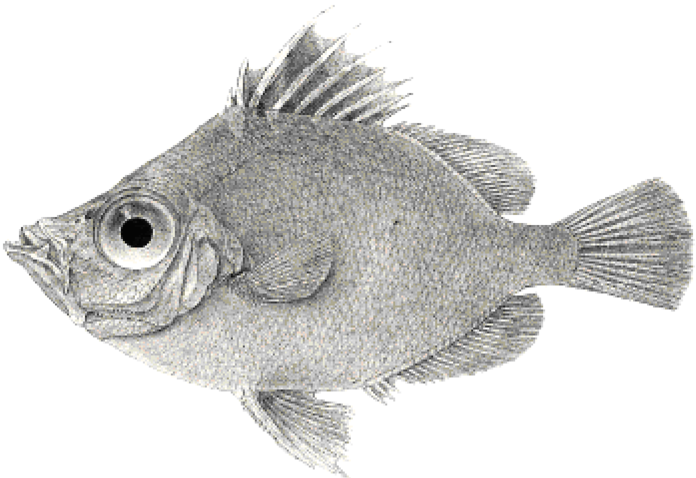
FEAS Survey Series: 2014/03

Boarfish Acoustic Survey Cruise Report

10 July – 31 July, 2014



Day (1966)

MFV Felucca

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Table of Contents

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 (prominent dorsal spines) 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 yr) 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), which 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*).

A precautionary interim management plan was adopted in November 2010 covering ICES Divisions VI, VII and VIII and an EU TAC of 33,000t was set. Of this the Irish allocation for 2011 was 22,000t. This precautionary TAC was based on 50-75% of total landings from the period 2007-2009 which peaked at over 83,400t (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 2014 the EU TAC was set at 127,509t a 55% increase from 2013 with an Irish allocation of 88,115t.

This survey represents the fourth dedicated research survey for boarfish in the time series. The commercial fishing vessel MFV *Felucca* was used for the third time and was equipped with a calibrated scientific echosounder (Simrad EK 60) and transducer within a towed body.

Data from this survey will be presented to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2014 and as part of the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2015 (WGIPS).

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity
FEAS	Ciaran O'Donnell	Acoustics (SIC)
FEAS	Turloch Smith	Analyst
FEAS	Michael McAuliffe	Analyst
Contractor	Martin Oliver	Analyst

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 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 3,552nmi (nautical miles) of cruise track was undertaken by both vessels over 130 transects relating to a total area coverage of 56,202nmi^2. Transect spacing was set at 15nmi for the *Felucca* and 15 and 7.5nmi for the *Explorer* component. For the area covered by the *Explorer* only strata bordering the shelf edge were considered during the analysis.

Coverage extended in coastal areas from the c.50m contour to the shelf slope (250m). An elementary distance sampling unit (EDSU) of 1nmi 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 was mounted within a towbody frame and deployed on the port side via a towing boom to a working depth of 3-3.5m (Appendix 1).

Cruising speed was largely determined by the weather and the affects 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 (V5.3) 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 (V5.3). 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 296m in total length with a 78m brailer (codend) was used during the survey. The horizontal net spread averaged 90m from wing to wing Mesh size in the wings was 12.8m through to 2cm 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 on the northwest herring acoustic survey (RV *Celtic Explorer*). Surveys were timed to ensure a continuous quasi-synoptic coverage over 45 days without interruption from north (58°30'N) to south (47°30'N).

Eighteen hauls were carried out by the *Felucca* during the survey, 9 of which contained boarfish (Figure 1, Table 2). An additional 3 carried out by the *Explorer* were used in the analysis. In total, 3,160 lengths and 1,102 length/weight measurements were taken in addition to 397 individual boarfish otiliths 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	2,227	133,713	71.2
Probably	830	51,461	27.4
Mixture	41	2,605	1.4
Total estimate	**3,098**	**187,779**	**100**
Possibly	-	-	
SSB Estimate			
Definelty	2,223	133,600	71.2
Probably	829	51,449	27.4
Mixture	41	2,605	1.4
SSB estimate	**3,093**	**187,654**	**100**
Possibly	-	-	

3.1.3 Boarfish distribution

Overall, total observed stock biomass was 57% lower than during the same time period in 2013. All survey areas showed a decrease in biomass with the exception of the northern area where more was observed than in previous years. Geographical occurrence of boarfish followed a similar pattern to previous years with core spawning areas containing the largest abundance. However, in 2014 the distribution of biomass followed a more northward trend than in previous years. This was most apparent in the northern area (54-59ºN) and western areas (54-51º30'N) which combined contained more biomass in 2014 than the southern area which is the largest geographically and historically the most productive.

A total of 611 boarfish echotraces were identified during the survey. Of this 71% were categorised as 'definitely' boarfish (403 echotraces), 27% as 'probably' (207) and a single echotrace represented 1% of 'boarfish in a mixture'. A full breakdown of school categorisation, abundance and biomass by ICES statistical rectangle is provided in Table 9. A total of 66 ICES rectangles were covered by the survey representing combined area coverage of 56,202nmi^2, a decrease of 1% from 2013.

Of the biomass observed in 2014 the southern area contained the largest proportion of stock biomass (over 39%), ranking second was the western area where 36% of biomass was recorded. The northern area and Porcupine Bank contributed 17% and 8% 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). Echotraces here were categorised as 'Probably' boarfish as it was not possible to trawl due to technical difficulties onboard (Figure 1, Table 2). However, the likelihood is that these echotraces were indeed 'def' boarfish based on previous observations. The number (n=70) and acoustic density of echotraces observed was lower than in 2013 and similar to that observed in 2012 which was considered as high (54,200t). Biomass for this region was 14,600t representing c.8% of the total. Biological information from nearby hauls (western area) were applied during the analysis.

The northern area contributed 17% (32,000t) to the total biomass and 15.8% (488.7 million) to total abundance. This is markedly higher than previous years (13,900t in 2013; 9,800t in 2012) in what was historically regarded as a peripheral area. Echotraces were greater in number and acoustic density, and more widespread than previous years (Figures 2 & 5b). Boarfish samples were composed of mature, ripe and spawning fish (4-15+yrs yrs). Area coverage and survey effort were comparable to previous years.

The western area contributed c.36% (67,400t) to total biomass and 35% (1087.7 million) to total abundance. This area was characterised by clusters of medium and high density echotraces predominantly located west of 11ºW (Figures 2 & 5c). Overall the number and acoustic density of echotraces was lower resulting in a biomass 27% less than 2013. However, the single highest density cluster of echotraces for the entire survey was observed in the western area relating to 22,700t of biomass within a single ICES rectangle (Table 9). Area coverage and survey effort were comparable to previous years.

The southern area contributed 39% (73,700t) to total biomass and 41% (1279.5 million) to total abundance. Distribution was comparable to previous years, however, the number and acoustic density of boarfish echotraces was much reduced. A difference in biomass of almost 200,000t as compared to 2013 was observed. Off the southwest coast, spawning fish were observed close to the shelf edge and further to the east around a number of offshore banks (Figure 5d). A second area was located in the east around a complex of offshore banks along 08ºW line of longitude and contained spawning aggregations (Figure 5e). A third area, in the south of the survey contained spawning aggregations of boarfish close to the bottom along the shelf edge.

3.1.4 Boarfish stock structure

An age length key compiled primarily from commercial samples collected during 2012/2013 fishery was applied during the analysis of survey data. This ALK was used in place of a survey derived ALK due to the unavailability of aged samples during the analysis.

Age distribution as determined from survey samples indicate that the stock is dominated by the following age classes in terms of biomass: 15+, 7, 10 and 9 year old fish representing over 66% of the total biomass and 15+, 7, 8 and 9 years in terms of abundance (Figure 3, Tables 3, 5 & 6).

Immature fish were observed in all survey regions albeit in small numbers (Tables 7&8). Immature boarfish (< 9.7 cm TL) were observed in the highest abundance in the southern (0.1% of biomass and 0.16% of abundance) in line with previous observations. Some of the largest fish were again observed in the northern and western survey areas with more mixed length cohorts further south (Figure 4).

3.2 Other pelagics

3.2.1 Herring

In total 47 herring (*Clupea harengus*) echotraces were observed during the survey but no trawl samples were taken. The distribution of herring was divided into two areas; northwest of the Aran Islands and southwest of Ireland in the Mizen area. The largest single herring echotrace was observed southwest of Mizen Head and would likely form part of the autumn spawning component of the Celtic Sea stock.

3.2.2 Horse mackerel

Horse mackerel (*Trachurus trachurus*) were encountered in 28% of survey hauls and were most frequently encountered in deeper waters (>80m) and often occurred in catches with boarfish (Table 2).

A total of 247 echotraces were assigned to horse mackerel and 155 were measured and 284 length and weights were recorded. The modal length of horse mackerel was 30.3cm (range 21-37cm) and mean weight was 241g.

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.

As in previous years stomach contents analysis revealed horse mackerel to be actively feeding on boarfish eggs where the two species were encountered together.

3.2.3 Blue whiting

Blue whiting (*Mircomesistius poutassou*) were widespread throughout the survey occurring in 28% of trawl catches. Acoustically, blue whiting were the most abundant species observed this year and were of the highest density observed so far. The appearance of large numbers of 0-group blue whiting is in line with the recent period of strong recruitment within this stock. High density clusters of echotraces dominated the west coast and shelf edge contours in the Celtic Sea appearing as juvenile 0-group fish and to a lesser extent as mature fish (Figure 5h). High densities were also reported further north during the *Explorer* survey.

A total of 1,144 blue whiting were measured and 574 length and weights were recorded. The modal length occurred at 16.3cm (range 8-29cm) and mean weight was 28g.

3.3 Trawl mounted camera

A camera system was installed in the trawl close to the joining section with the brailer (codend). The system was used as a means to help groundtruth acoustic observations using optics and catch composition against the corresponding trawled echotrace. Camera and lighting specification are detailed in Appendix 2. As this system was being trailed for the first time during the survey it was not deployed until weather conditions were ideal.

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 6 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. The net employed during this survey is a standard commercial trawl and brailer (section 2.3.6) fitted with a 20mm brailer liner for the purposes of the survey.

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 little downtime. Survey design, timing, transect spacing and geographical coverage were maintained in 2014 from 2012 baselines. Area coverage was comparable with 2013 (1% difference) as was transect mileage. The number of survey hauls was lower as a consequence of the lower abundance observed.

The total number of echotraces and acoustic density of those echotraces was lower in 2014 than previous years. Unquantified sonar observations during routine surveying as well as off track investigations in areas targeted during the fishery (specific Banks in the Celtic Sea) indicated that echosounder observations were indeed representative of aggregations present in the wider area. The single highest value echotrace observed in 2014 was in fact larger than the equivalent in 2013, however, echotrace count was down overall. Echotrace identification was considered accurate with over 71% of the total biomass attributed to the 'definitely' category. The higher proportion of 'probably' boarfish this year (c.27%) can be attributed to firstly, the inability to trawl on the Porcupine Bank due to technical issues onboard resulting in all echotraces (n=70) being categorised as 'probably' and secondly the higher proportion of boarfish observed in the northern area (Celtic Explorer) in close proximity to higher density blue whiting echotraces.

Overall, the total stock biomass was 57% lower than at the same time in 2013 while survey effort, geographical coverage and timing remained unchanged. Observed biomass was lower in all areas with the exception of the northern area and this was due to the more northward distribution of the stock than in previous years. The most pronounced change in biomass was noted in the southern area (down by c.200,000t from 2013) which is the largest geographically and has previously contained upwards of 60% of the stock.

The stock was considered to be well contained within the survey area, the northward distribution was bounded by the surveys northern limits and a relatively small amount of biomass was observed along the southern most transect. Information from the IFREMER PELGAS acoustic survey in the Bay of Biscay (May-June) confirms that low abundances of boarfish were observed overall and particularly in northern Biscay (Pierre Pettitgas *pers comm.*).

4.2 Conclusions

Acoustically derived estimates of abundance are used as a relative index of abundance 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.

Geographical coverage can now be considered as established for core spawning areas covered during the survey. The more northern distribution of the stock in 2014 was contained within the survey area and information from other acoustic survey (IFREMER Bay of Biscay) supports our observations that no significant amounts of biomass were missed to the south of our survey limit. Real time information from demersal fishermen working in the mid Celtic Sea support our observations of lower numbers of boarfish overall and eastern distribution was considered contained within the survey area as no boarfish were observed on eastern transect legs.

The identification of boarfish echotraces is considered accurate and aided by targeted directed trawling. The high abundance of juvenile blue whiting this year within core boarfish areas, most notably in the west and south, made analysis more difficult due to the large numbers of non boarfish echotraces encountered. However, the acoustic characteristics of the 2 species are distinctly different enough to aid separation using a single acoustic frequency.

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 cohort group within the time series thus validating the ability of the survey to capture the age structure of the spawning population.

Overall the 2014 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. The 2014 estimate is the third point in the current comparable time series and is the third successive survey to record a decrease in boarfish biomass.

4.3 Recommendations

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

- The timing of the survey should continue to be aligned with the northwest herring survey to extend the area coverage in the northern area and ensure northern containment of the stock.
- 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.
- To increase the precision of the survey it is recommended that this survey be conducted onboard dedicated research platform with the capacity to collect multi frequency acoustic data.
- It is recommended that supporting hydrographic data is collected to compliment acoustic observations for future surveys. This can best be carried out using a dedicated research platform.

Acknowledgements

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References

Blanchard, F. and Vandermeirsch, F. 2005. Warming and exponential abundance increase of the subtropical fish *Capros aper* in the Bay of Biscay (1973-2002). Comptes Rendus Biologies, 328: 505-509.

Carrea, P. (2001). Acoustic abundance estimates from the multidisciplinary survey PELACUS 0401. Working document to the ICES Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. Copenhagen, 4-13 September 2001.

Dalen, J. and Nakken, O. (1983) "On the application of the echo integration method" *ICES CM 1983/B:19*

Day, F. (1884). The Fishes of Great Britain and Ireland. Publishers Williams and Norgate.

Fassler, S.M.M, Fernandes, P.G., Semple, S.I.K., and Brierley, A.S. 2009. Depth-dependent swimbladder compression in herring Clupea harengus observed using magnetic resonance imaging. Journal of Fish Biology (2009) 74, 296–303.

Fässler, S. M. M., O'Donnell, C., and Jech, J.M. Boarfish (*Capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. – ICES Journal of Marine Science, doi:10.1093/icesjms/fst095.

Farrell, E.D., Hüssy, K., Coad, J.O., Clausen, L.W. & Clarke, M.W. (in review). Reproductive biology of boarfish (*Capros aper*) in the Northeast Atlantic. ICES Journal of Marine Science.

Foote, K.G. (1987). Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am.* 82: 981-987

Foote, K. G. (1980a). Importance of the swimbladder in acoustic scattering by fish: a comparison of gadoid and mackerel target strengths. Journal of the Acoustical Society of America, 67: 2084-2089.

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

Hüssy, K., Coad, J.O., Farrell, E.D., Clausen, L.W. & Clarke, M.W. (2012). Age verification of boarfish (*Capros aper*) in the Northeast Atlantic. ICES Journal of Marine Science (2012), 69(1), 34–40. doi:10.1093/icesjms/fsr168

J van der Kooij, S Warnes, F Luxford, A Plirú, R Scott and B Roel, 2011. Cruise report CEND09-11. PELTIC11: sardine and other small pelagic fish in the western Channel and Celtic Sea

Marques, V., Chaves, C., Morais, A., Cardador, F. and Stratoudakis, Y. (2005). Distribution and abundance of pipefish (*Macroramphosus* spp.) off Portugal (1998-2003). Scientia Marina 69 (4): 563-576.

Nolan, C., O'Donnell, C., Campbell, A., Sullivan, M., Mullins, E., and Keogh, H. (2012). Northwest Herring Acoustic Survey Report, 2013.

O'Donnell, C., Griffin, K., Mullins, E., Egan, A., Smith, T. and Bunn. R. (2004). Northwest Herring Acoustic Survey Cruise Report, 2004.

O'Donnell, C., Mullins, E., Johnston, G., Nolan, C. and Power, J. (2012). Blue whiting Acoustic Survey Cruise Report, 2012. FEAS survey series 2012/01.

Saunders, R, O'Donnell, C, Campbell, A. and Mullins, C (2011). Northwest herring acoustic survey report 2011. FSS Survey series: 2011/02

O'Donnell, C., Farrell, E.D., Nolan, C., and Campbell, A. 2013. Boarfish Acoustic Survey Cruise Report. 2013/03 Marine Institute, Galway, Ireland. http://hdl.handle.net/10793/916

O'Donnell, C., Farrell, E.D., Nolan, C., and Campbell, A. 2012. Boarfish Acoustic Survey Cruise Report. 2012/03 Marine Institute, Galway, Ireland. http://hdl.handle.net/10793/822

O'Donnell, C., Farrell, E. D., Saunders, R. A., and Campbell, A. 2011. Boarfish Acoustic Survey Cruise Report. 2011/03 Marine Institute, Galway, Ireland. http://hdl.handle.net/10793/675

Table 1. Survey settings and calibration report (38 kHz) for the tow body system (Simrad ER60 echosounder).

Echo Sounder System Calibration

Vessel : F/V Felucca		Date : 11.07.14	
Echo sounder : EK60 Tow Body		Locality : Donegal Bay	
Type of Sphere : CU 64	TS Sphere: -33.50 dB (Corrected for soundvelocity o	Depth(Sea floor) 16 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	Beamtype	Split
Gain	26.03 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.00 deg	Along. Beam Angle	7.03 deg
Athw. Offset Angle	0.26 deg	Along. Offset Angl	-0.10 deg
SaCorrection	-0.67 dB	Depth	5.00 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.	9.1 dB/km	Sound Velocity	1506.5 m/s

Beam Model results:

Transducer Gain =	26.28 dB	SaCorrection =	-0.69 dB
Athw. Beam Angle =	6.99 deg	Along. Beam Angle =	7.03 deg
Athw. Offset Angle =	0.10 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:
RMS = 0.15 dB
Max = 0.38 dB No. = 252 Athw. = -3.7 deg Along = 3.1 deg
Min = -0.59 dB No. = 259 Athw. = 4.9 deg Along = -0.9 deg

Data deviation from polynomial model:
RMS = 0.08 dB
Max = 0.24 dB No. = 255 Athw. = 3.5 deg Along = -0.3 deg
Min = -0.21 dB No. = 49 Athw. = 1.0 deg Along = 1.8 deg

Comments :
Flat calm conditions
Wind Force : 2-5 kn. **Wind Direction :** S
Raw Data File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\BFAS 2014\Tow body
Calibration File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\BFAS 2014\Tow body

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	13.07.14	52.98	-14.38	09:33	220	120	Foul					
2	15.07.14	53.45	-11.40	15:19	136	60-80	2,000	95.0	1.0		4.0	
3	16.07.14	53.19	-10.43	10:28	100	0-40	2,500	1.0				99.0
4	16.07.14	52.11	-11.66	18:00	162	65	1,500	86.8	3.1		10.1	
5	17.07.14	52.69	-10.74	10:18	130	30-70	4,000					100.0
6	17.07.14	52.45	-10.69	15:22	119	20-70	500					100.0
7	18.07.14	51.95	-11.41	01:54	217	60-80	1,500	49.2	29.8		21.0	
8	18.07.14	51.70	-10.78	17:50	156	15-80	2,500					100.0
9	19.07.14	51.21	-10.43	11:46	159	100	3,500	48.1	4.4		47.5	
10	20.07.14	50.95	-11.14	08:22	190	120	0					
11*	21.07.14	50.45	-8.75	10:08	125	0-15	2,000		12.8		4.0	83.2
12*	22.07.14	49.84	-7.96	18:55	85	15-35	4,500	100.0				
13*	23.07.14	49.95	-10.44	10:29	134	0-40	5,000					100.0
14	24.07.14	49.47	-8.14	11:24	120	0-40	3,000	98.6	1.4			
15*	24.07.14	49.45	-10.55	23:08	144	0-18	7				100.0	
16*	25.07.14	49.21	-10.26	13:28	158	40-60	4,000					100.0
17*	28.07.14	47.93	-7.31	18:28	182	0-30	1,500	100.0				
18	29.07.14	47.42	-6.00	11:37	155	40-70	1,000	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	28.06.14	57.71	-9.28	07:19	150	135	88	92.7	4.7	2.3		0.4
11	30.06.14	56.53	-8.94	15:22	148	143	500	95.1	2.9			2.0
19	05.07.14	55.71	-9.24	12:22	137	127	49	99.4				0.6

^ Includes non target pelagic/demersal species and other taxa

Table 3. Age length key compiled from commercial catch and survey samples collected during 2011-2013.

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
7	1														
7.5	1	1													
8		1													
8.5		1	1												
9		1	1												
9.5			1												
10			1												
10.5			2	10	3										
11			1	29	14	2	2								
11.5				9	21	21	18	2	2	1					1
12				4	17	22	38	12	8					1	1
12.5					5	9	42	37	14	6	2		1	1	5
13					2	4	31	28	24	12	6	2	3	2	11
13.5					1	3	26	22	21	14	6	5	4	1	20
14							6	8	18	22	8	3	7	6	30
14.5						1	1	2	3	8	1	6	6	2	19
15							1	1		2	2	2	5	2	19
15.5										2					8
16															1
16.5															1
17															1
17.5															1
18															1
18.5															
19															

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

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Abundance (millions)	Biomass (000s t)	Mn wt (g)
4.5																		
5																		
5.5																		
6																		
6.5																		
7																		
7.5																		
8																		
8.5																		
9																		
9.5																		
10			8.8													8.8	0.2	23.9
10.5			4.11	20.6	6.2											30.9	0.9	27.4
11			2.14	62	29.9	4.3	4.3									102.7	3.2	31.3
11.5				10.1	23.5	23.5	20.2	2.2	2.2	1.1						82.9	2.9	35.5
12				5.53	23.5	30.4	52.6	16.6	11.1						1.4	141.1	5.7	40.1
12.5					7.58	13.6	63.7	56.1	21.2	9.1	3.0		1.5	1.5	1.5	178.9	8.1	45.0
13					7.53	15.1	117	105	90.3	45.2	22.6	7.5	11.3	3.8	18.8	444.0	22.4	50.4
13.5					4.07	12.2	102	89.6	85.5	57.0	24.4	20.4	16.3	8.1	44.8	464.2	26.1	56.1
14							38.1	50.8	114	140	50.8	19.0	44.4	6.4	127	590.3	36.8	62.3
14.5						5.78	5.78	11.6	17.3	46.2	5.78	34.7	34.7	34.7	173	369.9	25.5	68.8
15							11.7	11.7		23.3	23.3	23.3	58.3	23.3	221	396.3	30.1	75.8
15.5										10.8				10.8	103	124.1	10.3	83.3
16															109	109.2	10.0	91.2
16.5															19.8	19.8	2.0	99.7
17															30.9	30.9	3.4	108.6
17.5															2.46	2.5	0.3	118.0
18															1.99	1.99	0.25	127.9
18.5																		
19																		
19.5																		
20																		
SSN			12.87	96.1	102	105	415	344	342	332	130	105	166	88.6	855	3,093.5		
SSB			0.336	3.03	3.82	4.65	21.1	18.4	19.1	20.5	7.97	6.86	11.1	6.16	64.6		187.7	
Mn wt (g)			25.9	31.4	37.5	44.3	50.8	53.6	56	61.6	61.4	65.4	66.8	69.6	75.5			
Mn L (cm)			10.5	11.3	11.9	12.6	13.2	13.5	13.7	14.2	14.1	14.5	14.6	14.8	15.2			

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	37D9	0	0	0	0.1	0.2	0.2	1.4	1.3	1.4	1.5	0.6	0.5	0.9	0.4	4.1	12.4
	38D9	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.2	0.5
	39E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40E0	0	0	0	0	0	0.1	0.5	0.5	0.6	0.8	0.3	0.3	0.5	0.3	3.1	6.9
	41E0	0	0	0	0	0	0	0.2	0.2	0.2	0.3	0.1	0.1	0.2	0.1	1.1	2.5
	42E1	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.3	0.6
	42E0	0	0	0	0	0	0	0.3	0.3	0.4	0.5	0.2	0.2	0.3	0.2	2.1	4.7
	43E1	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.2	0.5
	43E0	0	0	0	0	0	0	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.9	2
	44E0	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.7	1.7
	45E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2
Porc	36D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2
	35D5	0	0	0	0.1	0.1	0.2	1.1	1	0.9	0.9	0.4	0.3	0.5	0.3	2.6	8.4
	35D6	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.3	0.9
	34D5	0	0	0	0	0.1	0.1	0.7	0.6	0.6	0.6	0.2	0.2	0.3	0.2	1.6	5.1
	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	0.1	0.1	0.1	1	1	1	1.1	0.4	0.4	0.7	0.3	2.9	9
	36D9	0	0	0	0	0	0.1	0.4	0.4	0.4	0.4	0.2	0.2	0.3	0.1	1.2	3.8
	35D7	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.2	0.6
	35D8	0	0	0	0	0.1	0.1	0.5	0.5	0.5	0.5	0.2	0.2	0.3	0.1	1.4	4.4
	35D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	34D7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34D8	0	0	0	0.2	0.4	0.6	2.9	2.6	2.6	2.6	1	0.9	1.3	0.8	7	22.7
	34D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D8	0	0	0	0.1	0.2	0.3	1.4	1.3	1.3	1.3	0.5	0.4	0.7	0.4	3.8	11.5
	33D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	32D8	0	0	0	0	0.1	0.2	1.3	1.3	1.4	1.6	0.7	0.6	1	0.5	6.5	15.1
	32D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
South	31D8	0	0	0	0	0.1	0.1	0.3	0.3	0.3	0.3	0.1	0.1	0.2	0.1	1.3	3.3
	31D9	0	0	0	0.1	0.2	0.2	0.8	0.7	0.7	0.8	0.3	0.3	0.5	0.3	3.3	8.2
	31E0	0	0	0	0	0	0	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0	0.6	1.5
	30D8	0	0	0	0	0.1	0.1	0.4	0.3	0.3	0.4	0.2	0.1	0.2	0.1	1.6	3.9
	30D9	0	0	0	0.1	0.1	0.2	0.6	0.6	0.6	0.7	0.3	0.2	0.4	0.2	2.6	6.5
	30E0	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0	0.4	0.9
	30E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D9	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0	0.6	1.5
	29E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.5
	29E1	0	0	0	0.1	0.1	0.1	0.4	0.4	0.4	0.5	0.2	0.1	0.3	0.2	2.1	4.8
	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	0.1	0.2
	28E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E1	0	0	0	0.1	0	0.1	0.3	0.2	0.3	0.3	0.1	0.1	0.2	0.1	1.3	3
	28E2	0	0	0	0.1	0.1	0.1	0.6	0.6	0.6	0.7	0.3	0.2	0.4	0.2	3.1	7.1
	27D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27D9	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0	0	0	0	0.1	1
	27E0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0	0	0	0	0.1	0.9
	27E1	0	0	0.1	0.4	0.4	0.3	1	0.7	0.7	0.5	0.2	0.1	0.2	0.1	0.8	5.5
	27E2	0	0	0	0.3	0.3	0.2	0.7	0.5	0.5	0.4	0.2	0.1	0.1	0.1	0.6	3.9
	26D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E1	0	0	0	0.2	0.1	0.1	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0	0.3	2.1
	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	0.1	0.2
	25E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25E1	0	0	0.1	0.5	0.5	0.4	1.4	1.1	1	1	0.4	0.3	0.5	0.3	2.8	10.4
	25E2	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.1	0.5
	25E3	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.2	0.7
	24E2	0	0	0	0.2	0.2	0.2	0.6	0.4	0.4	0.4	0.2	0.1	0.2	0.1	1.2	4.4
	24E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.3
	23E3	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.6
	23E4	0	0	0	0	0	0.1	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.4	1.8
	Total	0	0	0.4	3.1	3.8	4.6	21.1	18.4	19.1	20.5	8	6.9	11.1	6.2	64.6	187.8
	%	0	0	0.2	1.6	2	2.5	11.2	9.8	10.2	10.9	4.2	3.7	5.9	3.3	34.4	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	37D9	0	0	0.2	3.3	3.8	4.6	25.6	23.3	24.1	23.8	10.1	7.6	13.1	5.8	55.2	200.4
	38D9	0	0	0.0	0.1	0.1	0.2	0.9	0.8	0.9	0.9	0.4	0.3	0.5	0.3	2.5	7.7
	39E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40E0	0	0	0	0.1	0.7	1.6	8.9	8.7	10.0	12.2	4.4	4.5	6.8	4.2	40.3	102.4
	41E0	0	0	0	0.1	0.3	0.6	3.2	3.1	3.6	4.4	1.6	1.7	2.5	1.5	14.7	37.3
	42E1	0	0	0	0	0.0	0.1	0.6	0.6	0.8	1.1	0.4	0.4	0.6	0.4	3.5	8.5
	42E0	0	0	0	0	0.2	0.7	4.9	5.1	6.4	8.5	3.0	3.3	4.9	3.1	28.1	68.3
	43E1	0	0	0	0	0.0	0.1	0.5	0.6	0.7	0.9	0.3	0.4	0.5	0.3	2.9	7.3
	43E0	0	0	0	0	0.1	0.3	2.2	2.3	2.8	3.7	1.3	1.4	2.1	1.4	11.8	29.4
	44E0	0	0	0	0	0.1	0.3	1.8	1.9	2.4	3.1	1.1	1.2	1.7	1.1	9.8	24.4
	45E1	0	0	0	0	0.0	0.0	0.2	0.2	0.3	0.4	0.1	0.1	0.2	0.1	1.2	2.9
Porc	36D6	0	0	0.002	0.1	0.1	0.1	0.5	0.4	0.4	0.4	0.2	0.1	0.2	0.1	0.9	3.4
	35D5	0	0	0.1	2.2	3.3	4.5	21.1	18.2	17.0	15.5	5.9	5.1	7.2	4.3	35.2	139.6
	35D6	0	0	0.0	0.2	0.3	0.5	2.2	1.9	1.8	1.6	0.6	0.5	0.8	0.4	3.7	14.5
	34D5	0	0	0.0	1.3	2.0	2.7	12.9	11.1	10.3	9.4	3.6	3.1	4.4	2.6	21.4	84.8
	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	0.1	2.4	2.8	3.4	18.5	16.8	17.5	17.2	7.3	5.5	9.5	4.2	39.9	145.0
	36D9	0	0	0.1	1.0	1.2	1.4	7.9	7.2	7.4	7.3	3.1	2.3	4.0	1.8	17.0	61.6
	35D7	0	0	0.0	0.2	0.2	0.2	1.3	1.1	1.1	1.1	0.5	0.4	0.6	0.3	2.6	9.5
	35D8	0	0	0.0	1.1	1.6	2.0	10.2	9.0	8.8	8.3	3.3	2.7	4.2	2.2	18.9	72.3
	35D9	0	0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.5	1.7
	34D7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34D8	0	0	0.2	5.8	9.0	12.2	57.2	49.3	46.1	42.0	15.9	13.7	19.6	11.6	95.3	377.8
	34D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D8	0	0	0.1	2.6	4.1	5.7	27.3	23.7	22.6	21.1	8.1	6.9	10.1	5.8	50.9	188.9
	33D9	0	0	0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.4	1.2
	32D8	0	0	0.0	1.3	2.5	4.1	24.6	22.6	24.6	26.1	10.6	8.4	14.1	7.1	82.4	228.5
	32D9	0	0	0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.4	1.2
South	31D8	0	0	0.1	1.2	1.7	1.9	6.6	5.2	5.2	5.5	2.1	1.7	2.9	1.5	16.8	52.5
	31D9	0	0	0.2	2.9	4.2	4.8	16.4	13.0	13.0	13.6	5.3	4.3	7.3	3.8	41.9	130.7
	31E0	0	0	0.0	0.5	0.8	0.9	3.0	2.4	2.4	2.5	1.0	0.8	1.4	0.7	7.7	24.2
	30D8	0	0	0.1	1.4	2.0	2.3	7.8	6.2	6.2	6.5	2.5	2.1	3.5	1.8	20.0	62.5
	30D9	0	0	0.1	2.3	3.3	3.8	12.9	10.3	10.3	10.7	4.2	3.4	5.8	3.0	33.2	103.4
	30E0	0	0	0.0	0.3	0.5	0.5	1.8	1.5	1.5	1.5	0.6	0.5	0.8	0.4	4.7	14.6
	30E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D9	0	0	0.0	0.5	0.8	0.9	2.9	2.3	2.3	2.4	1.0	0.8	1.3	0.7	7.5	23.5
	29E0	0	0	0.0	0.2	0.2	0.3	0.9	0.8	0.8	0.8	0.3	0.2	0.4	0.2	2.5	7.6
	29E1	0	0	1.1	2.9	2.1	1.8	7.9	6.8	7.3	7.8	3.0	2.2	3.8	2.2	26.3	75.2
	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	0.1	0.3	0.3	0.2	0.6	0.4	0.4	0.4	0.1	0.1	0.2	0.1	0.7	3.9
	28E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E1	0	0	0.7	1.9	1.3	1.2	5.0	4.3	4.6	5.0	1.9	1.4	2.4	1.4	16.7	47.9
	28E2	0	0	1.7	4.4	3.2	2.7	11.7	10.1	10.8	11.7	4.4	3.3	5.7	3.4	39.3	112.4
	27D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27D9	0	0	0.5	2.2	1.9	1.4	3.6	2.4	2.2	1.6	0.6	0.4	0.6	0.2	2.1	19.7
	27E0	0	0	0.5	2.2	1.9	1.4	3.5	2.4	2.2	1.6	0.6	0.4	0.6	0.2	2.1	19.5
	27E1	0	0	2.6	12.4	10.8	8.3	20.5	13.6	12.6	9.5	3.7	2.3	3.3	1.4	11.9	112.8
	27E2	0	0	1.9	8.9	7.8	5.9	14.7	9.8	9.1	6.8	2.7	1.6	2.4	1.0	8.5	80.9
	26D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E1	0	0	1.0	4.8	4.2	3.2	7.9	5.3	4.9	3.7	1.4	0.9	1.3	0.5	4.6	43.8
	26E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E3	0	0	0.0	0.3	0.2	0.2	0.5	0.4	0.4	0.3	0.1	0.1	0.2	0.1	0.7	3.6
	25E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25E1	0	0	2.3	16.5	13.5	10.2	29.4	20.9	19.3	16.7	6.9	4.7	8.1	3.9	38.2	190.4
	25E2	0	0	0.1	0.7	0.6	0.4	1.3	0.9	0.9	0.7	0.3	0.2	0.4	0.2	1.7	8.5
	25E3	0	0	0.2	1.1	0.9	0.7	2.0	1.4	1.3	1.2	0.5	0.3	0.6	0.3	2.7	13.2
	24E2	0	0	0.9	6.8	5.5	4.2	12.2	8.7	8.0	7.0	2.9	2.0	3.4	1.7	16.3	79.6
	24E3	0	0	0.1	0.5	0.4	0.3	1.0	0.7	0.6	0.6	0.2	0.2	0.3	0.1	1.3	6.4
	23E3	0	0	0.0	0.3	0.4	0.5	1.9	1.5	1.4	1.2	0.5	0.3	0.5	0.3	2.1	10.9
	23E4	0	0	0.1	1.0	1.3	1.4	5.5	4.4	4.1	3.6	1.3	1.0	1.5	0.8	6.2	32.1
	Total	0	0	15.0	98.2	102.3	104.9	414.6	343.9	341.9	332.3	129.9	104.9	166.5	88.6	855.2	3098.3
	%	0	0	0.5	3.2	3.3	3.4	13.4	11.1	11.0	10.7	4.2	3.4	5.4	2.9	27.6	100
	Cv (%)	NA	NA	25.7	22.4	18.8	16.9	16.1	16.0	15.5	15.3	15.5	15.2	14.8	14.8	14.4	NA

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

Region	Strata	Imm	Mature	Spent	Total
North	37D9	0	12.4	0	12.4
	38D9	0	0.5	0	0.5
	39E0	0	0	0	0
	40E0	0	6.9	0	6.9
	41E0	0	2.5	0	2.5
	42E1	0	0.6	0	0.6
	42E0	0	4.7	0	4.7
	43E1	0	0.5	0	0.5
	43E0	0	2	0	2
	44E0	0	1.7	0	1.7
	45E1	0	0.2	0	0.2
Porc	36D6	0	0.2	0	0.2
	35D5	0	8.4	0	8.4
	35D6	0	0.9	0	0.9
	34D5	0	5.1	0	5.1
	34D6	0	0	0	0
	33D5	0	0	0	0
	33D6	0	0	0	0
West	36D8	0	9	0	9
	36D9	0	3.8	0	3.8
	35D7	0	0.6	0	0.6
	35D8	0	4.4	0	4.4
	35D9	0	0.1	0	0.1
	34D7	0	0	0	0
	34D8	0	22.7	0	22.7
	34D9	0	0	0	0
	33D8	0	11.5	0	11.5
	33D9	0	0.1	0	0.1
	32D8	0	15.1	0	15.1
	32D9	0	0.1	0	0.1
South	31D8	0	3.3	0	3.3
	31D9	0	8.2	0	8.2
	31E0	0	1.5	0	1.5
	30D8	0	3.9	0	3.9
	30D9	0	6.5	0	6.5
	30E0	0	0.9	0	0.9
	30E1	0	0	0	0
	30E2	0	0	0	0
	29D8	0	0	0	0
	29D9	0	1.5	0	1.5
	29E0	0	0.5	0	0.5
	29E1	0	4.8	0	4.8
	29E2	0	0	0	0
	28D8	0	0	0	0
	28D9	0	0.2	0	0.2
	28E0	0	0	0	0
	28E1	0	3	0	3
	28E2	0	7.1	0	7.1
	27D8	0	0	0	0
	27D9	0	1	0	1
	27E0	0	0.9	0	0.9
	27E1	0	5.5	0	5.5
	27E2	0	3.9	0	3.9
	26D9	0	0	0	0
	26E0	0	0	0	0
	26E1	0	2.1	0	2.1
	26E2	0	0	0	0
	26E3	0	0.2	0	0.2
	25E0	0	0	0	0
	25E1	0	10.4	0	10.4
	25E2	0	0.5	0	0.5
	25E3	0	0.7	0	0.7
	24E2	0.1	4.3	0	4.4
	24E3	0	0.3	0	0.3
	23E3	0	0.6	0	0.6
	23E4	0	1.8	0	1.8
	Total	0.1	187.7	0	187.8
	%	0.1	99.9	0	100

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

Region	Strata	Imm	Mature	Spent	Total
North	37D9	0.08	200.36	0	200.44
	38D9	0	7.72	0	7.72
	39E0	0	0	0	0
	40E0	0	102.44	0	102.44
	41E0	0	37.30	0	37.30
	42E1	0	8.47	0	8.47
	42E0	0	68.27	0	68.27
	43E1	0	7.30	0	7.30
	43E0	0	29.44	0	29.44
	44E0	0	24.45	0	24.45
	45E1	0	2.91	0	2.91
Porc	36D6	0	3.42	0	3.42
	35D5	0	139.57	0	139.57
	35D6	0	14.49	0	14.49
	34D5	0	84.81	0	84.81
	34D6	0	0	0	0
	33D5	0	0	0	0
	33D6	0	0	0	0
West	36D8	0.06	144.95	0	145.01
	36D9	0.02	61.61	0	61.63
	35D7	0	9.52	0	9.52
	35D8	0.01	72.27	0	72.29
	35D9	0.00	1.71	0	1.71
	34D7	0	0	0	0
	34D8	0	377.79	0	377.79
	34D9	0	0	0	0
	33D8	0	188.86	0	188.86
	33D9	0	1.22	0	1.22
	32D8	0	228.53	0	228.53
	32D9	0	1.17	0	1.17
South	31D8	0.04	52.46	0	52.50
	31D9	0.09	130.59	0	130.68
	31E0	0.02	24.14	0	24.16
	30D8	0.04	62.43	0	62.47
	30D9	0.07	103.35	0	103.42
	30E0	0.01	14.61	0	14.62
	30E1	0	0	0	0
	30E2	0	0	0	0
	29D8	0	0	0	0
	29D9	0.02	23.52	0	23.54
	29E0	0.01	7.61	0	7.61
	29E1	0.39	74.81	0	75.21
	29E2	0	0	0	0
	28D8	0	0	0	0
	28D9	0.02	3.85	0	3.87
	28E0	0	0	0	0
	28E1	0.25	47.61	0	47.86
	28E2	0.59	111.81	0	112.40
	27D8	0	0	0	0
	27D9	0.13	19.53	0	19.66
	27E0	0.13	19.38	0	19.51
	27E1	0.74	112.07	0	112.81
	27E2	0.53	80.38	0	80.92
	26D9	0	0	0	0
	26E0	0	0	0	0
	26E1	0.29	43.50	0	43.79
	26E2	0	0	0	0
	26E3	0.02	3.57	0	3.58
	25E0	0	0	0	0
	25E1	0.81	189.57	0	190.38
	25E2	0.04	8.42	0	8.45
	25E3	0.06	13.14	0	13.20
	24E2	0.33	79.24	0	79.57
	24E3	0.03	6.36	0	6.39
	23E3	0.01	10.90	0	10.91
	23E4	0.03	32.02	0	32.06
	Total	4.84	3093.45	0.00	3098.30
	%	0.16	99.84	0.00	100.00

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	37D9	4	21	1	20	0	25	1	11.4	0	12.4	12.4	200.4
	38D9	4	10	0	10	0	25	0	0.5	0	0.5	0.5	7.7
	39E0	3	0	0	0	0	100	0	0	0	0	0	0
	40E0	4	22	15	7	0	0	6.8	0.2	0	6.9	6.9	102.4
	41E0	3	4	0	4	0	33	0	2.5	0	2.5	2.5	37.3
	42E1	4	14	4	10	0	25	0.2	0.4	0	0.6	0.6	8.5
	42E0	2	14	0	14	0	0	0	4.7	0	4.7	4.7	68.3
	43E1	1	5	0	5	0	0	0	0.5	0	0.5	0.5	7.3
	43E0	2	15	0	15	0	0	0	2	0	2	2	29.4
	44E0	2	15	11	4	0	0	1.5	0.2	0	1.7	1.7	24.4
	45E1	1	4	0	4	0	0	0	0.2	0	0.2	0.2	2.9
Porc	36D6	1	3	0	3	0	0	0	0.2	0	0.2	0.2	3.4
	35D5	2	39	0	39	0	0	0	8.4	0	8.4	8.4	139.6
	35D6	2	8	0	8	0	0	0	0.9	0	0.9	0.9	14.5
	34D5	2	20	0	20	0	0	0	5.1	0	5.1	5.1	84.8
	34D6	2	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	1	0	0	0	0	100	0	0	0	0	0	0
West	36D8	3	31	18	13	0	0	2.5	6.5	0	9	9	145.0
	36D9	3	16	0	16	0	33	0	3.8	0	3.8	3.8	61.6
	35D7	2	4	4	0	0	50	0.6	0	0	0.6	0.6	9.5
	35D8	2	26	26	0	0	0	4.4	0	0	4.4	4.4	72.3
	35D9	2	2	2	0	0	0	0.1	0	0	0.1	0.1	1.7
	34D7	2	0	0	0	0	100	0	0	0	0	0	0
	34D8	2	41	41	0	0	0	22.7	0	0	22.7	22.7	377.8
	34D9	2	0	0	0	0	100	0	0	0	0	0	0
	33D8	2	21	19	2	0	0	11.4	0.1	0	11.5	11.5	188.9
	33D9	2	1	1	0	0	50	0.1	0	0	0.1	0.1	1.2
	32D8	2	36	36	0	0	0	15.1	0	0	15.1	15.1	228.5
	32D9	2	3	3	0	0	50	0.1	0	0	0.1	0.1	1.2
South	31D8	2	15	15	0	0	0	3.3	0	0	3.3	3.3	52.5
	31D9	2	15	14	0	1	50	5.6	0	2.6	8.2	8.2	130.7
	31E0	1	13	13	0	0	0	1.5	0	0	1.5	1.5	24.2
	30D8	1	9	9	0	0	0	3.9	0	0	3.9	3.9	62.5
	30D9	2	21	21	0	0	0	6.5	0	0	6.5	6.5	103.4
	30E0	2	5	5	0	0	50	0.9	0	0	0.9	0.9	14.6
	30E1	1	0	0	0	0	100	0	0	0	0	0	0
	30E2	1	0	0	0	0	100	0	0	0	0	0	0
	29D8	2	0	0	0	0	100	0	0	0	0	0	0
	29D9	2	1	1	0	0	50	1.5	0	0	1.5	1.5	23.5
	29E0	2	4	4	0	0	0	0.5	0	0	0.5	0.5	7.6
	29E1	2	11	11	0	0	50	4.8	0	0	4.8	4.8	75.2
	29E2	2	0	0	0	0	100	0	0	0	0	0	0
	28D8	1	0	0	0	0	100	0	0	0	0	0	0
	28D9	2	2	2	0	0	50	0.2	0	0	0.2	0.2	3.9
	28E0	2	0	0	0	0	100	0	0	0	0	0	0
	28E1	2	16	15	1	0	0	2.9	0.1	0	3	3	47.9
	28E2	2	9	8	1	0	0	6.5	0.7	0	7.1	7.1	112.4
	27D8	2	0	0	0	0	100	0	0	0	0	0	0
	27D9	2	2	2	0	0	50	1	0	0	1	1	19.7
	27E0	2	6	6	0	0	0	1	0	0	1	0.9	19.5
	27E1	2	27	27	0	0	0	5.5	0	0	5.5	5.5	112.8
	27E2	2	10	10	0	0	0	3.9	0	0	3.9	3.9	80.9
	26D9	2	0	0	0	0	100	0	0	0	0	0	0
	26E0	2	0	0	0	0	100	0	0	0	0	0	0
	26E1	2	14	14	0	0	50	2.1	0	0	2.1	2.1	43.8
	26E2	2	0	0	0	0	100	0	0	0	0	0	0
	26E3	1	2	2	0	0	0	0.2	0	0	0.2	0.2	3.6
	25E0	1	0	0	0	0	100	0	0	0	0	0	0
	25E1	2	14	8	6	0	0	7.7	2.7	0	10.4	10.4	190.4
	25E2	2	6	1	5	0	0	0	0.4	0	0.5	0.5	8.5
	25E3	2	4	4	0	0	0	0.7	0	0	0.7	0.7	13.2
	24E2	2	15	15	0	0	0	4.4	0	0	4.4	4.3	79.6
	24E3	2	4	4	0	0	0	0.4	0	0	0.4	0.3	6.4
	23E3	1	6	6	0	0	0	0.6	0	0	0.6	0.6	10.9
	23E4	1	5	5	0	0	0	1.8	0	0	1.8	1.8	32.1
	Total	130	611	403	207	1	34	133.7	51.5	2.6	187.8	187.7	3098.3
	CV (%)	-	-	-	-	-	-	-	-	-	15.1	NA	15.1

Table 10. Boarfish survey time series, updated with new TS-Length relationship.

Age (Yrs)	2011	2012	2013	2014
0	-	-	-	-
1	4.9	21.5	-	-
2	11.3	10.8	78.0	-
3	54.2	174.1	1,842.9	15.0
4	176.0	64.8	696.4	98.2
5	404.7	95.0	381.6	102.3
6	1,068.0	736.1	253.8	104.9
7	1,052.0	973.8	1,056.6	414.6
8	632.5	758.9	879.4	343.8
9	946.1	848.6	800.9	341.9
10	831.8	955.9	703.8	332.3
11	259.7	650.9	263.7	129.9
12	457.2	1,099.7	202.9	104.9
13	281.7	857.2	296.6	166.4
14	257.2	655.8	169.8	88.5
15+	1,746.0	6,353.7	1,464.3	855.1
TSN (mil)	8,183	14,257	9,091	3,098
TSB ('000t)	456,115	863,446	439,890	187,779
SSB ('000t)	455,375	861,544	423,158	187,654
CV	17.5	10.6	17.5	15.1

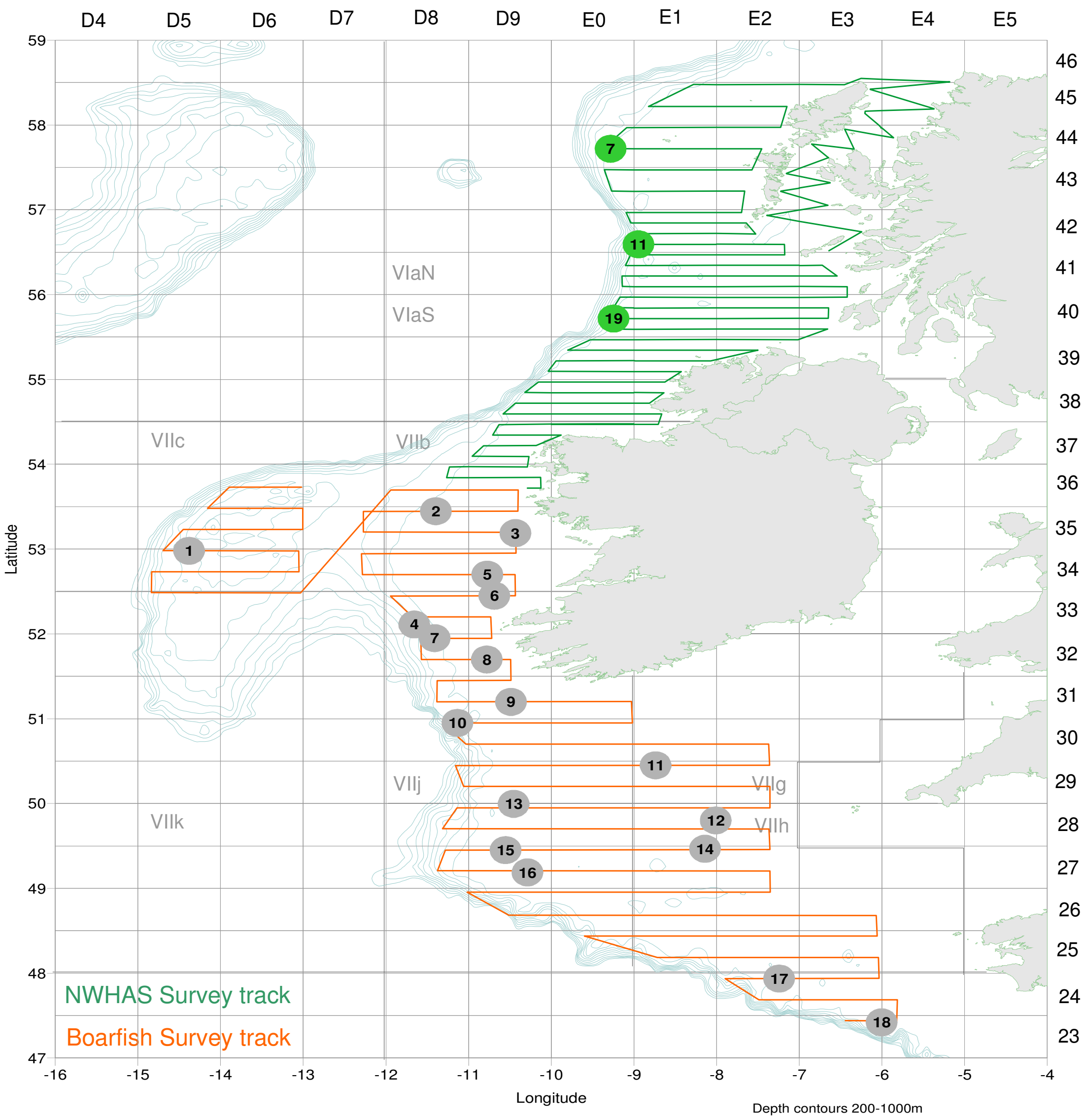


Figure 1. Cruise tracks and haul positions for the FV *Felucca* (orange) and RV *Celtic Explorer* (green) that contained boarfish.

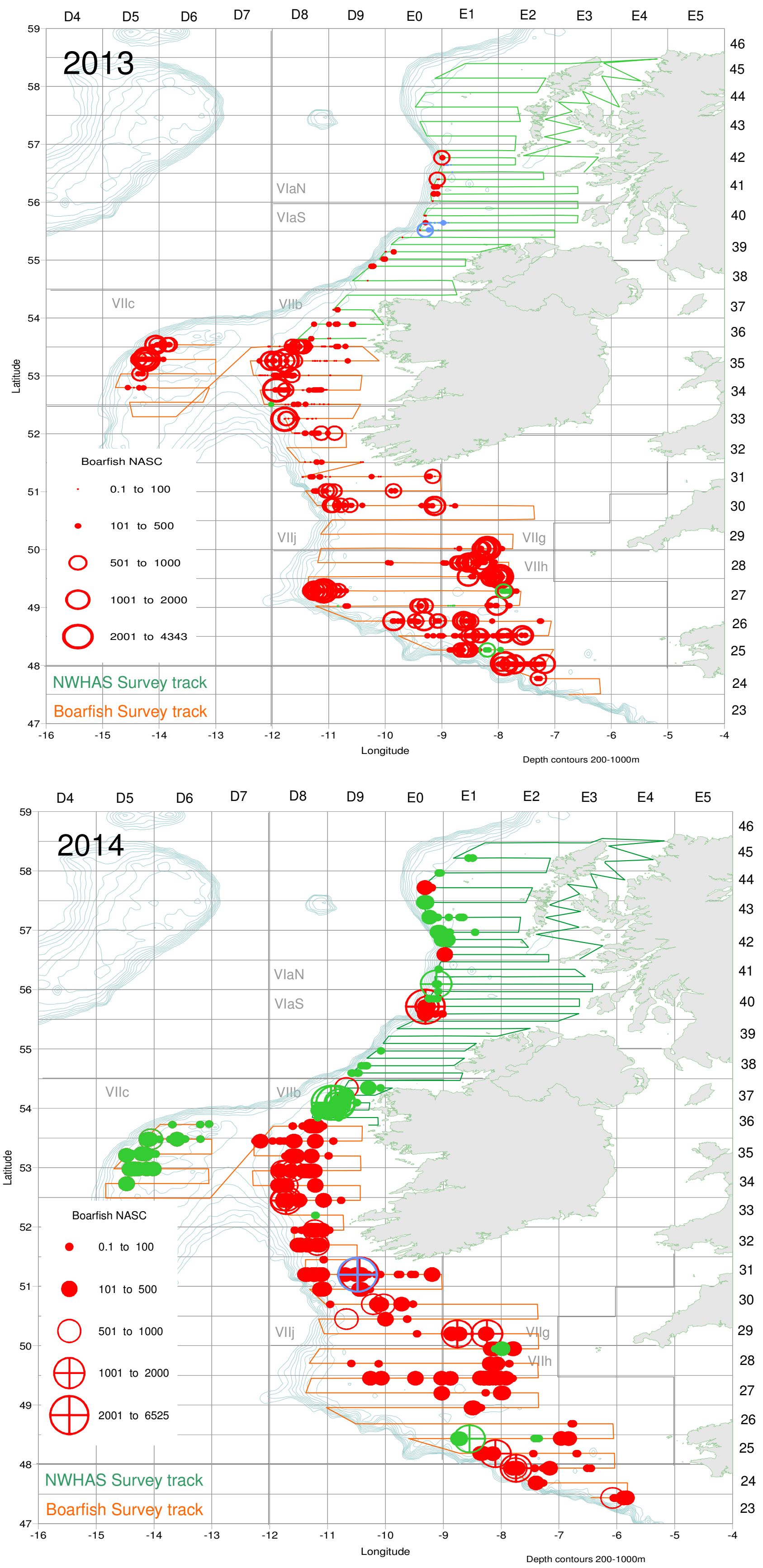
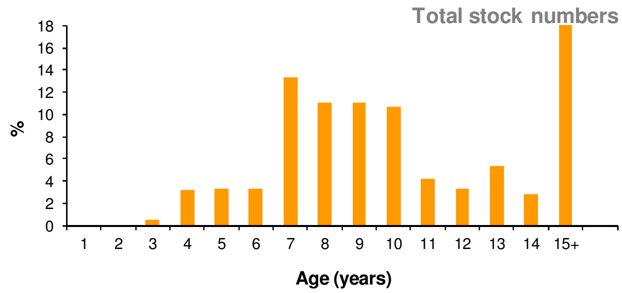


Figure 2. NASC plot of boarfish distribution. Circle size proportional to NASC value. Red circles represent 'definitely' boarfish, green; 'probably boarfish' and blue; 'boarfish mix'.



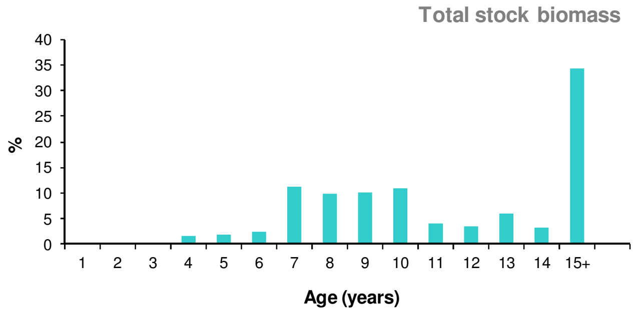
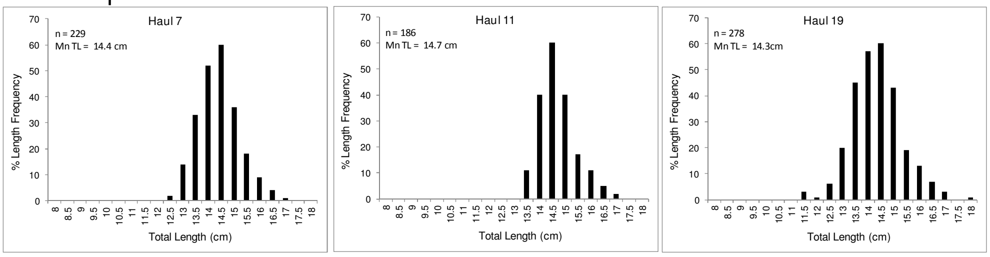


Figure 3. Percentage breakdown of total stock numbers (top) and total stock biomass (bottom) of survey stock.

Celtic Explorer Hauls



Felucca Hauls

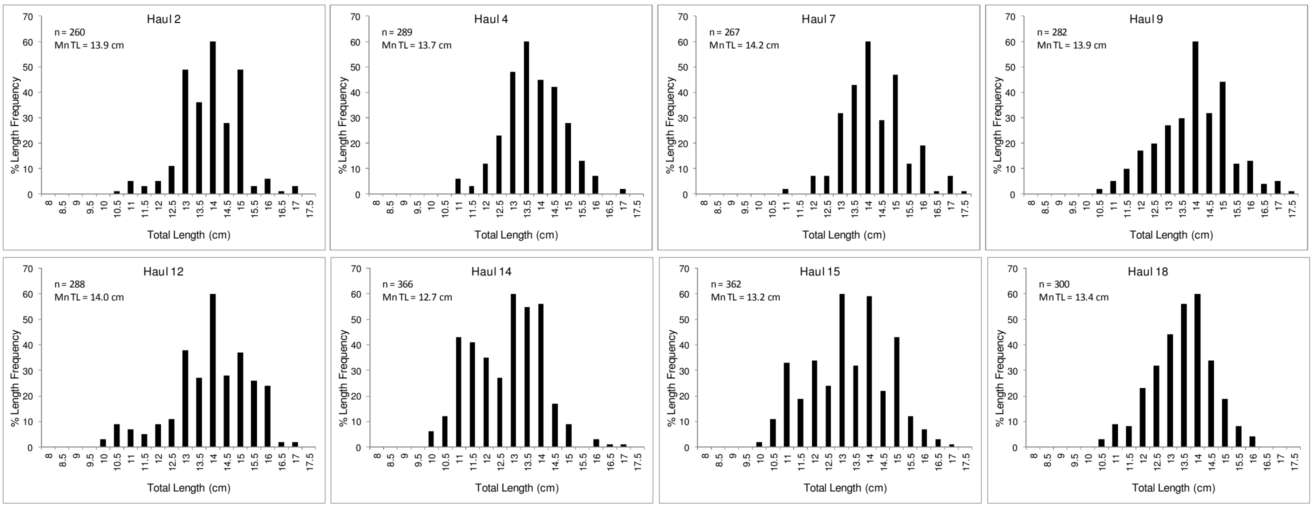
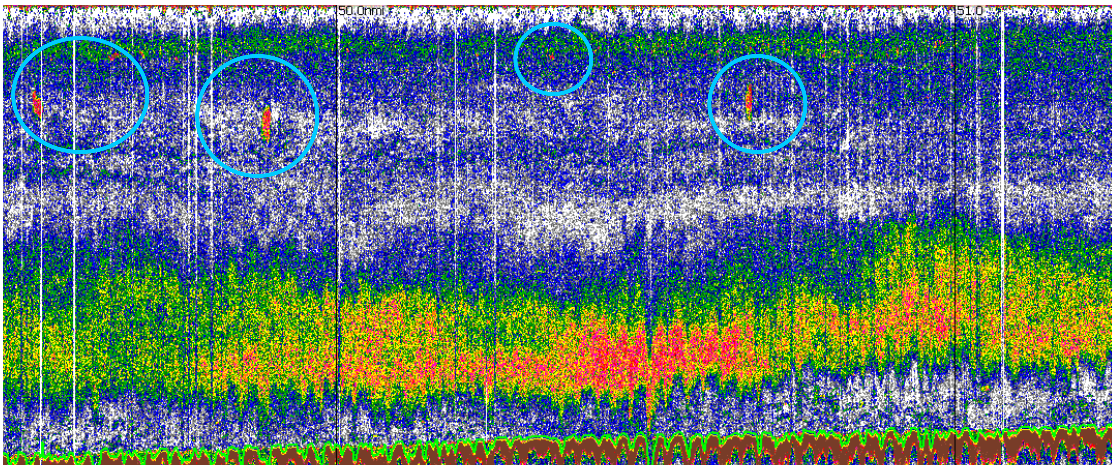
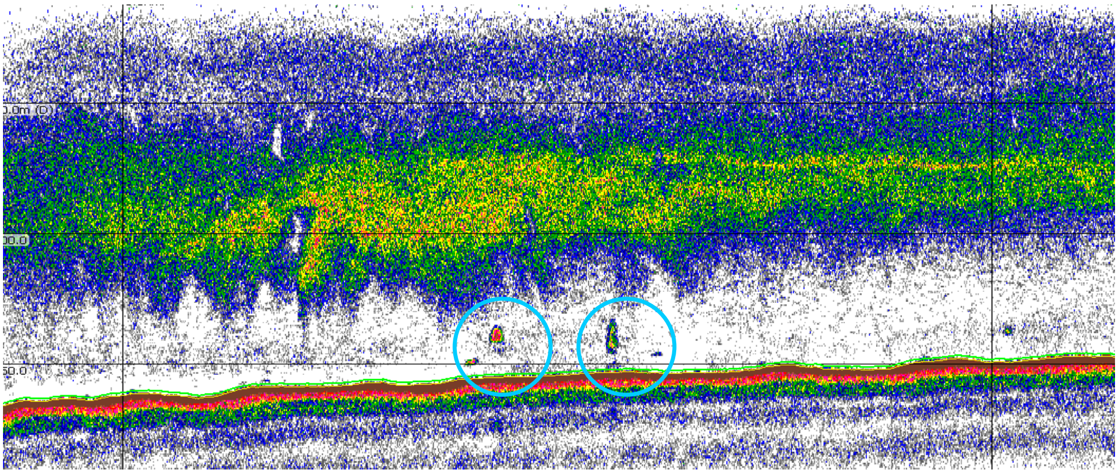


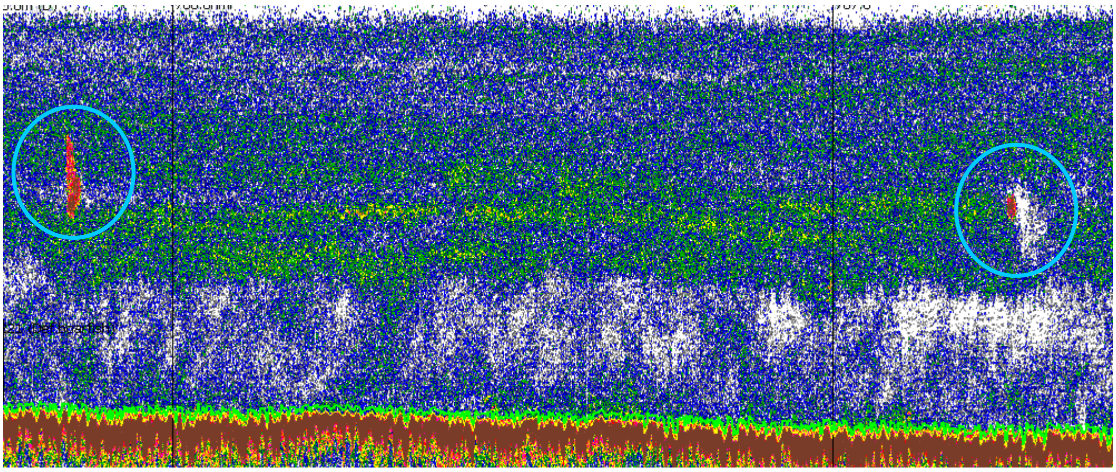
Figure 4. Mean length and length distribution of boarfish by haul.



a). Highest density boarfish echotraces (circled) observed to the west of the **Porcupine Bank**. Bottom depth is 220m with boarfish at 40-60m below the surface.

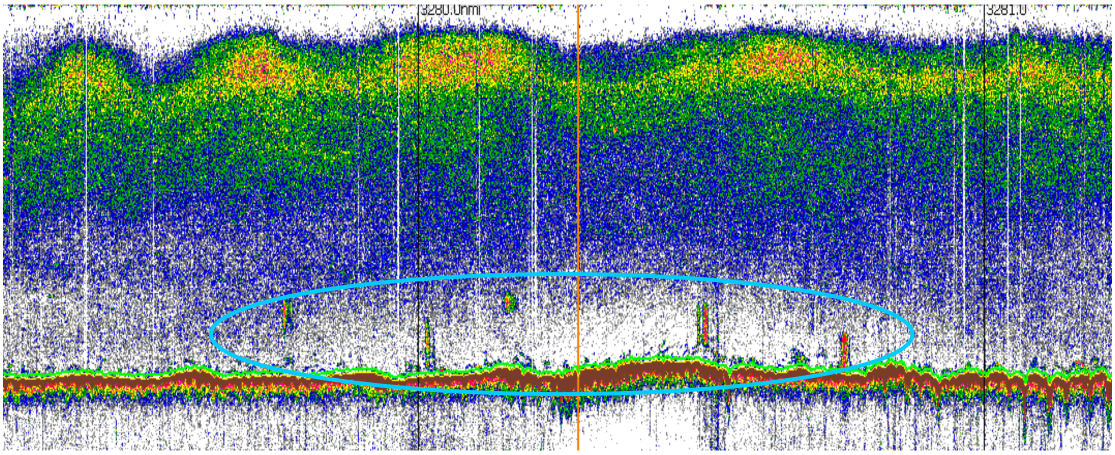


b). Boarfish echotraces from **northern area** at 57°30N recorded prior to Haul 07 by the *Celtic Explorer.* Bottom depth is 150m with targets at 0-20m.

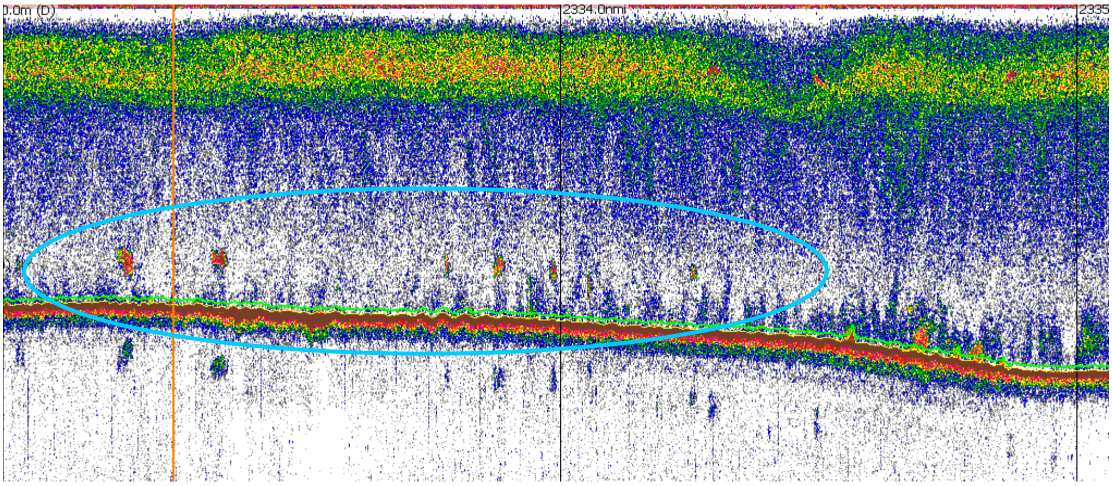


c). High density midwater boarfish schools (circled) typical of those encountered in the **western area** (51°-54°N). Recorded prior to Haul 03. Bottom depth is 150m with target schools at 40-60m.

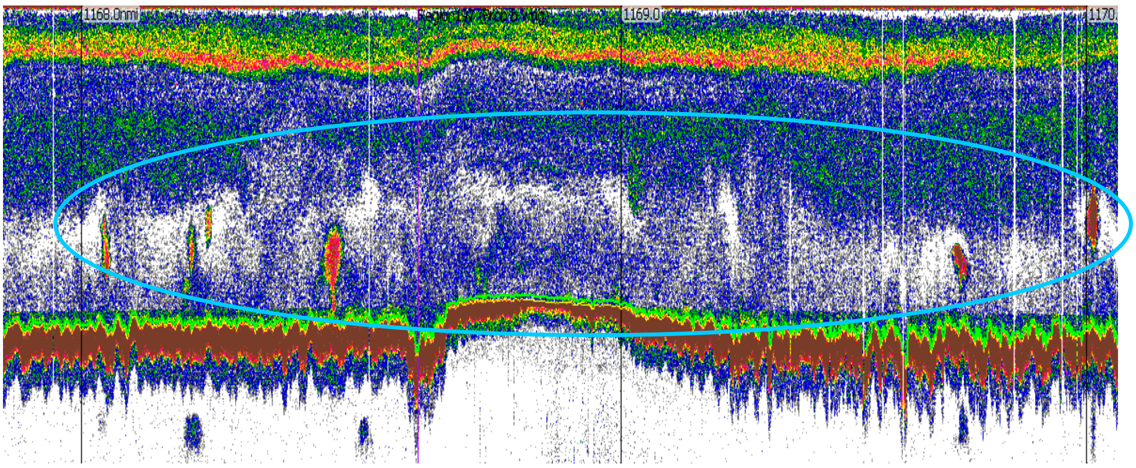
Figures 5a-h. Echotraces recorded at 38 kHz. Note: vertical bands on echograms represent 1nmi (nautical mile) sampling intervals.



d). Medium density boarfish echotraces recorded prior to Haul 16 located close to the shelf edge in the **southern area**. Bottom depth is 182m with targets extending from 0-30m off the bottom.

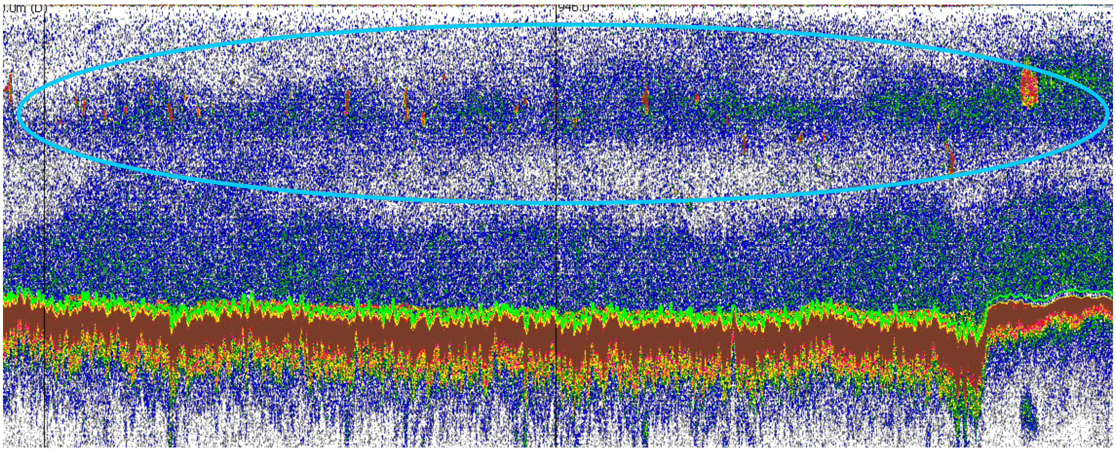


e). High density **off** bottom echotraces of boarfish typical of those encountered on the Banks in the east of the **southern area** (south of 50°N and east of 09ºW). Echogram recorded prior to Haul 13. Bottom depth is 120m with targets extending from 15-25m off the bottom.

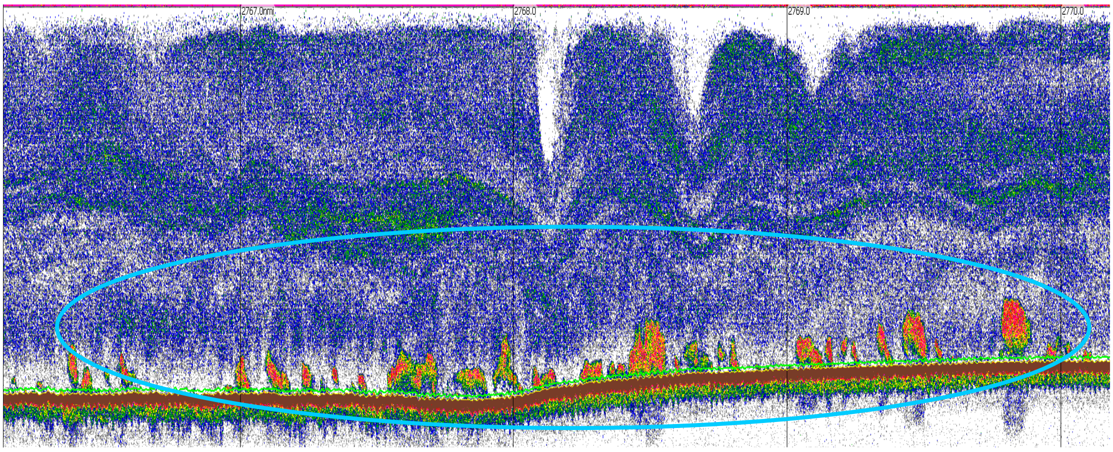


f). High density aggregations of juvenile 0-group blue whiting, recorded in the western area prior to Haul 07. Bottom depth is 70m with targets extending from 0-35m off the bottom.

Figures 5a-h. continued.



g). Surface aggregations of juvenile sprat recorded in the western area prior to Haul 05. Bottom depth is 115m with sprat occurring between 20-40m below the surface.



h). High-density aggregations of 0-group juvenile blue whiting as commonly observed in the southern region within a range of 20nmi from the shelf edge. Mark intensity and size typical of those encountered from 50º-48ºN.

Figures 5a-h. continued.

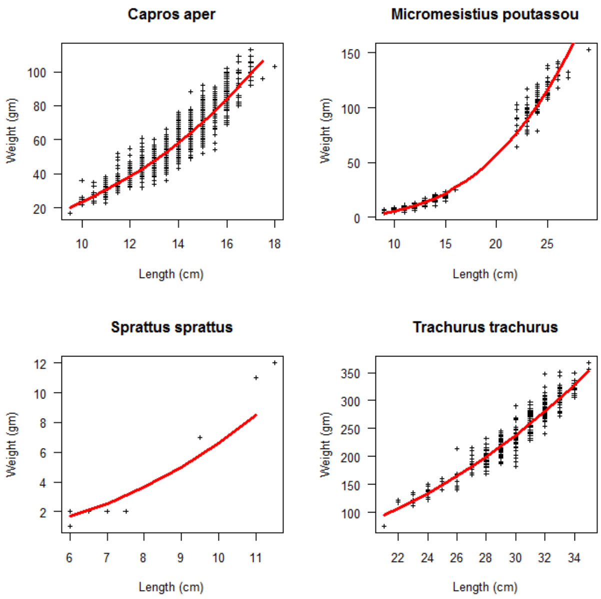


Figure 6. Length weight plots of major trawl component species.

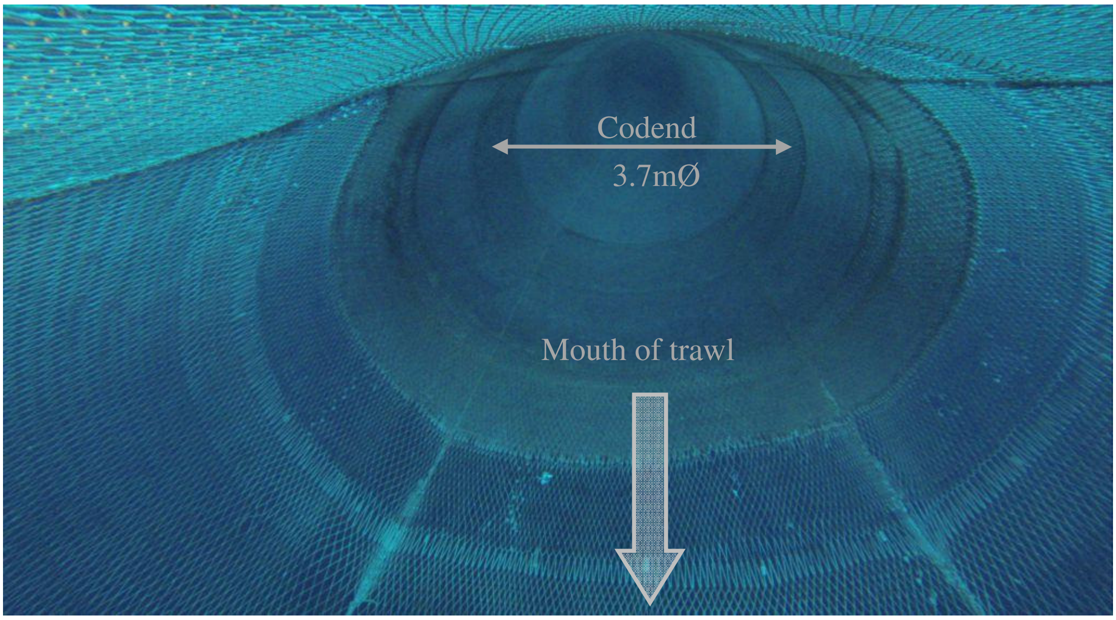


Figure 7. Unobstructed view of 4 panel single midwater trawl with standardised camera positioning.

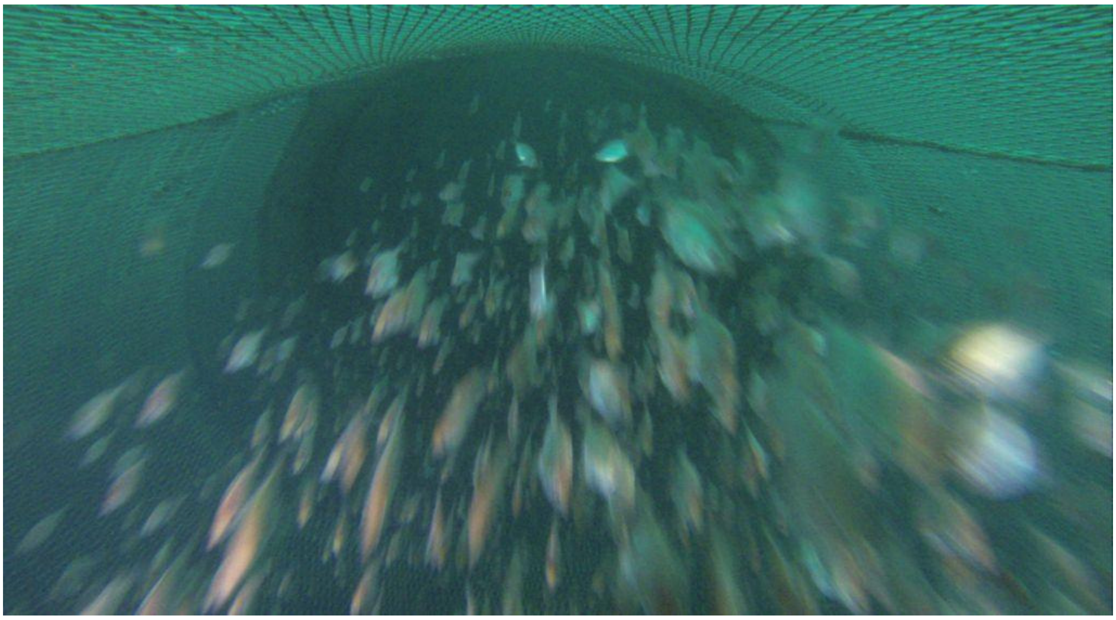


Figure 8. Haul 11. Catch 4.5t of 100% boarfish sampled within 45m of the bottom with a water depth of 85m. High plankton density in localised area resulted in a green hue to images.

Figure 9. Haul 12. Catch 5t of 100% juvenile blue whiting sampled within 45m of the bottom with a water depth of 134m.

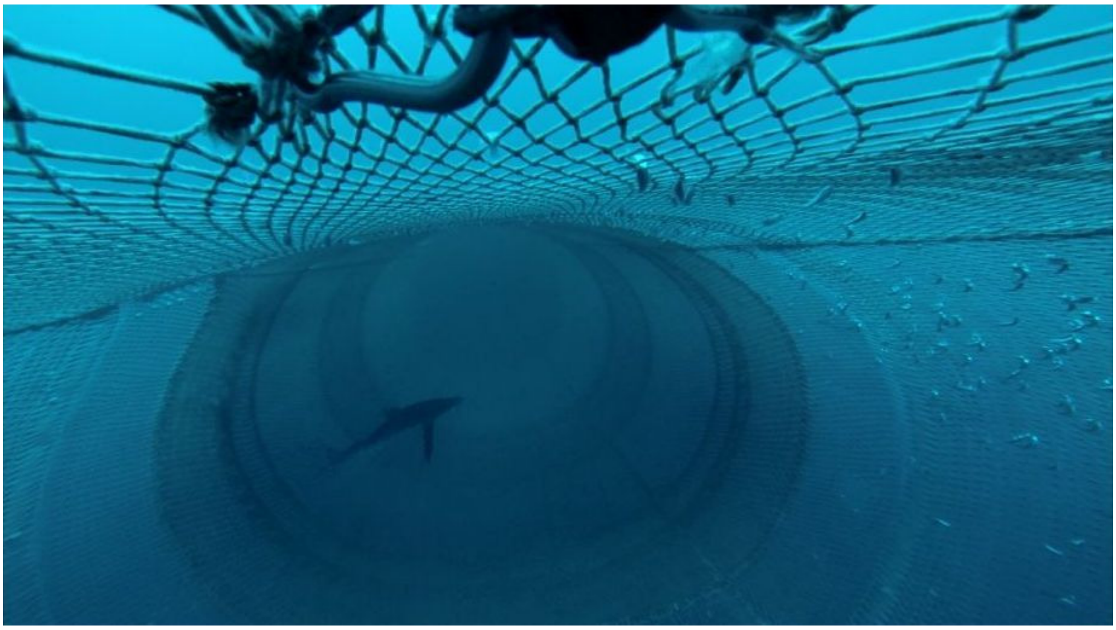


Figure 10. Haul 16. Blue shark (*Prionace glauca)* bycatch from catch of 4t of juvenile blue whiting (99%) and mackerel (1%) sampled within 45m of the bottom, water depth of 120m.

Appendix 1

Details of the charter vessel and tow body set up used during the survey.

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

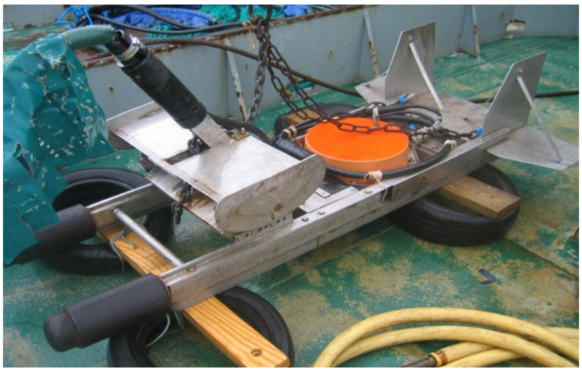


Figure 2. Tow sled with 38 kHz split beam transducer (orange centre screen).

Figure 3. Towing boom c.3m long, with support stays.

Figure 4. Top side monitoring station located on the bridge. Laptop (left) running Echoview and EK60 topside PC unit (right).

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.

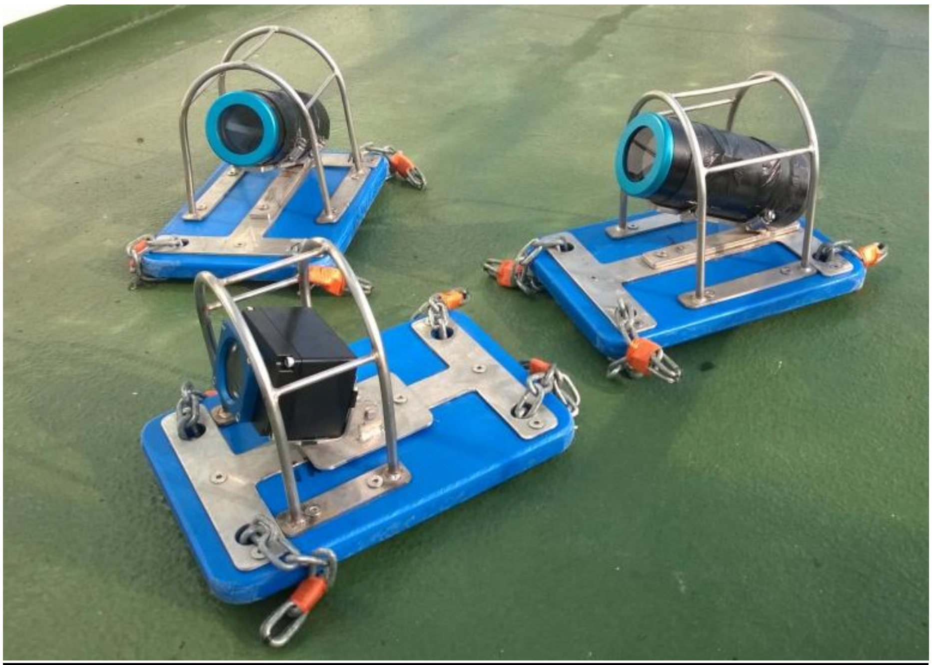


Figure 1 Camera (bottom) and lights on mounting plates.

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.

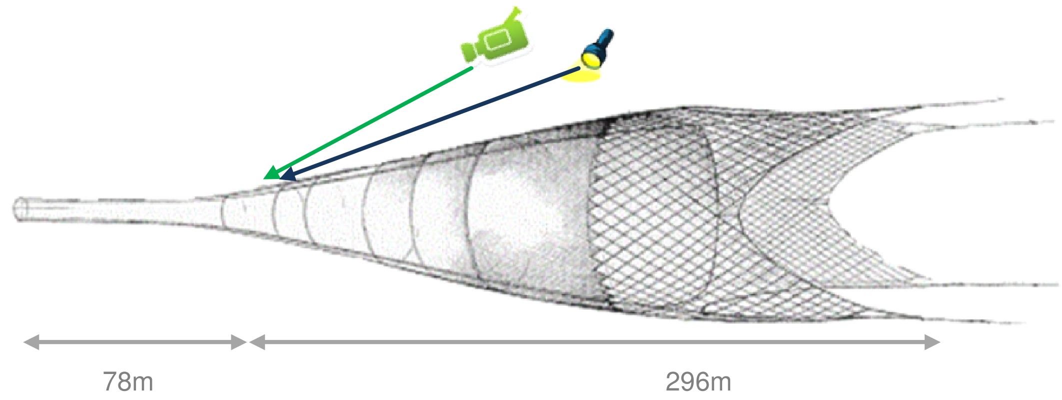


Figure 2 Schematic of pelagic trawl and positioning of camera and light rig. Rig was positioned on the top sheet (60mm half mesh) facing the mouth of the brailer. Net has a fishing circle of 1,050m with a vertical opening of c.50m.

<u>Data collection</u>
Continuous video and still shots (5 sec intervals) were 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 Microsoft office software.