FEAS Survey Series: Industry Acoustic Survey/01/2018

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

1 – 10 November, 2018

Herring (*Clupea harengus*) Linnaeus 1758

Horse Mackerel (*Trachurus trachurus*) Linnaeus 1758

MFV Eilean Croine S238 and *MFV Sparkling Star D437*

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Foras na Mara

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Table of Contents

1. Introduction

An acoustic survey of Atlantic herring *Clupea harengus* and horse mackerel *Trachurus trachurus* was conducted in ICES areas 6aS/7b in November 2018. This survey is the third 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 previous surveys in 2016 and 2017 are reported in O'Malley et al (2017) and O'Malley et al (2018). 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 autumn.. This survey for 6aS and 7b herring is conducted in winter. The timing of these surveys coincides with herring spawning/pre-spawning aggregations of these stocks; therefore abundance indices 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.

The 2018 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 Working Group meeting for International Pelagic Surveys (WGIPS) in January 2019 and the data and results are documented there also.

Figure 1. 6aS/7b industry acoustic survey in 2018: 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 2018.

Survey objectives

The overall 6a 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. The work continues the time-series of abundance and biomass data on the individual spawning components of herring stocks in 6aN, 6aS and 7b. Abundance and biomass indices for herring and horse mackerel in 6aS/7b are generated as per standard acoustic survey protocols. Samples from spawning herring 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 biomass and distribution of herring and horse mackerel in 6aS/7b
- Collect morphometric and genetic data on spawning herring to distinguish whether the 6aS and 7b stocks can be differentiated from the stocks in 6aN

Survey plan

The 2018 survey was conducted using the pair trawl vessels *MFV Eilean Croine S238* and *MFV Sparkling Star D437* (Figure 1; appendix 3). 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 involved 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 fishing sonar in areas off-transect (e.g. Lough Swilly, Lough Foyle, Donegal Bay, Broadhaven Bay, Killala Bay and around Achill). 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 2018 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. 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 is not designed to contain this stock.

Survey design

The 2018 survey with parallel transect design (with 7.5 nmi spacing) is shown in Figure 3. Waypoints for the survey in 2018 are given in Appendix 6. The survey area covered up to the 56.4°N line in the north and 7.3°W line in the east. To the west, the survey was bounded approximately by 10.24°W and south to 53.3N approximately, off the west coast of Galway near Inishbofin. The straight line transects were completed at constant speed (or as close to as possible). Deviations from the planned transects were documented on acoustic log sheets. When the vessel deviated from transect for any reason (e.g. fishing) it returned to the same position to resume the survey.

In 2018, the survey starting point was in Lough Swilly, Co. Donegal. Transect design in Lough Swilly was zig-zag, due to the narrowness of the inlet; this is an adequate survey design for narrow estuarine or riverine channel areas (Simmonds and MacLennan 2005). The survey then proceeded to do a similar zig-zag survey in Lough Foyle. The transects in Lough Foyle were exploratory and were not used in the work-up of the survey. There were reports of herring in Lough Foyle but this is a very shallow area and it is uncertain whether it is possible to conduct an adequate survey in this area. The offshore transects began off the Inishowen Peninsula north of Donegal to the east of Inishtrahull Island (55°24N and 6.7°0W, Figure 2). Transects were parallel, 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 1,408nmi of cruise track was completed using 37 transects

and related to a total area coverage of approximately 5,600 nmi². Parallel transect spacing was set to 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 where possible. The survey track in Lough Swilly was designed using the deepest part of the channel as the centreline for the strata area. Approximately 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.

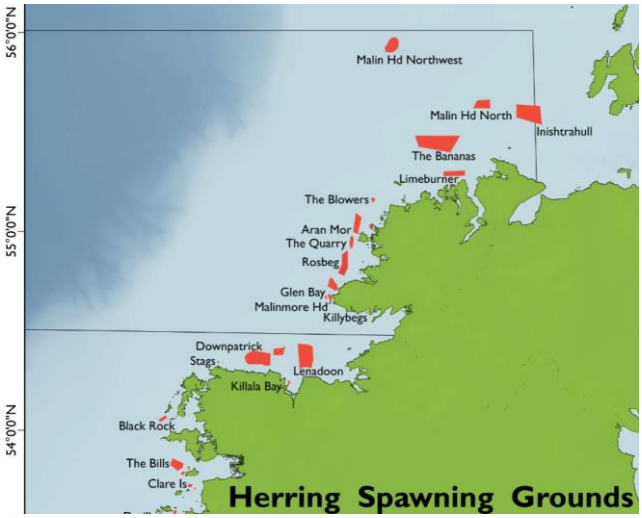

Figure 2. 6aS/7b industry acoustic survey in 2018: herring spawning grounds in 6aS and 7b (from O'Sullivan, 2013).

Table 1. 6aS/7b industry acoustic survey in 2018: Spawning areas, spawning grounds and spawning beds in 6aS and 7b. 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

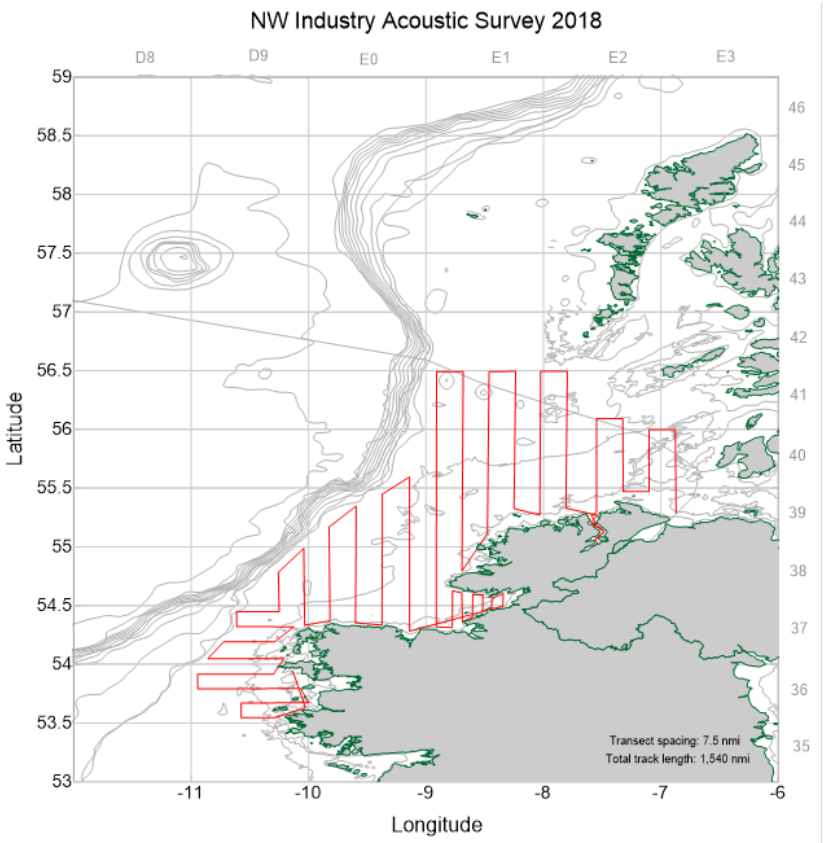

Figure 3. 6aS/7b industry acoustic survey in 2018: Acoustic survey area for 6aS and 7b. The total planned transect length was 1540 nmi (start 55˚17N and 6.52˚W) with progress from east to west. The survey design allows for some intense surveys in areas where fish are observed and also in areas known to contain herring from information from the fleet (e.g. Lough Swilly, Lough Foyle, Inver Bay, Bruckless Bay, Teelin, Killala Bay, and around Glen Head/Rathlin O'Beirne).

Scientific personnel

Organisation	Name	Capacity
MI (FEAS)	Michael O'Malley	Acoustics (Chief Scientist)
MI (FEAS)	Marcin Blaszkowski	Analyst (Biology)
MI (FEAS)	Emma White	Biologist
MI (FEAS)	Sinead O'Brien	Analyst (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 was mounted on a towed body. 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, reduced as needed depending on sea conditions. In 2018 this meant survey speed was generally around 8kts. 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

Calibration of the EK60 towed body transducer was attempted in Lough Swilly prior to the start of the survey. Conditions were poor, although the calibration site was in a relatively sheltered area, the winds were strong and the currents at depth were also strong. A chain clump was dropped off the stern of the *Eilean Croine* to assist in keeping the vessel in position but the vessel moved laterally with the current and wind. Water depth was approximately 20m at the calibration site. It was decided to abort the calibration and use the results from the successful calibration obtained during the previous survey in 2017. This 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 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.

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 (V8.0) 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 2018: Acoustic settings

Area	Vessel	Transducer and frequency	Echosounder	Power/ pulse duration ping interval	Environment	Calibration location/ 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 relies upon (i) evidence from the targeted hauls made during the survey, (ii) prior experience (e.g. fishermen and acoustic scientists), (iii) multi-frequency analysis where possible and (iv) knowledge of fish behavior. Following agreed guidelines for classification (e.g. ICES 2015c) of marks greatly improves the consistency in scrutiny, 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 2g):

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, or information from the fishery
3. **Sprat** - confident that the marks were sprat based on either evidence from a targeted haul or proximity, similarity to other schools known to be sprat, or information from the fishery
4. **Unclassified** – confident that the marks were not herring, sprat 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, sprat or horse mackerel schools, or information from the fishery

No survey fishing took place in areas where the fleet were actively fishing on herring. The current fishery is a monitoring TAC allowed on herring in 6aS. The stock is considered to be vulnerable, but the low-level monitoring fishery is kept open 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 herring 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 and 2017. The monitoring fishery TAC has been relatively low the past few years (circa 1600 t) 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 would be particularly difficult with the commercial pair-trawl. In 2017 and 2018,

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 to capture fish samples for the purposes of:

(i) Confirming the species identity of acoustic marks, particularly those suspected to be herring, horse mackerel or sprat
(ii) Collecting samples for biological analysis (length, weight, sex, maturity, age and genetics)

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 commercially 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 horse mackerel, 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 (appendix 4). 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.

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, 100 length/weight and a further sample of fish length only measurements were taken up to 60 individual fish in a single length class. 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 and a further sample of fish length only measurements were taken up to 60 individual fish in a single length class.

Length measurements

The length of herring in the subsample was measured and recorded to the nearest 0.5 cm below for herring. 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

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 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 (North West, Donegal Bay, Achill and Lough Swilly – Figure 4) and the overall strata areas combined were generated using the RStox package (version 1.9).

Figure 4. 6aS/7b industry acoustic survey in 2018: StoX strata delineated for the 4 scrutiny areas for herring (Lough Swilly, Northwest, Achill and Donegal Bay). The Northwest strata was also used in the horse mackerel abundance and biomass estimation. The haul samples 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 4 areas surveyed represents a strata in 6aS/7b [Figure 4]), 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 averaged 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 4). 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 the Donegal Bay and Achill strata, 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. .

3. Results

Acoustic and biological

Approximately 1,400nmi of transects were completed successfully. A total of four samples were obtained from commercial tows during the survey (Figure 5, 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 the commercial gear available. The monitoring fishery was being conducted on smaller boats in the same areas and at the same time as the survey. 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 and Bruckless Bay as close spatially and temporally as possible to the survey in these areas (Table 3). Samples were also obtained from the Celtic Explorer during the groundfish survey, but these were not used in the survey estimation. These fish were young (0 and 1 – wr) and not considered representative of the marks observed on echograms during the survey.

Table 3. 6aS/7b industry acoustic survey in 2018: details and number of biological samples from the hauls used in the survey estimates.

Haul No	Date	Target Species	Location	Fish (measured lengths)	Age, weight, maturity, sex
1	08/11/2018	*Trachurus trachurus*	Stags of Broadhaven	329	50
2	08/11/2018	*Trachurus trachurus*	Stags of Broadhaven	305	50
3	07/11/2018	*Clupea harengus*	Lough Swilly	254	61
4	07/11/2018	*Clupea harengus*	Lough Swilly	256	63
5	12/11/2018	*Clupea harengus*	Lough Swilly	364	68
6	12/11/2018	*Clupea harengus*	Lough Swilly	397	72
7	12/11/2018	*Clupea harengus*	Lough Swilly	455	75
8	16/11/2018	*Clupea harengus*	Lough Swilly	195	47
9	21/11/2018	*Trachurus trachurus*	Stags of Broadhaven	49	49*
10	20/11/2018	*Trachurus trachurus*	Stags of Broadhaven	31	31*
11	13/11/2018	*Trachurus trachurus*	Stags of Broadhaven	38	38*
12	05/11/2018	*Trachurus trachurus*	Stags of Broadhaven	0**	0**
13	20/11/2018	*Clupea harengus*	Bruckless Bay	271	70
14	21/11/2018	*Clupea harengus*	Bruckless Bay	273	67
15	20/11/2018	*Clupea harengus*	Bruckless Bay	353	77
16	21/11/2018	*Clupea harengus*	Bruckless Bay	338	70

* not aged
** no sample

The location of survey hauls and samples from the fishery is shown in Figure 5. The monitoring fishery in 6aS/7b began in early November and continued throughout the survey period. Most of the fishing activity was inshore in shallow water. Very strong herring marks 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, Donegal Bay (appendix 2c) and Glen Head (appendix 2d) 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, Donegal Bay and Bruckless Bay–

Figure 6). There were also small marks of herring off Inishbofin, Inishmurray and Glen Head. There were a lot of horse mackerel marks in the area to the north and west of the Stags of Broadhaven off the north Mayo coast (Figure 11 and Appendices 2e and 2f). Sprat marks were confined mostly to the Donegal Bay area (Figure 14). Sprat were not sampled on the survey in 2018 and therefore a biomass and abundance estimate was not worked up for sprat.

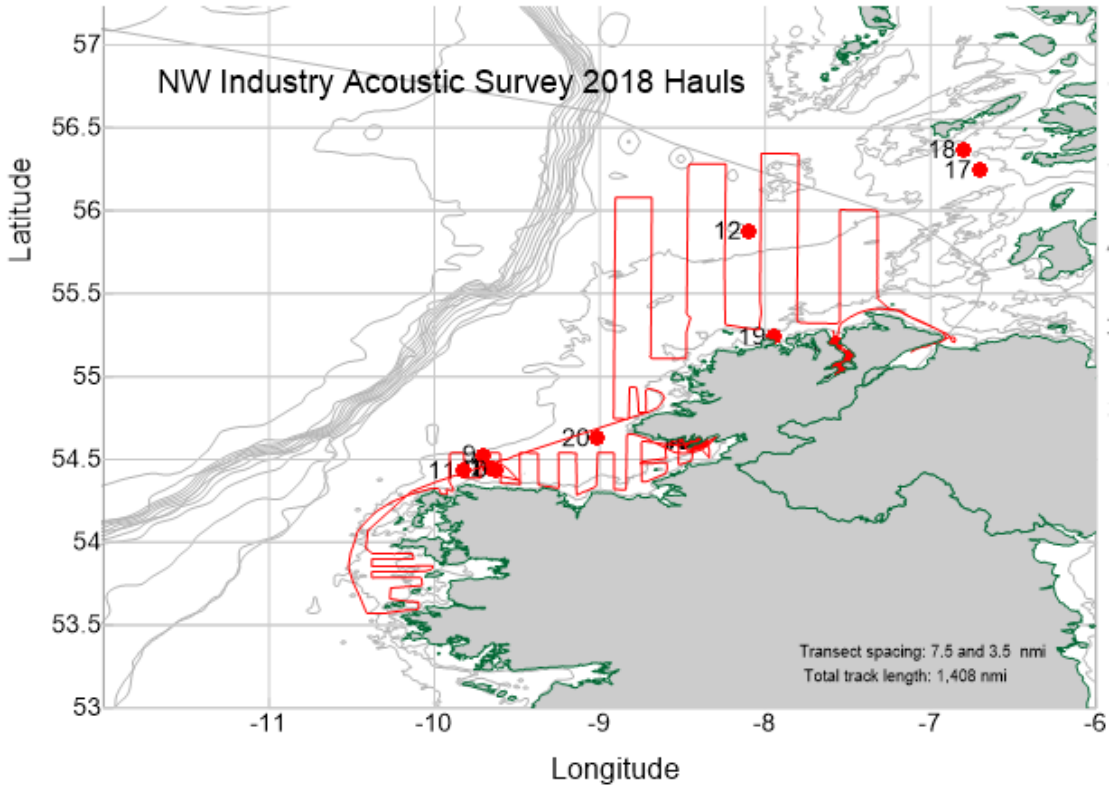

Figure 5. 6aS/7b industry acoustic survey in 2018: distribution of biological samples, including samples from the survey (hauls 1-2 and 9-12) and the monitoring fishery (3-8 and 13-16). Hauls 17-20 were from the Celtic Explorer and not used in the survey estimates.

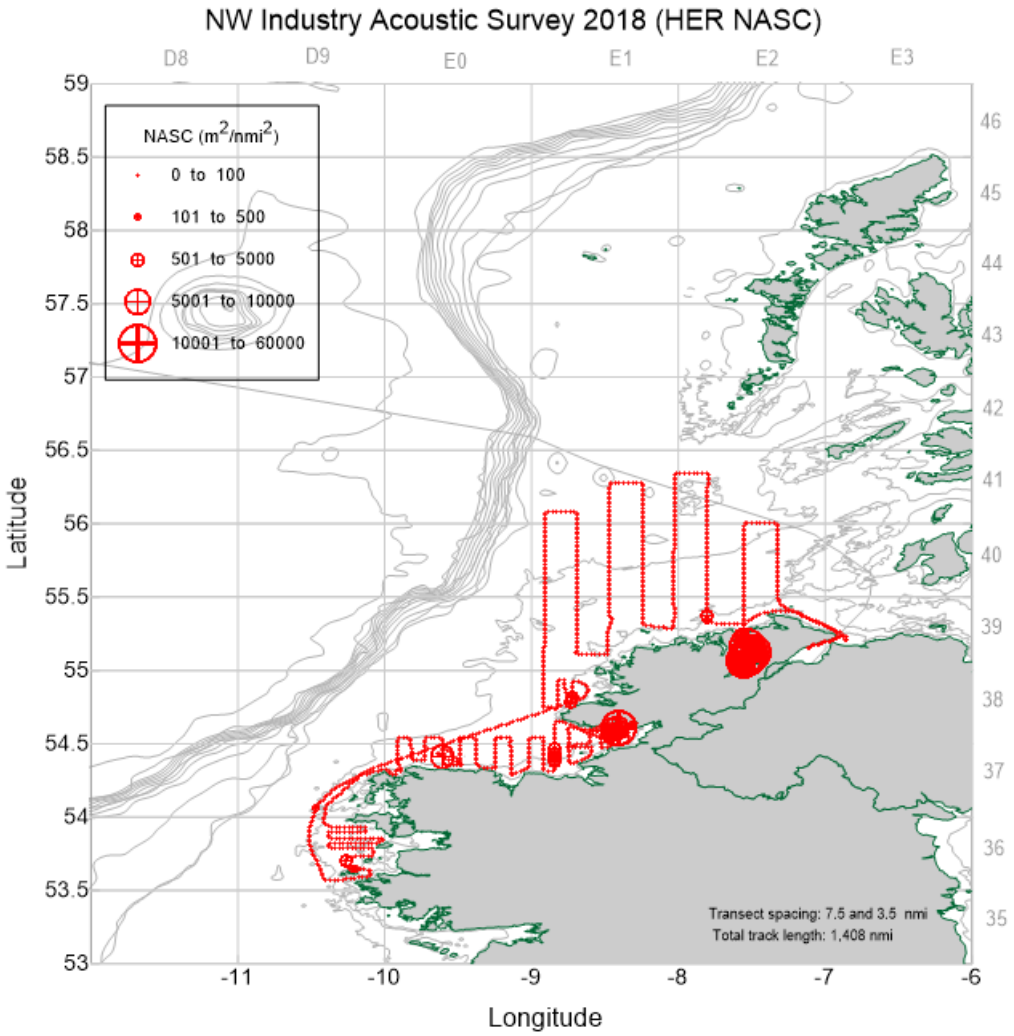

Figure 6. 6aS/7b industry acoustic survey in 2018: distribution of NASC allocated to herring.

Length frequency

The relative length frequency distributions of herring in the hauls/samples is shown in Figure 7. Strong modes were evident in all of the samples, with the majority of fish were > 23 cm. All hauls show a single mode in the distribution of herring between 26 and 28cm. The samples were dominated by mature fish (Table 5), 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 to the north of the Stags of Broadhaven (Figure 11). Horse mackerel length distribution was dominated by a mode at 26cm (Figure 12). This corresponded to a dominance of 4-wr fish (~89%) in all of the samples (Figure 13).

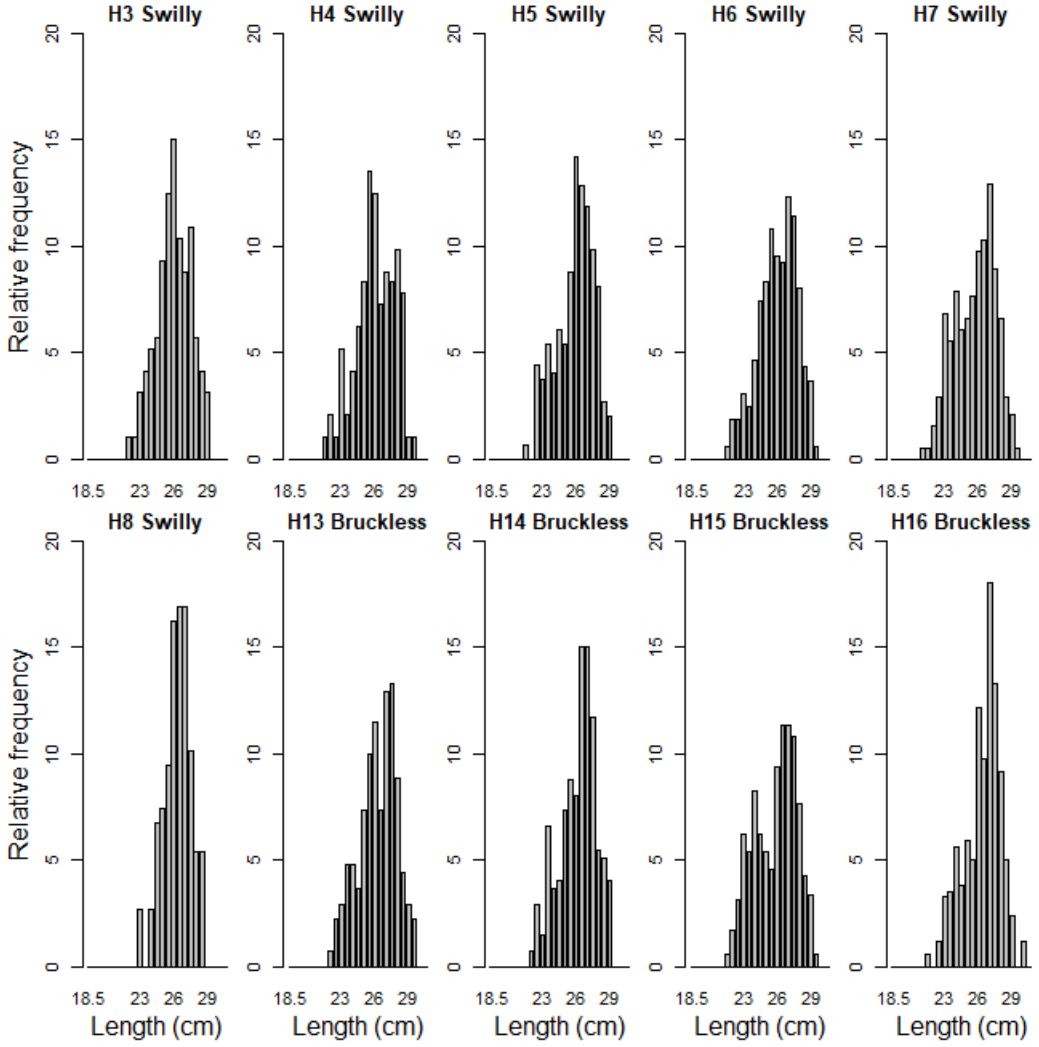

Figure 7. 6aS/7b industry acoustic survey in 2018: relative length (cm) frequency distributions of herring in each haul.

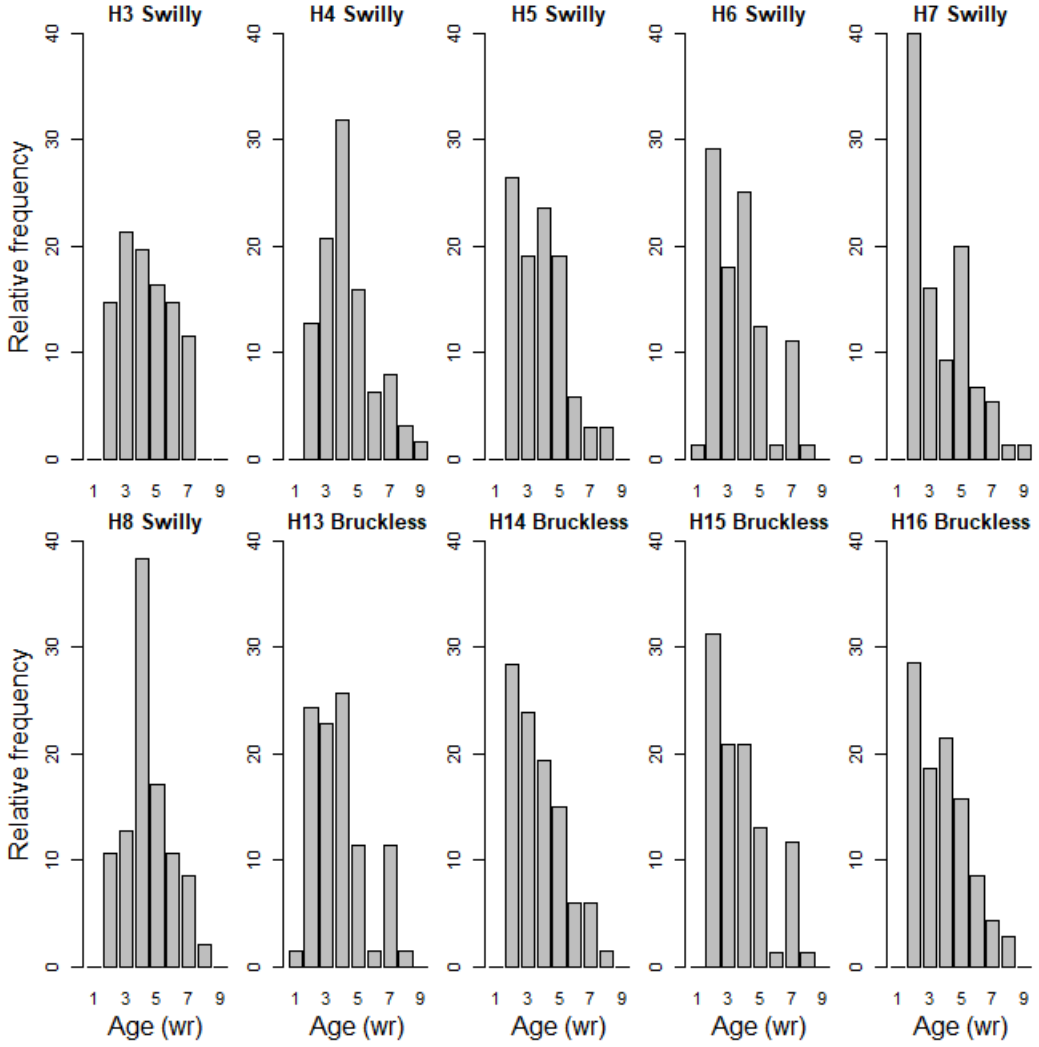

Figure 8. 6aS/7b industry acoustic survey in 2018: relative age (-wr) frequency distributions of herring in each haul.

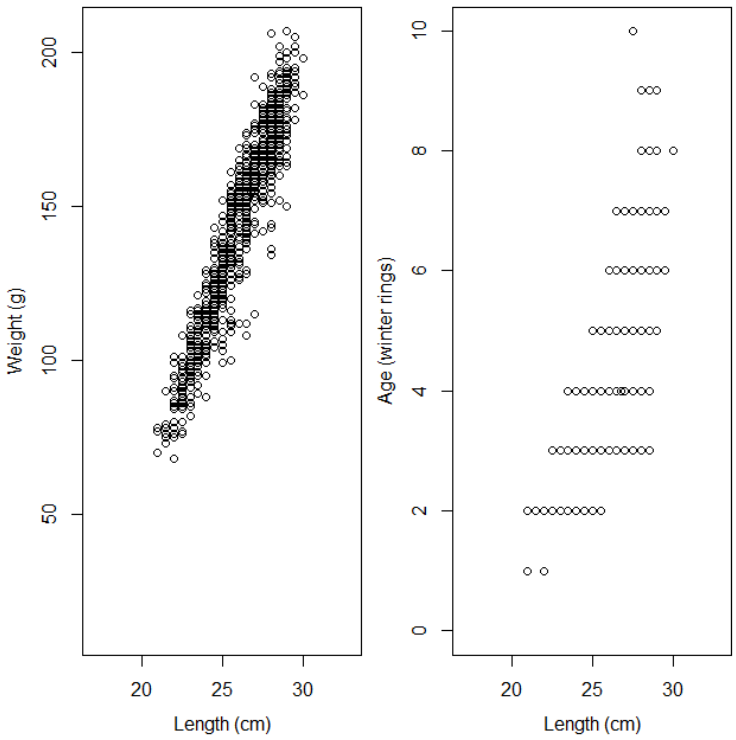

Figure 9. 6aS/7b industry acoustic survey in 2018: weight at length and age at length of herring.

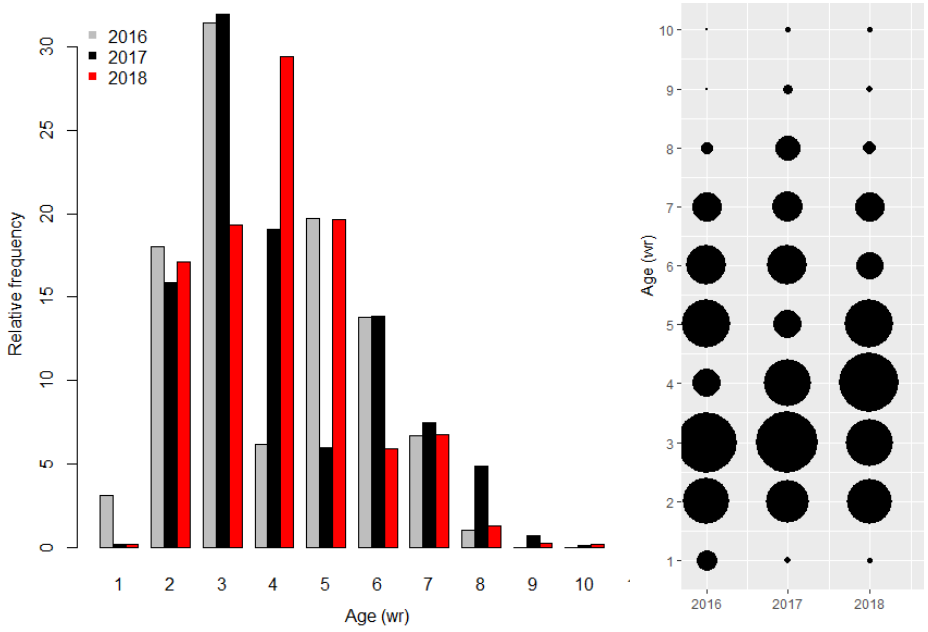

Figure 10. 6aS/7b industry acoustic survey in 2018: relative frequency of total herring ages (-wr) comparison between surveys in 2016, 2017 and 2018.

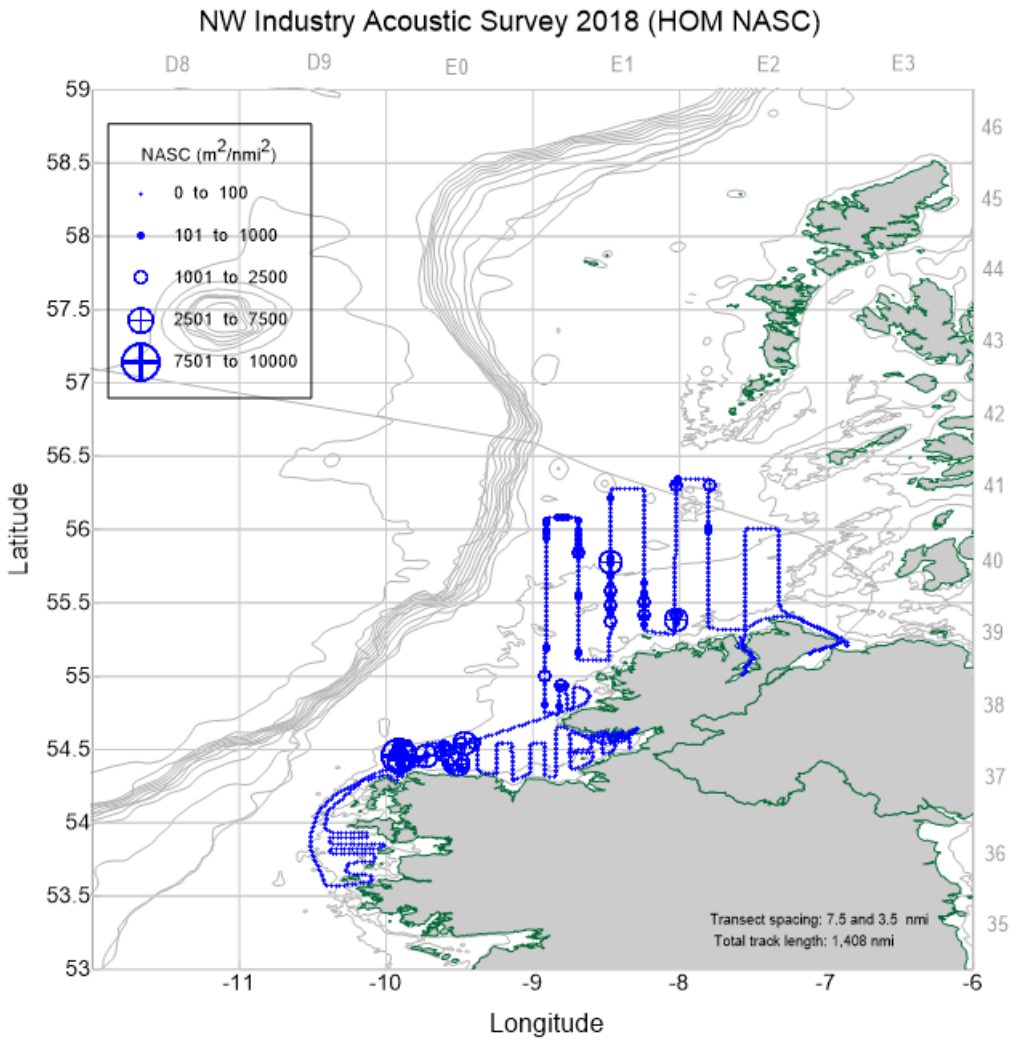

Figure 11. 6aS/7b industry acoustic survey in 2018: distribution of NASC allocated to horse mackerel.

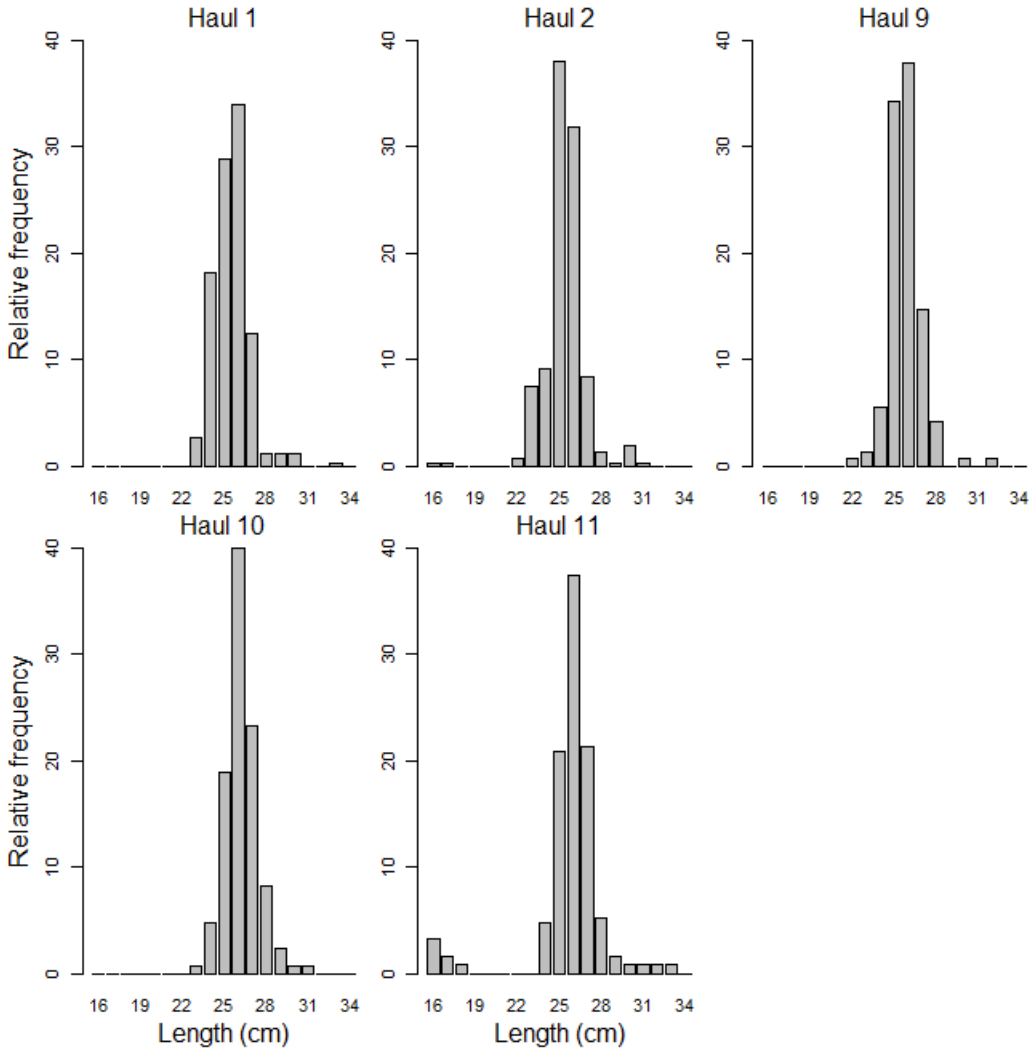

Figure 12. 6aS/7b industry acoustic survey in 2018: relative length (cm) frequency distributions of horse mackerel in hauls 1, 2, 9, 10 and 11.

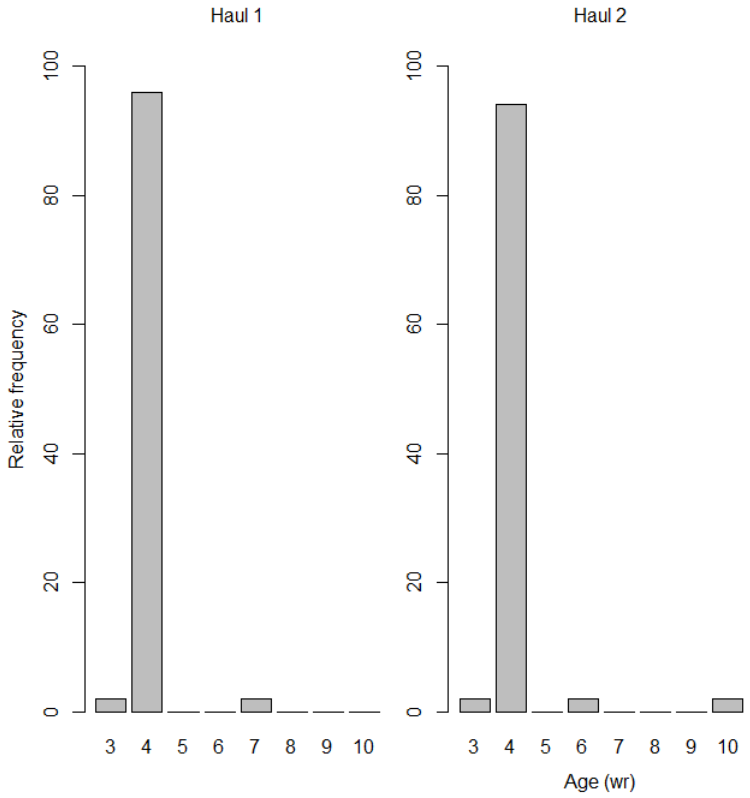

Figure 13. 6aS/7b industry acoustic survey in 2018: relative age (wr) frequency distributions of horse mackerel in hauls 1, and 2.

Maturity and age (-wr) distribution

The 4-wr age class of herring constituted 29% of the overall numbers, followed by 20% at 5-wr, and 19% at 3-wr, 17% at 2-wr (Figure 10 and Table 4). Maturity at age for 6aS/7b herring is shown in Table 5. 50% of 1-wr herring were immature, and 5.3% of 2-wr herring were immature. Maturity scales used for herring are shown in Appendix 7a.

The relative frequency of age (-wr) classes for herring for 2016, 2017 and 2018 is shown in Figure 10. The survey in 2018 was dominated by 4-wr after being dominated by 3-wr fish in 2017. The 4-wr fish in 2016 and the corresponding 5-wr fish in 2017 and 6-wr fish in 2018 are all relatively low.

Horse mackerel were dominated by 4-wr fish ~89% of the total numbers (Figure 13). Horse mackerel were 20% immature at age 3-wr. Maturity scales for horse mackerel are shown in Appendix 7b.

Table 4. 6aS/7b industry acoustic survey in 2018: relative age (wr) distribution for 6aS/7b herring and horse mackerel in 2018.

Age (winter rings)	*Relative age distribution (%) Herring*	*Relative age distribution (%) Horse mackerel*
1	0.19	0
2	17.12	3.68
3	19.29	2.55
4	29.41	88.92
5	19.63	0
6	5.87	0.51
7	6.77	1.19
8	1.25	0
9	0.27	0
10	0.19	3.14

Table 5. 6aS/7b industry acoustic survey in 2018: maturity at age for 6aS/7b herring in 2018.

Age (winter rings)	*Immature (%)*	*Mature (%)*
1	50	50
2	5.3	94.7
3	0.8	99.2
4	1.3	98.7
5	0	100

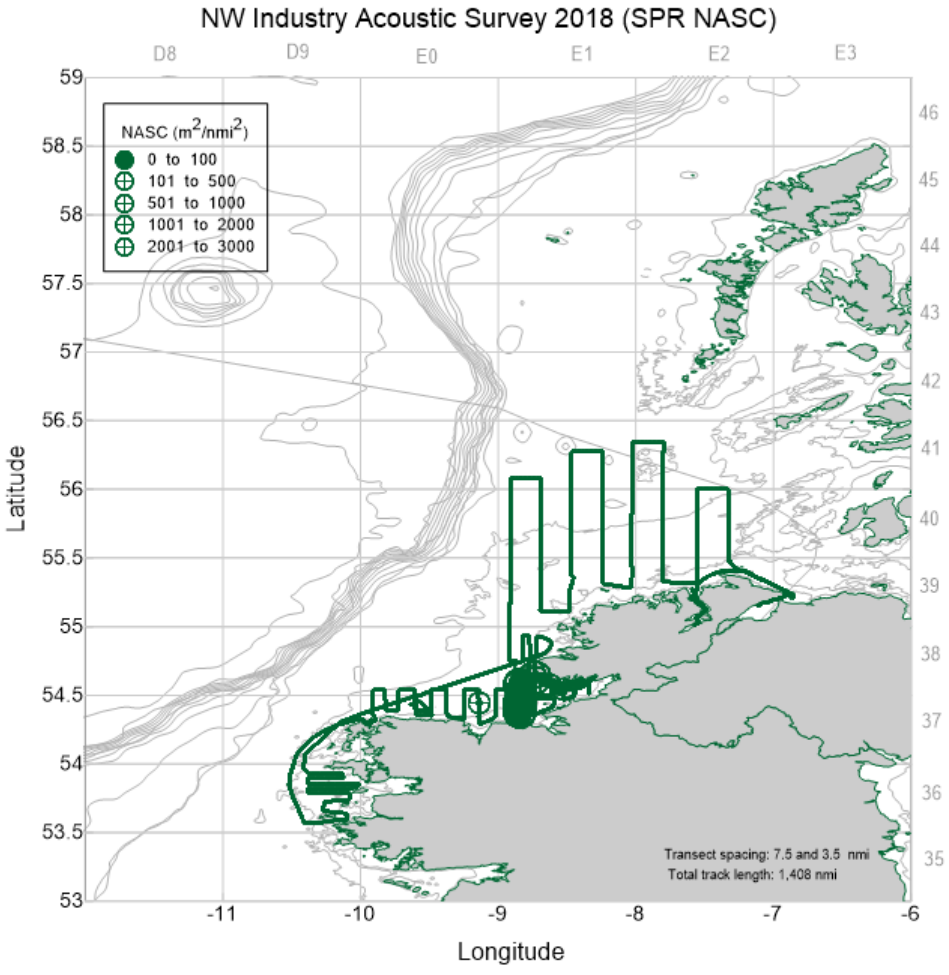

Figure 14. 6aS/7b industry acoustic survey in 2018: distribution of NASC allocated to sprat.

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 - 9. 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 three other stratum; NW (parallel transects, 7.5 nmi. Spacing throughout) and Donegal Bay and Achill (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 10. The TSB estimate of herring for the combined 6aS/7b area was 50,145 tonnes (Lough Swilly = 32,372 tonnes, Donegal Bay = 9,517 tonnes, NW area = 7,710 tonnes and Achill = 545 tonnes). The time series of age disaggregated herring data for the Industry acoustic survey is shown in table 12a and 12b.
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 11. The TSB estimate of horse mackerel for the total surveyed area in 6aS/7b area was 57,162 tonnes.

Table 6. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey Lough Swilly area. The estimated TSB for the Lough Swilly strata = 32,372 tonnes.

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

	age												
LenGrp		1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5		-	244	-	-	-	-	-	-	-	-	244	18.8	77.00
21.5-22.0		-	1262	-	-	-	-	-	-	-	-	1262	100.0	79.25
22.0-22.5		426	2450	-	-	-	-	-	-	-	-	2876	250.8	87.22
22.5-23.0		-	4545	296	-	-	-	-	-	-	-	4842	435.6	89.98
23.0-23.5		-	9945	221	-	-	-	-	-	-	-	10166	1040.4	102.35
23.5-24.0		-	5496	1763	726	-	-	-	-	-	-	7985	883.0	110.58
24.0-24.5		-	8104	1424	1971	-	-	-	-	-	-	11499	1314.6	114.32
24.5-25.0		-	4214	9482	1405	-	-	-	-	-	-	15100	1844.1	122.12
25.0-25.5		-	476	10818	4993	594	-	-	-	-	-	16881	2176.4	128.92
25.5-26.0		-	1552	8832	7877	3700	-	-	-	-	-	21960	3150.2	143.45
26.0-26.5		-	-	7358	13751	4342	844	-	-	-	-	26296	3869.9	147.17
26.5-27.0		-	-	-	12257	8092	2856	-	-	-	-	23204	3570.4	153.87
27.0-27.5		-	-	928	9981	9749	1857	2321	-	-	-	24837	4062.8	163.58
27.5-28.0		-	-	-	5698	9652	2210	3024	-	-	581	21165	3602.2	170.19
28.0-28.5		-	-	-	4262	6336	2074	2995	691	-	-	16358	2912.6	178.06
28.5-29.0		-	-	-	739	862	4065	3696	1232	616	-	11210	1985.4	177.10
29.0-29.5		-	-	-	-	1253	627	2297	835	209	-	5221	972.9	186.34
29.5-30.0		-	-	-	-	-	-	957	-	-	-	957	182.5	190.67
TSN(1000)		426	38287	41122	63660	44581	14532	15290	2758	825	581	222064	-	-
TSB(1000 kg)		32.0	4057.8	5418.9	9699.4	7238.1	2442.9	2747.4	498.6	142.3	95.4	-	32372.7	-
Mean length (cm)		22.00	23.39	25.09	26.29	27.00	27.57	28.11	28.53	28.63	27.50	-	-	-
Mean weight (g)		75.00	105.98	131.78	152.36	162.36	168.10	179.68	180.74	172.49	164.00	-	-	145.78

Table 7. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey Northwest area. The estimated TSB for the Northwest strata = 7,710 tonnes.

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

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	27	110	-	-	-	-	-	-	-	-	137	10.4	75.80
21.5-22.0	-	261	-	-	-	-	-	-	-	-	261	20.5	78.65
22.0-22.5	89	655	-	-	-	-	-	-	-	-	744	63.8	85.86
22.5-23.0	-	1161	44	-	-	-	-	-	-	-	1205	108.4	89.99
23.0-23.5	-	1897	70	-	-	-	-	-	-	-	1967	196.0	99.62
23.5-24.0	-	1429	374	107	-	-	-	-	-	-	1910	201.6	105.58
24.0-24.5	-	1676	416	308	-	-	-	-	-	-	2400	268.9	112.06
24.5-25.0	-	912	1751	103	-	-	-	-	-	-	2766	336.7	121.74
25.0-25.5	-	136	2485	773	61	-	-	-	-	-	3455	436.7	126.40
25.5-26.0	-	161	2303	1595	467	-	-	-	-	-	4526	628.8	138.91
26.0-26.5	-	-	1779	3008	709	205	-	-	-	-	5700	830.1	145.63
26.5-27.0	-	-	223	3259	1733	334	16	-	-	-	5565	837.6	150.52
27.0-27.5	-	-	201	3943	1593	325	402	-	-	-	6463	1025.0	158.59
27.5-28.0	-	-	121	1560	2530	394	636	-	-	91	5332	894.8	167.82
28.0-28.5	-	-	176	965	2071	579	702	228	18	-	4740	825.4	174.15
28.5-29.0	-	-	100	341	562	1004	1145	402	40	-	3595	639.9	178.01
29.0-29.5	-	-	-	-	273	386	771	112	48	-	1591	291.6	183.27
29.5-30.0	-	-	-	-	-	41	413	-	-	-	455	87.2	191.91
30.0-30.5	-	-	-	-	-	-	-	35	-	-	35	6.7	192.00
TSN(1000)	116	8399	10043	15963	9999	3268	4086	777	106	91	52846	-	-
TSB(1000 kg)	8.3	862.5	1314.2	2426.6	1644.1	556.9	728.5	136.1	18.2	14.9	-	7710.3	-
Mean length (cm)	21.76	23.31	25.27	26.51	27.23	27.85	28.30	28.49	28.64	27.50	-	-	-
Mean weight (g)	71.68	102.70	130.86	152.02	164.43	170.44	178.30	175.09	171.43	164.00	-	-	145.90

Table 8. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey Donegal Bay area. The estimated TSB for the Donegal Bay strata = 9,517 tonnes.

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

LenGrp	age 1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	195	-	-	-	-	-	-	195	15.0	77.00
22.0-22.5	107	427	-	-	-	-	-	-	534	42.5	79.50
22.5-23.0	-	1592	-	-	-	-	-	-	1592	142.2	89.34
23.0-23.5	-	2343	-	-	-	-	-	-	2343	216.7	92.47
23.5-24.0	-	3260	166	-	-	-	-	-	3425	346.8	101.26
24.0-24.5	-	2329	1429	-	-	-	-	-	3758	404.3	107.58
24.5-25.0	-	1661	1339	-	-	-	-	-	3000	353.2	117.75
25.0-25.5	-	111	3551	721	-	-	-	-	4383	524.9	119.75
25.5-26.0	-	-	2954	1818	-	-	-	-	4773	612.1	128.25
26.0-26.5	-	-	2773	3372	326	435	-	-	6906	971.2	140.62
26.5-27.0	-	-	930	3939	2462	-	-	-	7331	1058.7	144.43
27.0-27.5	-	-	546	7095	1474	546	-	-	9660	1504.7	155.77
27.5-28.0	-	-	438	2465	4547	-	822	-	8273	1363.9	164.86
28.0-28.5	-	-	379	975	3087	271	271	271	5254	885.5	168.56
28.5-29.0	-	-	274	602	547	547	1095	109	3175	567.0	178.60
29.0-29.5	-	-	-	-	165	496	1322	165	2149	380.2	176.97
29.5-30.0	-	-	-	-	-	117	351	-	469	89.7	191.50
30.0-30.5	-	-	-	-	-	-	-	199	199	38.3	192.00
TSN(1000)	107	11918	14780	20987	12609	2412	3861	745	67418	-	-
TSB(1000 kg)	7.3	1194.1	1891.6	3150.8	2056.7	411.1	680.3	125.1	-	9517.0	-
Mean length (cm)	22.00	23.43	25.51	26.70	27.39	27.80	28.51	28.83	-	-	-
Mean weight (g)	68.00	100.20	127.99	150.13	163.12	170.45	176.19	167.95	-	-	141.16

Table 9. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey Achill area. The estimated TSB for the Achill strata = 545 tonnes.

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

LenGrp	age 1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	11	-	-	-	-	-	-	11	0.9	77.00
22.0-22.5	6	24	-	-	-	-	-	-	31	2.4	78.80
22.5-23.0	-	91	-	-	-	-	-	-	91	8.4	91.79
23.0-23.5	-	134	-	-	-	-	-	-	134	12.4	92.51
23.5-24.0	-	177	19	-	-	-	-	-	196	19.6	99.98
24.0-24.5	-	127	88	-	-	-	-	-	215	23.2	107.58
24.5-25.0	-	92	80	-	-	-	-	-	172	20.2	117.54
25.0-25.5	-	6	200	44	-	-	-	-	251	29.8	118.76
25.5-26.0	-	-	182	91	-	-	-	-	273	35.1	128.42
26.0-26.5	-	-	131	206	34	25	-	-	396	56.0	141.51
26.5-27.0	-	-	50	260	110	-	-	-	420	60.6	144.34
27.0-27.5	-	-	34	419	72	28	-	-	553	85.9	155.34
27.5-28.0	-	-	13	110	311	-	41	-	474	78.9	166.50
28.0-28.5	-	-	19	50	177	16	9	31	301	50.3	167.13
28.5-29.0	-	-	16	34	47	28	53	3	182	32.6	179.47
29.0-29.5	-	-	-	-	13	22	79	9	123	21.9	178.21
29.5-30.0	-	-	-	-	-	3	23	-	27	5.2	192.13
30.0-30.5	-	-	-	-	-	-	-	11	11	2.2	192.00
TSN(1000)	6	664	831	1214	763	122	206	55	3861	-	-
TSB(1000 kg)	0.4	66.5	105.7	181.0	125.9	20.9	36.2	9.0	-	545.5	-
Mean length (cm)	22.00	23.42	25.42	26.67	27.44	27.70	28.58	28.62	-	-	-
Mean weight (g)	68.00	100.11	127.17	149.13	165.00	170.68	175.91	162.94	-	-	141.29

Table 10. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in total survey area. The total estimated TSB for the entire survey area = 50,145 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)
21.0-21.5	27	354	-	-	-	-	-	-	-	-	382	29.2	76.57
21.5-22.0	-	1730	-	-	-	-	-	-	-	-	1730	136.5	78.89
22.0-22.5	628	3557	-	-	-	-	-	-	-	-	4184	359.6	85.93
22.5-23.0	-	7390	340	-	-	-	-	-	-	-	7729	694.7	89.87
23.0-23.5	-	14319	291	-	-	-	-	-	-	-	14610	1465.5	100.31
23.5-24.0	-	10362	2322	833	-	-	-	-	-	-	13516	1451.1	107.36
24.0-24.5	-	12236	3356	2280	-	-	-	-	-	-	17872	2011.0	112.52
24.5-25.0	-	6879	12651	1508	-	-	-	-	-	-	21038	2554.3	121.41
25.0-25.5	-	729	17054	6532	655	-	-	-	-	-	24970	3167.7	126.86
25.5-26.0	-	1713	14272	11381	4167	-	-	-	-	-	31532	4426.2	140.37
26.0-26.5	-	-	12042	20336	5412	1509	-	-	-	-	39298	5727.2	145.74
26.5-27.0	-	-	1203	19715	12396	3190	16	-	-	-	36520	5527.3	151.35
27.0-27.5	-	-	1710	21437	12887	2756	2723	-	-	-	41513	6678.4	160.88
27.5-28.0	-	-	572	9834	17040	2603	4522	-	-	672	35244	5939.7	168.53
28.0-28.5	-	-	573	6252	11671	2939	3977	1221	18	-	26652	4673.8	175.37
28.5-29.0	-	-	390	1717	2019	5645	5988	1746	656	-	18162	3224.9	177.57
29.0-29.5	-	-	-	-	1704	1530	4470	1123	257	-	9084	1666.7	183.48
29.5-30.0	-	-	-	-	-	162	1746	-	-	-	1907	364.7	191.19
30.0-30.5	-	-	-	-	-	-	-	246	-	-	246	47.2	192.00
TSN(1000)	655	59268	66776	101824	67951	20334	23443	4336	931	672	346189	-	-
TSB(1000 kg)	48.0	6180.9	8730.5	15457.7	11064.8	3431.8	4192.3	768.7	160.4	110.3	-	50145.5	-
Mean length (cm)	21.96	23.39	25.21	26.41	27.11	27.64	28.22	28.57	28.63	27.50	-	-	-
Mean weight (g)	73.20	104.29	130.74	151.81	162.83	168.77	178.83	177.30	172.37	164.00	-	-	144.85

Table 11. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of horse mackerel in total survey area. The total estimated TSB for the entire survey area = 57,162 tonnes.

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

	age									
LenGrp	2	3	4	6	7	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	8551	-	-	-	-	-	-	8551	295.0	34.50
17-18	4276	-	-	-	-	-	-	4276	153.9	36.00
18-19	2138	-	-	-	-	-	-	2138	89.8	42.00
19-20	-	-	-	-	-	-	-	-	-	-
20-21	-	-	-	-	-	-	-	-	-	-
21-22	-	-	-	-	-	-	-	-	-	-
22-23	-	2191	-	-	-	-	-	2191	199.3	91.00
23-24	-	8163	6122	-	-	-	-	14285	1472.2	103.06
24-25	-	-	59329	-	-	-	-	59329	6888.3	116.10
25-26	-	-	94993	-	-	-	-	94993	12409.6	130.64
26-27	-	-	94130	-	-	-	-	94130	13251.8	140.78
27-28	-	-	57420	-	-	-	-	57420	8892.9	154.87
28-29	-	-	35793	-	-	-	-	35793	6056.4	169.21
29-30	-	-	13391	-	-	-	-	13391	2551.1	190.50
30-31	-	-	-	2077	4847	2077	-	9002	2101.0	233.38
31-32	-	-	-	-	-	-	4758	4758	1132.5	238.00
32-33	-	-	-	-	-	-	3796	3796	939.5	247.50
33-34	-	-	-	-	-	-	2138	2138	729.0	341.00
TSN(1000)	14965	10353	361178	2077	4847	2077	10692	406190	-	-
TSB(1000 kg)	538.7	1041.7	50679.9	479.9	1128.7	492.3	2801.0	-	57162.3	-
Mean length (cm)	16.57	22.79	25.83	30.00	30.00	30.00	31.75	-	-	-
Mean weight (g)	36.00	100.62	140.32	231.00	232.86	237.00	261.97	-	-	140.73

Table 12a. 6aS/7b industry acoustic survey in 2018: Time series of TSB age-disaggregated numbers at age of herring ('000) from the industry acoustic survey 2016 – 2018.

Year	1	2	3	4	5	6	7	8	9	10	TSB
2016	7,284	34,055	71,229	15,781	46,066	31,877	14,956	2,244	0	0	35,475
2017	587	45,184	91,109	54,292	17,021	39,439	21,321	13,938	1,998	387	40,646
2018	655	59,268	66,776	101,824	67,951	20,334	23,443	4,336	931	672	50,145

Table 12b. 6aS/7b industry acoustic survey in 2018: Time series of SSB age-disaggregated numbers at age of herring ('000) from the industry acoustic survey 2016 – 2018.

Year	1	2	3	4	5	6	7	8	9	10	SSB
2016	1,894	34,048	71,229	15,781	46,066	31,877	14,956	2,244	0	0	35,038
2017	194	42,157	89,924	54,075	17,021	39,439	21,321	13,938	1,998	387	40,132
2018	328	56,127	66,242	101,500	67,951	20,334	23,443	4,336	931	672	49,523

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 13 (herring) and Table 14 (horse mackerel). The CV estimates on biomass and abundance are high (~0.51 for herring and ~ 0.36 for horse mackerel) for the survey in 2018. For herring, this is mostly caused by the over-reliance on a few strong acoustic marks of herring in Lough Swilly in particular. For horse mackerel, the CV is better than previous years, but stock containment remains an issue. Bias considerations for the survey are outlined in Table 15. 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 13. 6aS/7b industry acoustic survey in 2018: uncertainty estimates of herring (with CV) by weight and number for the Donegal Bay, Northwest (NW), Lough Swilly (Swilly), Achill and the total survey area.

```
[1] "Ton by stratum"
       Stratum    Ton.5%    Ton.50%   Ton.95%   Ton.mean     Ton.sd    Ton.cv
1:      Achill  512.5926   581.7675  1829.982   886.7029   471.3188 0.5315408
2: Donegal Bay 8746.6620 10097.5722 27649.355 14255.9233  6488.4314 0.4551393
3:          NW 2465.2072  7898.0693 18811.965  8987.4503  5088.7114 0.5662019
4:      Swilly 4752.9862 32234.1447 66688.921 33289.8429 23544.0212 0.7072434
[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:      Achill   3632267    4141036   12982351     6295877   3363918 0.5343050
2: Donegal Bay  61615879   71510324  195534080   100794792  45824524 0.4546319
3:          NW  16815697   54006783  129682579    61732420  35135394 0.5691563
4:      Swilly  32668678  221474954  454784639   228333981 161470769 0.7071692
[1] "Ton by survey"
     Ton.5% Ton.50%  Ton.95% Ton.mean   Ton.sd   Ton.cv
1: 13062.79 48940.9 98402.33 51205.38 26181.46 0.511303
[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:  91285569  337057511  681577237   353428606 179922781 0.5090782
```

Table 14. 6aS/7b industry acoustic survey in 2018: 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 29812.09 57139.45 96243.96 59038.19 21339.85 0.3614583
[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 209552009  406872766  686139108   420292688 153273845 0.3646836
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 29812.09 57139.45 96243.96 59038.19 21339.85 0.3614583
[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: 209552009  406872766  686139108   420292688 153273845 0.3646836
```

Table 15. 6aS/7b industry acoustic survey in 2018: Bias considerations for acoustic surveys

Bias Considerations	Comment
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.
Avoidance effect	unquantified
Overlapping survey layers	NA
Shallow water	Survey design needs to be considered in inshore areas (e.g. Lough Swilly).
Water temperature and the propagation of the sonar beam	No problems
Quality of raw material used	Poor weather throughout the survey in 2018. Towed body performed well and good quality raw data was collected
Accuracy of calibration constant	Calibration in 2018 was unsuccessful, however a good calibration from the previous survey in 2017 was used (results shown in Appendix 1). This was considered to be appropriate in this instance.
Biomass species composition	Trawl information, results from monitoring fishery and acoustic expert agreement
The actual accuracy problem of acoustic surveys	Bias and sampling error – the CV as expected was high for the herring survey (~0.51) 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 (~0.36) due to the over reliance of two transects in particular.

Stock containment

There was good evidence of offshore containment of herring in 6aS/7b in the 2018 survey, 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 (~0.51). Additional areas off the west Mayo and Galway coasts were covered by this survey again in 2018. These included a number of grounds that were known to have spawning in the past (Figure 1), however, few herring aggregations were located in these areas apart from a couple of marks in near Inishbofin. 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 2018.
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

Industry/science surveys are becoming more common as a way of improving understanding of some commercial stocks (ICES 2007; Fassler *et al* 2016; 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 2018. The timing of the survey was brought forward by 3 weeks compared to 2017, however herring were again distributed inshore, particularly in Lough Swilly. The inshore distribution of herring made containment of the stock difficult. Although there is a lot of good information on spawning areas of herring in 6aS, the timing of migration into the spawning areas is difficult to predict. This needs to be weighed up against the need for the stock to be within the 6aS/7b area and also separated from the 6aN stock at the time of the survey.

Approximately 1,400 miles of transects were completed, with four commercial fishing hauls completed during the survey. Ideally more haul samples of herring would be obtained from the survey itself, but the decision was taken to use herring samples from the monitoring fishery instead in 2018. There was evidence of very large marks of herring inshore in shallow areas, particularly in Lough Swilly. Most of the obvious herring marks were inshore in shallow water not possible to fish with large commercial net available to this industry survey. Smaller boats in the fleet were fishing in these inshore areas during the survey and samples from this fishing were used to work up estimates from the survey. There were a few herring marks in discreet areas around Glen Head, Bruckless Bay, Inishmurray and Inishbofin. These were small marks and not fished on for identification. The results from the survey in 2018 were 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 the Broadhaven Stags.

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 the stock inshore, but most likely contained the stock offshore. Weather was poor throughout the survey and this resulted in reduced area coverage for the survey. Increased transect intensity was achieved in some areas due to the extra time gained as a result of the reduced area coverage.

There appears to be good cohort tracking of herring in the survey between 2016, 2017 and 2018. 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 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 third year of this current survey effort; the survey is a good proof of concept that industry/science partnership is possible on this stock and can provide a fisheries independent survey index for this stock. The survey has provided the third data point on a new index of 6aS/7b TSB 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. The survey provides a platform to continue work on splitting and stock identification of herring in the greater Malin Shelf area and also provides information on pre-spawning behaviour in inshore areas.

5. Conclusions

- The survey is a good example of industry/science survey partnerships, providing a third data point to what may become a time-series of herring surveys in the 6aS/7b area at this time of the year.
- It is reasonable to consider the herring surveyed were 6aS/7b fish due to the inshore distribution and proximity to the spawning grounds.
- The survey reflected what was experienced in the monitoring fishery occurring at the same time.
- The 2018 TSB estimate of 50,145 tonnes is considered to be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey
- The majority of herring marks were observed inshore in shallow areas, particularly in Lough Swilly. The stock appears to have been largely contained, however these is still a concern regarding containment inshore in very shallow areas and in bays not covered by the survey
- The inshore/shallow distribution of herring meant that it was difficult to obtain samples on the survey. Industry nets are large, therefore it was decided to obtain samples from the fishery rather than targeting relatively large marks. The potential to obtain samples that were too large for the purpose of the survey was a consideration; this is a vulnerable stock, and it was decided in 2018 that this was the best approach. The fishery is conducted on the same marks and at the same time as the survey, therefore the sampling is considered representative of the surveyed biomass.
- Cohort tracking - there appears to be good cohort tracking in the survey over the 3-year time-series
- The survey in 2018 was conducted ~ 3 weeks earlier than in 2017. It was hoped that earlier timing would capture herring as they migrate towards the inshore spawning areas and before they hyper-aggregate. This was achieved in Bruckless and Inver Bays in the south, but was not achieved in Lough Swilly in the north. The survey began before the fishery started in 2018. The fish were in Lough Swilly in large numbers before the beginning of the survey on November 1st. 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 inshore 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. 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. It is hoped that a survey review workshop on herring acoustic spawning surveys (WKHASS 2019) will examine the survey design and recommend a design that reduces the uncertainty in the survey
- There is a need to develop protocols in areas where large aggregations or hyper aggregating behaviour of herring is observed (i.e. in areas like Lough Swilly)
- For horse mackerel the TSB estimate of 57,162 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 survey was dominated by 4-wr horse mackerel, following on from the 3-wr fish picked up in the survey last year. This appears to 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.

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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
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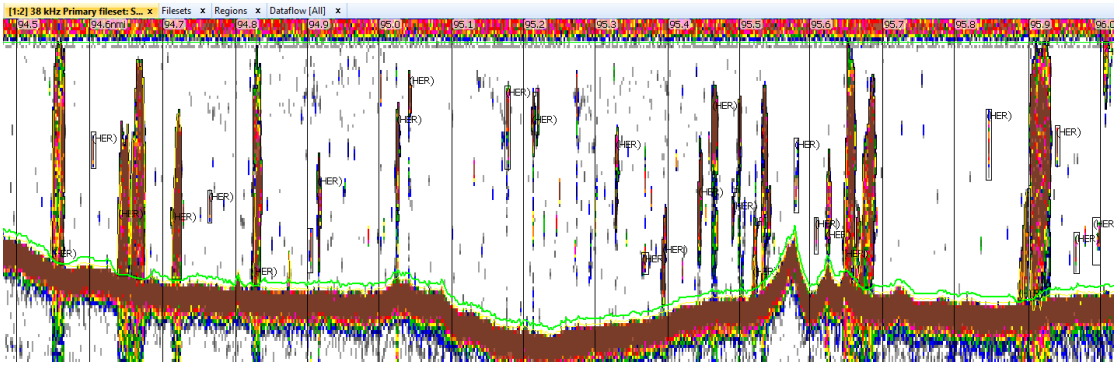
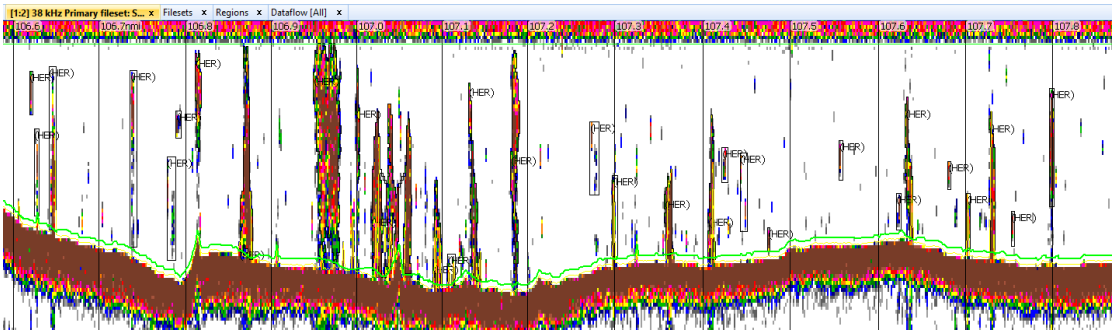
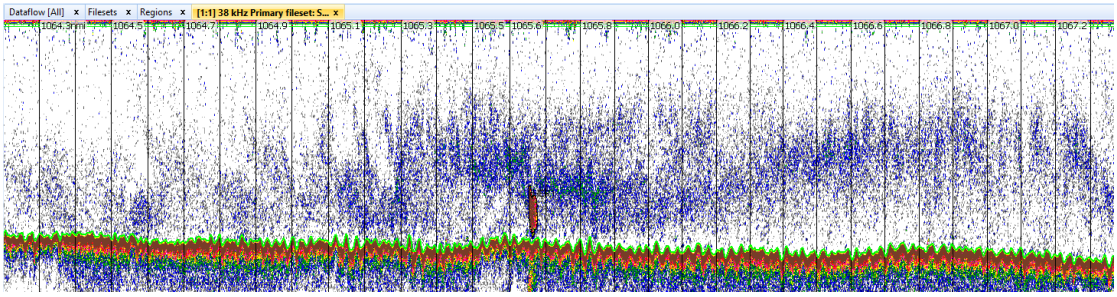


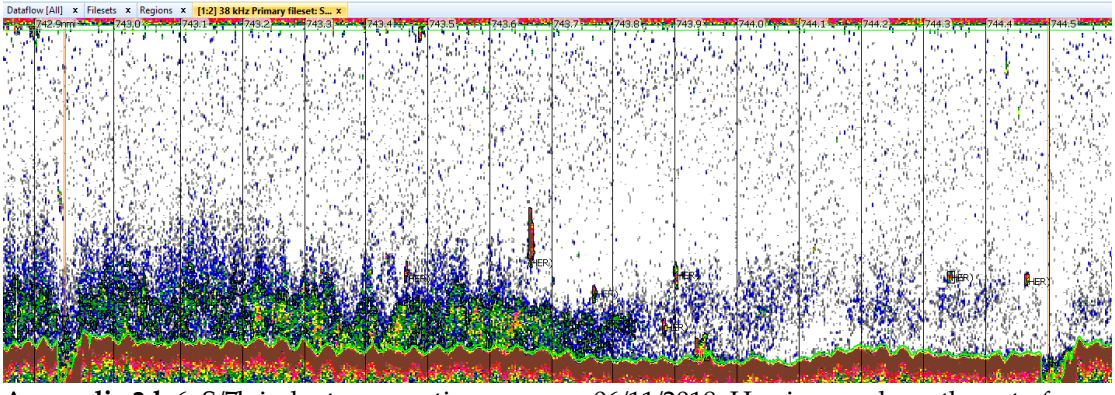
Appendix 2a. 6aS/7b industry acoustic survey on 02/11/2018: Series of herring marks in Lough Swilly, Co. Donegal (ICES area 6aS). Water depth ~ 18m approximately.



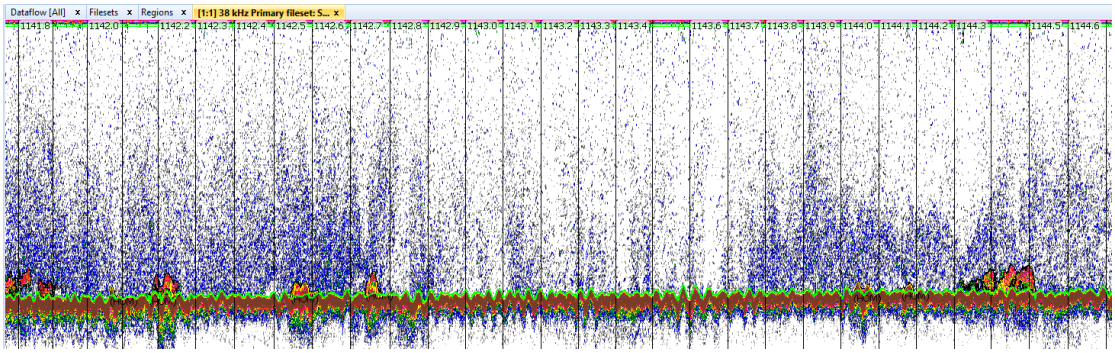
Appendix 2b. 6aS/7b industry acoustic survey on 02/11/2018: Series of herring marks in Lough Swilly (ICES area 6aS). Water depth ~ 16m approximately.



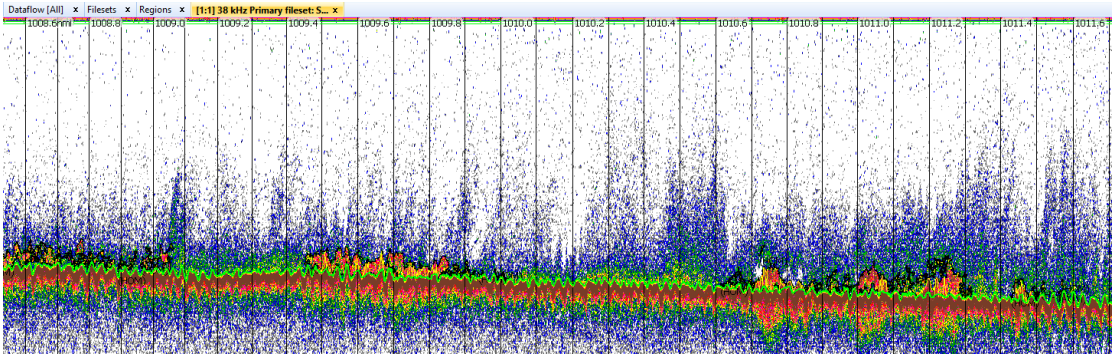
Appendix 2c. 6aS/7b industry acoustic survey in 08/11/2018: Herring mark in Donegal Bay (ICES area 7b). Water depth ~ 80m approximately.



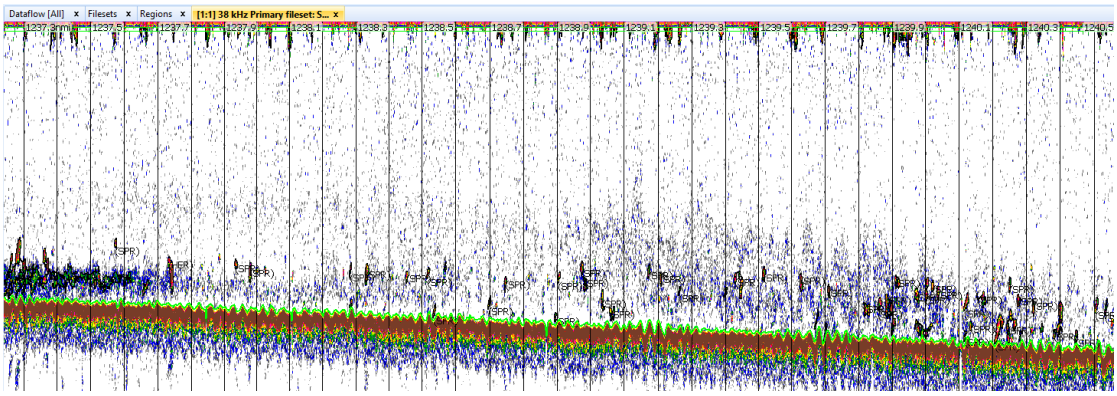
Appendix 2d. 6aS/7b industry acoustic survey on 06/11/2018: Herring mark northwest of Glen Head (ICES area 6aS). Water depth ~ 60m approximately.



Appendix 2e. 6aS/7b industry acoustic survey on 08/11/2018: Horse mackerel marks north of the Stags of Broadhaven area (ICES area 6aS). Water depth ~ 90m approximately.



Appendix 2f. 6aS/7b industry acoustic survey on 08/11/2018: Horse mackerel marks north of the Stags of Broadhaven area (ICES area 6aS). Water depth ~ 85m approximately.



Appendix 2g. 6aS/7b industry acoustic survey on 09/11/2018: Sprat and herring mix in Donegal Bay (ICES area 7b). Water depth ~ 65 m approximately.

Appendix 3. 6aS/7b industry acoustic survey in 2018: 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

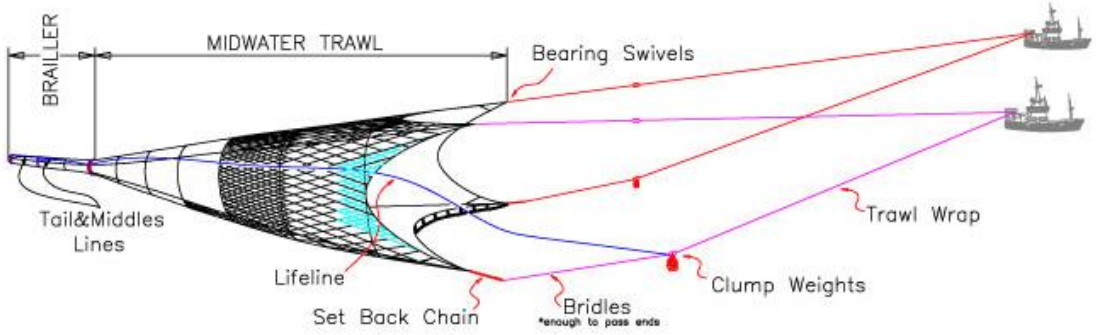
MFV Eilean Croine S238

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 2018: Pair trawl net details (from: www.swannetgrundy.com)



Appendix 5. 6aS/7b industry acoustic survey in 2018: Top side monitoring station located in the wheelhouse of the *MFV Eilean Croine* (left). 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. Tow body mounted 38 kHz transducer (right)

Appendix 6. 6aS/7b industry acoustic survey in 2018: Waypoints for survey (transects shown in Figure 3) in 6aS and 7b, start and end positions in 2018 (precise numbers are just advisory).

Waypoint	Distance (nmi)	Cumulative dist. (nmi)	Lat. (deg.)	Lat. (min.)	Long. (deg.)	Long. (min.)
W 000	0.0 Nm	n/a	55	17.1547	6	52.207
W 001	42.8 Nm	42.8 Nm	55	59.9347	6	52.6465
W 002	7.5 Nm	50.3 Nm	55	59.9347	7	6.0498
W 003	31.7 Nm	81.9 Nm	55	28.2653	7	6.0498
W 004	7.5 Nm	89.4 Nm	55	28.2653	7	19.2334
W 005	37.2 Nm	126.6 Nm	56	5.4573	7	19.4532
W 006	7.5 Nm	134.1 Nm	56	5.4573	7	32.8564
W 007	47.7 Nm	181.8 Nm	55	17.7802	7	32.8564
W 008	2.3 Nm	184.0 Nm	55	16.0674	7	35.4657
W 009	3.6 Nm	187.7 Nm	55	12.5988	7	33.653
W 010	1.1 Nm	188.8 Nm	55	11.7679	7	35.0262
W 011	1.4 Nm	190.2 Nm	55	11.0546	7	32.9251
W 012	0.8 Nm	191.0 Nm	55	10.3645	7	33.4882
W 013	2.0 Nm	193.0 Nm	55	9.4232	7	30.3433
W 014	2.1 Nm	195.1 Nm	55	7.453	7	29.176
W 015	2.4 Nm	197.5 Nm	55	5.3634	7	31.2497
W 016	1.9 Nm	199.4 Nm	55	3.9561	7	33.5431
W 017	1.5 Nm	200.9 Nm	55	2.4695	7	32.9389
W 018	0.7 Nm	201.6 Nm	55	1.8556	7	32.3621
W 019	1.3 Nm	203.0 Nm	55	0.7927	7	33.804
W 020	0.7 Nm	203.6 Nm	55	0.5645	7	34.9026
W 021	0.7 Nm	204.3 Nm	55	0.8479	7	33.8727
W 022	1.0 Nm	205.3 Nm	55	1.5171	7	32.5406
W 023	0.7 Nm	206.0 Nm	55	2.2332	7	32.5131
W 024	1.1 Nm	207.1 Nm	55	3.1932	7	33.4744

W 025	1.2 Nm	208.4 Nm	55	4.4358	7	33.3234
W 026	1.4 Nm	209.8 Nm	55	5.442	7	31.6068
W 027	2.3 Nm	212.0 Nm	55	7.4216	7	29.6567
W 028	1.0 Nm	213.1 Nm	55	8.4029	7	29.2447
W 029	1.6 Nm	214.6 Nm	55	9.2584	7	31.5244
W 030	0.8 Nm	215.4 Nm	55	9.9567	7	30.9613
W 031	2.2 Nm	217.6 Nm	55	11.0075	7	34.3396
W 032	1.0 Nm	218.6 Nm	55	11.9169	7	33.6118
W 033	1.5 Nm	220.1 Nm	55	12.5125	7	36.0974
W 034	4.2 Nm	224.3 Nm	55	16.0986	7	32.1698
W 035	10.0 Nm	234.3 Nm	55	19.7107	7	48.512
W 036	70.0 Nm	304.4 Nm	56	29.745	7	47.7979
W 037	7.5 Nm	311.9 Nm	56	29.6236	8	1.4209
W 038	73.4 Nm	385.3 Nm	55	16.1768	8	1.8604
W 039	8.2 Nm	393.6 Nm	55	19.5543	8	15.044
W 040	70.1 Nm	463.6 Nm	56	29.6236	8	14.1651
W 041	7.5 Nm	471.2 Nm	56	29.5023	8	27.7881
W 042	82.7 Nm	553.9 Nm	55	6.7698	8	28.667
W 043	20.6 Nm	574.5 Nm	54	47.5909	8	41.6309
W 044	101.9 Nm	676.4 Nm	56	29.5023	8	40.9717
W 045	7.5 Nm	683.9 Nm	56	29.5023	8	54.5948
W 046	130.5 Nm	814.3 Nm	54	19.0485	8	54.8145
W 047	4.8 Nm	819.2 Nm	54	18.7922	8	46.5747
W 048	18.8 Nm	837.9 Nm	54	37.5626	8	46.4649
W 049	2.9 Nm	840.8 Nm	54	36.5448	8	41.7407
W 050	14.9 Nm	855.7 Nm	54	21.6746	8	41.4111
W 051	3.9 Nm	859.6 Nm	54	24.1058	8	36.2476
W 052	11.5 Nm	871.1 Nm	54	35.5902	8	36.1377
W 053	3.0 Nm	874.1 Nm	54	35.4471	8	30.9742
W 054	8.7 Nm	882.7 Nm	54	26.7903	8	31.084
W 055	3.5 Nm	886.3 Nm	54	29.0889	8	26.4698
W 056	4.4 Nm	890.7 Nm	54	33.5366	8	26.3324
W 057	4.3 Nm	895.0 Nm	54	36.1631	8	20.5371
W 058	6.5 Nm	901.4 Nm	54	29.6954	8	20.7019
W 059	30.5 Nm	932.0 Nm	54	16.9489	9	8.3826
W 060	78.7 Nm	1010.7 Nm	55	35.6718	9	8.4375
W 061	11.7 Nm	1022.4 Nm	55	26.9649	9	22.2803
W 062	66.9 Nm	1089.3 Nm	54	20.0577	9	22.5
W 063	8.0 Nm	1097.3 Nm	54	21.1464	9	36.0681
W 064	59.7 Nm	1157.0 Nm	55	20.8821	9	35.6836
W 065	13.3 Nm	1170.4 Nm	55	10.1135	9	49.5264
W 066	47.9 Nm	1218.3 Nm	54	22.2026	9	49.0869
W 067	7.9 Nm	1226.2 Nm	54	20.0255	10	2.0508
W 068	39.1 Nm	1265.3 Nm	54	59.1701	10	2.4903
W 069	14.2 Nm	1279.6 Nm	54	47.0366	10	15.4541
W 070	20.2 Nm	1299.8 Nm	54	26.8059	10	15.0147
W 071	12.6 Nm	1312.4 Nm	54	26.8063	10	36.7676
W 072	7.5 Nm	1320.0 Nm	54	19.2567	10	36.7676
W 073	17.0 Nm	1337.0 Nm	54	19.1286	10	7.5439
W 074	9.4 Nm	1346.5 Nm	54	11.5555	10	17.212
W 075	15.3 Nm	1361.8 Nm	54	11.4271	10	43.3594
W 076	9.7 Nm	1371.5 Nm	54	2.9276	10	51.4893

W 077	22.8 Nm	1394.4 Nm	54	2.9276	10	12.5977
W 078	8.6 Nm	1403.0 Nm	53	54.9166	10	17.981
W 079	22.8 Nm	1425.8 Nm	53	54.9166	10	56.7627
W 080	7.5 Nm	1433.3 Nm	53	47.3992	10	56.6529
W 081	31.0 Nm	1464.4 Nm	53	47.6588	10	4.1382
W 082	7.8 Nm	1472.1 Nm	53	40.3152	9	59.8535
W 083	20.5 Nm	1492.6 Nm	53	40.2501	10	34.4605
W 084	7.5 Nm	1500.1 Nm	53	32.7542	10	34.4605
W 085	10.1 Nm	1510.2 Nm	53	32.6888	10	17.5415
W 086	10.7 Nm	1520.9 Nm	53	37.7105	10	1.6113
W 087	19.4 Nm	1540.3 Nm	53	56.7277	10	8.0933

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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