FEAS Survey Series: Industry Acoustic Survey/01/2017

Atlantic Herring and Horse Mackerel in 6aS/7b, Industry Acoustic Survey Cruise Report

17 – 27 November, 2017

Herring (*Clupea harengus*) Linnaeus 1758

Horse Mackerel (*Trachurus trachurus*) Linnaeus 1758

MFV Eilean Croine S238 and MFV Sparkling Star D437

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Marine Institute
Foras na Mara

Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
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An Roinn Talmhaíochta, Bia agus Mara

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1. Introduction

An acoustic survey of Atlantic herring *Clupea harengus* and horse mackerel *Trachurus trachurus* was conducted in ICES areas 6aS/7b in November 2017. This survey is the second in a time series that is hoped will be developed into a long-term index of spawning/pre-spawning herring and horse mackerel in 6aS/7b, for use in stock assessments in the future. The 2016 survey is reported in O'Malley *et al* (2017). Following the ICES benchmark workshop on Atlantic herring in 6aN, 6aS and 7b, c (ICES 2015a), the individual stock assessments have been combined into one assessment encompassing both stocks. ICES still considers two separate stocks exist. The main reason for the merging has been that the catches of mixed aggregations in the commercial fishery and in the summer acoustic survey could not be separated into the different stock components. The consequence of this has been a zero TAC advice for herring in these areas since 2015 (ICES 2015b). Acoustic/trawl surveys are conducted in 6aN on spawning aggregations there in Aug/Sept., this document outlines a similar survey effort for 6aS and 7b in November. For herring, the timing of these surveys coincides with spawning/pre-spawning aggregations of these stocks; therefore abundance indices generated may be used as stock specific indices in the future. The timing of the 6aS survey also coincides with aggregating horse mackerel in this area during this time.

This survey was completed in 6aS/7b during November on the more dominant winter spawning herring in this area. Spawning is known to occur outside these times in 6aS/7b; however the timing was considered to be appropriate considering the resources available. This report considers the survey conducted in 6aS/7b, only. Results from both surveys were presented to the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) in January 2018 and the data and results are documented there also.

Figure 1. 6aS/7b industry acoustic survey in 2017: Pair-trawl vessels, *MFV Eilean Croine S238* and *MFV Sparkling Star D437* used in the Atlantic Herring and Horse Mackerel in 6aS/7b Industry Acoustic Survey in 2017.

Survey objectives

The survey is part of a collaborative partnership between Ireland, The Netherlands and UK (Scotland) that aims to improve understanding of the individual stock components of herring in 6a and 7b, c. The work continues the time-series of abundance and biomass data on the spawning components of herring stocks in 6aN and 6aS and 7b, c. Abundance and biomass indices for horse mackerel in 6aS/7b were also generated as per WGIPS protocols. Samples

from spawning herring when obtained are used for morphometric studies, ageing, genetic analyses and otolith microstructure. The overall survey objectives are:

- Conduct an acoustic/trawl survey in 6aS/7b; targeting pre-spawning and spawning aggregations of herring
- Conduct a synoptic acoustic/trawl survey in 6aS/7b; targeting horse mackerel
- Collect acoustic data and detailed biological information (length, weight, sex, maturity, age) of herring and horse mackerel to allow estimation of the size of spawning components of herring and distribution of horse mackerel in 6aS/7b
- Collect morphometric and genetic data on spawning herring to distinguish whether the 6aS and 7b, c stocks can be differentiated from the stocks in 6aN

Survey plan

The survey was conducted using the pair trawl vessels *MFV Eilean Croine S238* and *MFV Sparkling Star D437* (Figure 1). The *Eilean Croine* was the designated 'acoustic' vessel and the *Sparkling Star* was the designated 'biological' vessel. The acoustic vessel conducted all the acoustic operations and therefore stayed on transect (Figure 3) at all times apart from during fishing. The biological vessel was invoved in all the fishing hauls and the scientists processed all the biological samples on this vessel only. The biological vessel also conducted extra searching using their sonar in areas off-transect (e.g. Lough Swilly). The survey is designed to collect acoustic information and samples from pre-spawning aggregations of herring in 6aS and 7b. Known herring spawning areas are shown in Figure 2. The survey objective in 2017 covers the area in 6aS and 7b, focussed on areas where herring are known to be either spawning or in pre-spawning migrations during this time of the year. Spawning time in this area is variable, generally between October and February (Table 1), however, it is expected that a significant proportion of the 6aS/7b herring stock is contained by this survey design. The 6aS/7b area is also known to contain horse mackerel during this period, and is an important area for this fishery. From age analysis of the 2016 survey, horse mackerel were found to be dominated by 2-3 winter ring (wr) fish in this area (O'Malley *et al* 2017). The survey is designed to produce a concurrent index for the abundance and biomass of horse mackerel in this area during this time also, however, the survey in 2017 is not designed to contain this stock.

Survey design

The 2017 survey with parallel transect design (with 7.5 nmi spacing) is shown in Figure 3. Waypoints for the survey in 2017 are given in Appendix 6. The survey area covers up to the 56.75°N line in the north and 6.7°W line in the east. To the west, the survey was bounded approximately by the 200m depth contour and south to 53.75N approximately, off the west coast of Mayo near Inishturk. The straight line transects should be completed at constant speed (or as close to as possible). Deviations from the planned transects are documented on acoustic log sheets. When the vessel deviated from transect for any reason (e.g. fishing, or for landing spawning samples) it returned to the same position to resume the survey.

In 2017, the survey starting point was off the Inishowen Peninsula north of Donegal to the east of Inishtrahull Island (55°24N and 6.7°0W, Figure 2). Transects were generally north/south, and the survey progressed from east to west. The survey area coverage was based on the predicted distribution of herring in this area during this time. In total 1,482nmi of cruise track was completed using 27 transects and related to a total area coverage of approximately 2,200 nmi². Parallel transect spacing was set at 7.5nmi for the wider area, and

3.5 nmi for Donegal Bay. Coverage extended from inshore coastal areas to the 200 m contour in the west and north. A mini survey was carried out in Lough Swilly using a zig-zag design; this is an adequate survey design for narrow estuarine or riverine channel areas (e.g. Simmonds and MacLennan 2005) and is particularly suitable when surveying shallower areas like in Lough Swilly. The additional survey track in Lough Swilly was designed using the deepest part of the channel as the centreline for the strata area. 250m either side of this centre line was delineated as the boundary area; zig-zag transects were then placed within the strata boundaries. An elementary distance sampling unit (EDSU) of 1nmi was used during the analysis throughout the survey area. The survey was carried out over 24 hours each day.

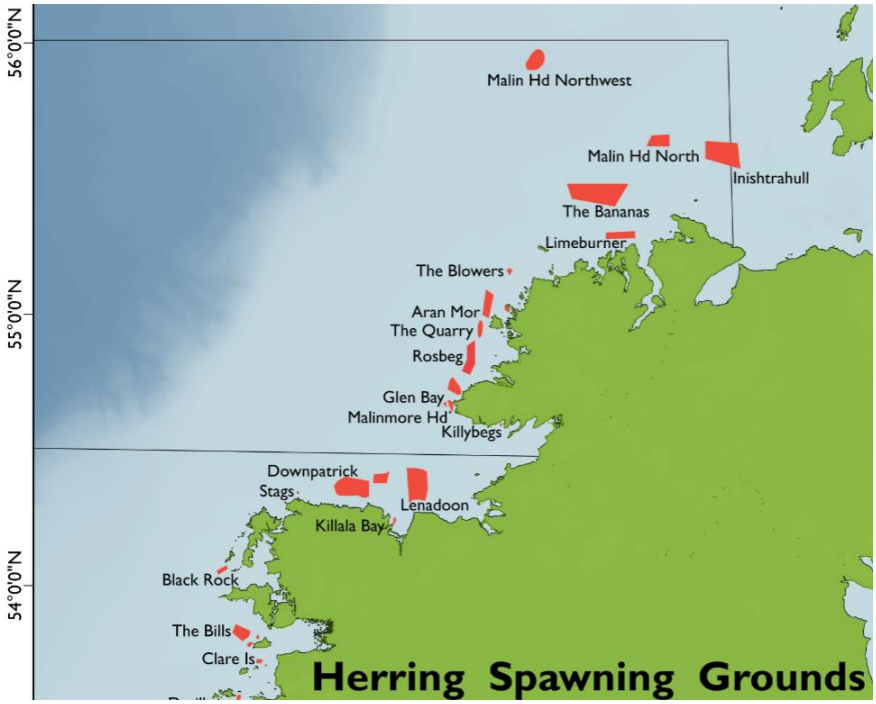


Figure 2. 6aS/7b industry acoustic survey in 2017: herring spawning grounds in 6aS and 7b (from O'Sullivan, 2013).

Table 1. 6aS/7b industry acoustic survey in 2017: Spawning areas, spawning grounds and spawning beds in 6aS and 7b, c. Area (km²) and depth (m) refer to individual spawning beds (from O'Sullivan, 2013).

Spawning Area	Spawning Ground	Spawning Bed	Depth (m)	Area (Sq Km)	Activity
North Donegal	Malin Head	Inishtrahull	45	121.58	November
		Malin Head North	90	39.06	November
	Limeburner	Limeburner	30	33.28	November
		The Bananas	58	169.17	Nov and Feb
	Tory	Malin Head Northwest	70-90	47.42	Nov and Feb
West Donegal	The Blowers	The Blowers	30	3.96	Oct/Nov
		Stags	20	0.89	Nov/Dec
	Aran Mor	Aran Mor 1	43	32.35	Oct/Nov
		The Quarry	70-80	11.84	October
	Rosbeg 1	Rosbeg 1.1	32-36	0.13	Oct/Nov
	Rosbeg 2	Rosbeg 2.1	43	44.06	October
	Glen Head	Glen Bay	32-36	24.17	Nov/Dec
		Malinmore Head 1	18	6.31	November
		Malinmore Head 2	90	1.59	Jan/Feb
Donegal Bay	Killybegs	Killybegs 1	20	1.01	Dec/Jan
	Lennadoon	Lennadoon 1	32-42	101.92	Jan/Feb
		Killala Bay	25	3.05	January
	Downpatrick	Downpatrick West	32	23.66	November
		Downpatrick/Ceide Fields	34-45	97.05	Dec/Jan
Mayo	The Stags	The Stags 1	36	0.89	November
	Blackrock	Blackrock 1	36	7.74	Oct/Nov
	Clare Island	The Bills	36	29.83	November
		Clare Island 1	32	3.07	Oct/Nov
		Clare Island 2	36	1.58	Oct/Nov
		South Clare Island 1	45	3.71	December
		South Clare Island 2	~40-45	2.01	Nov/Dec
	Lecky Rock	Davillaun/Lecky Rock	20	3.63	Sept/Oct

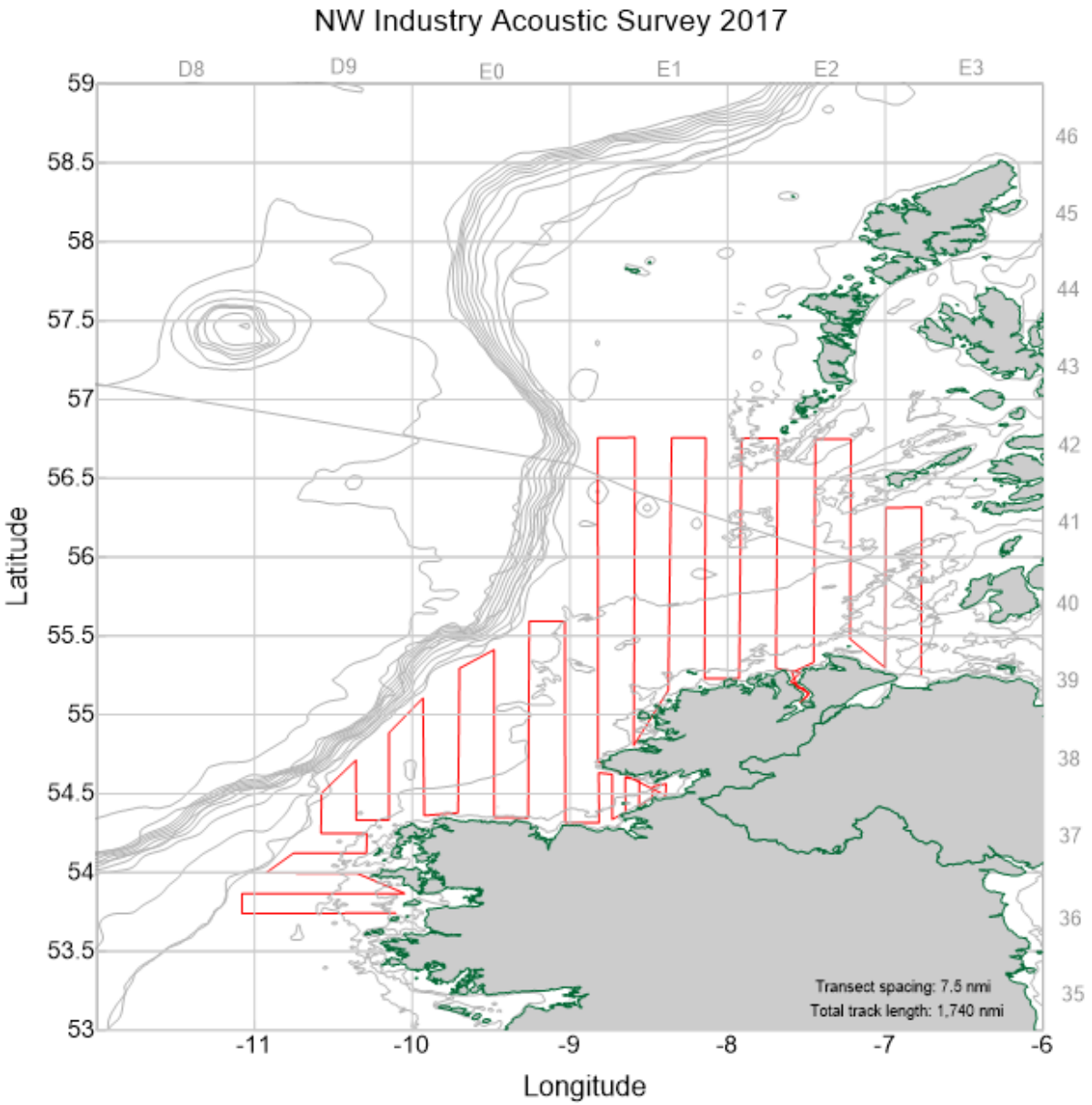


Figure 3. 6aS/7b industry acoustic survey in 2017: Acoustic survey area for 6aS and 7b. The total planned transect length was 1740 nmi (start 55˚24N and 6.7˚0W) with progress from east to west. The survey design allows for some intense surveys in areas where fish are observed and also in areas known to contain herring from information from the fleet (e.g. Lough Swilly, Inver Bay, Bruckless Bay, Killala Bay, and around Glen Head/Rathlin O'Beirne).

Scientific personnel

Organisation	Name	Capacity
MI (FEAS)	Michael O'Malley	Acoustics (Chief Scientist)
MI (FEAS)	Turloch Smith	Analyst (Biology)
Contractor	William Hunt	Acoustics
Contractor	Karl Bentley	Biology

2. Materials and Methods

Sampling protocols and equipment specifications

Acoustic data were collected using a SIMRAD EK60 scientific echosounder from the MFV *Eilean Croine* only. The Simrad ES-38B (38 kHz) split-beam transducer mounted on a towed body was calibrated before the survey near Rathmullan Pier in Lough Swilly, Co. Donegal. GPS feeds were obtained from the vessel, and the whole topside system was powered by an un-interrupted power source (UPS) and located in the wheelhouse. Vessel details and set up are provided in Appendices 4 and 5.

Acoustic survey protocols

The survey was conducted continuously over 24 hours due to the limited daylight in November and scale of coverage planned. Survey speed was approximately 10 knots, reducing as needed depending on sea conditions. In 2017 this meant survey speed was generally between 8 and 10kts. To improve the quality of data recorded, the *Eilean Croine* took on board ballast water to aid stability of the vessel and reduce the chances of drop-out on the echograms. In addition, all other acoustic sounders that might cause interference with the EK60 - 38 kHz were turned off. During fishing operations, the towed body was lifted out of the water and placed on the deck. During off-track searching other acoustic instruments, including the ship's sonar were occasionally used. Survey log sheets were used to record all transect data, including transect position, haul position and other events taking place on and off transect.

Calibration of acoustic equipment

The EK60 towed body transducer was calibrated in Lough Swilly prior to the start of the survey in calm conditions. A chain clump was dropped off the stern of the *Eilean Croine* to assist in keeping the vessel in position. Water depth was approximately 20m at the calibration location. The calibration was carried out using standard methodology as described by Foote *et al* (1987). Standard LOBE calibration (SIMRAD 2003; Demer *et al* 2015) was carried out on the *Eilean Croine* on the morning of 18/11/2017. The successful calibration was made possible by good conditions in the deep water in the Lough (~20m depth). There was minimal interference from biota in the water column during the calibration. Acoustic settings are given in Table 2. Results of the calibration are presented in Appendix 1.

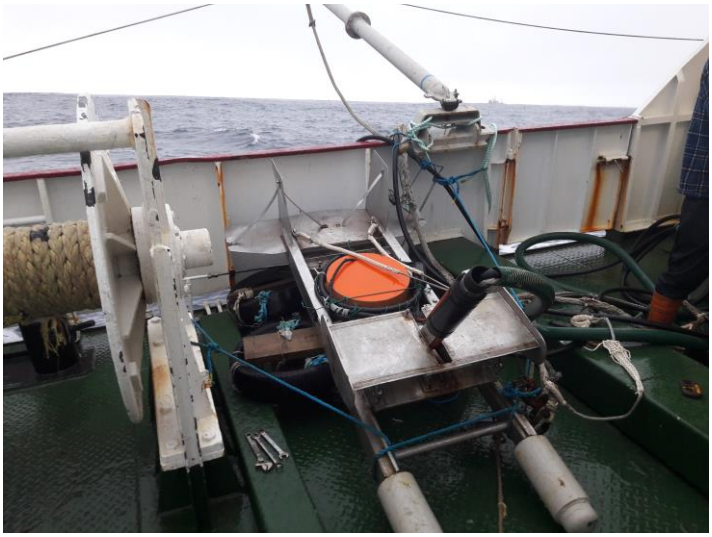


Figure 3. 6aS/7b industry acoustic survey in 2017: tow body mounted 38 kHz echosounder (*MFV Eilean Croine S238*) was calibrated in Lough Swilly, Co. Donegal.

Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing computer. Acoustic settings are shown in Table 2. 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 (V7.1) 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 and intertransects. Acoustic raw data files were backed up every 24 hrs

Acoustic settings

Table 2. 6aS/7b industry acoustic survey in 2017: Acoustic settings

Area	Vessel	Transducer **and** frequency	Echosounder	Power/ **p**ulse duration **p**ing interval	Environment	Calibration **l**ocation/ date	Standard target reference
6aS/7b	*Eilean Croine*	Towed body split beam ES38B (38kHz)	SIMRAD EK60	Power = 2000W (38kHz); Pulse duration = 1.024ms Ping interval = 0.33	Temp = 10.2˚C, Salinity = 33.3ppt, Sound speed = 1488.6 m/s	Lough Swilly, Co. Donegal 18th November 2017	-42.37dB

Echogram scrutinisation

Scrutinising echograms involves identifying fish marks and assigning them to species, and ensuring that any non-fish acoustic signals are not included as fish (e.g. bottom signals). Assigning fish marks to species is a heuristic process that relies upon (i) evidence from the targeted hauls made during the survey, (ii) prior experience of 'experts' (fishermen and acoustic scientists) based on their knowledge of what was caught when certain types of fish marks were fished upon in the area in previous surveys occurring around the same time, (iii) multi-frequency analysis where possible and (iv) knowledge of fish behavior. While it's impossible to be 100% confident when assigning fish marks to species, following agreed guidelines for classification (e.g. ICES 2015c) of marks greatly improves the consistency in the way that acoustic data from different surveys are scrutinized, and hence in the quality and comparability of the biomass estimates.
Acoustic fish marks were classified in to the following categories (See example echograms showing herring and horse mackerel aggregations in Appendices 2a to 2f):

1. **Herring** – confident that the marks were herring based on either evidence from a targeted haul or proximity, similarity to other schools known to be herring, or information from the fishery.
2. **Horse mackerel** – confident that the marks were horse mackerel based on either evidence from a targeted haul or proximity and similarity to other schools known to be horse mackerel.
3. **Unclassified** – confident that the marks were not herring or horse mackerel based on either evidence from a targeted haul or proximity and similarity to other schools known to not to be herring, or characteristic atypical of herring or horse mackerel schools.

No survey-driven fishing took place in areas where the fleet was fishing on herring. The current fishery is a monitoring TAC allowed on herring in 6aS as part of an effort to continue the long time series of catch data coming from the fishery (ICES 2016). The Chief Scientist took the decision that samples from the fishery would be adequate to work up an acoustic estimate from areas where the fishery was sampled at the same time as the survey. This was similar to the approach taken in 2016. The monitoring fishery TAC has been relatively low the past few years (circa 1600 t in 2017) and therefore the vulnerability of the stock was taken into consideration here. Herring marks were very strong in some areas and were in extremely localised aggregations. They were also located in shallow areas close to shore which meant that taking a relatively small sample (4-5 baskets) required for sampling purposes particularly difficult with the pair-trawl. In 2017, fishing during the survey occurred on offshore aggregations in deeper water only on primarily horse mackerel marks.

Echograms were processed and subsequently analysed as separate transects. Off track events, such as data collected during fishing, transiting to the start point, and off-track searching using sonar 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 three categories above. The echograms were generally analysed at a threshold of -70 dB. The echo-integrals were calculated at a threshold of -70 dB. How strongly the acoustic marks are displayed on the screen (backscatter threshold) can have a bearing on the interpreters classification of the acoustic marks and their selection using school detection algorithms. While it is desirable to be consistent in the setting of this parameter, in practice the setting is determined largely by the need to filter out fish schools from other acoustic signals that create noisy backscatter data.

Fishing operations for scientific samples

During the acoustic survey, selected fish marks were targeted with a fishing operation (Figure 4) to capture fish samples for the purposes of:

(i) Confirming the species identity of acoustic marks, particularly those suspected to be herring or horse mackerel and to confirm that they were definitely not herring or horse mackerel
(ii) Collecting samples for biological analysis (length, weight, sex, maturity, and age)

The fishing operations for samples were directed to take a catch of the smallest possible size sufficient for biological sampling. Commercial catches of horse mackerel during the survey were often larger (50 – 100 t), these fish were landed by the vessel. Samples were also taken from the commercial catch of horse mackerel, thus reducing waste to a minimum.

The vessel was granted a derogation to discard fish that were not retained for biological sampling and to retain any catches of herring, up to the maximum specified quota taken either during or outside the survey period.

A single pelagic midwater pair trawl was used during the survey. The trawl speed averaged about 5kts. The vessels were approximately 0.25nmi apart during towing. The net was fished with a vertical mouth opening averaging 35m. The net opening during fishing was observed using a cable linked SIMRAD FS 900 netsonde (200 kHz). The net was fitted with catch and tunnel sensors to monitor the catch entering the trawl.

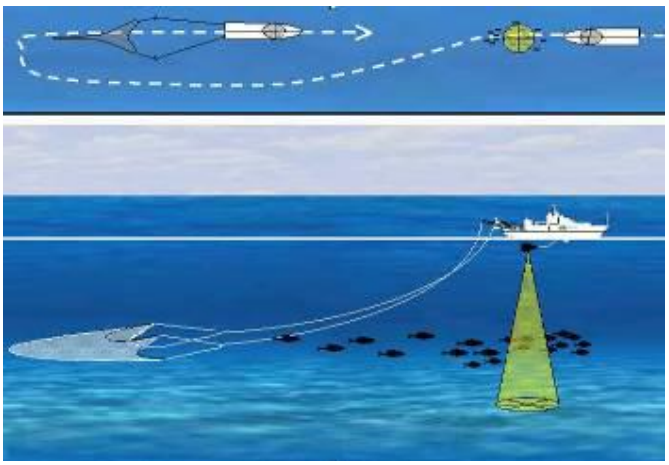


Figure 4. 6aS/7b industry acoustic survey in 2017: schematic description of a typical fishing operation to collect a biological catch sample during an acoustic survey.

Haul information

Haul data were recorded using the same template for all Marine Institute surveys (one sheet per haul). Information was recorded on the date, time, fishing position, depth, gear, catch composition, total weight of catch and weight of the sub sample taken for length frequency and biological sampling. For hauls used in helping to scrutinize the acoustic data, additional information was recorded on the sheets to show how the acoustic traces looked on the netsonde and echosounder. A screen grab from the echosounder was also taken of each mark. In the comments box, comments were made on whether or not the targeted schools were captured by the trawl, and any other relevant information, including whether fish were spawning (based on "running" eggs and milt upon capture).

Biological sampling

All components of the catch were sorted to species level and weight by species was recorded. Length, weight, sex, maturity data were recorded and otoliths extracted for individual herring/horse mackerel in a random 50 fish sample from each trawl haul. In addition, a further 100 length/weight and a further approximately 200 fish length frequency only measurements were taken from each haul. No ageing 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. For species other than herring and horse mackerel, length and weight measurements were taken for 100 individuals per trawl.

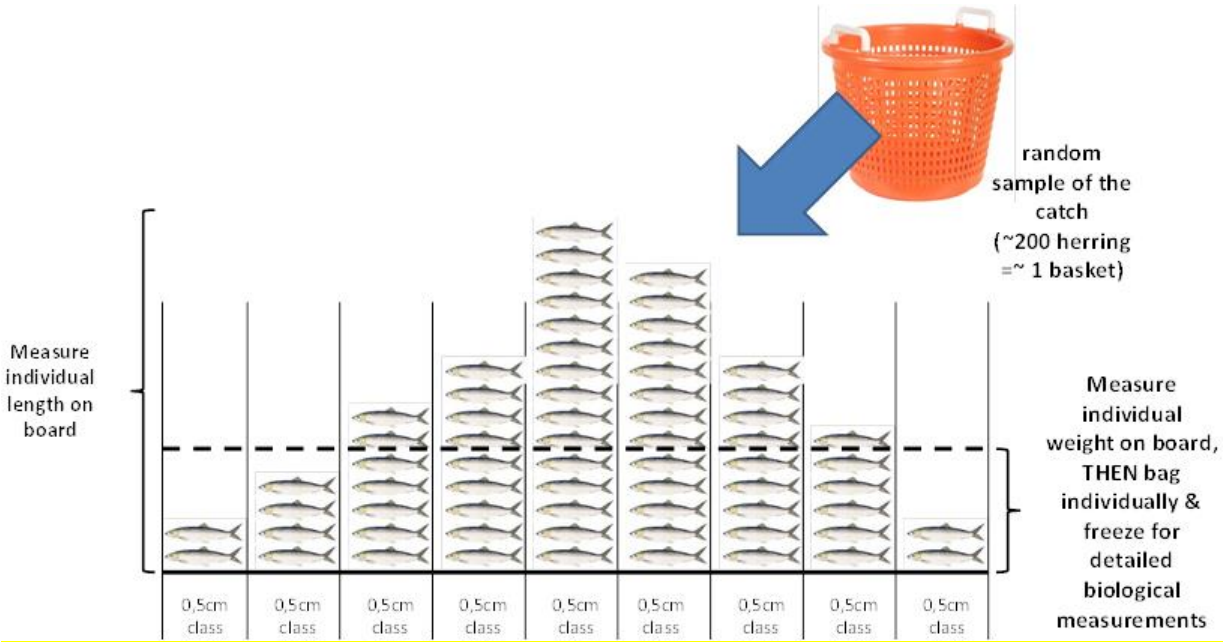


Figure 5. 6aS/7b industry acoustic survey in 2017: Illustration of the required catch sampling procedure.

Length measurements

The length of herring in the subsample was measured and recorded to the nearest 0.5 cm below. This data is used to determine a length frequency distribution of the catch and subsequently to apply an age-disaggregated estimate of biomass. Horse mackerel were measured to the nearest 1.0 cm below

Otoliths for age (wr) determination

Taking the 50 fish for ageing, each measured fish was assigned an ID number and the otoliths extracted for age (wr) determination at the lab.

Standard procedures for age determination from the growth rings on the otoliths (ear bones) of herring were used to determine the age (wr) of fish sampled. This age data was used to create an age-length key for herring (Figure 12).

Analysis methods - age disaggregated abundance estimate

The recordings of area back scattering strength per nautical mile (nautical area backscattering coefficient – NASC [m^2/nmi^2]) were averaged over a one nautical mile EDSU (Elementary distance sampling unit), and the allocation of NASC values to herring and horse mackerel schools and other acoustic targets was based mainly on the composition of the trawl catches, the appearance of the echotraces, multi-frequency techniques, reports from the fleet in the same area, and experience.

The following TS-length relationships used were those recommended in the manual for international acoustic surveys (ICES 2015d):

Herring TS = $20\log_{10}L - 71.2$ dB per individual (L = length in cm)

Horse mackerel TS = $20\log_{10}L - 67.5$ dB per individual (L = length in cm)

The process for estimating abundance and biomass of herring from the acoustic data is shown in its component parts in Figure 6.

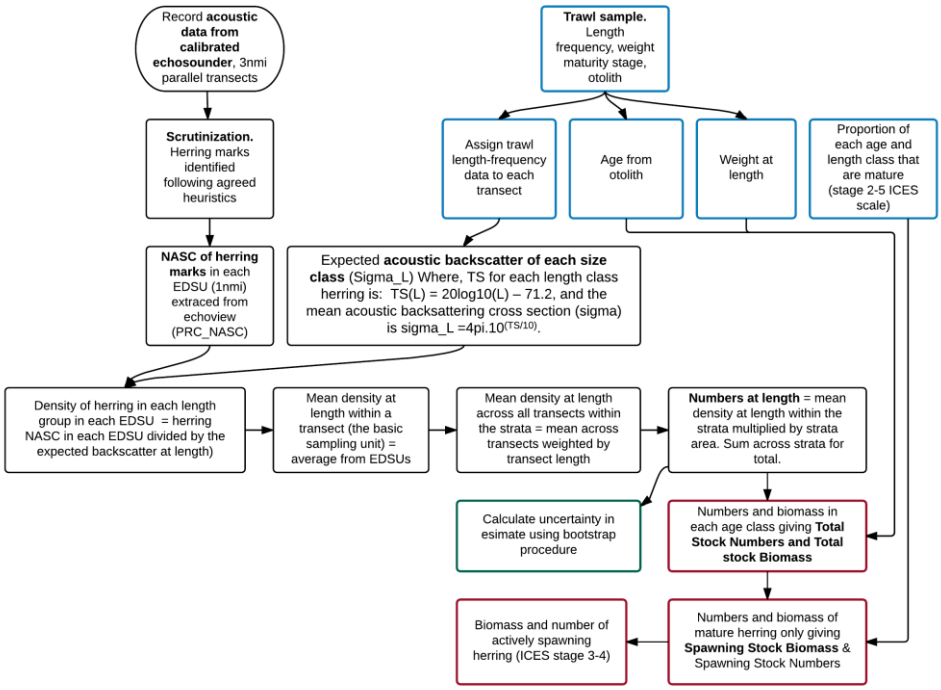


Figure 6. 6aS/7b industry acoustic survey in 2017: Flow diagram of the analysis methods to estimate abundance and biomass. Blue boxes – biological data; black boxes – treatment of acoustic data; red boxes- derived abundances indices; green box – uncertainty estimates

The StoX software (http://www.imr.no/forskning/prosjekter/stox/nb-no) was used to calculate the age disaggregated acoustic abundance and biomass estimates. StoX is an open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application built in Java for easy sharing and further development in cooperation with other institutes, and is now routinely used to derive abundance estimates from WGIPS coordinated surveys. Documentation and user guides are available from the website. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Coefficient of variance (CV) estimates of biomass and abundance for the survey strata

(Northwest, Donegal Bay and Lough Swilly – Figure 7) and the overall strata areas combined were generated using the RStox package (version 1.7).

Figure 7. 6aS/7b industry acoustic survey in 2017: StoX strata delineated for the 3 scrutiny areas for herring (Lough Swilly, Northwest, and Donegal Bay). The Northwest strata was also used in the horse mackerel abundance and biomass estimation. The 8 haul/sample stations where herring were obtained for length frequency analysis are also shown as blue squares.

Following scrutinisation of the echograms, the EDSU (1nmi) specific Nautical Area Scattering Coefficient (NASC - the area backscattering coefficient for a particular integration region in areal units (m^2/nmi^2)) assigned to herring marks (represented as PRC_NASC in Echoview) is exported. The calculation of age disaggregated abundance was as follows:

1. **Assigning fish length data from trawls to acoustic transects.** For each transect within each survey strata (where each of the 3 areas surveyed represents a strata in 6aS/7b [Figure 7]), the length distribution of herring associated with each transect was determined as the un-weighted mean of all trawls allocated to the respective transects.
2. **Expected backscattering cross section of fish in each length group.** The mean acoustic backscattering cross-section "sigma" (σ_{bs}) for each length group of herring was calculated from the length frequency data assigned to each transect using the target strength-length relationships for herring recommended by the ICES Working Group on International Pelagic Surveys (ICES 2015d). The target strength (TS) relationship used to calculate the mean acoustic backscattering cross-sections for herring is:

$$TS = 20\log10\ (L) - 71.2 \quad [\text{at } 38 \text{ kHz}] \textit{ for herring}$$
$$TS = 20\log10\ (L) - 67.5 \quad [\text{at } 38 \text{ kHz}] \textit{ for horse mackerel}$$

The mean acoustic backscattering cross section is:

$$\sigma_{bs} = 10^{(TS/10)}$$

3. **The average density of fish in each length class on a single transect** is calculated by dividing the NASC within each 1nmi EDSU of each transect by the length-specific σ_{bs} (acoustic backscatter cross-section) assigned to each transect. This is then averaging over the EDSUs.
4. **Numbers of fish in a single stratum & total numbers.** For each length group, a weighted average (weighted by transect length) of the mean density of herring in each transect is multiplied by the area of the stratum. Total numbers at length is the sum for each stratum.
5. **The numbers and biomass per age & maturity class.** Trawl data on the relationship between length, age (wr) and maturity stage were used to partition the numbers at length in to estimates of numbers and biomass in each age class and maturity stage. The 9 point maturity stage classification was used for herring (Appendix 7a), and the 6-point scale was used for horse mackerel (Appendix 7b).
6. **Estimate of the relative sampling error.** A bootstrap procedure using StoX was used to estimate the CV of the estimate of numbers at length. The procedure randomly selects transects within a stratum with replacement, and for each selected transect, the trawl stations which are assigned for the selected transect are randomly sampled with replacement. Thereafter, each run follows the same estimation procedure as used in StoX and described above.
7. **Estimates from the intensely surveyed (mini grids).** In Lough Swilly, a zig-zag transect pattern was executed, therefore this area was treated as a separate strata in StoX (Figure 7). The boundaries of the strata were delineated approximately 250m either side of the centre line of the deepest part of the Lough Swilly channel in approximately 10 – 20m water depth. The zig-zag transect lines were laid out within the boundaries set out. In Donegal Bay, reduced transect spacing was used (3.5nmi). This included Bruckless and Inver Bays, where reports from the fishery indicated that fish were distributed in the area, particularly inshore. It was decided that reduced transect spacing would be beneficial in this small relatively small area.

Acoustic data were saved on hard-drives at sea and uploaded to network facilities at the Marine Institute. The acoustic metadata and cleaned post-processed EV files are stored at the Marine Institute following established procedures. Estimates of abundance made from the surveys are also stored in the ICES WGIPS acoustic database.

3. Results

Acoustic and biological

After calibration of the towed body mounted 38 kHz transducer at Rathmullan in Lough Swilly, approximately 1,500nmi of transects were completed successfully. A total of four hauls were taken, however, only three were landed on deck as the net was torn during haul 2 and obtaining a sample from this haul was impossible (Figure 8, Table 3). In some areas where marks of herring were observed on the echosounder, the vessel was unable to fish due to the shallow water depth (e.g. <20m in Lough Swilly) and size of gear available. The monitoring fishery was being conducted at the same time as the survey, on smaller boats in the same areas. Biological samples from some of these vessels were used to augment the samples from the survey. Samples were taken from boats fishing in Lough Swilly, Bruckless Bay and Inver Bay as close spatially and temporally as possible to the survey in these areas (Table 4).

Table 3. 6aS/7b industry acoustic survey in 2017: total weight (kg) of sub-samples of the catch by species in hauls conducted.

Haul No	Species name	Total sub-sample weight (kg)
1	*Trachurus trachurus*	90.44
2	n/a (torn net)	n/a (torn net)
3	*Trachurus trachurus*	55.23
3	*Merlangus merlangus*	0.356
3	*Melanogrammus aglefinus*	0.336
4	*Trachurus trachurus*	44.94
4	*Melanogrammus aglefinus*	1.82
4	*Scomberus scombrus*	0.45

Table 4. 6aS/7b industry acoustic survey in 2017: biological sampling summary statistics from survey hauls (1 - 4) and samples from the monitoring fishery (5 – 12). Haul 2 did not obtain any samples because of a torn net.

Haul/Station	Date	Location	Fish (measured/lengths)		Ages/maturity/sex
			Clupea Harengus	*Trachurus trachurus*	
1	20/11/2017	NW Tory Is.		259	50
2	21/11/2017	NW Tory Is.	n/a	n/a	n/a
3	21/11/2017	NW Tory Is.		294	50
4	24/11/2017	NW Tory Is.		232	50
5	14/11/2017	Lough Swilly	338		338
6	20/11/2017	Inver Bay	124		124
7	21/11/2017	Lough Swilly	211		211
8	04/12/2017	Inver Bay	165		165
9	01/12/2017	Lough Swilly	64		64
10	24/11/2017	Inver Bay	54		54
11	30/11/2017	Bruckless Bay	125		125
12	12/04/2017	Bruckless Bay	118		118

The location of survey hauls and samples from the fishery is shown in Figure 8. The monitoring fishery in 6aS/7b began in mid-November and continued throughout the survey period. Most of the fishing activity, particularly in late November/early December was inshore in shallow water. Very strong herring marks (e.g. > 2nmi long, 200m wide and ~18m deep) were evident in Lough Swilly (appendix 2a), also an area where smaller boats in the fishery were concentrating effort. There was also a series of strong herring marks in Bruckless Bay (appendix 2b) and Inver Bay (appendix 2c) in discreet areas. There were very few herring marks offshore. Consequently, the distribution of herring NASC values is dominated by three areas in particular (i.e. Lough Swilly Bruckless Bay and Inver Bay for herring – Figure 9). There were also small marks of herring in Killala Bay and to the north of Inishtrahull Island. There were a lot of horse mackerel marks in the area to the north and west of Tory Island (Figure 14 and Appendices 2e and 2f).

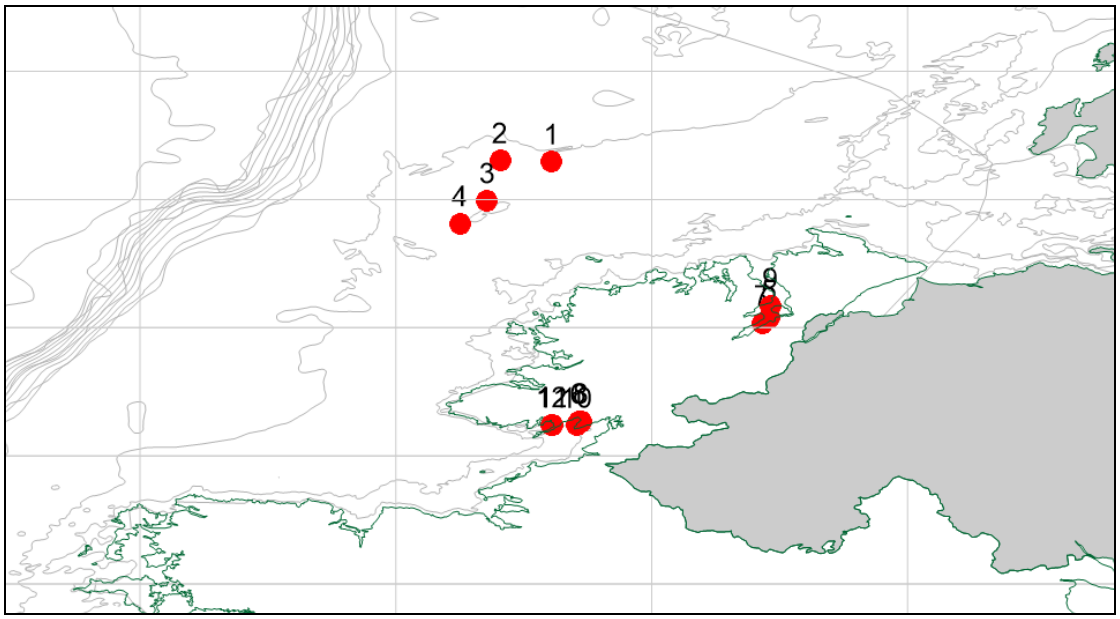


Figure 8. 6aS/7b industry acoustic survey in 2017: distribution of biological samples, including samples from the survey (hauls 1-4) and the monitoring fishery (5-12).

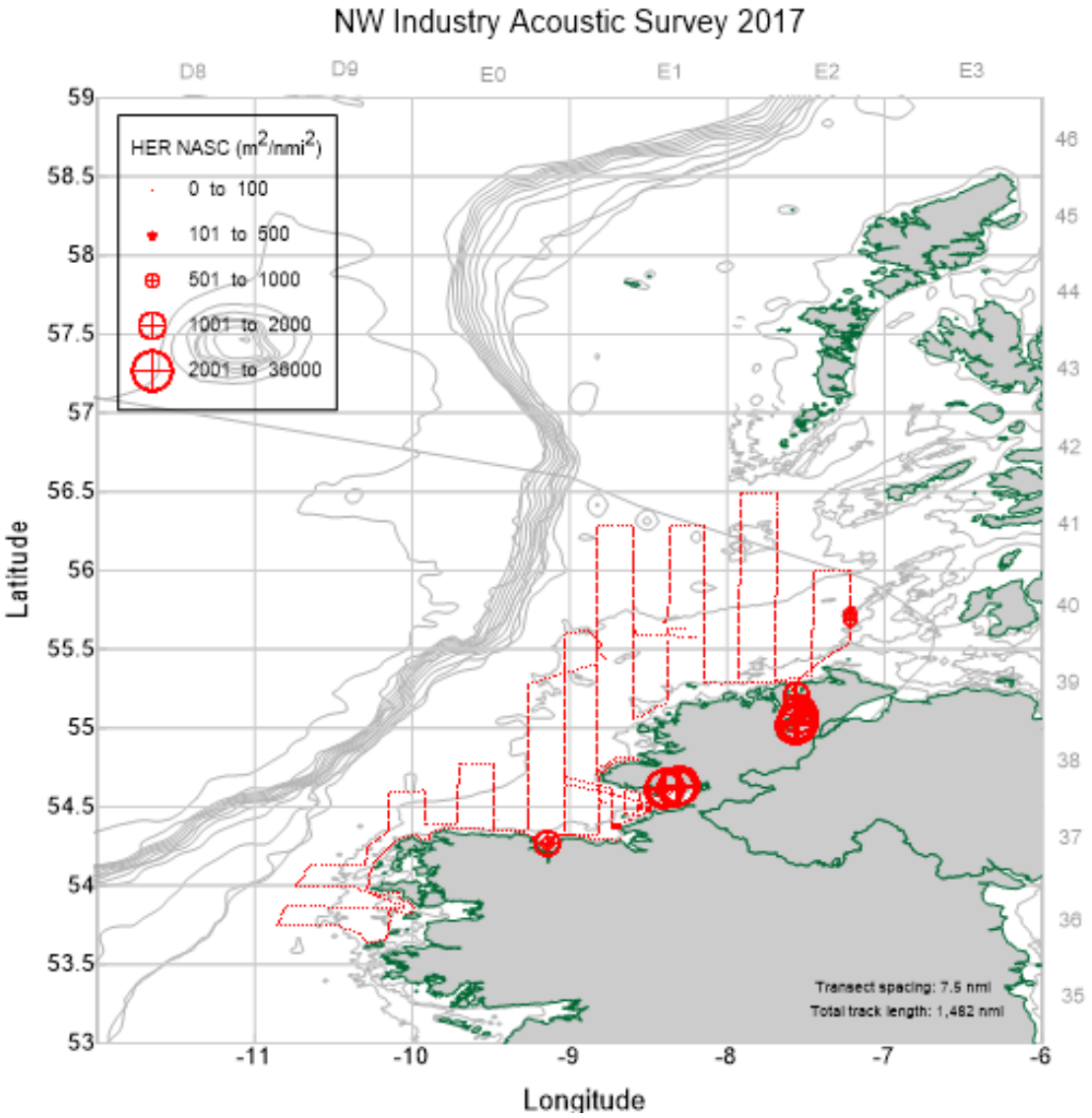


Figure 9. 6aS/7b industry acoustic survey in 2017: distribution of NASC allocated to herring.

Length frequency

The relative length frequency distributions of herring in the hauls/samples is shown in Figure 10. Strong modes were evident in all of the samples, with the majority of fish were > 24 cm. All hauls show a single mode in the distribution of herring between 26 and 28cm. The samples were dominated by mature fish (Table 5b), expected in fish captured close to areas and times where spawning is known to occur during this time (Table 1).

Horse mackerel were distributed throughout the survey area, but particularly throughout the area west of Tory Island (Figure 14). Horse mackerel length distribution was dominated by a mode at 24cm, with a smaller mode at 30cm (Figure 15). This corresponded to a dominance of 3-wr fish (~67%) in all of the samples (Figure 16).

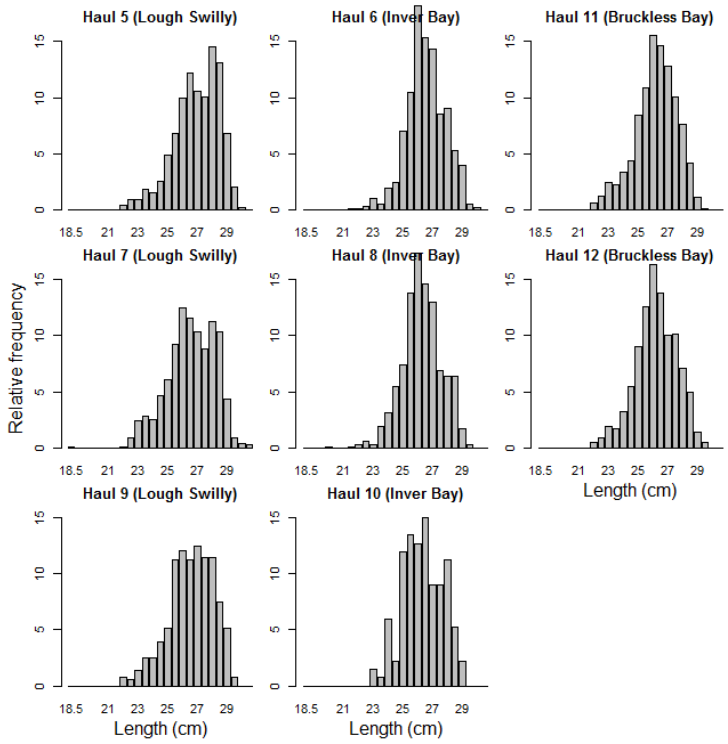


Figure 10. 6aS/7b industry acoustic survey in 2017: relative length (cm) frequency distributions of herring in each haul.

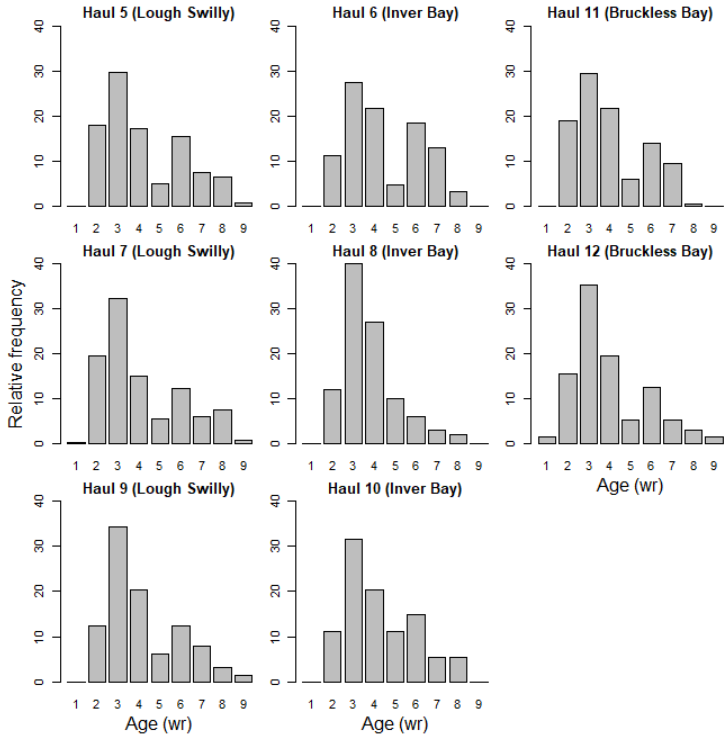


Figure 11. 6aS/7b industry acoustic survey in 2017: relative age (-wr) frequency distributions of herring in each haul.

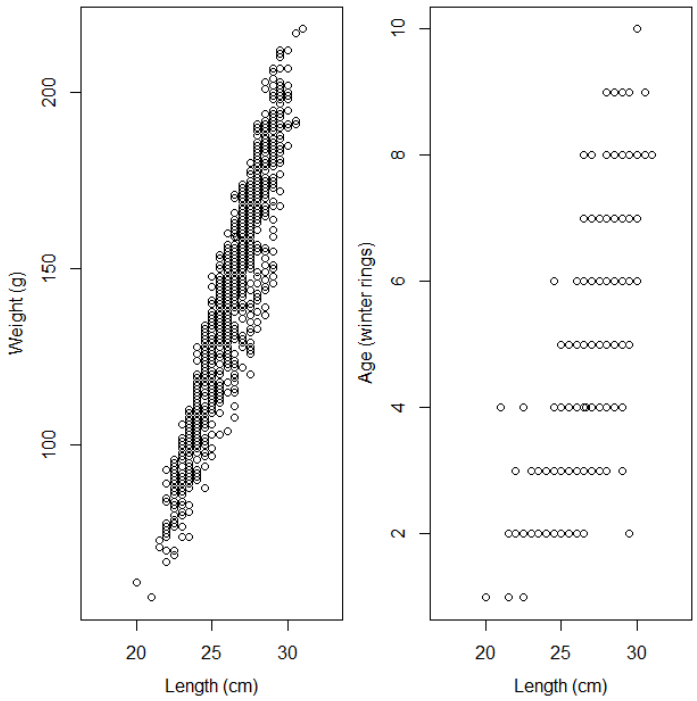


Figure 12. 6aS/7b industry acoustic survey in 2017: weight at length and age at length of herring.

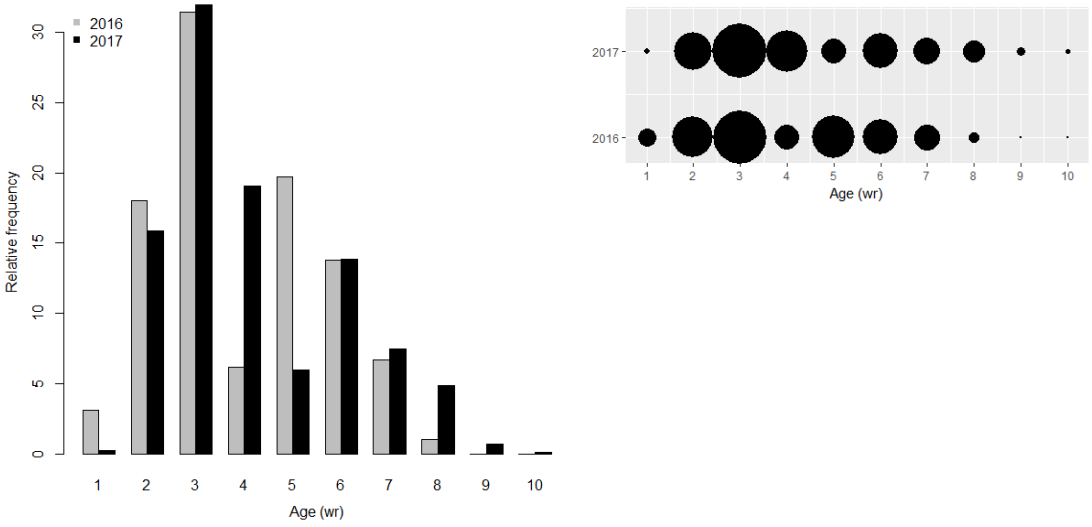


Figure 13. 6aS/7b industry acoustic survey in 2017: relative frequency of total herring ages (-wr) comparison between survey in 2016 and 2017.

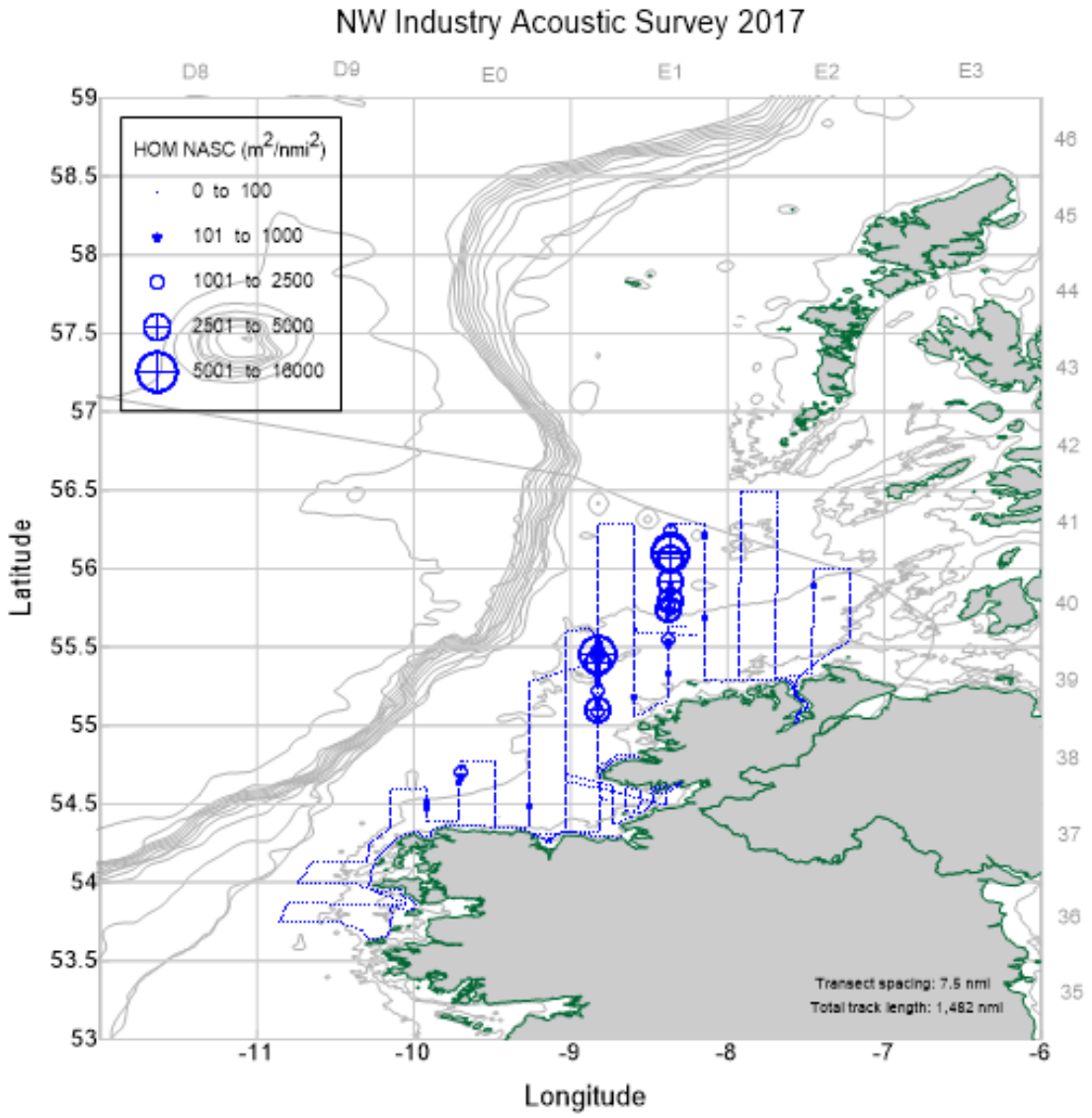


Figure 14. 6aS/7b industry acoustic survey in 2017: distribution of NASC allocated to horse mackerel.

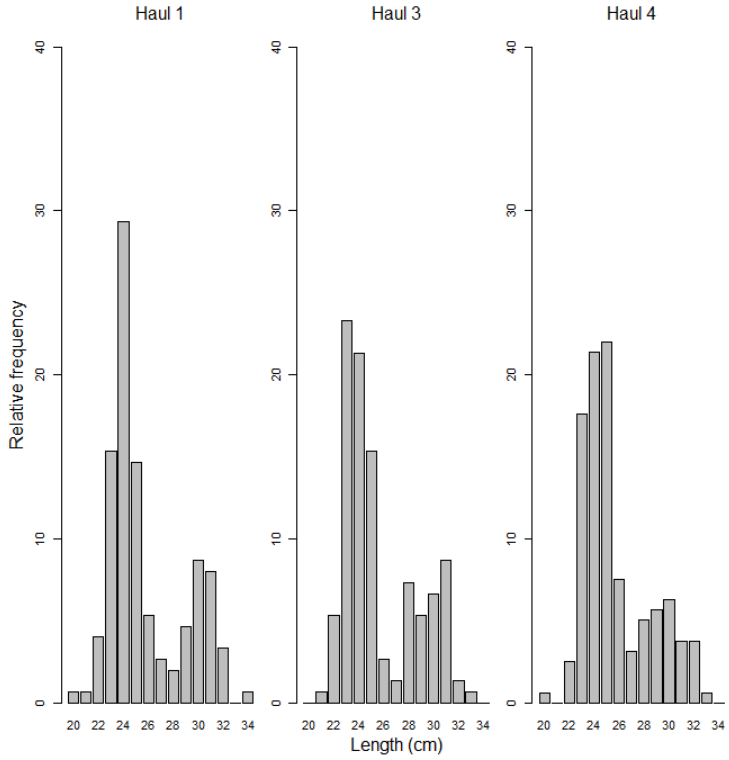


Figure 15. 6aS/7b industry acoustic survey in 2017: relative length (cm) frequency distributions of horse mackerel in hauls 1, 3 and 4.

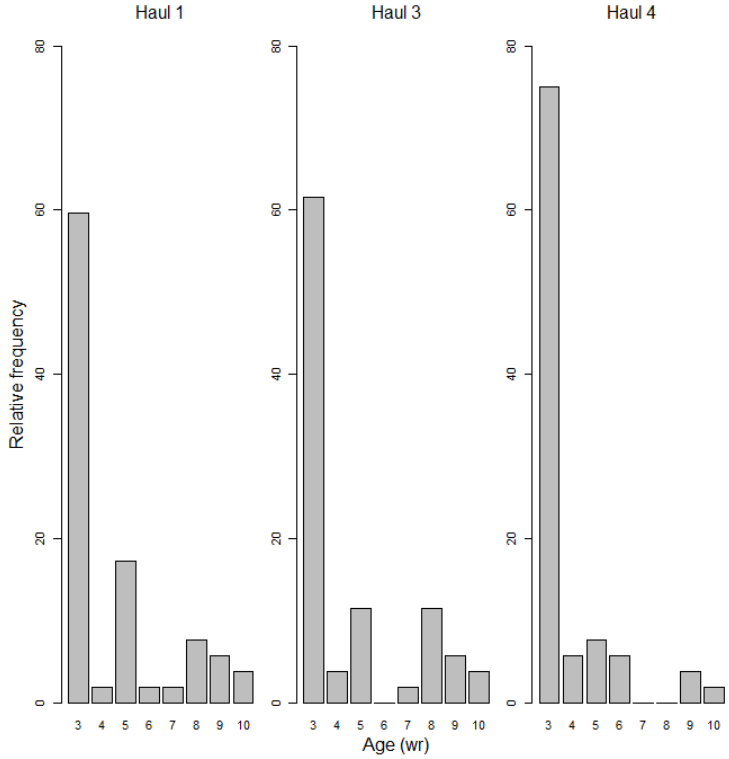


Figure 16. 6aS/7b industry acoustic survey in 2017: relative age (wr) frequency distributions of horse mackerel in hauls 1, 3 and 4.

Maturity and age (wr) distribution

Herring were dominated by 3-wr fish in all hauls (Figures 11 and 13). The 3-wr age class constituted 32% of the overall numbers, followed by 19% at 4-wr, 15% at 2-wr, 14% at 6-wr 7% at 7-wr (Table 5a). Maturity at age for 6aS/7b herring is shown in Table 5b. 66% of 1-wr herring were immature, and 6.7% of 2-wr herring were immature. Maturity scales for herring are shown in Appendix 7a.

The relative frequency of age (-wr) classes for herring for 2016 and 2017 is shown in Figure 13. The survey was dominated by 3-wr fish in both years. The 4-wr fish in 2016 and the corresponding 5-wr fish in 2017 are both relatively low.

Horse mackerel were totally dominated by 3-wr fish ~67% of the total numbers (Figure 16). 4-wr, 5-wr and 8-wr all made up ~8% each of the total distribution (Table 5b). Horse mackerel from all the samples were 100% mature. Maturity scales for horse mackerel are shown in Appendix 7b.

Table 5a. 6aS/7b industry acoustic survey in 2017: relative age (wr) distribution for 6aS/7b herring and horse mackerel in 2017.

Age (winter rings)	Relative age distribution (%) Herring	Relative age distribution (%) Horse mackerel
1	0.21	0
2	15.84	0
3	31.94	66.53
4	19.03	7.45
5	5.97	8.25
6	13.82	2.88
7	7.47	1.75
8	4.89	3.36
9	0.70	8.48
10	0.14	1.29

Table 5b. 6aS/7b industry acoustic survey in 2017: maturity at age for 6aS/7b herring in 2017.

Age (winter rings)	Immature	Mature
1	66%	33%
2	6.7%	93.3%
3	1.3%	98.7%
4	0.4	99.6
5	0%	100%

Biomass and abundance

The estimated total stock biomass (TSB), number at age (TSN), numbers at length class and mean weight of herring found in each of the survey strata areas is shown in Tables 6 - 8. The transects in Lough Swilly were conducted in a zig-zag pattern due to the shallow nature of the habitat, therefore for estimation purposes, Lough Swilly was treated as a separate strata within StoX. There were two other stratum; NW (parallel transects, 7.5 nmi. Spacing throughout) and Donegal Bay (parallel transects with 3.5nmi. spacing). The combined estimated numbers at age and biomass at age over the entire survey area is also shown in Table 9. The TSB estimate of herring for the combined 6aS/7b area was 40,646 tonnes (Lough Swilly = 12,098 tonnes, Donegal Bay = 23,157 tonnes, and the remaining NW area = 5,391 tonnes).
The estimated TSB, number at age (TSN), numbers at length class and mean weight of horse mackerel found in the northwest strata areas is shown in Table 10. The TSB estimate of horse mackerel for the total surveyed area in 6aS/7b area was 68,079 tonnes.

Table 6. 6aS/7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in survey Lough Swilly area. The estimated TSB for the Lough Swilly strata = 12,098 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: Swilly
SpecCat: Clupea herangus

	age											
LenGrp	1	2	3	4	5	6	7	8	9	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	138	-	-	-	-	-	-	-	-	138	8.4	61.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	140	140	-	-	-	-	-	-	-	280	20.2	72.00
22.0-22.5	-	432	-	-	-	-	-	-	-	432	31.1	72.00
22.5-23.0	-	1821	-	-	-	-	-	-	-	1821	155.0	85.14
23.0-23.5	-	2456	682	-	-	-	-	-	-	3139	291.5	92.87
23.5-24.0	-	2425	943	-	-	-	-	-	-	3368	325.9	96.76
24.0-24.5	-	1937	4358	-	-	-	-	-	-	6295	678.4	107.77
24.5-25.0	-	1747	4659	437	-	-	-	-	-	6843	769.1	112.38
25.0-25.5	-	613	5055	1991	153	-	-	-	-	7812	941.5	120.53
25.5-26.0	-	308	4152	2615	461	-	-	-	-	7536	979.8	130.02
26.0-26.5	-	153	3837	2609	767	307	-	-	-	7674	1046.1	136.32
26.5-27.0	-	-	2456	4451	153	460	153	-	-	7674	1061.1	138.28
27.0-27.5	-	-	1701	3711	1237	773	-	155	-	7576	1143.3	150.92
27.5-28.0	-	-	612	2907	765	2601	612	-	-	7497	1161.2	154.88
28.0-28.5	-	-	303	606	757	3181	1818	303	-	6968	1161.2	166.65
28.5-29.0	-	-	-	307	1383	2919	2151	307	154	7221	1237.2	171.32
29.0-29.5	-	-	-	153	459	1223	1835	765	153	4587	811.5	176.90
29.5-30.0	-	-	-	-	-	280	420	420	-	1121	216.7	193.25
30.0-30.5	-	-	-	-	-	142	-	142	-	285	58.9	207.00
TSN(1000)	278	12032	28758	19786	6136	11888	6990	2092	307	88267	-	-
TSB(1000 kg)	18.6	1174.3	3615.9	2780.6	946.2	1944.5	1188.8	373.4	55.8	-	12098.1	-
Mean length (cm)	20.76	23.55	25.21	26.44	27.37	28.00	28.43	28.80	28.75	-	-	-
Mean weight (g)	67.05	97.60	125.74	140.53	154.20	163.57	170.09	178.45	182.00	-	-	137.06

Table 7. 6aS/7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in survey Northwest area. The estimated TSB for the Northwest strata = 5,391 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: NW
SpecCat: Clupea herangus

	age												
LenGrp	1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	30	-	-	-	-	-	-	-	-	-	30	1.8	61.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	30	-	-	-	-	-	-	30	1.7	57.00
21.5-22.0	30	30	-	-	-	-	-	-	-	-	61	4.4	72.00
22.0-22.5	-	250	55	-	-	-	-	-	-	-	305	24.1	78.91
22.5-23.0	27	844	-	27	-	-	-	-	-	-	898	77.3	86.00
23.0-23.5	-	1134	170	-	-	-	-	-	-	-	1304	120.6	92.54
23.5-24.0	-	1359	414	-	-	-	-	-	-	-	1773	173.8	98.07
24.0-24.5	-	1119	1390	-	-	-	-	-	-	-	2509	270.3	107.73
24.5-25.0	-	766	1914	128	-	32	-	-	-	-	2839	324.5	114.31
25.0-25.5	-	129	2264	614	97	-	-	-	-	-	3105	383.6	123.55
25.5-26.0	-	162	1976	810	97	-	-	-	-	-	3045	403.4	132.47
26.0-26.5	-	32	1651	1133	162	97	-	-	-	-	3075	428.6	139.38
26.5-27.0	-	32	1229	1552	65	129	65	32	-	-	3105	443.7	142.90
27.0-27.5	-	-	715	1624	390	260	32	32	-	-	3054	470.0	153.91
27.5-28.0	-	-	323	969	323	937	485	-	-	-	3037	484.2	159.45
28.0-28.5	-	-	96	450	257	1413	546	128	32	-	2922	495.9	169.70
28.5-29.0	-	-	-	97	485	1133	809	388	65	-	2977	526.4	176.80
29.0-29.5	-	-	32	64	385	866	577	449	64	-	2437	444.5	182.38
29.5-30.0	-	27	-	-	82	300	191	409	55	-	1063	204.0	191.79
30.0-30.5	-	-	-	-	-	79	159	159	-	40	436	86.4	198.09
30.5-31.0	-	-	-	-	-	-	-	53	26	-	79	15.8	200.00
31.0-31.5	-	-	-	-	-	-	-	30	-	-	30	6.5	218.00
TSN(1000)	87	5884	12229	7499	2343	5246	2863	1681	242	40	38113	-	-
TSB(1000 kg)	6.3	582.8	1575.2	1087.2	380.7	894.2	501.6	312.3	43.6	7.6	-	5391.4	-
Mean length (cm)	21.30	23.56	25.30	26.50	27.68	28.15	28.42	29.02	29.01	30.00	-	-	-
Mean weight (g)	71.71	99.05	128.81	144.98	162.51	170.46	175.19	185.80	180.36	191.00	-	-	141.46

Table 8. 6aS/7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in survey Donegal Bay area. The estimated TSB for the Donegal Bay strata = 23,157 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: Donegal Bay
SpecCat: Clupea herangus

	age												
LenGrp	1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	-	-	-	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	251	-	-	-	-	-	-	251	14.3	57.00
21.5-22.0	-	-	-	-	-	-	-	-	-	-	-	-	-
22.0-22.5	-	1263	505	-	-	-	-	-	-	-	1768	146.5	82.86
22.5-23.0	222	3771	-	222	-	-	-	-	-	-	4214	365.1	86.63
23.0-23.5	-	4991	227	-	-	-	-	-	-	-	5218	481.2	92.22
23.5-24.0	-	6979	1745	-	-	-	-	-	-	-	8723	863.6	99.00
24.0-24.5	-	5750	3833	-	-	-	-	-	-	-	9583	1032.0	107.69
24.5-25.0	-	3243	7567	270	-	270	-	-	-	-	11351	1322.1	116.48
25.0-25.5	-	-	9719	1576	525	-	-	-	-	-	11821	1501.0	126.98
25.5-26.0	-	788	8931	2102	-	-	-	-	-	-	11821	1597.4	135.13
26.0-26.5	-	-	6830	4728	-	263	-	-	-	-	11821	1687.8	142.78
26.5-27.0	-	262	5774	4986	262	262	262	262	-	-	12072	1785.6	147.91
27.0-27.5	-	-	2890	6830	1051	788	263	-	-	-	11821	1858.0	157.18
27.5-28.0	-	-	1576	2890	1313	3152	2890	-	-	-	11821	1943.6	164.42
28.0-28.5	-	-	263	2627	788	6042	1313	525	263	-	11821	2042.9	172.82
28.5-29.0	-	-	-	263	1576	4203	2890	2627	263	-	11821	2157.7	182.53
29.0-29.5	-	-	262	262	2362	4986	1575	2362	262	-	12072	2244.9	185.96
29.5-30.0	-	221	-	-	664	1992	885	2655	443	-	6860	1313.1	191.42
30.0-30.5	-	-	-	-	-	348	1391	1043	-	348	3129	613.7	196.11
30.5-31.0	-	-	-	-	-	-	-	439	220	-	659	131.8	200.00
31.0-31.5	-	-	-	-	-	-	-	251	-	-	251	54.7	218.00
TSN(1000)	222	27268	50122	27007	8542	22306	11468	10165	1450	348	158899	-	-
TSB(1000 kg)	18.2	2733.7	6605.6	4066.4	1476.0	3940.9	2073.9	1915.3	260.7	66.4	-	23157.0	-
Mean length (cm)	22.50	23.56	25.39	26.57	28.05	28.29	28.44	29.10	29.11	30.00	-	-	-
Mean weight (g)	82.00	100.25	131.79	150.57	172.79	176.67	180.83	188.41	179.80	191.00	-	-	145.73

Table 9. 6aS/7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in total survey area. The total estimated TSB for the entire survey area = 40,646 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: Clupea herangus

LenGrp \ age	1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	168	-	-	-	-	-	-	-	-	-	168	10.2	61.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	281	-	-	-	-	-	-	281	16.0	57.00
21.5-22.0	170	170	-	-	-	-	-	-	-	-	341	24.5	72.00
22.0-22.5	-	1944	561	-	-	-	-	-	-	-	2505	201.7	80.50
22.5-23.0	249	6435	-	249	-	-	-	-	-	-	6933	597.4	86.16
23.0-23.5	-	8581	1079	-	-	-	-	-	-	-	9660	893.3	92.47
23.5-24.0	-	10763	3101	-	-	-	-	-	-	-	13864	1363.3	98.34
24.0-24.5	-	8806	9581	-	-	-	-	-	-	-	18387	1980.7	107.72
24.5-25.0	-	5756	14141	835	-	302	-	-	-	-	21033	2415.7	114.85
25.0-25.5	-	742	17038	4182	776	-	-	-	-	-	22738	2826.2	124.29
25.5-26.0	-	1258	15060	5526	559	-	-	-	-	-	22402	2980.6	133.05
26.0-26.5	-	186	12318	8470	929	667	-	-	-	-	22570	3162.5	140.12
26.5-27.0	-	295	9458	10990	481	852	481	295	-	-	22851	3290.4	144.00
27.0-27.5	-	-	5305	12165	2677	1821	295	187	-	-	22450	3471.3	154.62
27.5-28.0	-	-	2511	6766	2402	6690	3986	-	-	-	22355	3589.0	160.55
28.0-28.5	-	-	662	3682	1802	10636	3677	957	295	-	21711	3700.0	170.42
28.5-29.0	-	-	-	667	3444	8255	5850	3322	481	-	22020	3921.3	178.08
29.0-29.5	-	-	295	479	3205	7075	3987	3575	479	-	19096	3500.8	183.32
29.5-30.0	-	249	-	-	746	2572	1496	3485	497	-	9044	1733.7	191.69
30.0-30.5	-	-	-	-	-	569	1549	1344	-	387	3850	759.0	197.14
30.5-31.0	-	-	-	-	-	-	-	492	246	-	738	147.5	200.00
31.0-31.5	-	-	-	-	-	-	-	281	-	-	281	61.3	218.00
TSN(1000)	587	45184	91109	54292	17021	39439	21321	13938	1998	387	285278	-	-
TSB(1000 kg)	43.1	4490.8	11796.8	7934.1	2802.8	6779.5	3764.3	2600.9	360.1	74.0	-	40646.5	-
Mean length (cm)	21.50	23.56	25.32	26.51	27.76	28.19	28.43	29.05	29.04	30.00	-	-	-
Mean weight (g)	73.39	99.39	129.48	146.14	164.67	171.90	176.55	186.60	180.21	191.00	-	-	142.48

Table 10. 6aS/7b industry acoustic survey in 2017: age-disaggregated estimate of horse mackerel in total survey area. The total estimated TSB for the entire survey area = 68,079 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: NW
SpecCat: Trachurus trachurus

LenGrp \ age	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	1822	-	-	-	-	-	-	-	1822	185.9	102.00
21-22	1208	-	-	-	-	-	-	-	1208	91.8	76.00
22-23	16952	-	-	-	-	-	-	-	16952	1546.9	91.25
23-24	93298	-	-	-	-	-	-	-	93298	9434.9	101.13
24-25	97558	-	-	3049	-	-	-	-	100607	11391.4	113.23
25-26	74193	11050	6314	-	-	-	-	-	91557	11525.2	125.88
26-27	10012	16686	-	-	-	-	-	-	26697	3784.4	141.75
27-28	3293	-	-	-	8233	-	-	-	11527	1826.1	158.43
28-29	5866	7333	7333	4400	-	2933	-	-	27864	5116.8	183.63
29-30	1533	-	12265	6132	-	3066	-	3066	26063	5520.7	211.82
30-31	7575	-	4545	-	-	-	18180	-	30301	6695.0	220.95
31-32	-	-	8411	-	-	9813	8411	-	26636	6622.6	248.63
32-33	-	-	-	-	-	-	13349	-	13349	3490.7	261.50
33-34	-	-	-	-	-	-	-	3030	3030	846.9	279.50
TSN(1000)	313311	35069	38868	13581	8233	15813	39941	6096	470911	-	-
TSB(1000 kg)	36502.6	5175.4	7725.7	2465.8	1342.0	3574.1	9809.0	1484.7	-	68079.2	-
Mean length (cm)	24.14	26.10	28.71	27.55	27.00	30.06	30.88	30.99	-	-	-
Mean weight (g)	116.51	147.58	198.76	181.56	163.00	226.03	245.59	243.54	-	-	144.57

Estimates of uncertainty

The results of the uncertainty estimates (CV) for abundance and biomass of herring and horse mackerel in 6aS/7b are shown in Table 11 (herring) and Table 12 (horse mackerel). The CV estimates on biomass and abundance are high (~0.50 for herring and ~ 0.62 for horse mackerel) for the survey in 2017. For herring, this is mostly caused by the over-reliance on a few acoustic marks of herring in Lough Swilly and Bruckless/Inver Bays in particular. For horse mackerel, this is most likely caused by and over-reliance of two transects in particular. Bias considerations for the survey are outlined in Table 13. Many of the considerations are common to all acoustic surveys and should be dealt with and reduced if possible at the survey design stage.

Table 11. 6aS/7b industry acoustic survey in 2017: uncertainty estimates of herring (with CV) by weight and number for the Donegal Bay (D Bay), Northwest (NW), Lough Swilly (Swilly) and the total survey area.

```
[1] "Ton by stratum"
Stratum   Ton.5%   Ton.50%  Ton.95%  Ton.mean    Ton.sd    Ton.cv
1: D Bay  118.767 23091.366 73572.28 24878.826 23274.821 0.9355273
2:    NW 2198.340  5370.212 13627.43  6237.623  3901.170 0.6254257
3:Swilly 3575.446 11567.025 25760.01 12692.914  6986.635 0.5504358
[1] "Total number by stratum (mill)"
Stratum  Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1: D Bay   819329.6  158898506  498289810   169956545 158258712 0.9311716
2:   NW 15600734.3   37962976   96473163    44105833  27367061 0.6204862
3:Swilly 26034763.9   83362205  186394088    92292342  50498829 0.5471616
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 12267.22 39595.01 84213.44 42650.17 22117.12 0.5185706
[1] "Total number by survey (mill)"
   Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1:  88078598  279530401  581915173   298241571 151197768 0.5069641
```

Table 12. 6aS/7b industry acoustic survey in 2017: uncertainty estimates of horse mackerel (with CV) by weight and number for the total survey area (NW).

```
[1] "Ton by stratum"
   Stratum   Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1:      NW 8525.341 40694.13 106966.6  47212.5 29220.25 0.6189091
[1] "Total number by stratum (mill)"
   Stratum Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1:      NW  59017570  281485615  739899322   326615007 202194086 0.6190594
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 8525.341 40694.13 106966.6  47212.5 29220.25 0.6189091
[1] "Total number by survey (mill)"
   Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1:  59017570  281485615  739899322   326615007 202194086 0.6190594
```

Table 13. 6aS/7b industry acoustic survey in 2017: Bias considerations for acoustic surveys

Bias Considerations	Comment
6.1 Directed movement of fish with respect to the survey tracks	No strong directed movement at this time that would make the 'flow' of herring across the strata greater than within. Pre-spawning and spawning aggregations.
6.2 Avoidance effect	unquantified
6.3 Overlapping survey layers	NA
6.4 Shallow water	Future design needs to be considered in inshore areas (e.g. Lough Swilly). Currently separate strata.
6.5 Water temperature and the propagation of the sonar beam	No problems
6.6 Quality of raw material used	Good weather throughout the survey in 2017. Good quality raw data from calibrated scientific equipment
6.7 Accuracy of calibration constant	Good calibration (results shown in Appendix 1)
6.8 Biomass species composition	Trawl information, results from monitoring fishery and acoustic expert agreement
6.9 The actual accuracy problem of acoustic surveys	Bias and sampling error – the CV as expected was high for the herring survey (~0.50) due to the over reliance of the estimates on relatively few very strong herring marks. The CV on the horse mackerel estimates were also high (~0.62) due to the over reliance of two transects in particular. There appeared to be a daytime/nightime effect also; horse mackerel were not marking at night as much as during the day.

Stock containment

There was good evidence of offshore containment of herring in 6aS/7b again in 2017, however, there is still a concern regarding stock containment inshore due to the hyper-aggregating behaviour and shallow distribution (<15m) of herring in some areas. There was evidence from the fishery and the survey itself (marks on the boundaries of the survey grid at the limit of where the vessel could go) of fish inshore in areas where the survey did not cover. The over-reliance of the estimate on few areas of high herring density led to the high CV on the estimates of abundance and biomass (~0.50). Additional areas off the west Mayo and Galway coasts were covered by this survey in 2017. These included a number of grounds that were known to have spawning in the past (Figure 1), however, no herring aggregations were located in these areas apart from a couple of marks in Killala Bay. Spawning is known to occur, but the lack of occurrence of herring marks in these areas suggest that timing of the survey may not have been adequate, and therefore containment may not have been achieved in these areas in 2017.

The horse mackerel stock was not contained by the survey; this species is known to inhabit a large geographical range (outside the area of the survey) therefore the index is only useful as a subset of the larger stock, albeit an important area for the horse mackerel fishery during this time of the year.

4. Discussion

The towed body transducer were successfully calibrated in Lough Swilly. Industry/science surveys are becoming more common as a way of improving understanding of some commercial stocks (ICES 2007; Fassler *et al* 2011; FAO 2012; O'Donnell and Nolan 2015). Using transducers already installed on the hull is a preferred option for this type of industry collaboration survey, but the towed body with the 38 kHz transducer was sufficient to complete a successful survey in 2017. The timing of the survey was not ideal in 2017; the inshore distribution of herring made containment of the stock inshore difficult. Although there is a lot of good information on spawning areas of herring in 6aS, the timing of spawning is difficult to predict. This needs to be weighed up against the need for the stock to be whitin the 6aS/7b area, separated from the 6aN stock. Late October is suggested as a more suitable time for the survey in the future.

Approximately 1500 miles of transects were completed, with four fishing hauls. Ideally more haul samples of herring would be obtained from the survey itself, but the decision was taken to use samples from the monitoring fishery instead in 2017. There was evidence of very large marks of herring inshore in shallow areas, particularly in Lough Swilly and in Donegal Bay (Inver Bay and Bruckless Bay). Most of the obvious herring marks were inshore in shallow water not possible to fish with large net available to this survey. Smaller boats in the fleet were fishing in these inshore areas during the survey. There were fewer herring marks offshore than in 2016, which was also confirmed from reports coming from the fleet; i.e. herring hard to find offshore, herring only found in shallow inshore areas, and there were lots of horse mackerel in the area to the north and west of Tory Island.

The high CV on the estimates of abundance and biomass was not unexpected due to the hyper-aggregating behaviour of herring observed on the survey and their shallow, inshore distribution. Also, the survey did not contain stock inshore, but most likely contained the majority of the stock offshore. The high CV on the horse mackerel estimate is disappointing, however, the distribution of horse mackerel is dominated by two transects in particular; interestingly there was one empty transect in between the two transects that dominated the estimate. This may be due to a day time/night time effect; horse mackerel during the survey were not marking particularly well during the night-time. If the horse mackerel during this time are not available to the echosounder during the night, then night transects would need to be excluded. There might also be an unknown weather effect as the conditions were poor on some days for conducting an acoustic survey.

There appears to be good cohort tracking of herring in the survey between 2016 and 2017. This is encouraging, for the survey to be useful in an assessment in the future, both containment and cohort tracking in the survey are important. The survey in space and time occurred close to the predicted spawning of herring in this area, therefore the survey most likely provides a measure of 6aS/7b fish only. This is also a prerequisite for its use as an independent index for this stock in an assessment in the future.

This is the second year of this current survey effort; the survey has particular value in relation to being a good proof of concept that industry/science partnership is a suitable way to survey this stock. The survey has provided the second data point on a new index of 6aS/7b SSB of herring for the surveyed area. Predicting the timing of spawning migrations of herring and the distribution of fish on the spawning grounds is a common issue with this type of survey design. However, the ability to survey and document changes in the timing of spawning and distribution at this time of year with an industry survey is an important development. The

survey provides a platform to continue work on splitting and stock ID in the greater Malin Shelf area (considered in the ICES working group on stock splitting [WKSIDAC 2017]), and provides information on pre-spawning behaviour in inshore areas.

5. Conclusions

The TSB estimate of 40,646 tonnes is considered to be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey. The survey in 2017 is a good example of how industry/science partnerships can work, providing a second data point to what may be a time-series of herring surveys in the 6aS/7b area at this time of the year. There is high confidence that the herring surveyed were 6aS/7b fish due to the inshore distribution and maturity stages of the fish sampled. The survey also reflected what was experienced in the monitoring fishery at the same time. There also appears to be good cohort tracking of herring in the survey between 2016 and 2017. However, there are issues with the survey that need to be addressed, including:

- Stock containment; the survey did not contain the herring stock inshore due to the inshore distributions observed on the survey and reported in the fishery. The vast majority of herring marks were inshore in shallow areas that could not be fished on with the large net available. All efforts should be made to ensure good containment of the stock in the inshore areas of the survey in the future.
- The timing of the survey was an issue in 2017 – earlier timing would target herring as they migrate towards the coast and before they hyper-aggregate in inshore shallow areas. However, consideration needs to be given to the benefits of surveying early and the increased risk of stock mixing with 6aN fish. It is reasonable to assume that fish close to the spawning ground in 6aS/7b in winter are most likely 6aS/7b fish. The further offshore the fish are, the more likely there is mixing occurring with stocks from further north (e.g. 6aN).
- There is a need to reduce uncertainty of estimate through better survey design and strata delineation. The CV would be reduced if schools were more widely distributed, before inshore hyper-aggregating behaviour is apparent. A design that deals with the inshore behaviour during this time could overcome this issue; including, using a smaller net from a smaller boat that can fish in shallow areas if this behaviour is evident in future
- Using samples from the fishery is useful, but not ideal – more trawl samples containing herring is needed during the survey
- There is a need to develop protocols surrounding mini-surveys, particularly when large aggregations or hyper aggregating behaviour is observed (i.e. in areas like Lough Swilly)

For horse mackerel the TSB estimate of 68,079 tonnes is considered to be a minimum estimate in the 6aS/7b survey area at the time of the survey. Horse mackerel are a widely distributed stock, therefore the stock was not contained by this survey. The dominance of 3-wr fish is interesting, as it may be a sign of a good year class coming through. The 6aS/7b area is known to contain young horse mackerel during this time of the year, therefore the survey could be useful as an index of the younger ages going forward.

6. References

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 pp

FAO. 2012. Fishing vessel execution of acoustic surveys of deep-sea species: main issues and way forward.: No. 1059.

Fassler, S. M. M., Brunel, T., Gastauer, S., and Burggraaf, D. 2013. Using acoustic data from pelagic fishing vessels to monitor pelagic fish stocks and their ecosystem. ICES C.M. 2013 / G:13.

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

ICES. 2007. Collection of Acoustic data from Fishing Vessels. Cooperative Research Report no. 287.

ICES. 2015a. Report of the Benchmark Workshop on West of Scotland Herring (WKWEST), 2-6 February 2015, Dublin. ICES C.M. 2015 / ACOM:34.

ICES. 2015b. Herring (Clupea harengus) in divisions VIa and VIIb,c (West of Scotland, West of Ireland). In Report of the ICES Advisory Committee, 2015. ICES Advice 2015, Book 5, Section 5.3.19.

ICES 2015c Report of the Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT) ICES CM 2015/SSGIEOM:18

ICES. 2015d. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES. 2015e. Report of the Workshop on Maturity Staging of Mackerel and Horse Mackerel (WKMSMAC2), 28 September–2 October 2015, Lisbon, Portugal. ICES CM 2015/SSGIEOM:17. 93 pp.

ICES 2016. EU request for advice on a scientific monitoring fishery for herring in ICES divisions 6.a, 7.b, and 7.c. Section 5.4.3 in ICES Special Request Advice Celtic Seas Ecoregion. 29 April 2016.

Jolly, G. M., and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences, 47: 1282-1291.

O'Donnell, C., & Nolan, C. 2015. Boarfish Acoustic Survey Cruise Report 10 July – 31 July, 2015. FEAS Survey Series: 2015/03. Marine Institute

O'Malley, M., Clarke, M., O'Donnell, C. & Murphy, I. 2017. Atlantic Herring in 6aS/7b, c Industry Acoustic Survey Cruise Report 28 November – 07 December, 2016. FEAS Survey Series: Industry Survey: 01/2016. Marine Institute

O'Sullivan, D., O'Keeffe, E., Berry, A., Tully, O. & Clarke, M. 2013. An Inventory of Irish Herring Spawning Grounds. Irish Fisheries Bulletin No. 42, 2013.

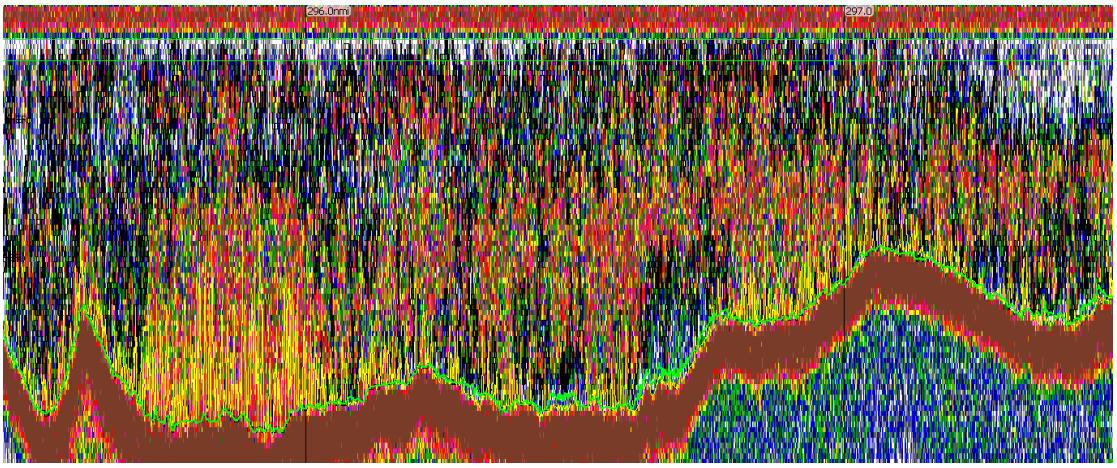
Simmonds, J., and MacLennan, D. N. 2005. Fisheries acoustics: theory and practice, John Wiley & Sons.

SIMRAD 2003. EK60 Scientific Echo Sounder System Instruction Manual. www.simrad.com

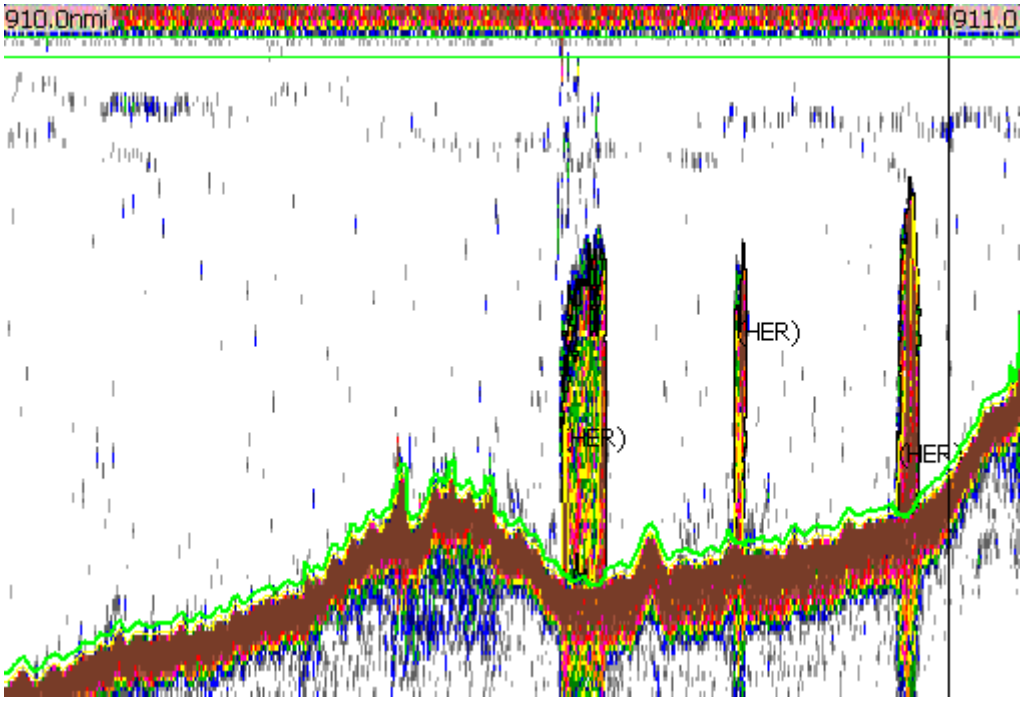
7. Appendices

Appendix 1. 6aS/7b industry acoustic survey in 2017: 38 kHz calibration results for *Eilean Croine* 18/11/2017

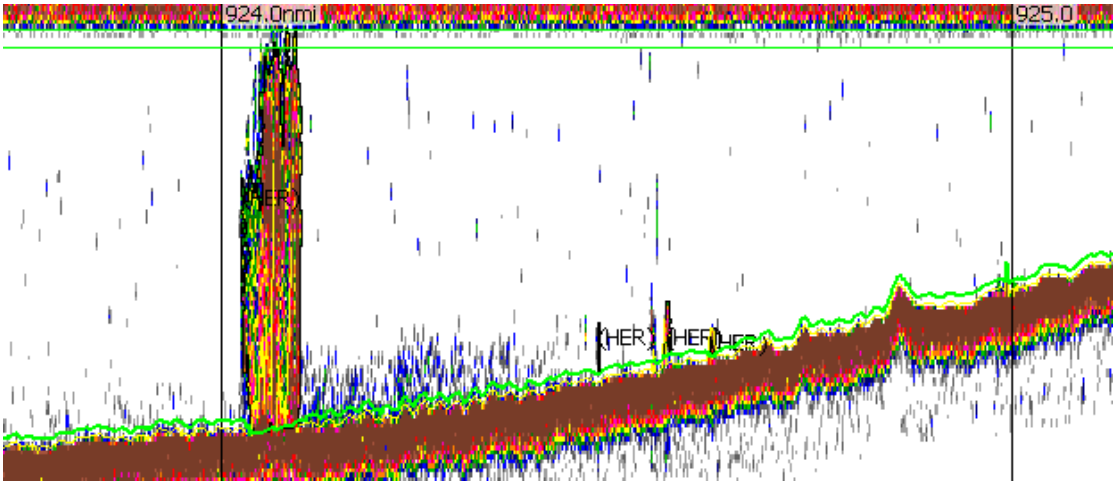
```
Calibration  Version   2.1.0.12

Date:  18.Nov.2017

Comments:Eilean Croine S238 Calibration 2: Rathmullan Pier, Co. Donegal


Reference Target:
  TS                  -42.40 dB       Min. Distance          8.00 m
  TS Deviation          5.0 dB        Max. Distance         10.50 m

Transducer:  ES38B  Serial No.   38
  Frequency            38000 Hz       Beamtype                Split
  Gain                 25.69 dB       Two Way Beam Angle    -20.6 dB
  Athw. Angle Sens.       21.90       Along. Angle Sens.       21.90
  Athw. Beam Angle     6.95 deg       Along. Beam Angle     6.95 deg
  Athw. Offset Angle   0.11 deg       Along. Offset Angle -0.02 deg
  SaCorrection         -0.67 dB       Depth                  1.00  m

Transceiver:  GPT  38 kHz 009072016d9f 1-1 ES38B
  Pulse Duration       1.024 ms       Sample Interval     0.191   m
  Power                 2000  W       Receiver Bandwidth   2.43 kHz

Sounder Type:
  EK60 Version  2.2.1

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.   9.8 dB/km       Sound Velocity     1493.9 m/s

Beam Model results:
  Transducer Gain    = 26.24 dB       SaCorrection       = -0.56 dB
  Athw. Beam Angle   = 6.90 deg       Along. Beam Angle  = 6.77 deg
  Athw. Offset Angle = 0.08 deg       Along. Offset Angle=-0.09 deg

Data deviation from beam model:
  RMS =    0.48 dB
  Max =    1.47 dB  No. =    48  Athw. =  1.3 deg  Along =  0.1 deg
  Min =   -2.33 dB  No. =   165  Athw. =  2.0 deg  Along =  1.8 deg

Data deviation from polynomial model:
  RMS =    0.47 dB
  Max =    1.44 dB  No. =    48  Athw. =  1.3 deg  Along =  0.1 deg
  Min =   -2.40 dB  No. =   165  Athw. =  2.0 deg  Along =  1.8 deg
```



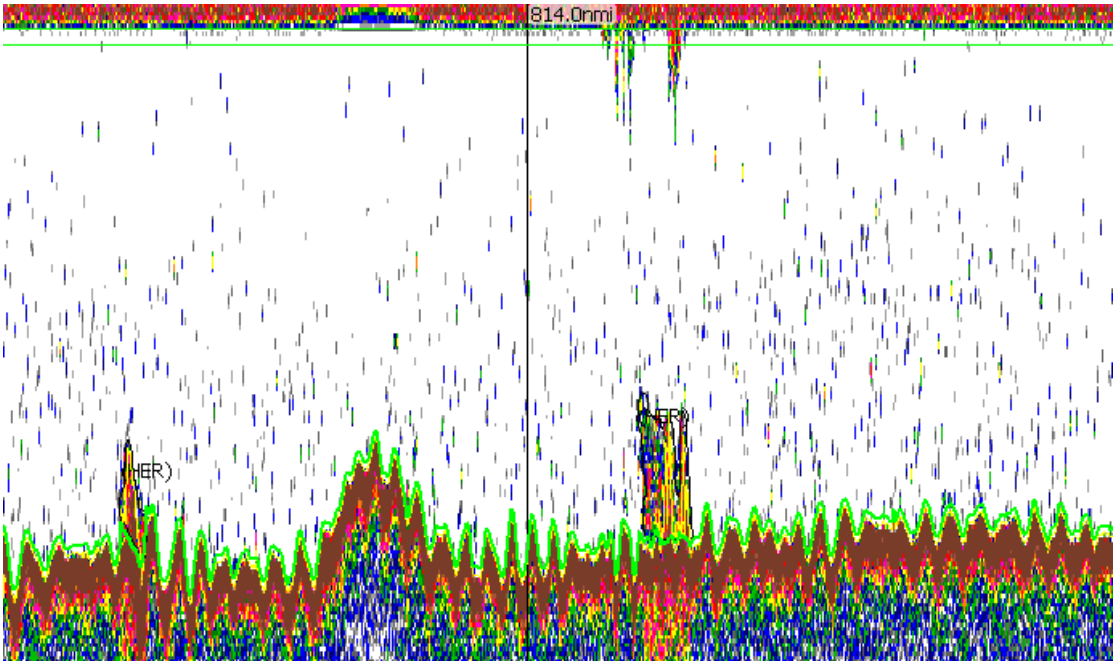
Appendix 2a. 6aS/7b industry acoustic survey in 2017: Large herring mark in Lough Swilly, Co. Donegal (ICES area 6aS). Water depth ~ 16m approximately.



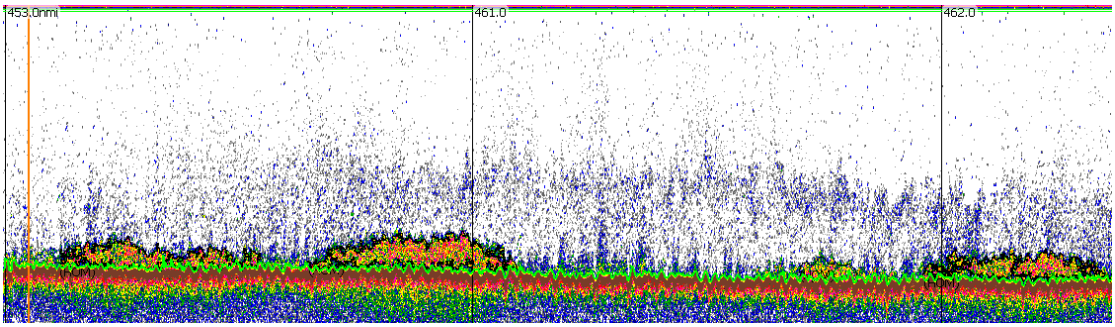
Appendix 2b. 6aS/7b industry acoustic survey in 2017: Series of herring marks in Bruckless Bay (ICES area 6aS). Water depth ~ 22m approximately.



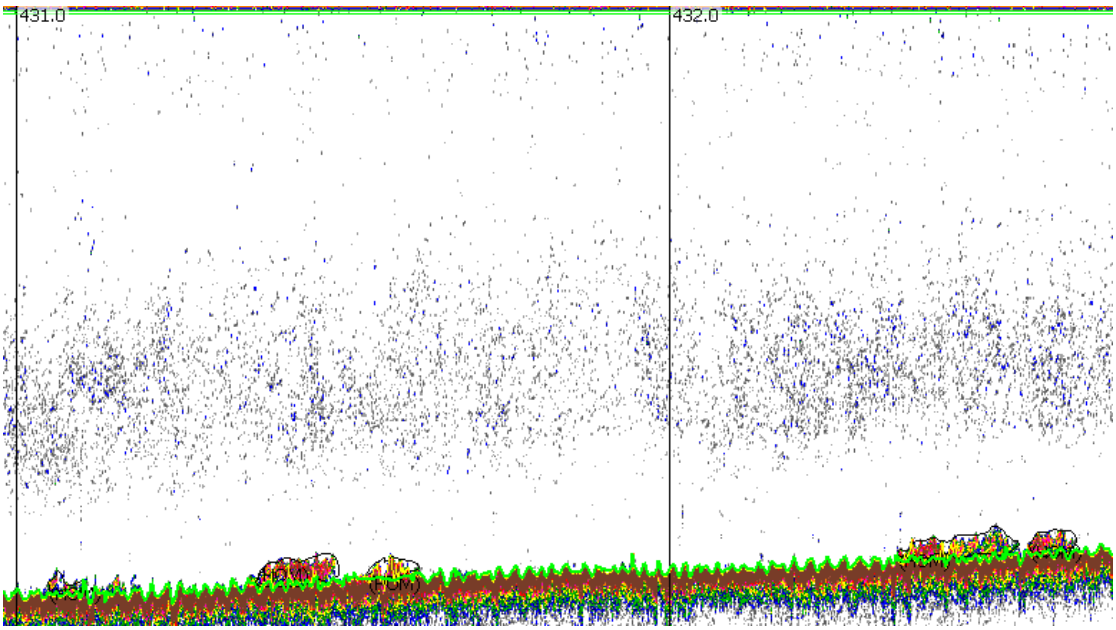
Appendix 2c. 6aS/7b industry acoustic survey in 2017: Large herring mark in Inver Bay (ICES area 6aS). Water depth ~ 20m approximately.



Appendix 2d. 6aS/7b industry acoustic survey in 2017: Herring marks in Killala Bay (ICES area 7b). Water depth ~ 20m approximately.



Appendix 2e. 6aS/7b industry acoustic survey in 2017: Horse mackerel marks observed throughout Tory Bank area (ICES area 6aS). Water depth ~ 90m approximately.



Appendix 2f. 6aS/7b industry acoustic survey in 2017: Horse mackerel marks observed throughout Tory Bank area (ICES area 6aS). Water depth ~ 130m approximately.

Appendix 3. 6aS/7b industry acoustic survey in 2017: Vessels details

Acoustic vessel details:

Name:	*MFV Eilean Croine*
Call sign:	EI5519
Type:	Fishing vessel (Pair-trawler -Pelagic RSW)
Registered:	Skibbereen Cork, Ireland
LOA:	33.29 m
Beam:	7.5 m
GT:	320 t
Net: Pelagic midwater pair trawl, 35m average vertical mouth opening during fishing	
IMO No.:	7904786
MMSI No.:	250242000

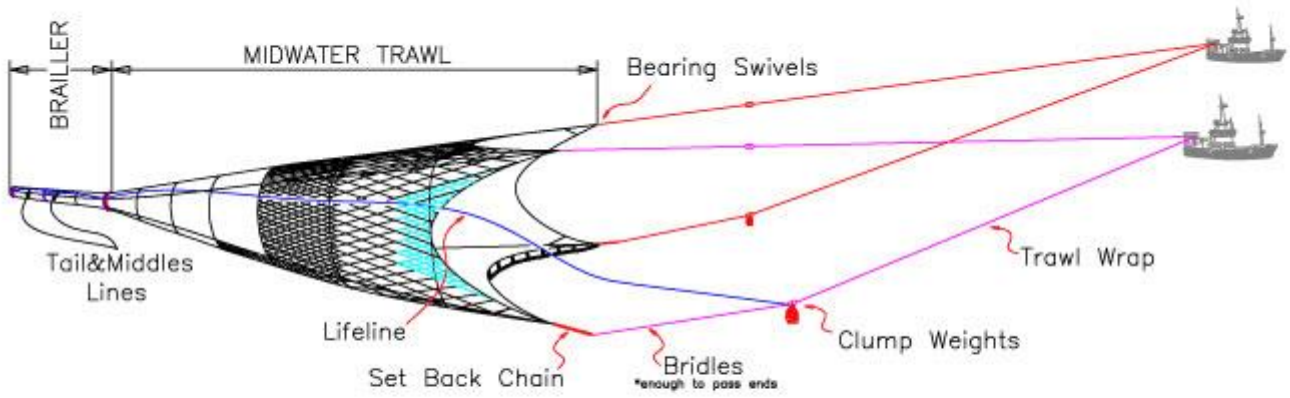
MFV Eilean Croine S238

Biological vessel details:

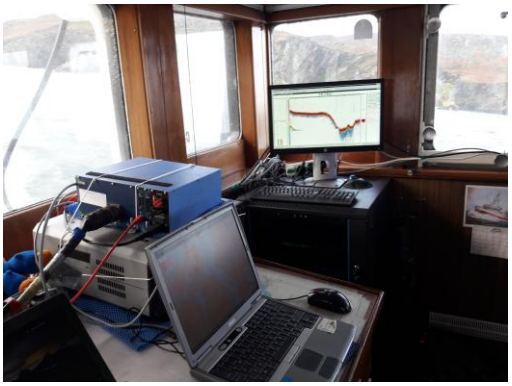
Name: *MFV Sparkling Star*
Call sign: EI6212
Type: Fishing vessel (Pair-trawler Pelagic RSW)
Registered: Dublin, Ireland
LOA: 33.4 m
Beam: 7.3 m
GT: 304 t
Net:Pelagic midwater pair trawl, 35m average vertical mouth opening during fishing
IMO No.: 7392945
MMSI No.: 250440000

MFV Sparkling Star D437

Appendix 4. 6aS/7b industry acoustic survey in 2017: Pair trawl net details (from: www.swannetgrundy.com)



Appendix 5. 6aS/7b industry acoustic survey in 2017: Top side monitoring station located in the wheelhouse of the *MFV Eilean Croine*. Laptop running Echoview and EK60 topside PC unit. GPS feeds (x2) from the ship were connected via straight (patch) ethernet cables to both the SIMRAD operating computer and the MaxSea navigation computer. A cross-over ethernet cable linked the raw data from the SIMRAD computer to the Echoview computer for live-viewing. The entire system was powered through an Uninterrupted Power Source (UPS) to prevent data loss in the event of power outage. All data was backed up on external hard-drives after every 24 hour period.



Appendix 6. 6aS/7b industry acoustic survey in 2017: Waypoints for survey (transects shown in Figure 3) in 6aS and 7b, start and end positions in 2017 (precise numbers are just advisory).

Waypoint	Distance (nmi)	Cumulative dist. (nmi)	Lat. (deg.)	Lat. (min.)	Long. (deg.)	Long. (min.)
W 000	0	n/a	53	44.5217	10	6.2256
W 001	34.6	34.6	53	44.3918	11	4.7828
W 002	7.5	42.2	53	51.918	11	4.7828
W 003	36.5	78.7	53	52.0151	10	2.8748
W 004	13.1	91.8	53	59.6157	10	21.0571
W 005	20.4	112.2	53	59.7448	10	55.7739
W 006	9.9	122.1	54	7.4183	10	45.1172
W 007	16.2	138.3	54	7.2896	10	17.4317
W 008	7.6	145.9	54	14.8756	10	17.3218
W 009	10.2	156.1	54	14.9398	10	34.79
W 010	15.2	171.4	54	30.1696	10	34.5703
W 011	14.7	186	54	42.7367	10	21.4417
W 012	22.9	208.9	54	19.8778	10	21.3868
W 013	7.3	216.2	54	19.8776	10	8.8623
W 014	33.3	249.5	54	53.1545	10	8.8623
W 015	15.1	264.6	55	6.3576	9	55.9534
W 016	44.7	309.3	54	21.6705	9	55.459
W 017	7.6	316.9	54	22.6946	9	42.605
W 018	55	371.8	55	17.6747	9	42.0557
W 019	10.3	382.1	55	24.7329	9	28.8721
W 020	63.8	446	54	20.9023	9	28.8721
W 021	7.6	453.5	54	20.7742	9	15.9082
W 022	74.8	528.3	55	35.5593	9	15.4688
W 023	7.6	535.9	55	35.5593	9	1.9555
W 024	76.7	612.7	54	18.8522	9	1.8457
W 025	7.6	620.2	54	18.7881	8	48.8818
W 026	19.1	639.3	54	37.8765	8	49.1016

W 027	3	642.3	54	37.3679	8	43.938
W 028	17.2	659.5	54	20.1976	8	43.938
W 029	4	663.5	54	22.8864	8	38.8843
W 030	13.1	676.6	54	36.0317	8	38.9942
W 031	3.2	679.8	54	35.3314	8	33.6109
W 032	10	689.8	54	25.3805	8	33.7207
W 033	4.3	694.1	54	28.5742	8	28.667
W 034	4.1	698.3	54	32.7202	8	28.4473
W 035	3.1	701.4	54	33.7397	8	23.3936
W 036	4.5	705.8	54	29.2766	8	23.6133
W 037	19.8	725.6	54	42.2607	8	49.3213
W 038	123.1	848.7	56	45.3342	8	49.4311
W 039	7.8	856.4	56	45.5145	8	35.2588
W 040	117.2	973.7	54	48.2837	8	35.6983
W 041	22.4	996	55	9.3406	8	22.6246
W 042	96	1092	56	45.3338	8	21.3061
W 043	7.1	1099.1	56	45.334	8	8.3423
W 044	91.6	1190.7	55	13.7307	8	8.7817
W 045	7.5	1198.3	55	13.7307	7	55.5982
W 046	91.5	1289.7	56	45.2139	7	54.7193
W 047	7.6	1297.3	56	45.2133	7	40.8765
W 048	87.5	1384.8	55	17.7372	7	41.6455
W 049	5.7	1390.5	55	16.0871	7	32.1561
W 050	4.3	1394.7	55	12.4928	7	36.1524
W 051	1.5	1396.3	55	11.913	7	33.653
W 052	1	1397.3	55	10.988	7	34.3945
W 053	2.3	1399.5	55	9.9684	7	30.8789
W 054	0.7	1400.3	55	9.3016	7	31.4557
W 055	1.8	1402	55	8.3677	7	28.819
W 056	4.1	1406.2	55	4.8013	7	32.4308
W 057	0.2	1406.4	55	4.7503	7	32.1149
W 058	3.1	1409.5	55	7.4177	7	29.2928
W 059	2.1	1411.5	55	9.3877	7	30.3433
W 060	2	1413.6	55	10.3647	7	33.4814
W 061	0.7	1414.3	55	11.0388	7	32.9251
W 062	1.4	1415.7	55	11.7679	7	35.0125
W 063	0.9	1416.6	55	12.5322	7	34.0787
W 064	3.6	1420.3	55	16.0711	7	35.4726
W 065	6	1426.3	55	19.9059	7	27.2809
W 066	84.9	1511.2	56	44.8334	7	26.5942
W 067	7.4	1518.6	56	44.8332	7	13.0811
W 068	76	1594.7	55	28.8257	7	13.4106
W 069	13.3	1607.9	55	17.9052	7	0.1172
W 070	60.9	1668.9	56	18.8409	6	59.7876
W 071	7.6	1676.4	56	18.9018	6	46.1646
W 072	63.6	1740	55	15.2769	6	46.3843

Appendix 7a. 6aS/7b industry acoustic survey in 2017: the 9-point herring maturity scale used by Marine Institute and the equivalent 6-point ICES scale

NINE POINT SCALE	EQUIVALENT ICES 6-POINT SCALE
1 Immature virgin	1 (Immature)
2 Immature	1 (Immature)
3 Early maturing	2 (Mature – but not included in spawning category))
4 Maturing	2 (Mature – but not included in spawning category)
5 Spawning prepared	3 (Mature – included in spawning category)
6 Spawning	3 (Mature – included in spawning category)
7 Spent	4 (Mature – Spent – included in spawning category)
8 Recovering/resting	5 (Mature – resting - not included in spawning category)
9 Abnormal	6 (Abnormal – not included in Mature or spawning categories)

Appendix 7b. 6aS/7b industry acoustic survey in 2017: the 6-point horse mackerel maturity scale (from ICES 2015e)

Stage	Name	Female	Male
1	Immature	Ovaries small. Ovaries wine red and clear, torpedo shaped.	Testes small, when fresh pale flattened and transparent. When frozen it may be opaque.
2	Developing	Ovaries occupying 1/4 to almost filling body cavity. Opaque eggs visible in ovaries giving pale pink to yellow to orange coloration. Largest oocytes may have oil globules.	Gonads occupying 1/4 to to almost filing body cavity. Testes off-white to creamy white., milt not running. When frozen testes can be bleuish.
3	Spawning	Ovaries characterized by externally visible hyaline oocytes no matter how few or how early the stage of hydration. Ovary size variable from full to < 1/4 of body cavity. Ovaries can be bloodshot.	Testes from filling to < 1/4 of body cavity, milt freely running. Testes can be shrivelled (wrinkled and contracted) at anus. When frozen there might be a change of structure and the testes needs a little pushing before running.
4	Regressing Regenerating	Ovaries occupying 1/4 or less of body cavity. Ovaries reddish and often murky (dark and gloomy) in appearance, sometimes with a scattering or patch of opaque eggs. The empty ovaries will ripple when pushed together.	Ovaries occupying 1/4 or less of body cavity. Testes opaque with brownish tint and no trace of milt. When frozen testes can be bleuish ore purple.
5	Omitted spawning	No evidence of omitted spawning	No evidence of omitted spawning
6	Abnormal	No evidence of abnormal ovaries	No evidence of abnormal testes

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