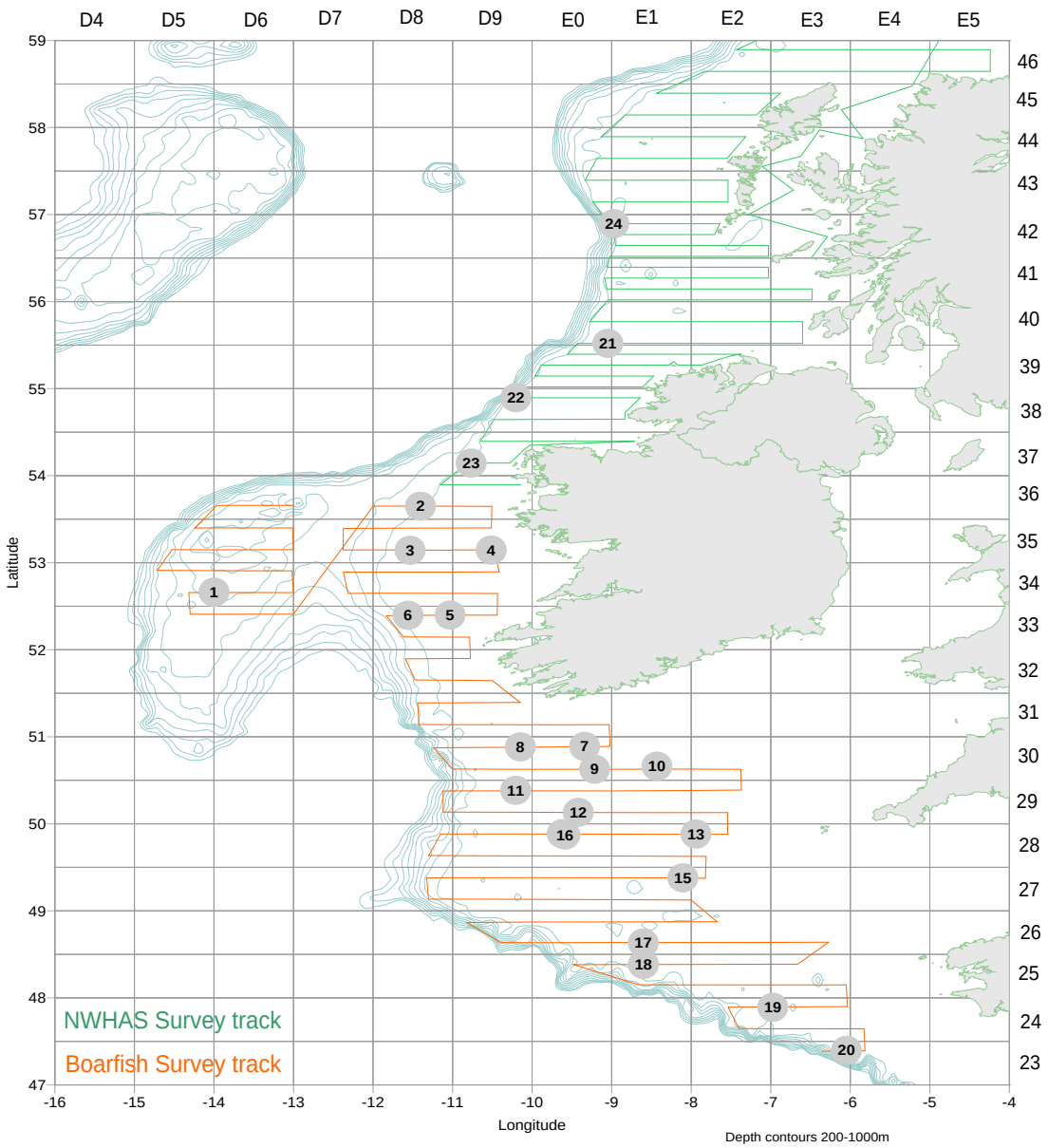


Figure 1. Cruise tracks and numbered haul positions for the FV *Felucca* (orange track) and RV *Celtic Explorer* (green track).

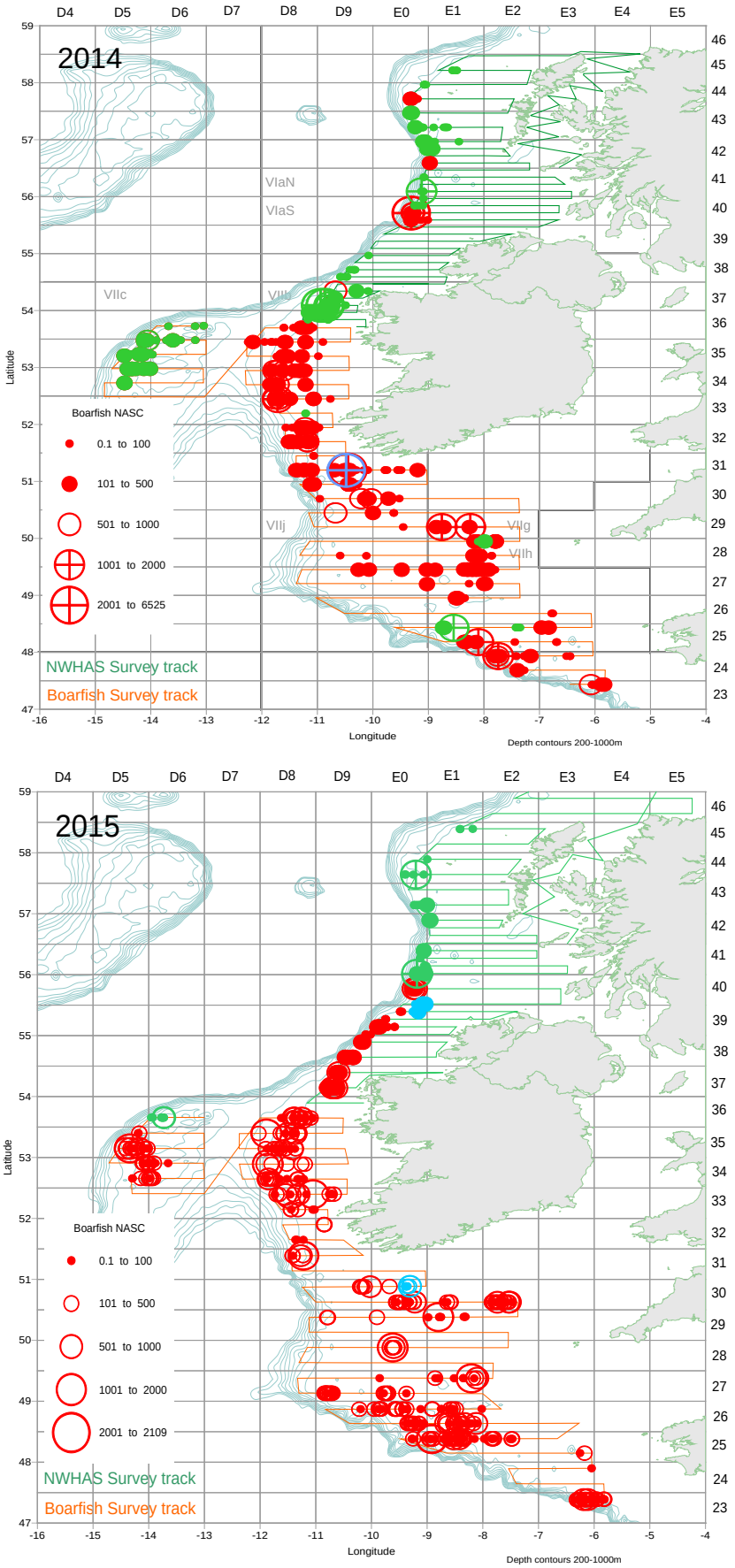


Figure 2. NASC plot of boarfish distribution. Circle size proportional to NASC value. Red circles represent 'definitely' boarfish, green; 'probably boarfish' and blue; 'boarfish mix'.

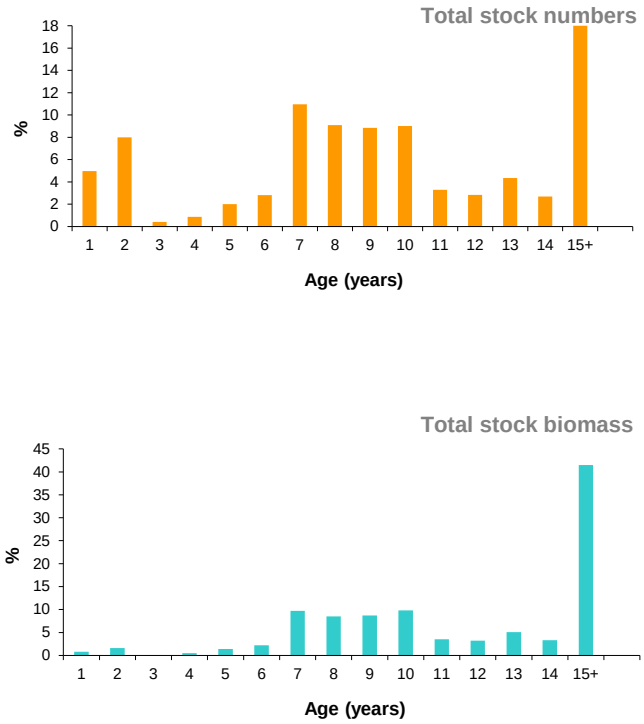
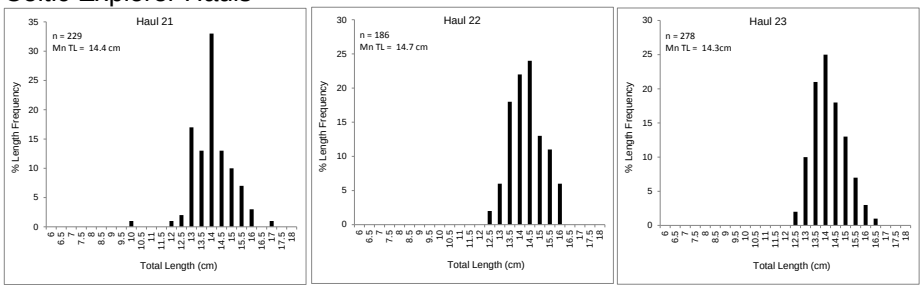


Figure 3. Percentage of total stock numbers (top) and total stock biomass (bottom) by age.

Celtic Explorer Hauls



Felucca Hauls

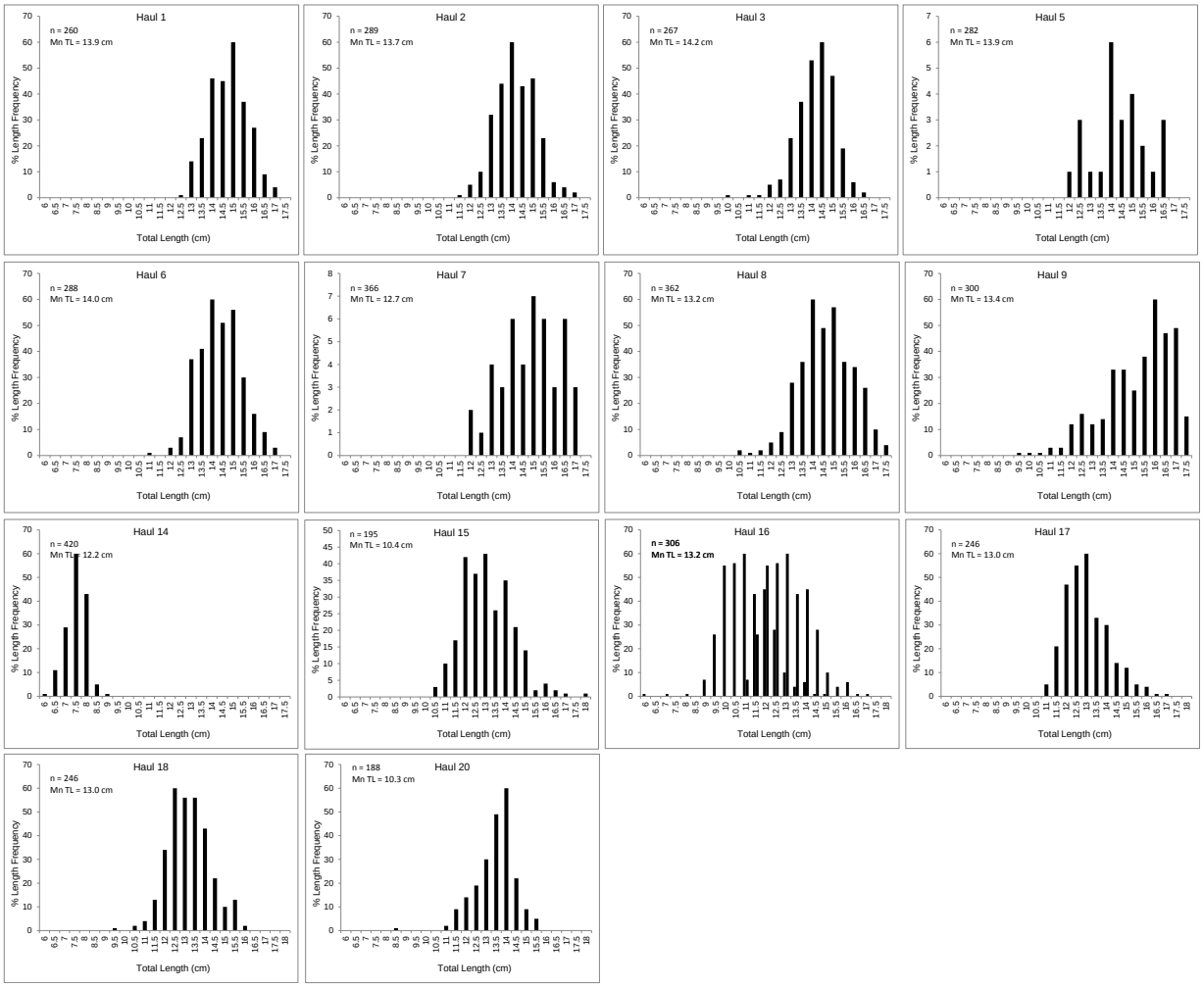
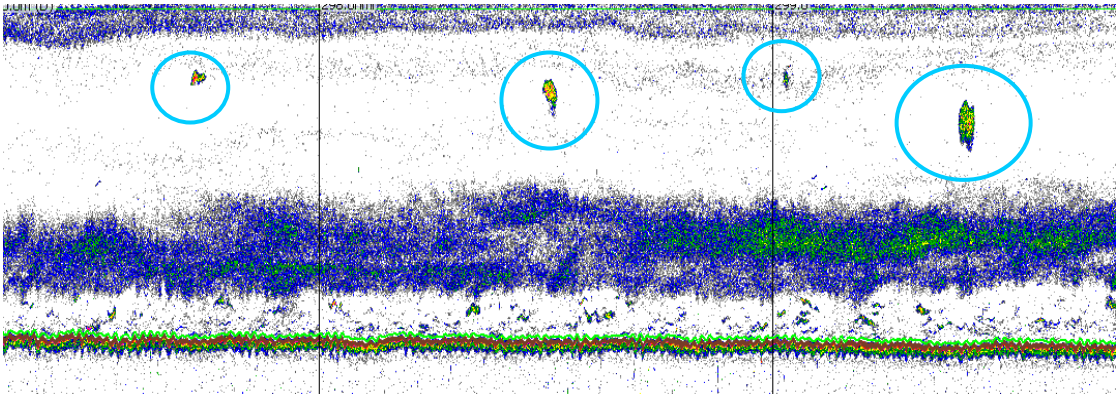
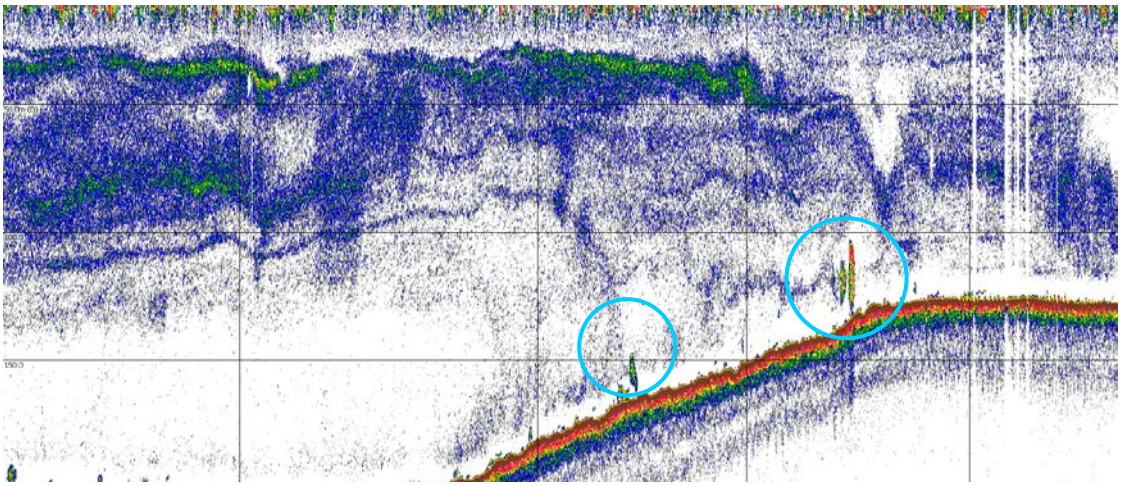


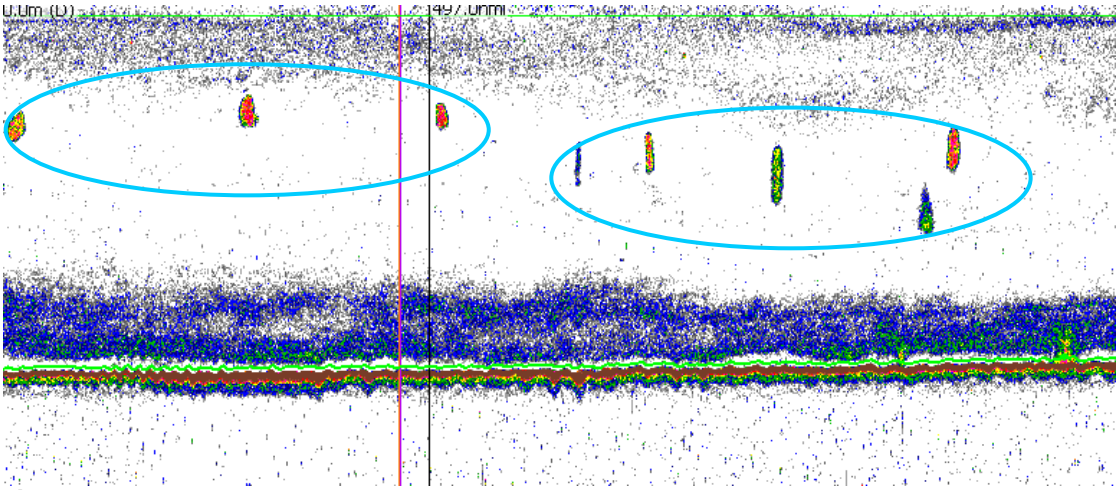
Figure 4. Mean length and length distribution of boarfish by haul.



a). High density boarfish echotraces (circled) observed to on the **Porcupine Bank**. Bottom depth is 210 m with boarfish at 35-60 m below the surface. Haul 01.

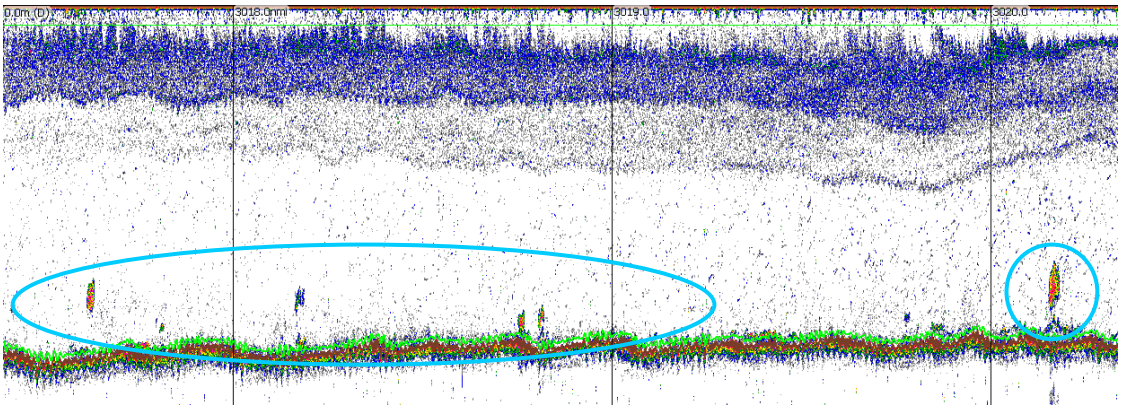


b). Boarfish echotraces from **northern area** (54°-59°N). recorded prior to Haul 22 by the *Celtic Explorer.* Bottom depth is 190 m with targets at 0-30 m.

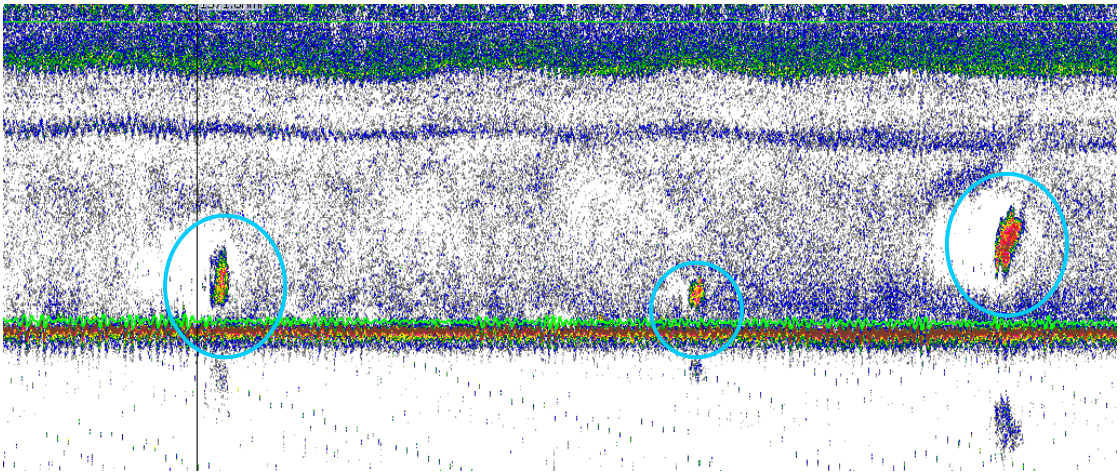


c). Cluster of high density midwater boarfish schools (circled) from the **western area** (51°-54°N). Recorded prior to Haul 02. Bottom depth is 150 m with target schools at 40-70 m.

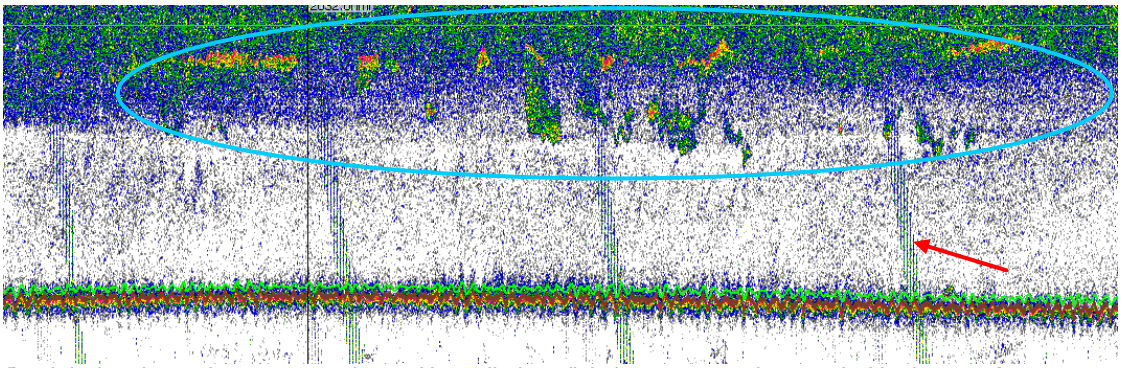
Figures 5a-h. Echotraces recorded at 38 kHz. Note: vertical bands on echograms represent 1 nmi (nautical mile) sampling intervals.



d). High density boarfish echotraces recorded prior to Haul 18 located close to the shelf edge in the **southern area** (51°'30-47°N). Bottom depth is 194 m with targets extending from 0-35 m off the bottom.

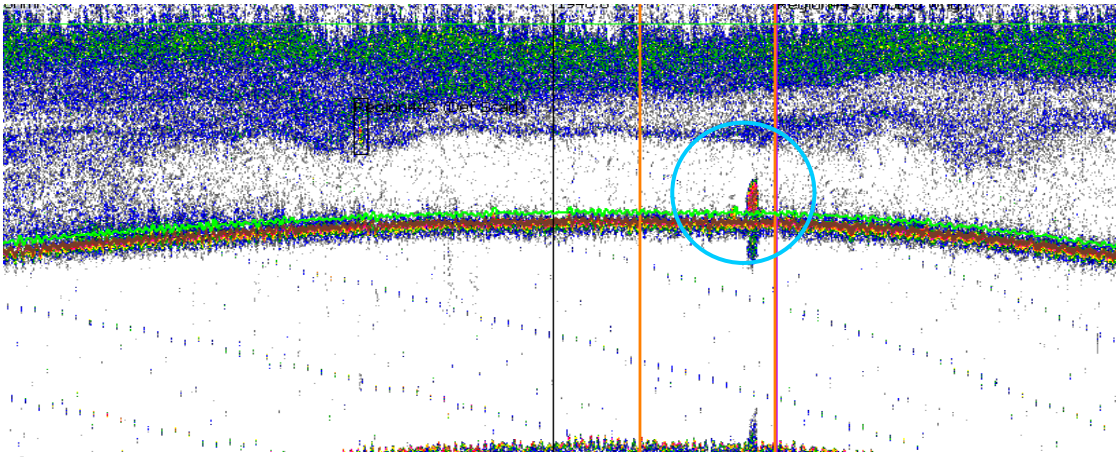


e). High density near bottom echotraces of boarfish typical of those encountered on the banks in the **southern area** (51°'30-47°N). Echogram recorded during to Haul 08. Bottom depth is 95 m with targets extending from 5-50 m off the bottom.

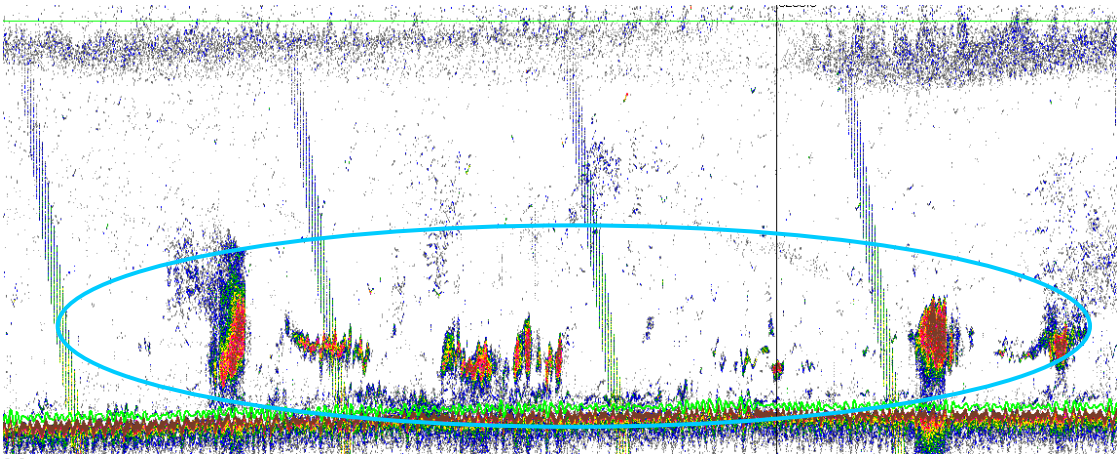


f). High density surface aggregations of juvenile boarfish (Mn L=7.5 cm), recorded in the **southern area** (51°'30-47°N) during Haul 14. Bottom depth is 120 m with targets extending from 20-70 m subsurface. Note: electronic interference (red arrow) is from the low frequency onmi directional sonar (25 kHz) used during fishing operations.

Figures 5a-h. continued.



g). Typical horse mackerel echotrace recorded in the **southern area** (51°'30-47°N) prior to Haul 13. Bottom depth is 109 m with targets occurring between 0-15 m.



h). High-density aggregations of 0-group juvenile blue whiting observed in the **southern area** (51°'30-47°N), recorded prior to Haul 19. Bottom depth is 165 m and schools extend vertically up to 45m.

Figures 5a-h. continued.

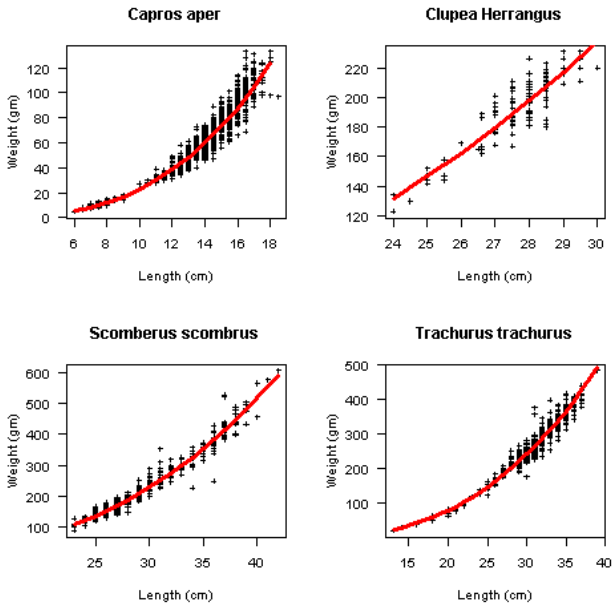


Figure 6. Length weight plots of major trawl component species.

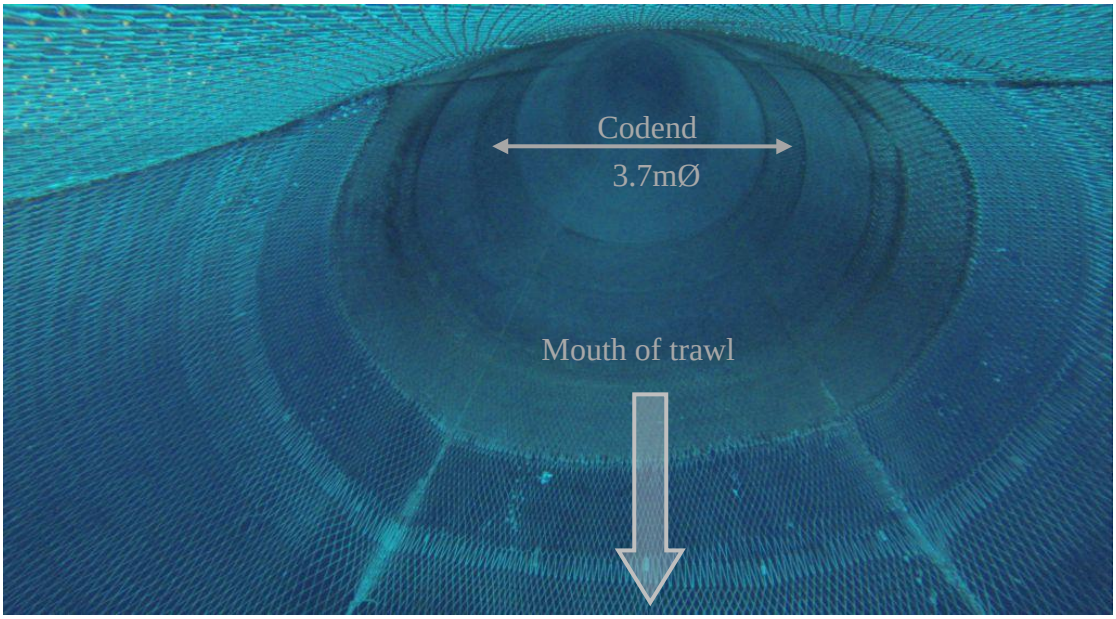


Figure 7. Unobstructed view of 4 panel single midwater trawl with standardised camera positioning.

Figure 8. Haul 20. Catch 3.0 t of 100% boarfish sampled within 0-20 m of the bottom with a water depth of 157m. Failing lights in the trawl resulted in darker image.

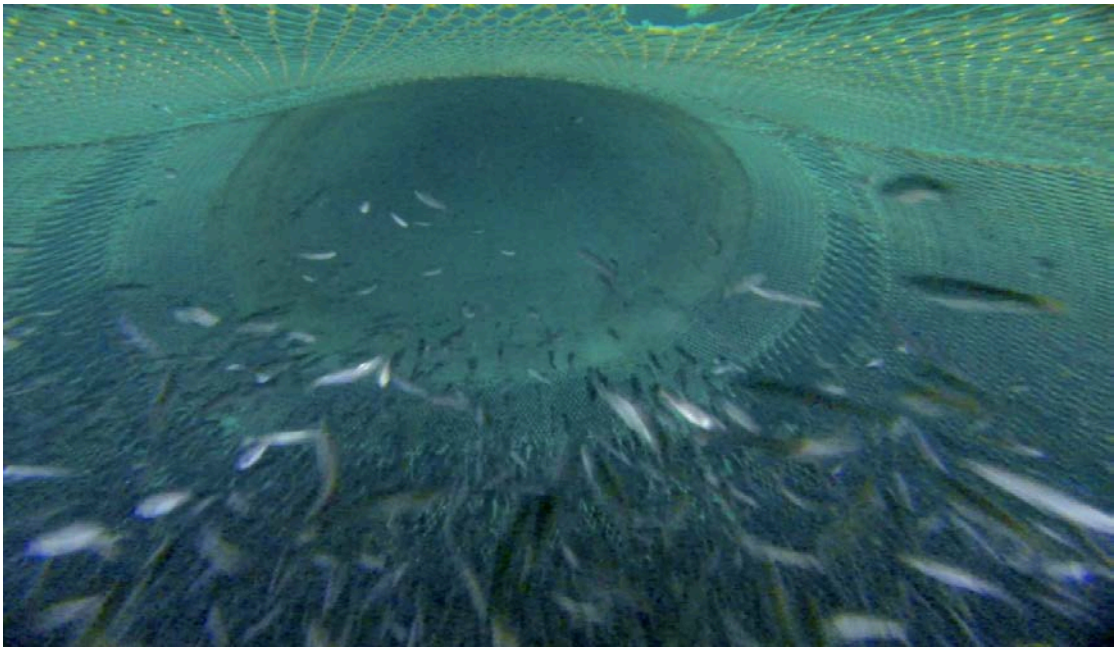


Figure 9. Haul 12. Catch 3 t of 100% juvenile blue whiting sampled within 0-17m of the bottom with a water depth of 140 m.

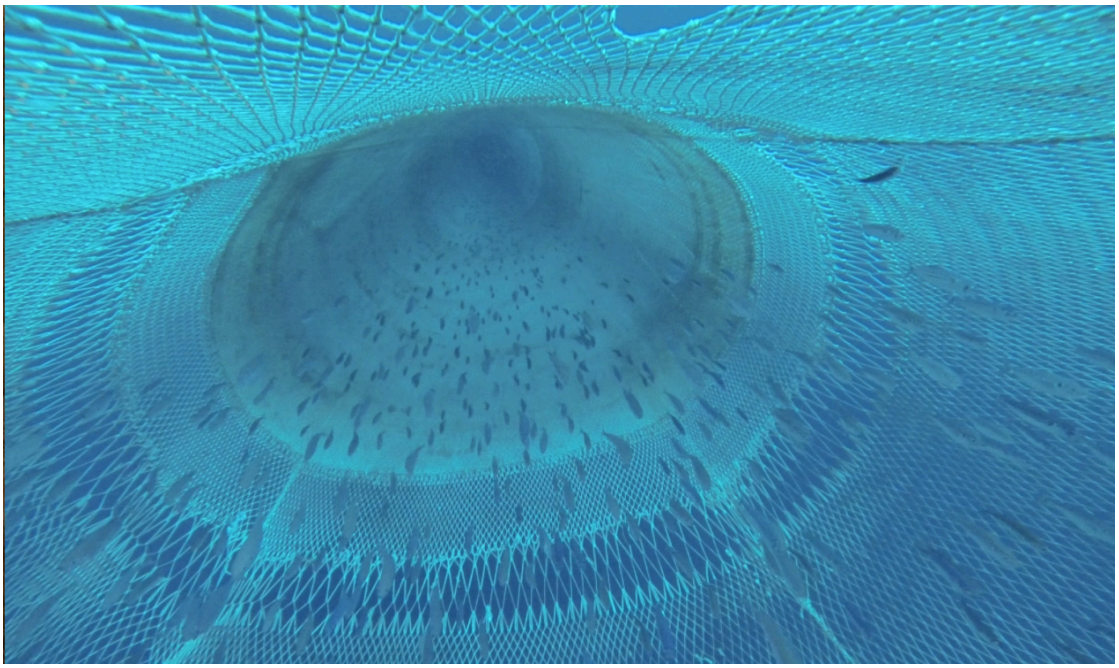


Figure 10. Haul 13. Catch 1 t, composition horse mackerel (38%), mackerel (55%), pilchard (0.1%) and a female blue shark (*Prionace glauca)*. Trawl within 15m of the bottom, water depth of 109m.

Appendix 1

Details of the charter vessel.

Figure 1. FV *Felucca* (SO 108). 54m LOA

Figure 2. Top side monitoring station located on the bridge. Laptop (left) running Echoview and EK 60 topside PC unit (right).

Vessel details:

Name:	MFV Felucca
Call sign:	EIGC
Type:	Fishing vessel (Pelagic RSW)
Registered:	Sligo, Ireland
LOA:	58 m
Beam:	11 m
GT:	1,093 t
IMO No.:	9131981
MMSI No.:	250000097

Appendix 2

Details of the in-trawl camera rig and positioning within the trawl.

The camera is a GoPro Hero 3+ black edition (www.gopro.com)
The camera allows a wide range of settings for stills and video capture. Details of settings are provided in the GoPro user manual (GoPro User Manual).

The camera housing
The camera housing is certified to a depth of 2,750m and is milled from a single block of anodised 6061 aircraft grade aluminium. The housing weighs 497 gr. The dimensions are: Length 8.3cm, Width 6.5cm, Height 5.4cm.

Light source
Light is provided by two modified Nautilux dive torches with an output of 2000 lumens. Modification increased the beam width to 120º from a narrow original spec. The torches have 3 constant light settings: High (2000 lumens), Medium (1400 Lumens), Low (600 Lumens). The high setting was used during the survey and provided c.2.5 hours of light more than enough for our needs. The light colour is neutral white at 4000K and provided by 3 x Cree XML LEDS.

Light housing
Lights were housed within two aluminium canisters depth rated to 1,250m.The outside dimensions of the cylindrical canister are 18cm long 18cm with a diameter of 7.6cm.

Mounting plates
Mounting plates were fabricated using polyethylene backing plates and strengthened using 316 grade stainless steel flat bar supports. A protective roll cage was constructed to protect the units during shooting and hauling. Both the camera and lights were attached to the mounting plates using adjustable angle mounts to fine tun field of view and illumination.

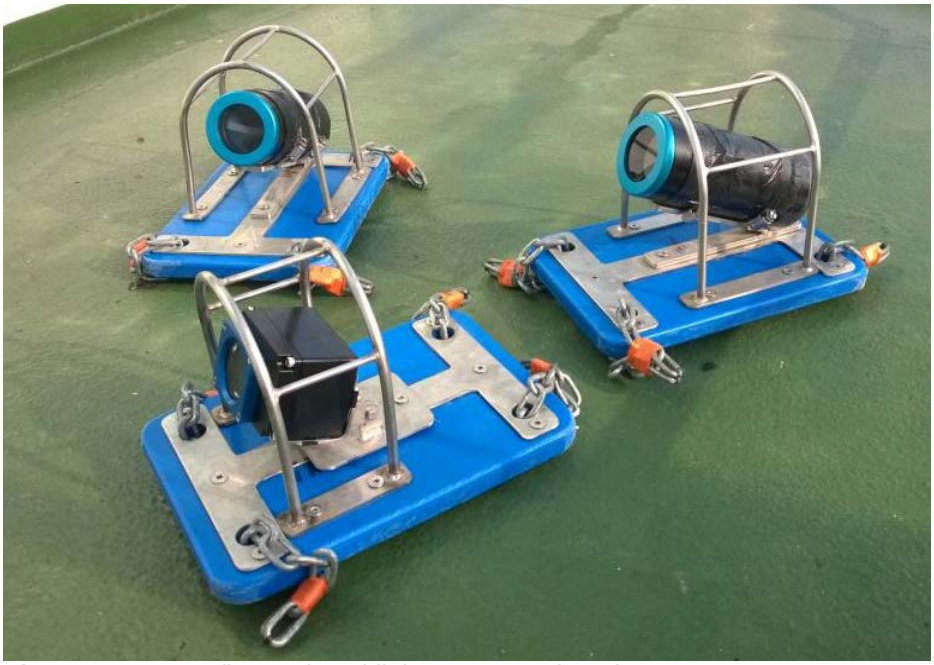


Figure 1 Camera (bottom) and lights on mounting plates.

Mounting within the trawl
Positioning of the camera was determined prior to the survey and marked out to allow ease of installation at sea. The rig was installed in the top of the net with the camera positioned along the mid line at a distance of 6m from the entrance to the brailer. The lights were positioned at 0.5m behind the camera and 0.5m to either side. This positioning allowed the entire net circle

within the field of view. Camera and lights were positioned facing backwards towards the brailer.

Mounting plates were installed upside down within the trawl through pre-cut holes and secured using screw lock clips to fixed mounting points. The rig was installed and removed for each trawl haul.

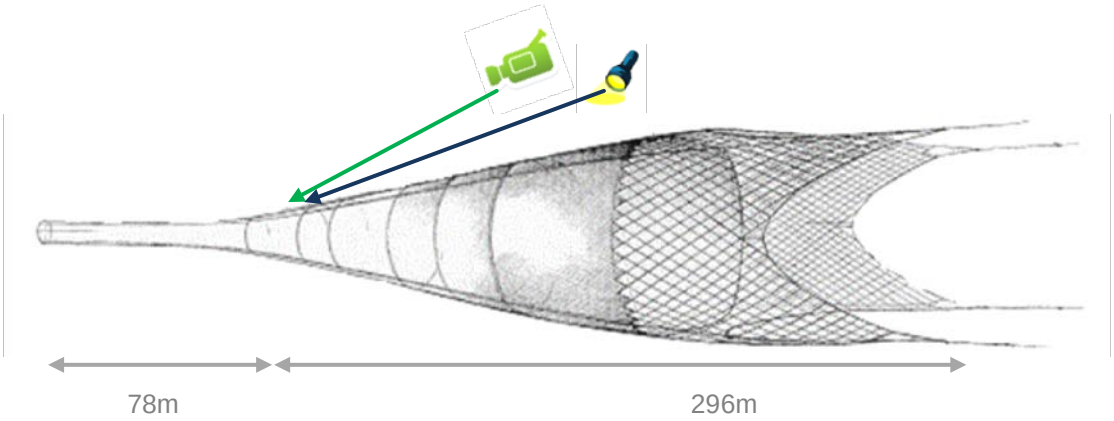


Figure 2 Schematic of pelagic trawl and positioning of camera and light rig. Rig was positioned on the top sheet (60mm half mesh) facing the mouth of the brailer. Net has a fishing circle of 1,050m with a vertical opening of c.50m.

Data collection

Continuous video was recorded for each for the duration of each haul and recorded onto a MicroSD card within the camera. Viewing was carried out post trawl using GoPro software.