WORKSHOP ON HERRING ACOUSTIC SPAWNING SURVEYS (WKHASS)

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editor

Pablo Carrera

Authors

Benoit Berges • Pablo Carrera • Steven O'Connell • Steven Mackinson • Michael O´Malley • Susan Mærsk Lusseau • Mathieu Lundy

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Contents

i Executive summary

The purpose of the Workshop on Herring Acoustic Spawning Surveys (WKHASS) was to review the methodology (survey design, timing, identification of the sources of uncertainties and how to address them, among other issues), and abundance estimates (including CV) provided from surveys carried out in 6a and 7a on commercial vessels. The results from this workshop will be analysed by the Working Group of International Pelagic Surveys (WGIPS) with the aim to establish a protocol to be included in a future update of the Manual for International Pelagic Surveys (SISP 9). This will ensure repeatability of the survey as reviewed, allow appropriate data quality checks and provide transparency of methodologies, as a prior step for using it as a fishery-independent index in assessment models. Workshop participants presented state of the art of each acoustic-trawl survey carried out on board commercial vessels in 6aN, 6aS/7bc and 7a targeted on herring at the spawning season.

Special emphasis was placed on examining survey strategies to increase the precision of the abundance estimates. The main issues with precision are related to both the aggregation and spatial patterns observed in the herring shoafils before and during the spawning period. These issues can be addressed by accounting for both the survey design and timing. For this purpose, a series of statistical analysis (e.g. geostatistics, bootstrap) were carried out not only for the acoustic records but also in the number of fishing hauls for biological (length and age among other biological parameters).

The three surveys analysed (6aN, 6aS/7b,c and 7a) give robust estimates of abundance although there is still room for increasing their precision. Herring behaviour is an important issue as fish change both the aggregation and spatial distribution patterns during the spawning season. In some areas, particularly where trawling is difficult or few marks are seen, it is difficult to confidently allocate echotraces to fish species, and the lack of enough biological data leads to an increase of the associated CV abundance estimates by age group. An increase in the number of tracks or even a reduction in Elementary Sampling Distance Unit, ESDU distance, both allowing for a better spatial resolution of the herring spawning aggregations, may help address some of these problems, and such tests have been underway. The use of cameras could be used to identify fish aggregations on non-trawlable areas to identify acoustic marks and make appropriate allocations to species. Prior scouting surveys would help to address other of the issues regarding with survey timing.

The analysis carried out during this workshop showed that both the 6aN and 6aS/7bc industry-led surveys are not yet sufficiently developed for them to be included in the SISP 9 survey manual because they are still undergoing regular changes as they learn from testing different designs regarding the issues and the solutions proposed to address them. It was recommended that the 7a survey in the Irish Sea is included in the SISP 9 manual for pelagic acoustic surveys. This survey is already used as a biomass index in the Irish Sea herring assessment.

ii Expert group information

Expert group name	Workshop on Herring Acoustic Spawning Surveys (WKHASS)
Expert group cycle	Annual
Year cycle started	2019
Reporting year in cycle	1/1
Chair	Pablo Carrera, Spain
Meeting venue and dates	15 – 17 October 2019, Vigo, Spain (7 participants)

1 Introduction

The Workshop on Herring Acoustic Spawning Surveys (WKHASS) took place in Vigo, Spain from 15 (10:00) until 17 (16:00) October 2019.

Purpose/Aim

Currently, herring in 6aN-S/7b,c is routinely surveyed in the summer (feeding) time on an acoustic-trawl survey whose estimates are used as fishery-independent information for assessment purposes. Together with this, two other surveys, carried out in cooperation with the industry, are covering areas in 6aN and 6aS/7b,c during the spawning season. Although the Irish Sea (7a) herring spawning survey have never been thoroughly reviewed by WGIPS, results from the survey are presented to the group annually and used by HAWG in the stock assessment for Irish Sea herring as an absolute estimate of abundance. The two herring spawning surveys under development for herring in 6aN and 6aS/7b,c in recent years have never been thoroughly reviewed. These surveys are similar in design and objectives to the Irish Sea Spawning Survey. WGIPS requests a workshop to establish and agree on survey design and protocols for coordinating and conducting these surveys.

The surveys

Acoustic survey in 6aN

1 Background

As explained in the following survey (6aS/7b,c) there is a need for better understanding of the identity and dynamics of the herring stock components cohabiting these divisions, which is expected to result in better information for assessment and management. Since 2016 acoustic surveys of herring during the spawning and pre-spawning period were undertaken as part of the monitoring fishery on this stock. The surveys cover known active spawning grounds in both 6aN and 6aS,7b at spawning time and aims to provide estimates of minimum spawning stock size in each of the areas.

2 Project Aim

The 6aN herring survey is an industry-led scientific survey that was instigated in response to a fishery closure since 2016 (ICES 2017a, 2018a). The aim is to improve the knowledge base for the spawning components of herring in 6aN and 6aS/7bc, and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan. Details of the acoustic survey (see. Obj 3) and results are reported in ICES WGIPS (2017b, 2018b, 2019a) and the full survey in Mackinson *et al.* 2017-19. It is hoped that acoustic indices may be used as a stock specific index in future assessments.

The overall survey objectives are:

1. Collect morphometric and genetic data to distinguish whether the 6aN stocks are different from the stocks in 6aS, 7b,c.
2. Collect biological information from commercial catches (on spawning aggregations) in order to maintain the stock assessment time series
3. Undertake scientific acoustic surveys to collect data and information on the size and age of herring to allow estimation of a minimum spawning stock biomass and abundance.

Acoustic survey in 6aS/7b, c

1 Background

An acoustic survey of Atlantic herring was conducted in 6aS/7b, c in Nov/Dec 2016, 2017, 2018 and 2019 (e.g. O'Malley *et al.* 2017, 2018, 2019). The survey is being developed into a long-term index of spawning/pre-spawning herring in 6aS/7b,c. Following the ICES benchmark workshop on herring in 6aN, 6aS and 7b, c (ICES, 2015), 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 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 for herring in these areas since 2016. Acoustic surveys conducted closer to the spawning time could potentially better discriminate fish in terms of stock identification. The timing of these surveys coincides with spawning/pre-spawning aggregations of the stock; therefore it is hoped that abundance and biomass indices generated may be used as a stock specific index in the future. The Nov/Dec timing of the 6aS/7b, c survey also coincides with aggregating horse mackerel *Trachurus trachurus* in this area; an important area for the Irish horse mackerel fishery during this time. A horse mackerel index for this area and time could potentially be an additional benefit of conducting this survey in the future.

2 Project Aim

The survey is part of a collaborative partnership between Ireland, UK (Scotland) and The Netherlands that aims to improve understanding of the individual stock components of herring in 6a and 7b, c. The survey collects acoustic information and echo trace validation samples from pre-spawning and spawning aggregations of herring. Timing of the surveys is targeted at times when the stocks (6aN and 6aS/7b, c) are expected to be largely separated. Samples from spawning herring fish are also being used for morphometric studies, genetic analyses and otolith microstructure. Abundance and biomass indices for horse mackerel are generated as per standard acoustic survey protocols (ICES, 2015). The overall survey objectives are:

- Conduct an acoustic/trawl survey in 6aS and 7b, c, targeting pre-spawning and spawning aggregations of herring
- Collect acoustic backscatter data and biological information (length, weight, sex, maturity, age) of herring to estimate the abundance and biomass of the spawning stock
- Collect morphometric and genetic data on spawning herring to assist in on-going work aimed at distinguishing between the 6aS/7b, c and 6aN stocks
- Concurrently conduct an acoustic/trawl survey in 6aS and 7b, c targeting horse mackerel
- Collect acoustic backscatter data and biological information (length, weight, sex, maturity, age) of horse mackerel to estimate the abundance and biomass of the stock in this area during this time

Irish Sea Herring Spawning survey

1 Background

In 7a (Irish Sea) an acoustic survey has been conducted since 1992 to estimate herring SSB. A key point for this survey is timing, with the survey being conducted when fish are migrating towards the spawning grounds. Additional information is now provided by chartered commercial fishing vessels that focus on the main spawning grounds, which comprise more than 75% of SSB. They make repeat passages over the sampling grid which is similar in design to the one used in the "routine survey", aiming at to find the best suitable time to conduct the survey on account the shoaling behaviour (aggregation pattern) and the spatial distribution pattern.

2 Project Aim

The overall survey objectives are:

- To generate a SSB index
- To provide an accurate age structured index

Terms of reference (ToR)

a) Review survey design and acoustic data collection methods of ongoing surveys not previously reviewed by WGIPS (Irish Sea Spawning Survey and 6a/7bc Industry -led Herring Acoustic Spawning Surveys). The review should address survey design, timing, stock identification, containment, biological sampling and acoustic data collection methods.

b) Explore the estimation methods of indices, including sensitivity to trawl and biological sampling allocations and echogram scrutinisation. Review and document methods used to produce measures of uncertainty (CV) in abundance and biomass for the survey by strata and the overall survey area.

c) Fully document methods for inclusion in the Manual for International Pelagic Surveys (SISP 9) to ensure repeatability of the survey as reviewed, allow appropriate data quality checks and provide transparency of methodologies.

d) Consider the relevance of additional information that is collected or could be collected for ICES advisory or science products, particularly ecosystem over-views and integrated ecosystem assessments.

*To see full resolution and Terms of reference (ToR) please go to Annex 2

2 ToR a

2.1 6aN Herring spawning acoustic survey

2.1.1 Survey overview

Aspect	Detail
Objective (acoustic)	Establish an acoustic time series of minimum spawning stock biomass
Time series	2016-2019, with plans for 2020
Platforms	Three commercial pelagic vessels, using either their own hull-mounted echosounders or towed body operated by staff from a marine institute.
Survey design	Grid design with 4 separate strata. Design has adapted over time (relatively minor) to better meet needs
Participants	Scotland, Netherlands, England. Coordinated by Industry and Marine Scotland Science. Staff from industry, MSS and WMR.
Survey References	ICES WGIPs (2017-2019), Mackinson *et al.* 2017, 2018, 2019

2.1.2 Rationale, aims and objectives

The 6aN herring survey is an industry-led scientific survey that was instigated in response to a fishery closure since 2016 (ICES 2017a, 2018a). The aim is to improve the knowledge base for the spawning components of herring in 6aN and 6aS/7bc, and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan. Details of the acoustic survey (see Obj 3) and results are reported in ICES WGIPS (2017b, 2018b, 2019a) and the full survey in Mackinson *et al.* 2017-19. The overall survey ojectives are:

1. Collect morphometric and genetic data to distinguish whether the 6aN stocks are different from the stocks in 6aS, 7b,c.
2. Collect biological information from commercial catches (on spawning aggregations) in order to maintain the stock assessment time series
3. Undertake scientific acoustic surveys to collect data and information on the size and age of herring to allow estimation of a minimum spawning stock biomass and abundance

2.1.3 Acoustic survey design principles

- Maximise the window of observation through scheduling the timing of the three vessels in each area. Each vessel surveys for 10 days
- Cover a wider search area than the main spawning aggregation areas that were identified from historical fishing activity and maps of spawning sites. The purpose of this is to establish appropriate survey boundaries
- Stratify by area (4 areas)
- Survey more intensively in some areas, or parts of some areas that are known to be important spawning sites
- Map spawning sites
- Adapt the design based on experience on the behavior of herring and the logistics of practical implementation across multiple platforms
- Where possible, minimize the survey variance, recognizing that in trying to do so there can be a trade-off between statistical precision of the survey and the understanding of the behavioural dynamics of herring during the survey

2.1.4 Evolution of the survey design

<u>2016 (Figure 2.1.4.1)</u>

- All strata with 3nmi spacing
- One vessel dedicated to each area, with multi repeats of the grid.

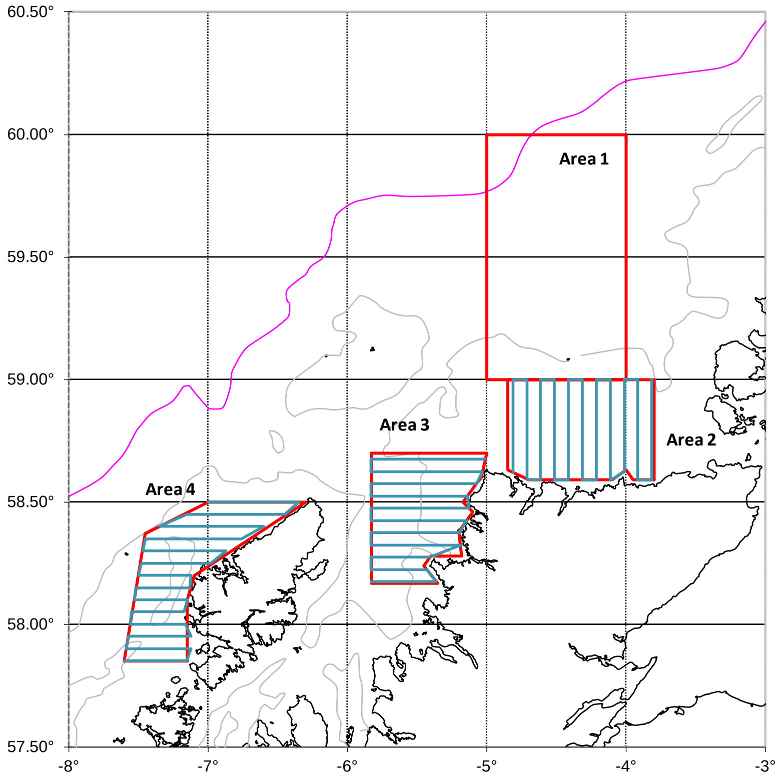

Figure 2.1.4.1 Limits of survey areas used in the 6aNorth surveys. Area 1- North pre-spawning mixing area, Area 2 -East of Cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides. Spacing 3nmi.

2017 (Figure 2.1.4.2)

- Nested design with two strata known to be important spawning areas, to allow for finer scale observation
- One vessel dedicated to each area, with multi repeats of the grid

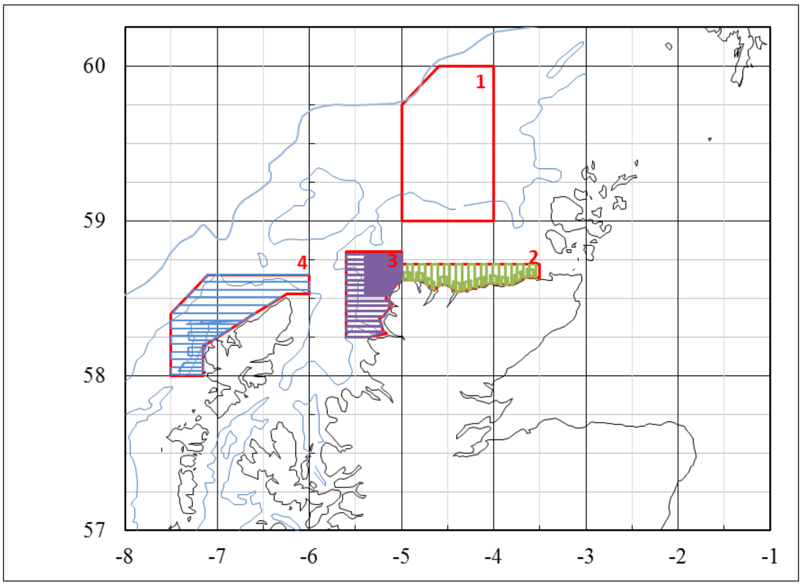

Figure 2.1.4.2. Planned survey areas used in the 6aNorth surveys. Area 1- North pre-spawning mixing area, Area 2 -East of cape Wrath (2nmi long legs, 2nmi short), Area 3 – The Minch (2nmi long legs, 2nmi short), Area 4 – Outer Hebrides (3nmi for long and short).

2018 and 2019 (Figure 2.1.4.3)

- One new strata added (area 5)
- Regular spacing of survey lines, more tightly spaced in areas known to be important for spawning
- Each vessel covers all areas, staggered timing to allow for long coverage and providing more efficient implementation logistics

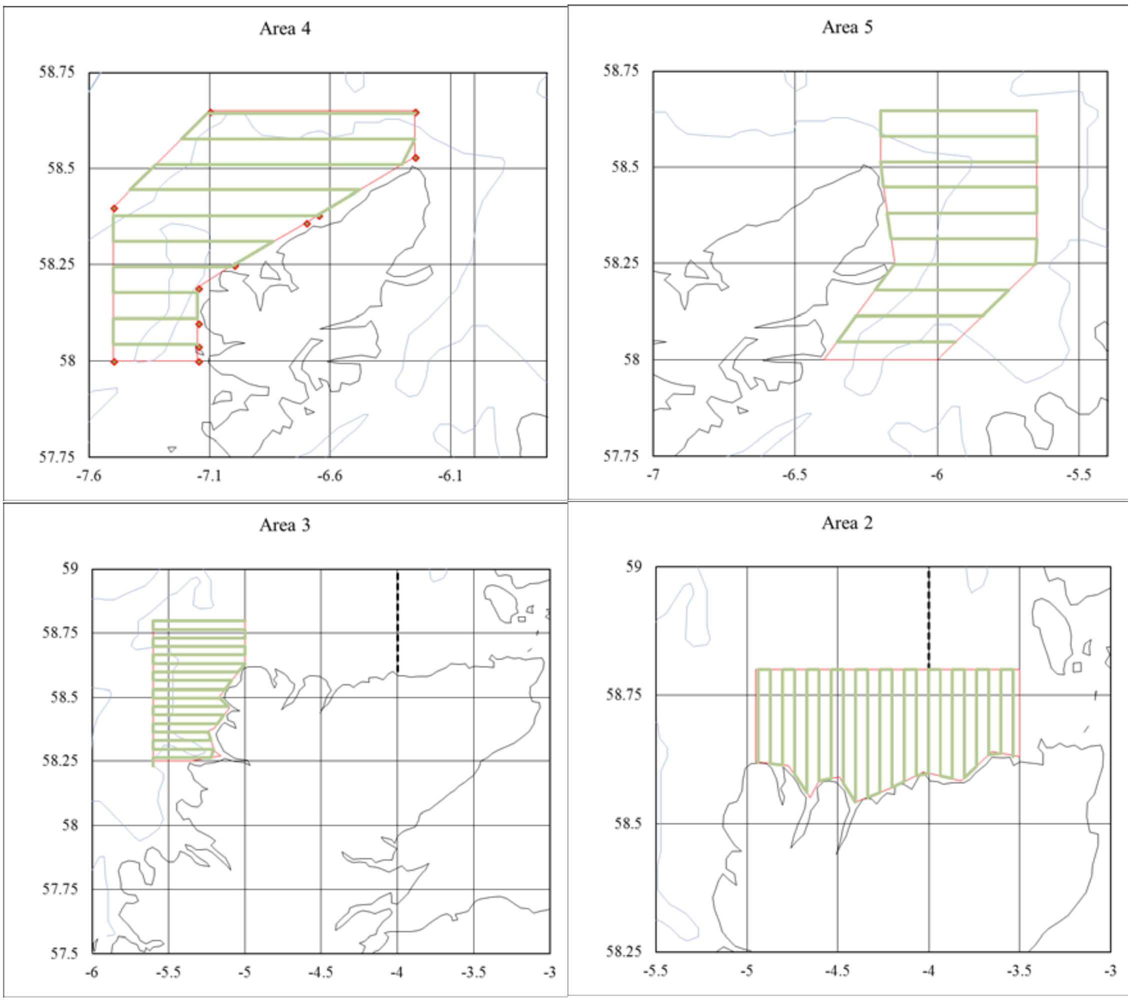

Figure 2.1.4.3. Generic tracks for the acoustic survey areas 4 & 5 (4nmi spacing), 3 & 2 (2nmi spacing).

2.1.5 Reflection on the survey implementation and utility

Since its inception in 2016, the survey has revealed a lot about the distribution and behaviour of autumn-spawning herring in the areas surveyed. Various designs have been tested to establish appropriate survey boundaries that achieve a good representation of distribution of herring. They have included looking more intensively in areas where herring have known to spawned in past, and also in new previously unexplored areas based on knowledge from pelagic fishermen's prior experience and from current reports from Nephrops vessels that see, and occasionally catch, herring during their work.

For one reason or another, there has often been challenges with getting sufficient biological samples to support scrutinization and to provide biological data for age disaggregation. This is contributing to high CVs on the survey abundance-at-age estimates (see section 2.1.5). Another factor causing high CVs on the survey, particularly in the West of Hebrides (Area 4) in September, is the occurrence of very large acoustic marks associated with rocky outcroppings, the identify of which is uncertain. These have been discussed on a number of occasions during survey data workshops and at WGIPS meetings, and subsequently classified as probably herring. To try and get a definitive answer on this, dedicated camera work was undertaken in July 2019 on board FV Grateful. Results showed with a relatively high confidence that these marks are more likely to be Norway pout and juvenile gadoids (whiting mainly). However, during camera work undertaken on spawning marks in the North Sea during September 2019 (FV Unity), no herring were seen on camera, despite the vessel making a commercial catch. Thus, there remains a concern regarding the possibility of light / object avoidance. Ideally, we would have the opportunity to conduct the work again in September 2020, focusing on dense spawning marks as well as large marks on rocky ground. Discussions at WKHASS proposed that a scrutinization workshop is carried out to share experience in identifying herring marks during the (pre) spawning period. Observations from camera work would be valuable to feed into such a workshop.

The addition of Area 5 strata in 2018 and 2019 has placed more pressure on the need to efficiently cover the survey grounds and is causing a trade-off with the time available to undertake trawl sampling. This time pressure increases when poor weather affects progression of the survey. The positive side however is that since the survey has typically deployed three vessels, there has generally been sufficient effort to get a good overall coverage in time and space. With changes in the timing of spawning of herring, an essential part of the survey design is the need to be maintain flexibility, so defining a smaller core survey, with the possibility to extend and adapt as conditions present themselves, could be one way to achieve this.

Two important questions raised and discussed during the discussions at WKHASS were:

What information can reliably be gleaned from the existing surveys?

The principal purpose of the acoustic survey is to be able provide an index of abundance and biomass for all mature stages and ages of herring, and separately for those in spawning condition (maturity stage 5-6). WKHASS discussed to what extent the existing surveys could be used to achieve this. [Note: The rationale for an index based on all mature stages and ages is based on the assumption / evidence from genetics that fish in the vicinity of spawning grounds will spawn in 6aN. This same rationale is used for the Irish Sea (pre)spawning herring survey index that is used by ICES HAWG in stock assessment.]

The survey has explored various designs during its evolution, but it has been constant in surveying two areas that have consistently been shown (since 2016) to be important spawning areas in recent times. These are designated Areas 2 and 3 in the survey. It was decided that attention should be given to exploring an abundance/ biomass index derived from these two areas alone. In addition, further examination of the distribution of herring schools within the areas should be undertaken with a view to considering an index from more restricted areas within Area 2 and 3. In particular, consideration should be given to (i) reducing the transects south in Area 2 where the ground is rocky and rough, which is unlike the flat-grounds where spawning marks are found, and because trawling to verify acoustic marks is not possible in these areas, and (ii) omitting some transects on the eastern side of area 3 so that the focus for an acoustic index is on the area where spawning sites are indicated by acoustic marks and fishing activity. Results from such post-stratification would likely improve CV estimates.

What design changes are advisable to make future surveys useable as indices for stock assessment?

Following on from the previous question, this question emerges out of the need to provide continuity of any time series that may be used as a survey index for stock assessment in the future. Given the results since 2016, it necessitates a need to maintain a focus on observations in Areas 2 and 3.

The discussion also considered the possibility that future surveys may have less resources, so designs that have high likelihood of being sustained are a priority. Future surveys should also address any present shortcomings and allow for continuous improvement. Section 2.1.6 covers this in detail.

2.1.6 Suggestions for future survey design

Design element	Aims	Supporting analyses required
Focus acoustic surveying in Areas 2 and 3	Extent of Area 2 and 3 to be reconsidered. In particular, reducing the transects south in Area 2, and on the eastern side of Area 3. Consider need for further stratification within areas. 80-120 m water is key for spawning areas it seems.	Plot distribution of all commercial catches of herring in Area 2 and 3 since 2016 and historical ones where available. Look at depths and substrate types. (example in Figure 2.1.4) Plot distribution of all schools, and herring only schools in Areas 2 and 3. (see below on scrutinization). Overlay plot on commercial catches to identify core spawning area survey strata. (example in Figure 2.1.4)
Improve confidence in identification of acoustic marks	Ensure sufficient trawling for representative biological samples Use cameras to identify acoustic marks where trawling is not possible and to confirm response of 'definite' herring marks to cameras.	Look at the biological sampling precision that has been achieved in the past to get an idea of how many samples might be needed. Workshop on scrutinization (recommendation of WKHASS). Remove 'cap hugger' marks if suspected not herring based on evidence from July 2019 camera surveys.
Timing of survey to be adaptable and maintain long wide window of observation	Aim for flexible survey timing (starting first week to mid-sept) with information from prior scouting to inform start date. Duration approx. 4 weeks. Consider options for scaled-down survey effort. For example: Three vessels each doing two passes back to back (approx. 6-8 days). Staggered timing, one after the other with possible gaps in between if previous passes indicate the need. Investigate the corridors that herring use on their way to spawning grounds. Possibility to use the vessel dedicated to genetic sampling to do this work. Consider possibility that one or more vessels could conduct their survey without the need for scientific staff, which would allow for greater flexibility in timing, but require the right skills and commitment. May require selection of specific vessel. Undertake a wider area scouting-search to investigate whether new (or just not observed before) spawning sites in 6aN are being used by autumn-spawning herring.	Prior catches from commercial fishing, fishermen's knowledge and data from HERAS surveys can be used to establish hypotheses which can provide a good place to start looking.

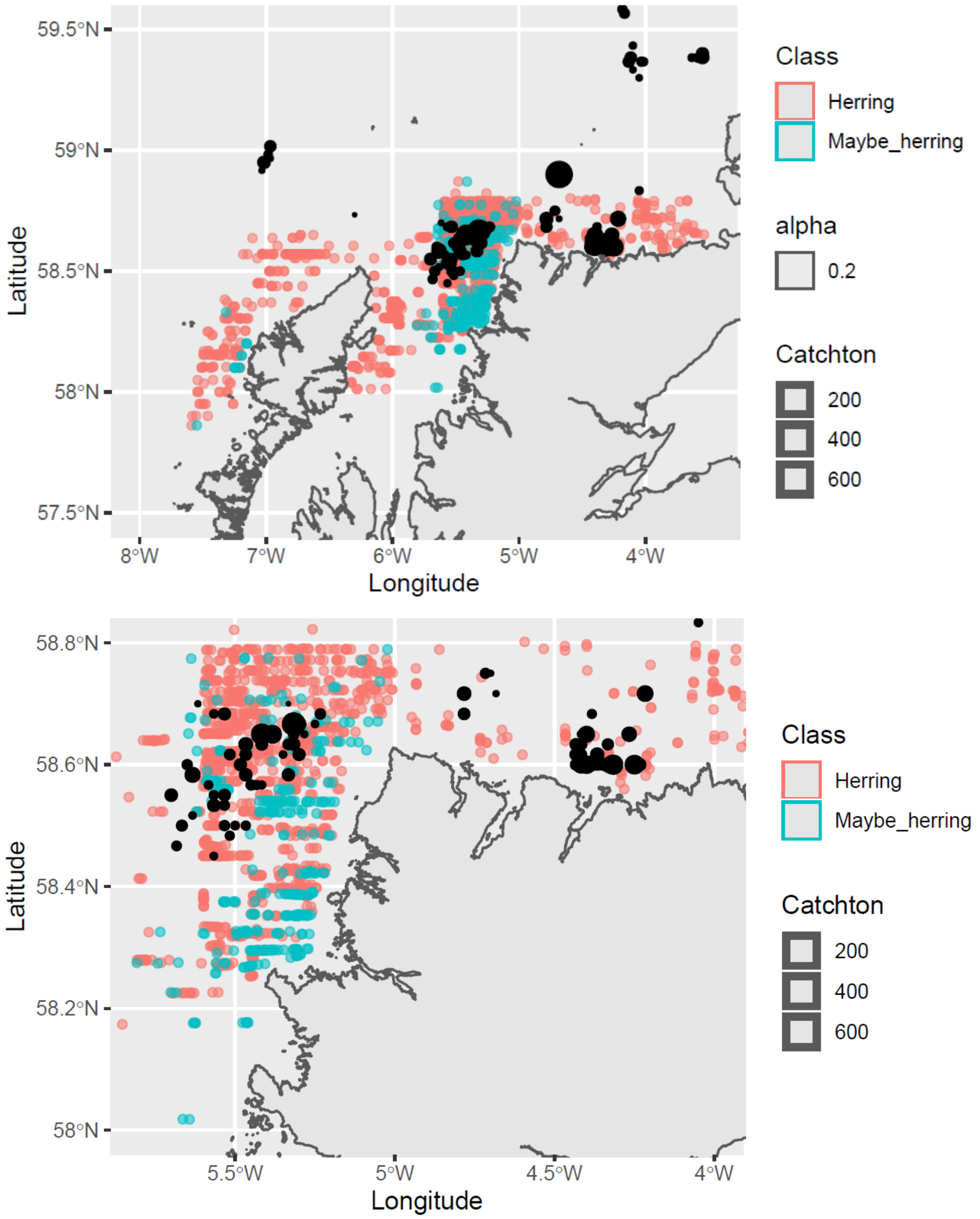

Figure 2.1.4. (a) Acoustic survey recordings of herring and 'maybe herring' marks and locations of commercial catches 2016-2019 for the whole survey area, noting that catches to north do not coincide with known spawning grounds (b) Acoustic survey recordings of herring and 'maybe herring' marks and locations of commercial catches 2016-2019 in survey Area 2 and 3 onlu, noting that the distribution of catches reflect spawning grounds. Catches (black dots) scaled proportionally. Acoustic marks are not scaled and denote location only.

2.2 Acoustic survey in 6aS/7b,c

2.2.1 Survey Design

2.2.1.1 Survey area

The survey is designed to collect acoustic information and samples from pre-spawning and spawning aggregations of herring in 6aS and 7b, c. A detailed inventory of individual herring spawning beds, grounds and areas around the coasts of the Republic of Ireland was produced by O'Sullivan *et al.* (2013). In this study, seabed classification data were used to compare the locations of known herring spawning beds with areas consisting of the necessary substrate. Known spawning areas from O'Sullivan (2013) are shown in Figure 2.3.1.1.1.

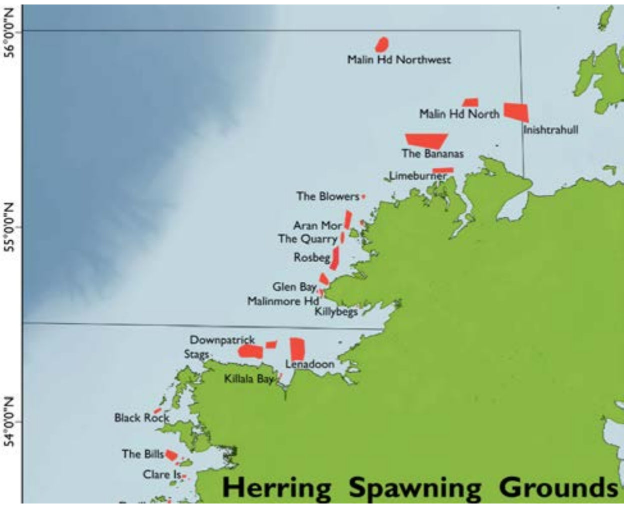

Figure 2.2.1.1.1. Acoustic survey of 6aS/7b, c. Herring spawning grounds in 6aS and 7b, c (from O'Sullivan *et al.*, 2013).

2.2.1.2 Survey Design

The survey is systematic parallel with a random starting point. The transect spacing is 3.5 and 7.5nmi for the parallel transects. Transect design and spacing is the same within each defined strata. There is also a zig-zag transect design in Lough Swilly and Lough Foyle, areas with good catches of herring in the fishery in recent years. Strata are treated separately for estimation of abundance and biomass. An example survey transect design is shown in Figure 2.2.1.3.1. There are 4 strata and these have varied slightly; example strata from the 2018 survey is shown in Figure 2.2.1.3.2. The survey area is almost exclusively in Irish waters, approximately up to the 56˚N line in the north and 6˚40'W line in the east. To the west, the greater survey area is bounded approximately by the 200m depth contour and south to 53˚N approximately.

Fish can be patchily distributed during pre-spawning and spawning; this requires flexibility in survey design and sometimes it is preferable to conduct more intense adaptive mini surveys in areas of high density. In areas where higher densities of fish are detected, transect lines are sometimes added to increase the resolution between the survey lines. This requires the addition or modification of the strata area.

Transects are straight lines carried out at constant speed (or as close to as possible). Any deviation from the planned transects are documented carefully on the acoustic log sheets. When the vessel deviates from transect for any reason (e.g. fishing, or for landing spawning samples) it returns to the same position to resume the survey. Where transects are drawn over objects (islands, rigs etc.), they are carried out as close as possible to the object following the straight line. The survey transect resumes on the other side starting the straight line from as close to the object as possible. Transect end and starting points that are along the coast are guidance only. Transects are continued to as close to the shore (within the survey area) as deemed safe by the skipper. Transects on the outer edges (away from shore) are continued if fish are still present; where fish are present on echograms transect will continue for 1nmi until no more fish are observed. The start and endpoints are documented in the log.

2.2.1.3 Elemental distance sampling unit (EDSU)

The EDSU for the survey in 6aS/7b, c has varied from 1.0nmi in 2016/17 to 0.1nmi in 2018/19. The short EDSU is designed to accommodate for the dense schooling of herring that is often found in inshore areas, for example, Lough Swilly. Transects are short (< 5nmi) in this area and the high resolution of the data allows for a more resolved picture of the distribution. The EDSU is representative of the spatial distribution as well as having enough samples to make the transect mean statistically meaningful.

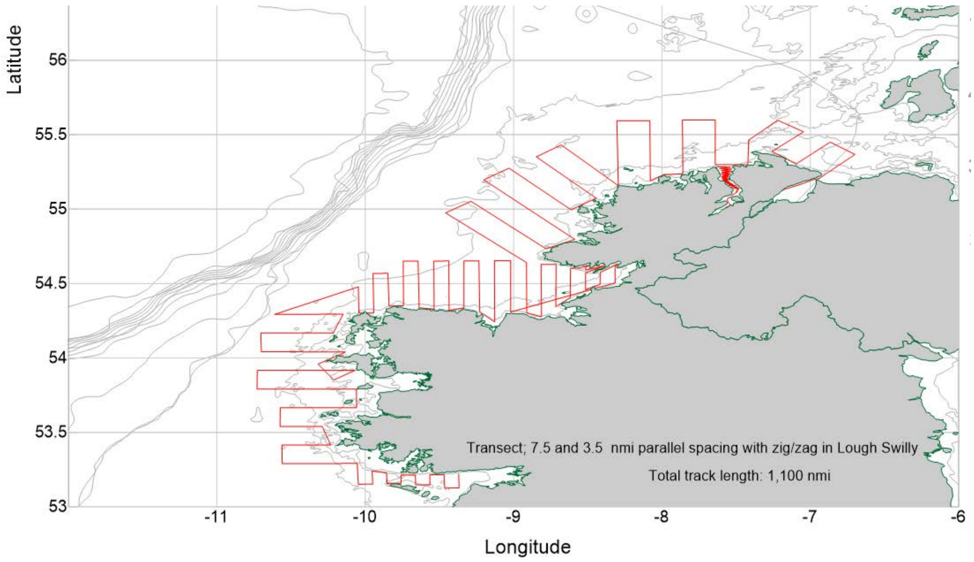

Figure 2.2.1.3.1. Acoustic survey of 6aS/7b, c. Acoustic survey area and transects for survey in 6aS/7b, c in 2019. The example transect lengths shown is 1,100nmi (start 53˚13N and 9˚22W, progress north).

Figure 2.2.1.3.2. Acoustic survey of 6aS/7b, c. Acoustic survey in 2018: StoX strata delineated for the scrutiny areas for herring (Lough Swilly, North West, Achill and Donegal Bay) in 2018. The haul samples stations in 2018 where herring were obtained for length frequency analysis are also shown as blue squares.

2.2.2 Timing

The survey objective is to cover the area in 6aS and 7b, c where herring are known to be either spawning or in pre-spawning aggregations during this time of the year. Spawning time in this area is variable, generally between October and February (Table 2.2.2.1). Survey timing has been variable in the past due to logistics, but the objective is to conduct the survey when the fish are inshore in Nov/Dec.

Horse mackerel aggregations are known to be present in this area during this time of the year also (e.g. O'Malley 2017, 2018, 2019). The survey could also be used to produce an abundance and biomass index of horse mackerel in this area.

Table 2.2.2.1: Acoustic survey of 6aS/7b, c. 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

2.2.3 Stock identification

The survey area encompasses most of the known spawning grounds in 6a/7b, c. The survey timing is such that the adult fish in the area is generally developing (pre-spawning) or spawning fish. It is therefore assumed that most of the adult fish sampled on the survey is of 6aS/7b,c origin. Work is ongoing to establish methods to accurately split herring on surveys and the fishery into 6aN and 6aS/7b,c components using genetics, body and otolith morphometrics.

2.2.4 Containment

There is generally good containment in this survey with most of the herring observed in shallow, inshore areas. There is a concern that because of the inshore distribution of herring during this time, there may be herring distributed inshore in areas too shallow to survey using current methods. Containment is not achieved for the widely distributed horse mackerel stock, however, 6aS is an important area for the horse mackerel fishery during Nov/Dec.

2.2.5 Biological catch sampling

During the acoustic survey, selected fish marks are targeted to capture fish for biological sampling using a midwater trawl. The objective is to catch enough fish for biological sampling and assign to marks with reasonable confidence.

2.2.5.1 Haul information

Haul information is recorded by the biological scientists using the standard Marine Institute haul sheet for acoustic surveys. This includes information 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.

2.2.5.2 Sorting the catch

The catch of all species is weighed, or if the catch is too large, take 2-3 baskets as a sub-sample of the catch and weighed.

- The catch is sorted into species and get the weight of the sample of each species
- Ideally, take 1-2 full baskets of herring and horse mackerel are weighed (need approx. 30kg). This subsample is used for the biological sampling

2.2.5.3 Pelagic species for sampling

Herring and horse mackerel are targeted for full sampling. The length of all the herring is measured to the nearest half centimeter (0.5cm) below. Measure the length of all the horse mackerel to the nearest centimeter (1.0 cm) below.

- 50 fish otoliths for ageing, length, weight (g), sexed, maturity stage
- 100 length/weights in addition
- Additional length frequency of up to 60 fish for the most abundant age class
- Genetic sample of the 50 herring for ageing in each sample

2.2.5.4 Other pelagics

Mackerel (1.0cm below), boarfish, blue whiting and sprat (all 0.5cm below)

- Length frequency of up to 60 fish for the most abundant age class

2.3.5.5 Additional Samples

Occasionally there are requests for other samples for full biological work up and genetic samples (e.g. herring for stock identification work)

2.3.5.6 Spawning herring samples

If hauls contain spawning herring (actually running) they may need to be landed within 24 hours for further processing at the Marine Institute. This is used as a baseline genetic sample. Approximately 120 herring per spawning haul sample is required for morphometric (SGHERWAY type) analysis. These need to be carefully laid flat, labelled inside (waterproof paper) and outside of bag and to be taken back to the laboratory for further processing. Information on label should indicate, vessel, area, date and haul number.

2.2.6 Acoustic data collection methods

Surveys are conducted on both industry and scientific survey vessels. Therefore the transducers used will depend on the vessel and whether a towed body or ship's own transducers are used. The GPTs, computer and cables are supplied by the Marine Institute.

2.2.6.1 Equipment

Tow body

- SIMRAD 38kHz scientific echosounder (EK60) with 4-sector split beam transducer
- SIMRAD 120kHz scientific echosounder (EK60) with 4-sector split beam transducer

Hull mounted

- SIMRAD 38kHz scientific echosounder (EK60) with 4-sector split beam transducer
- SIMRAD 120 or 200kHz scientific echosounder (EK60) with 4-sector split beam transducer

2.2.6.2 Calibration

Echosounder calibration is used to determine the on-axis sensitivity, the time varied gain of transceiver and equivalent beam angle of the transducer. It is essential for determining absolute fish abundance from acoustic data, and is performed before or during a survey.

2.2.6.3 Calibration procedure

The standard calibration procedure (LOBE; Simrad, 2001) involves the suspension of a sphere with known acoustic properties in the acoustic beam beneath the transducer. After a successful calibration (RMS error < 0.4; Demer at al 2015) the transducer gain and s_a correction settings (beam model) are updated on the echosounder. Positioning of the reference target in the acoustic beam is essential - prior knowledge of the transducer's position on the hull on commercial vessels speeds up the process. A complete calibration takes 6–8 hours. Ideally, calibration is carried out at a sheltered location and the water should be deep enough to allow the calibration sphere to be suspended in the far field of the transducer. Typically, calibration should be carried out with a minimum of 15 m between the transducer and the sphere.

2.2.6.4 Calibration location and time

Calibration is conducted at various locations (e.g. Killybegs pier/Killary Harbour/Lough Swilly) where the site is suitable in terms of depth and currents, etc. This occurs at some point during the survey, usually at the beginning if possible.

2.2.6.5 Survey log

Survey log sheets are used to record all transect data, including transect position, haul position and other events taking place on and off transect.

2.2.6.6 Survey hours

Survey is conducted 24 hours a day.

2.2.6.7 Survey speed

The target survey speed is 9 - 10 knots; this is reduced in poor sea state.

2.2.6.8 Echosounder settings and synchronisation

Gain settings are obtained during calibration and the beam model is updated after calibration.

- Pulse duration 1024µS
- Power (38kHz) 2000W; (120kHz) 300W; (200kHz) 300W
- Ping interval 0.33

- Sources of noise that may interfere with the signal of the scientific echosounder (e.g. other ship's sounders) are turned off when on survey transects

2.2.6.9 Data Quality

The survey objective is to get the best possible acoustic data from the instruments being used. The Chief Scientist is responsible for ensuring sufficient quality of data is recorded during the survey. If the sea state results in data being of insufficient quality, the survey is temporarily stopped and restarted again when data quality can be improved.

2.2.6.10 Data recording

A copy of the raw acoustic data is saved on external hard disks at the end of each day. Live viewing through Echoview software is arranged where possible. Sodena plotter is set up in the dry lab for scientists.

2.2.7 Data analysis

2.2.7.1 Estimating abundance and biomass indices:

Post-processing of raw acoustic data (scrutinising, cleaning and exporting) is handled at the Marine Institute for calculation of abundance indices and mapping. Abundance at age estimates is estimated using StoX software http://www.imr.no/forskning/prosjekter/stox/en

2.2.7.2 Storing the data

The acoustic and biotic files are uploaded to the ICES database for acoustic trawl surveys under the survey code 6aSPAWN http://ices.dk/marine-data/data-portals/Pages/acoustic.aspx

2.2.8 Publication and expected results

The results of the survey are intended to inform science and decision making for future catch options of the two herring stocks and horse mackerel in 6a/7b,c. In the short term, for herring, this will be achieved by deriving biomass estimates of the spawning components in 6aN and 6aS/7b, c. For the long term, the intention is to develop an acoustic survey time series that could be used for stock assessment. For horse mackerel, this is an exploratory survey time-series that is hoped may be used in horse mackerel stock assessment in the future, particularly as an index of younger ages.

2.3 Irish Sea (7a) Chartered Herring acoustic survey.

Aspect	Detail
Objective (acoustic)	Establish an acoustic time series of minimum spawning stock biomass
Time series	Ongoing: 2007-present
Platforms	A commercial pelagic vessel, using hull-mounted echosounders.
Survey design	Grid design with 4 separate strata. Design has adapted over time (relatively minor) to better meet needs
Participants	UK – Northern Ireland.
Survey References	ICES WGIPs (2019)

2.3.1 Survey objective

A ‘routine’ acoustic survey has been carried out in the Irish Sea during 1992 – present to estimate herring stock age structure and to provide an estimate of stock biomass. The survey takes place in the pre-spawning period and covers the entire of 7a North. Additionally data from temporal extended surveys series highlighted the temporal and spatial complexity of the herring distributions. Problems with the timing of the routine survey are further exacerbated by the significant interannual variation evident in the migration patterns. In an attempt to address these issues an acoustic survey focused on the main spawning period and area was developed. The design and methods are based on the routine survey but has been carried out in partnership with industry to utilise information on timing and movements of spawning herring onto the spawning grounds. The survey timing is designed to be flexible to coincide with spawning behaviour. During the survey an accurate calibration of the transducer is carried out and an estimate of the distribution, abundance and population structure of herring in the Irish Sea by echo-integration and targeted midwater trawling.

2.3.2 Survey area and sampling grid

The survey focuses on the Isle of Man coastal waters and Scottish coastal waters (Figure 2.3.2.1). The length of the transects are approximately 640 nautical miles, excluding distance covered during trawling. The Survey area represents >75% of SSB estimate during routine survey.

Acoustic sampling

Acoustic data at 38 kHz and 120 kHz are collected in 15-minute Elementary Distance Sampling Units (EDSUs) with the vessel transecting at 10 knots. Survey speed may be altered due to sea conditions to reduce disturbance of the acoustic signal. Due to the hull mounting of the transducer the sea state and weather conditions can have an effect on the quality of acoustic data collected. Conditions are deemed marginal at force 6 wind conditions, under which the survey will likely be temporarily suspended. Typically a Simrad EK-60 echosounder with hull-mounted split-beam transducer is employed, and data are logged and analysed using SonarData Echoview software, the parameter settings used during the survey are given in Table 2.3.2.1 During surveying some acoustic equipment might cause interference and should be deactivated. The acoustic system is calibrated at the commencement of the cruise using methods as defined by the hardware manufacturer. Transducer calibrations are carried out at the start of the survey and are only conducted following established methods (Foote *et al.*, 1987). Calibration results are only deemed acceptable within the guidelines issued by the hardware manufacturer. It is a requirement that calibration results for the 38 kHz transducer are reported annually. The nautical surface-area backscattering (NASC) estimates are calculated for schools, school groups and scattering layers using a threshold of -60 dB. Acoustic data are backed up every 24 hrs and scrutinised using Echoview post-processing software

On completion of calibration the vessel begins transects in NE coast of the Isle of Man (Figure 2.3.2.1; transect 1) and continues clockwise around the Isle of Man on all planned transects.

Biological sampling

Targets will be identified by mid-water trawling, both during daylight and darkness. Trawl catches will be sorted to species and length frequencies recorded in 0.5 cm length classes. Random samples of 50 herring (1+ gp) will be taken from each catch for recording of biological parameters and removal of otoliths. Random samples of 25 sprats and 25 0-gp herring per haul will be collected and frozen for extraction of otoliths on shore. Length-weight data will be collected for all fish species contributing to the catches. Biological sampling is carried out using a single pelagic midwater trawl with a vertical opening of c. 15 m. The standardized pelagic trawl operated during this survey is based. on a single vessel single pelagic midwater trawl design historically used in the herring fishery and fitted with a 20 mm codend liner to ensure the retention of small and juvenile fish. Trawl metrics are monitored using SCANMAR net monitoring suite of sensors. Net performance is determined by inspecting the measurements of the net during deployment. During trawling acoustic data are recorded along with measurements of the net position, depth, net opening, longitude and latitude to allow allocation of acoustic NASC to be validated with sampling information. No fixed trawl duration is employed during the survey with the emphasis on taking a representative sample of the targeted echotrace. Biological sampling is targeted at dominate spawning aggregations. Biological allocation to unsampled targets is supported by the trawl sampling carried out in the routine survey.

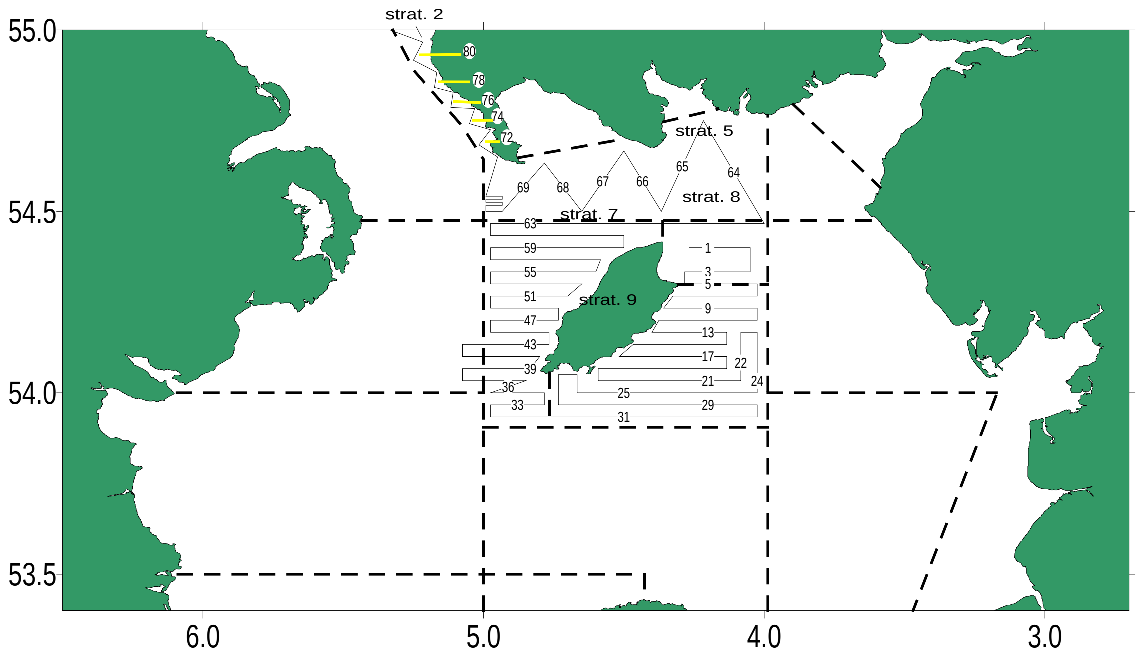

Figure 2.3.2.1: 7a herring industry-vessel chartered survey

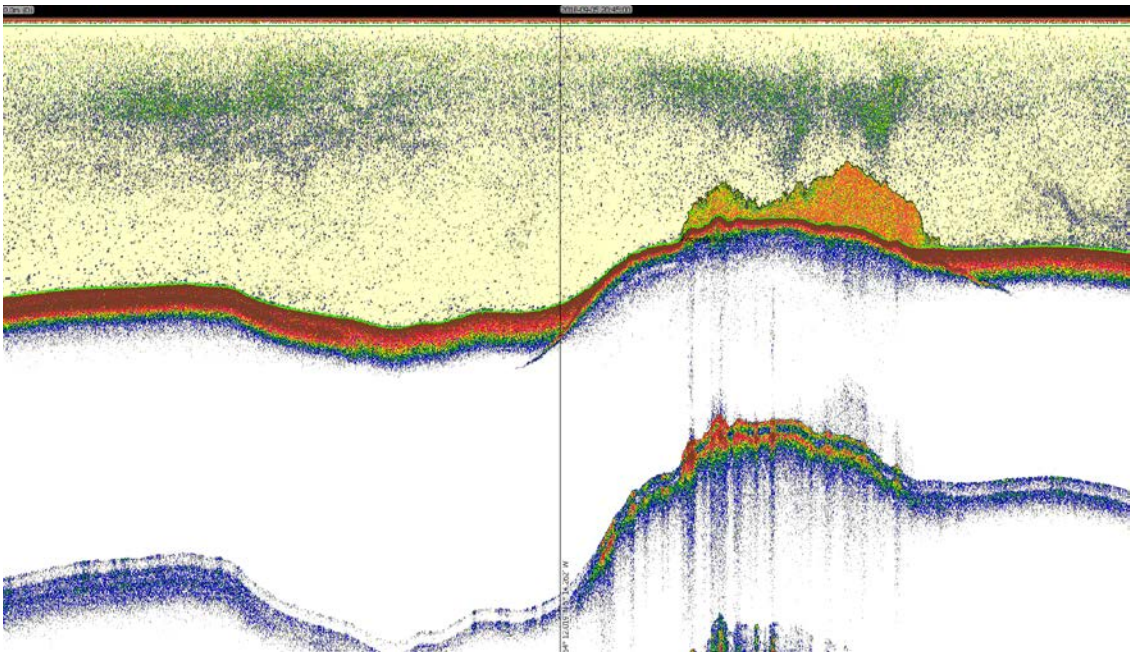

Figure 2.3.2.2. Typical spawning herring mark observed during spawning survey of 7aN

3 ToR b

3.1 6aN Herring spawning acoustic survey

3.1.1 Estimates of survey CVs

Survey CVs are estimated using StoX programme and are seen to be patchy and quite variable (Table 3.1.1.1), the main reason for this being a low number of trawl samples in some areas during some years. Efforts have been made continuously to improve this, but sometimes it has not been possible to take trawl samples for a variety of reasons including, weather, ground type, gear conflict, lack of marks.

Table 2.3.1.1. CV estimates for 6aN herring surveys

	CV on Abundance or (Biomass)			
Year/Area	**4**	**5**	**3**	**2**
2016	0.2-0.3 for ages 2-8	Not surveyed	~0.6 for ages 2-8, mainly because of low number of trawl samples	0.2-0.3 for ages 2-8
2017*	NA	Not surveyed	NA	NA
2018**	(0.68)	(0.26-0.8)	(0.39-0.61)	(0.23-0.4)
2019				

***Results of the uncertainty estimates are not available for 2017 survey due to difficulties with analyses the Stox software.**

**** In 2018 and 2019, each vessel surveyed each area so the range of CVs is given. Overall survey estimates for each vessel ranged 0.15-0.43.**

For one reason or another, there has often been challenges with getting sufficient biological samples to support scrutinization and to provide biological data for age disaggregation. This is contributing to high CVs on the survey abundance-at-age estimates. Another factor causing high CVs on the survey, particularly in the West of Hebrides (Area 4) in September, is the occurrence of very large acoustic marks associated with rocky outcroppings, the identify of which is uncertain. These have been discussed on a number of occasions during survey data workshops and at WGIPS meetings, and subsequently classified as probably herring.To try and get a definitive answer on this, dedicated camera work was undertaken in July 2019 on board FV Grateful. Results showed with a relatively high confidence that these marks are more likely to be Norway pout and juvenile gadoids (whiting mainly). However, during camera work undertaken on spawning marks in the North Sea during September 2019 (FV Unity), no herring were seen on camera, despite the vessel making a commercial catch. Thus, there remains a concern regarding the possibility of light / object avoidance. Ideally, we would have the opportunity to conduct the work again in September 2020, focusing on dense spawning marks as well as large marks on rocky ground.

Discussions at WKHASS proposed that a scrutinization workshop is carried out to share experience in identifying herring marks during the (pre) spawning period. Observations from camera work would be valuable to feed into such a workshop.

3.2 Acoustic survey in 6aS/7b,c

3.2.1 Estimation methods of indices

3.2.1.1 StoX

StoX is an open source software developed at IMR, Norway to calculate survey estimates from acoustic surveys. The input biological and acoustic .csv files to the 6aS/7b, c StoX project are extracted directly from the ICES acoustic/trawl surveys database, where the data from the survey are stored. Strata are created initially within StoX and saved in a well-known text (.wkt) format file for future use. The StoX program is a stand-alone application built in Java for easy sharing between surveys. Strata delineation, transect inclusion and haul allocation to transects are generally done using the user interface GUI with an interactive GIS module. Accessing StoX projects from R is an efficient way of processing time series or performing boot-strapping on one dataset.

3.2.1.2 Strata delineation

Ideally, each strata is defined before the survey to include all areas of known spawning and distribution of pre-spawning and spawning herring for the stock. The objective for any acoustic survey is to contain the stock within the survey area and therefore to keep the overall area and the stratas consistent between surveys. However, for the survey in 6aS/7b, c, the stratas have varied slightly, mainly because the survey has been in development. In delivering the objective to contain the stock within the bounds of the survey area, good knowledge of herring distribution for that time of year is required. Historic and current information from industry is taken into consideration. The strata currently delineated for the survey in 6aS/7b, c include all areas where inshore herring are known to spawn:

- North West (parallel transects, 7.5nmi spacing)
- Lough Swilly (zig-zag transects)
- Donegal Bay (parallel transects, 3.5nmi spacing)
- Achill ((parallel transects, 3.5nmi spacing)

It is hoped that the overall survey area and the strata will be fixed going forward with no expansion of the survey area for the purpose of herring estimation. It is sometimes necessary to conduct adaptive survey transects, within the greater survey area, which results in the creation of a new strata area. In these instances, a new strata is constructed. When these new strata are created within the survey area, this is relatively straightforward and can be included in the overall estimate provided part of the survey area is not duplicated. Transects within such strata are uniform (e.g. parallel transects at a constant transect spacing), but usually have more intense spacing. In areas like Lough Foyle, zig-zag transects are most suited because of the narrow channel.

3.2.1.3 Transects used for estimation

All on-transect recordings (per EDSU spacing) are selected in StoX for inclusion in the estimate. These include all transect recordings along the planned route, where the vessel speed is close to the target speed (9 – 10 knots). Off-transect recordings, including fishing and downtime for any other reason (e.g. inter-transects) are excluded at this stage. Parts of transects that fall outside of the strata delineation are excluded also.

3.2.1.4 Hauls allocated to transects

Hauls of herring where n ≥ 30 fish are deemed appropriate for selection. Hauls are selected as appropriate to allocate to each transect in the following order:

- Proximity to the transect (hauls on the transect line or from adjacent transects)
- Hauls with similar length frequency distribution and close proximity to the transect
- Hauls from the fishery within the survey area and obtained during the survey are used when there are no hauls from an area, also within close proximity to the transect location

3.2.2 Sensitivity to trawl and biological sampling

3.2.2.1 Exploring biological sample data from acoustic survey

The allocation of hauls to transect is a subjective process conducted by an experienced survey acoustician. Allocation of hauls to transect involves using as much information as possible to make decisions. The question of whether there are an appropriate number of samples is important to consider during the survey or at the survey design/planning stages. To investigate the precision of the samples from the survey in 6aS/7b, c a bootstrapping procedure was used to determine the number of individual samples required to meet an acceptable level of precision within the resulting catch-at-age matrix for the years 2016 - 2018. The sampling precision is calculated using a bootstrapping technique.

- N = number of available samples
- Random sample with replacement (each sample equivalent quality and carries same weight in analysis)
- Construct ALK using aged data from the bootstrapped samples
- Pass sample LF through ALK to generate numbers at age
- 1000 iterations
- Calculate a weighted CV
- N, N-1, N-2……..until N = 2

As a background, the DCF reporting structure (Commission Decision 2010/93/EU section B.B2.4) defines the level of precision for ageing as:

- 0 = 20+%
- 1 = 12.5 to 20%
- 2 = 2.5 to 12.5%
- 3 = 0 to 2.5%

A precision level of 2 (i.e. <12.5%) is the target for landings data for herring. This is not used for samples obtained during acoustic surveys, but useful as a guide.

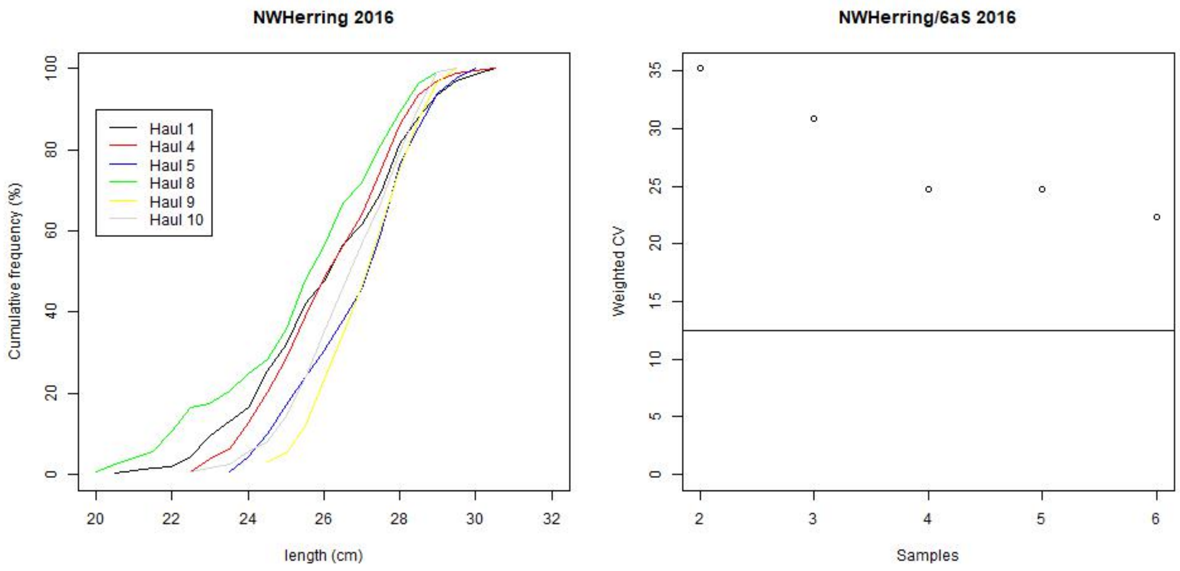

Figure 3.2.2.1.1. Acoustic survey of 6aS/7b, c. Cumulative frequency of length distributions from hauls used on the 6aS/7b, c survey in 2016 (left). Weighted CV per number of samples used in the bootstrapping procedure (right).

The cumulative frequency graph for the samples obtained during the 2016 survey show a reasonably similar distribution across the 6 samples (Figure 3.2.2.1.1). The samples show a gradual increase in the precision, reflected in the reduced CV of the biological samples to approximately 0.20 with 6 samples.

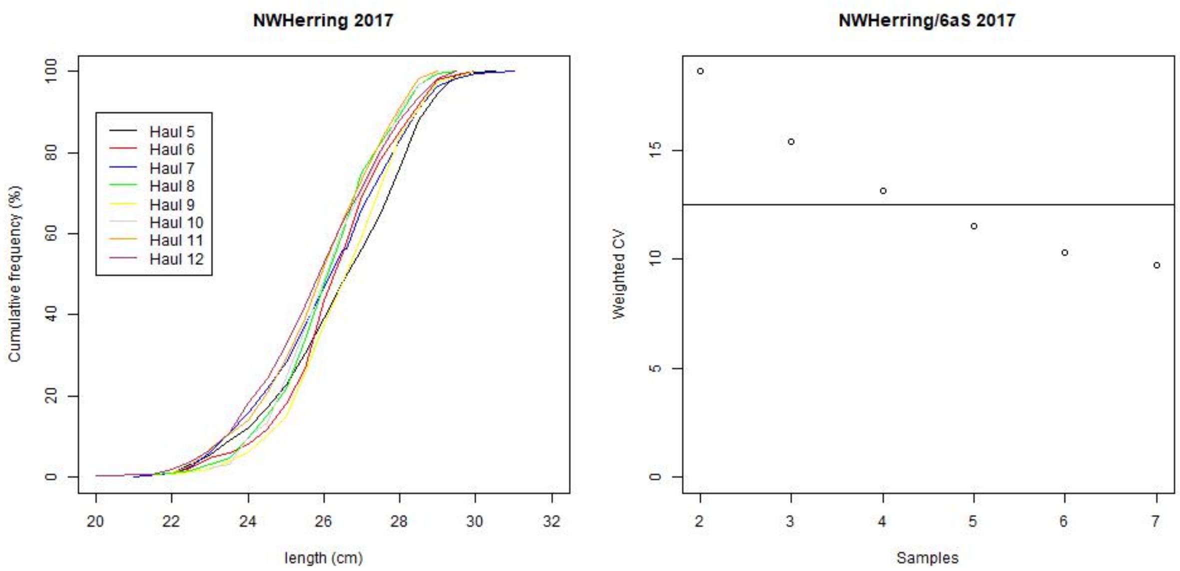

Figure 3.2.2.1.2. Acoustic survey of 6aS/7b, c. Cumulative frequency of length distributions from hauls used on the 6aS/7b, c survey in 2017 (left). Weighted CV per number of samples used in the bootstrapping procedure (right).

The cumulative frequency graph for the samples obtained during the 2017 survey show a similar distribution across the 7 samples (Figure 3.2.2.1.2). The samples show a gradual decrease in the CV of the biological samples to approximately 0.10 with 7 samples. The length distributions across all samples are similar, which is reflected in the reduced CV compared to 2016.

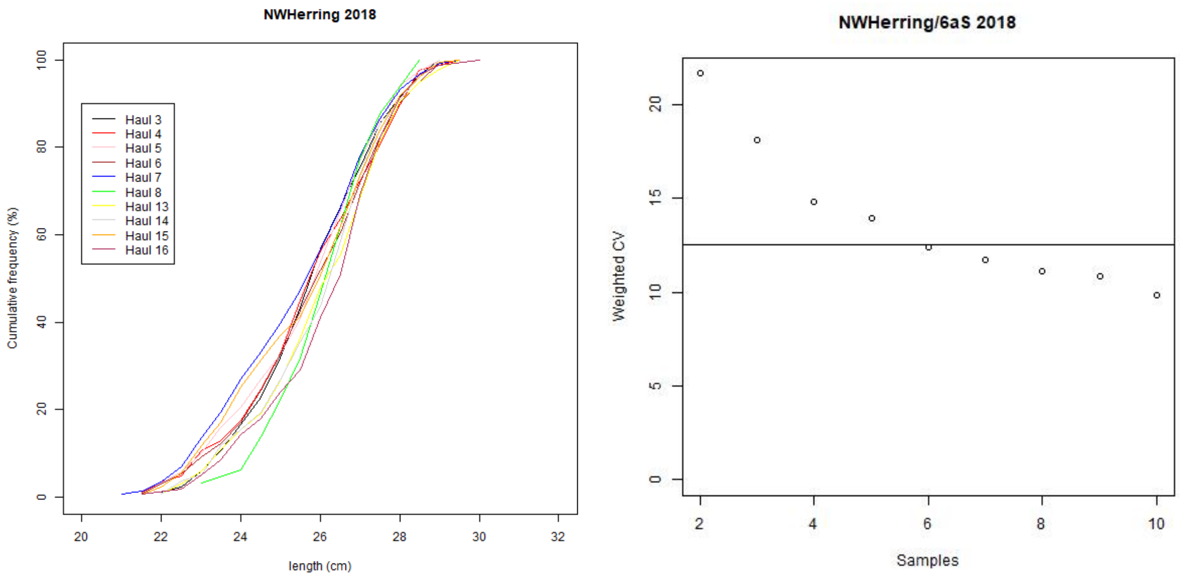

Figure 3.2.2.1.3. Acoustic survey of 6aS/7b, c. Cumulative frequency of length distributions from hauls used on the 6aS/7b, c survey in 2018 (left). Weighted CV per number of samples used in the bootstrapping procedure (right).

The cumulative frequency graph for the samples obtained during the 2018 survey show a similar distribution across the 10 samples (Figure 3.2.2.1.3). The samples show a gradual increase in the precision of the biological samples with the CV reducing to approximately 0.09 with 10 samples. The length distributions across all samples are similar, which is reflected in the good precision.

3.2.2.2 Appropriate number of biological samples

The overall precision of the samples obtained across the 3 years examined here (2016 – 2018) was good, with CV estimates generally low for the number of samples taken. This indicates that sampling is generally adequate for this survey. The cumulative frequency graphs highlights hauls that have different length and age distributions and the bootstrapping technique allows for a quick investigation into the precision on the level of sampling carried out during the survey. Good precision was achieved with relatively few hauls, particularly in 2017 and 2018. Filtering hauls with similar age/length distributions can give better precision, and it is important to be aware of the different length frequency distributions of the samples and groups of samples before allocating hauls to transect in StoX. The adequate number of hauls depends on length/age distribution, and the adequate number of fish in a sample likely depends on distribution also. This will vary for every survey.

3.2.3 Measures of uncertainty (CV)

3.2.3.1 Estimate of relative sampling error

For the baseline run StoX estimates the number of individuals by length group which can be further grouped into population characteristics such as numbers at age and sex. The user defines which trawl stations should be assigned to the individual acoustic primary samples (typically transects). In simple terms, a total length distribution of the species of interest is calculated by transect using all the trawl stations assigned to the individual transects. Conversion from s_A (by transect) to mean density by length group by stratum use the calculated length distribution and a standard target strength equation with user defined parameter values. Thereafter, the mean density by stratum is estimated by using a standard weighted mean function where each transect density is weighted by transect distance. The number of individuals by stratum is given as the product of stratum area and area density.

The bootstrap procedure to estimate the coefficient of variance follows the same principle as in the baseline run. However, for each run, transects within a stratum are selected randomly 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 described above. The output of all the runs is stored in a RData-file, which is used to calculate the relative sampling error.

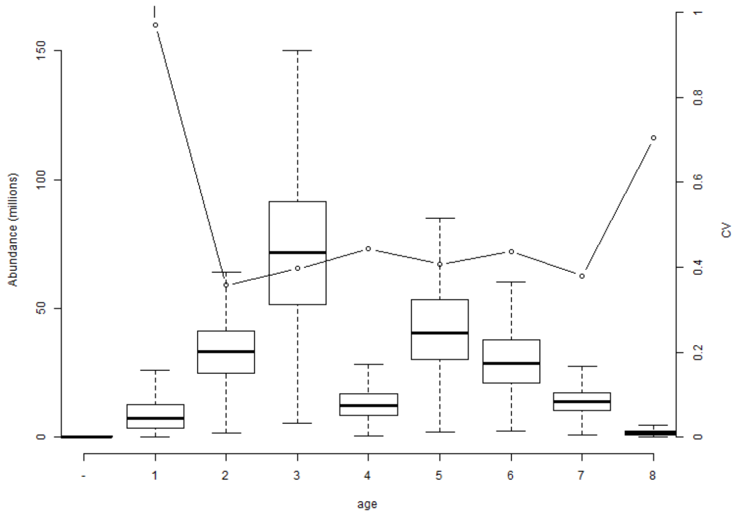

Figure 3.2.3.1.1. Acoustic survey of 6aS/7b, c. Results of the bootstrapping procedure in StoX to estimate CV by age for the acoustic survey of 6aS/7b, c in 2016. The overall CV on the abundance for the survey was 0.37 in 2016.

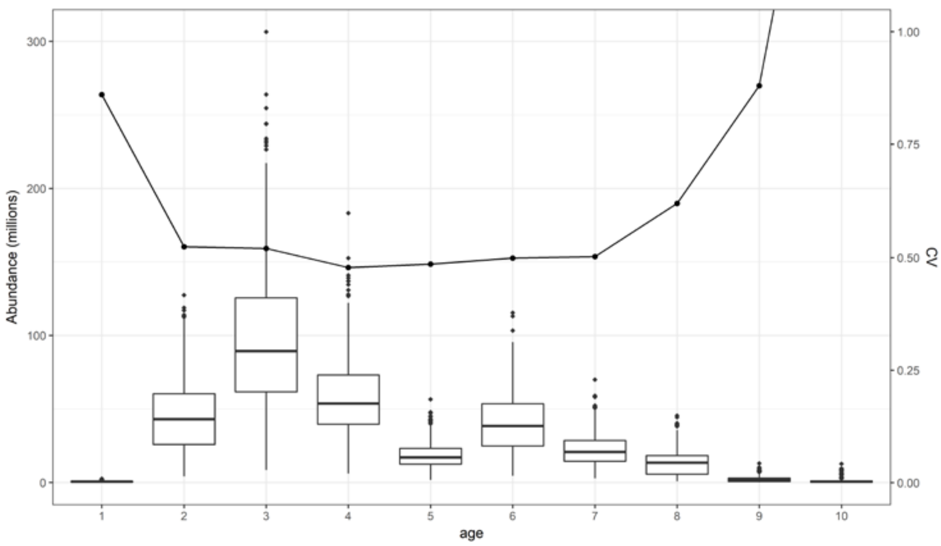

Figure 3.2.3.1.2. Acoustic survey of 6aS/7b, c. Results of the bootstrapping procedure in StoX to estimate CV by age for the acoustic survey of 6aS/7b, c in 2017. The overall CV on the abundance for the survey was 0.51 in 2017.

3.2.3.2 Results of relative sampling error (2016 – 2018)

The overall CVs on the survey abundance (2016 – 2018) are generally high (Figures 3.2.3.1.1-3). The herring stock in 6aS is currently very low, and the survey EDSUs have been recently dominated by zero sA values. The result is that many transects also have low mean sA values with some transects having relatively high sA values.

3.2.3.3 Biomass per transect

Biomass per transect was calculated using data from the StoX outputs for the surveys conducted (2016 – 2018). The differences in biomass per transect for the survey in 6aS/7b, c highlights some fundamental issues in the survey. During spawning or pre-spawning, herring tend to aggregate strongly in large marks (Figures **3.2.5.5** and **3.2.5.6**), resulting in a patchy distribution over the survey area. The result of this is many transects containing few fish, and for transects that contain fish, the contribution to the overall biomass from those transects is large. This patchy distribution contributes directly to high uncertainty (CV) in the survey overall. The survey design should alleviate the over-reliance on a low number of transects in situations when only a few transects contain fish. Increased transect intensity in a strata, or by using an adaptive design can alleviate the issue by increasing the chances of marking fish and reducing the number of transects containing low or no biomass.

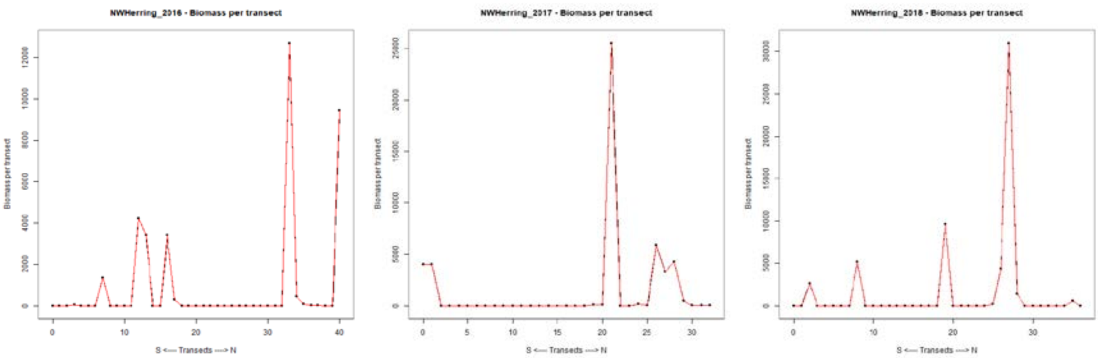

Figure 3.2.3.3.1. Acoustic survey of 6aS/7b, c. Biomass per transect for surveys (2016 – 2018).

3.2.3.4 CV and intertransect distance

The estimation of population abundance can be performed in one dimension (1D). The fish concentrations along the transect lines are estimated and a one-dimensional dataset made of fish biomass per transect is constructed (Petitgas, 1993). The variability of CV for different inter-transect distances was investigated using the ICES Handbook on Geostatistics (RGeostats package; Petitgas, 2017). The intertransect distance is varied to evaluate how survey precision changes. For each new intertransect distance, a 1D line grid is defined over the 1D domain, and the estimation variance is computed. For each intertransect distance, the geometric error variance term is also computed. The total estimation CV increases linearly with intertransect distance. Results for 2016 – 2018 is shown in Figures 3.2.3.4.1.

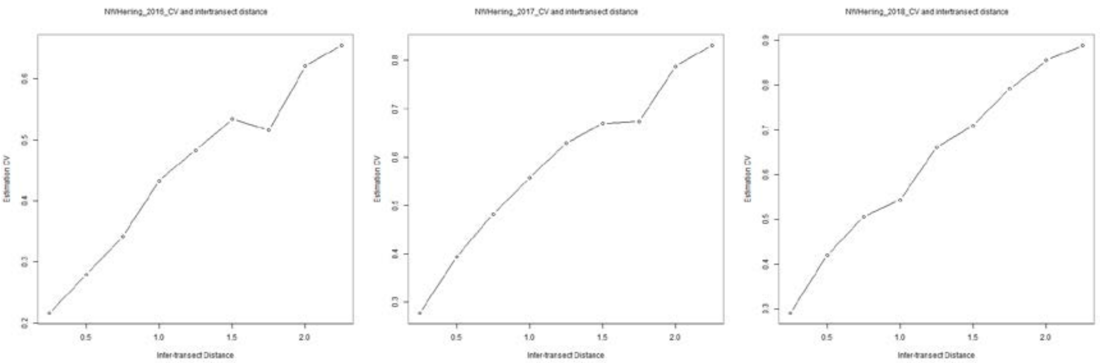

Figure 3.2.3.4.1. Acoustic survey of 6aS/7b, c. The relationship between CV and intertransect distance in the 2016 (left), 2017 (centre), and 2018 (right) surveys.

3.2.4 Variograms and kriging

3.2.4.1 Variograms

A variogram is a measure of the mean variability between any two points as a function of the distance vector between these points. Using the RGeostats package (Petitgas, 2017), variograms for the surveys 2016 – 2018 were constructed. The variograms reveal again some of the problems with this survey during its development. the variogram models resulted in a poor resolution of the data (Figure 3.2.4.1.1). The skewed data from the surveys is causing the variogram results to be poor. More transects within individual strata that contain herring and better balance between mean s_A values per transects (less highly skewed values) within a strata would improve the variogram models

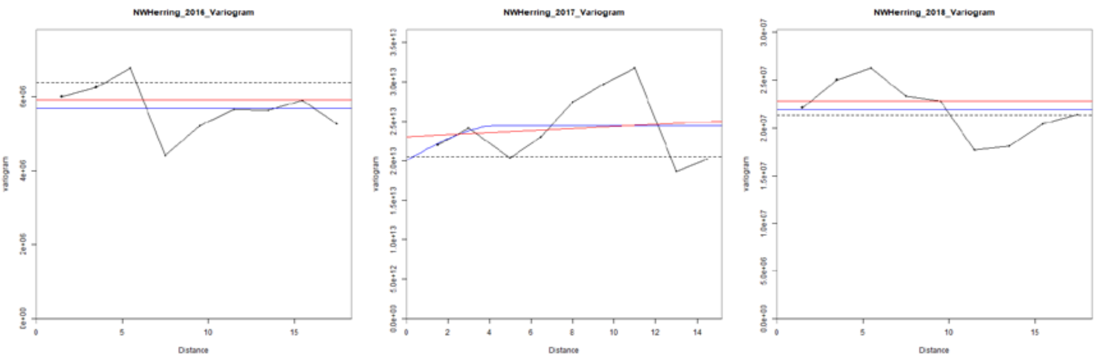

Figure 3.2.4.1.1.1. Acoustic survey of 6aS/7b, c. Variograms for the surveys conducted in 2016 (left), 2017 (centre) and 2018 (right).

3.2.4.2 Kriging

The acoustic survey of herring in 6aS/7b, c often shows high concentration values. This is evident from the kriging results (Figure 3.2.4.2.1) The topcut model provides a valuable substitute to linear kriging in the case of a skewed distribution with a few high values (RGeostats package; Petitgas *et al.*, 2017). The histogram of fish density is invariably skewed for this survey, and there are a small number of high values that can make statistics not robust. Structural analysis and mapping of the variable Z may be improved using the topcut model at a threshold z (Rivoirard *et al.*, 2013). The topcut threshold chosen was 150 t nmi^2. The topcut model constrains the estimation of the high values in areas where the probability is high for these to occur because of cokriging. In contrast, in ordinary kriging, where this constraint is not considered, the rich data values influence the estimate around them.

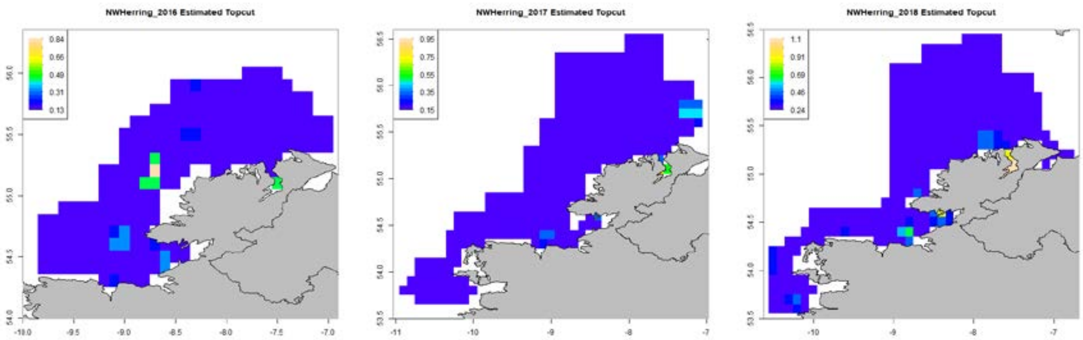

Figure 3.2.4.2.1. Acoustic survey of 6aS/7b, c. Variograms for the surveys conducted in 2016 (left), 2017 (centre) and 2018 (right).

3.2.5 Simulated results

To test whether increased transects and more evenly spread data between transects would improve results, data were simulated using data from Lough Swilly in 2018. The number or transects was increased from n = 4 to n = 16, and using the same data, biomass per transect were extracted from StoX.

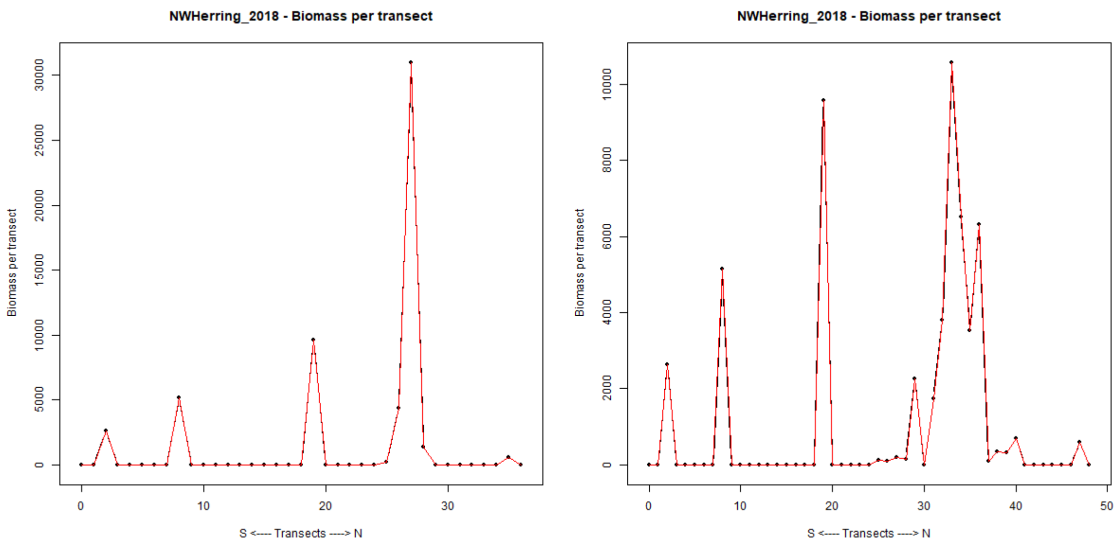

Figure 3.2.5.1. Acoustic survey of 6aS/7b, c. Biomass per transect for the entire survey when the number of transects in Lough Swilly is artificially increased, n = 4 (left), n = 16 (right).

There is a more even spread of mean sA values from individual transects resulting in reduced biomass per transect peaks (Figure 3.2.5.1).

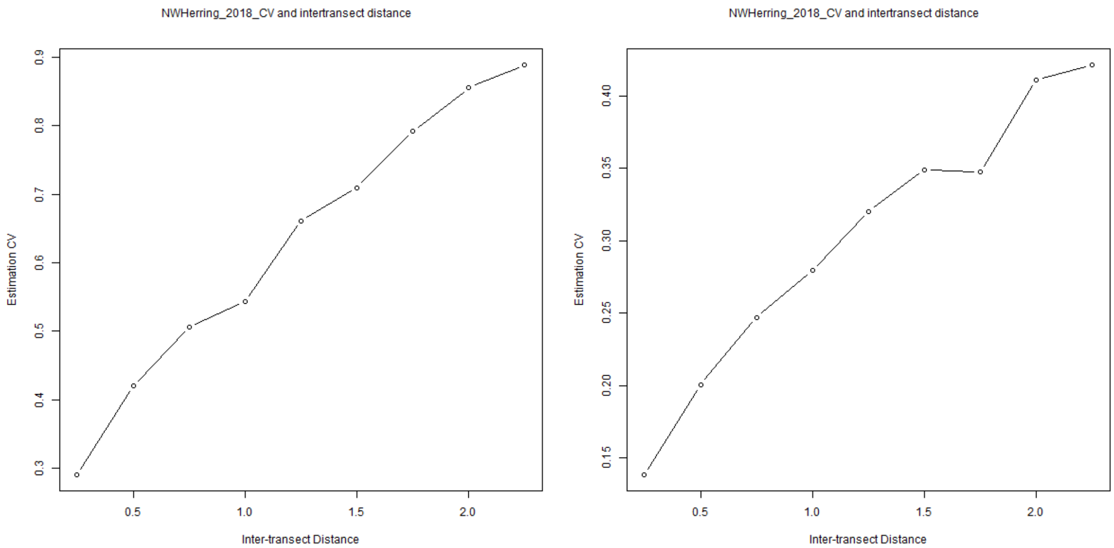

Figure 3.2.5.2. Acoustic survey of 6aS/7b, c. The relationship between CV and intertransect distance when n = 4 (left), and n = 16 (right) in Lough Swilly.

The CV is reduced when number of transects is increased in the Lough Swilly strata. A consequence of the increased number of transects is a more even spread of mean sA values from individual transects (Figure 3.2.5.2).

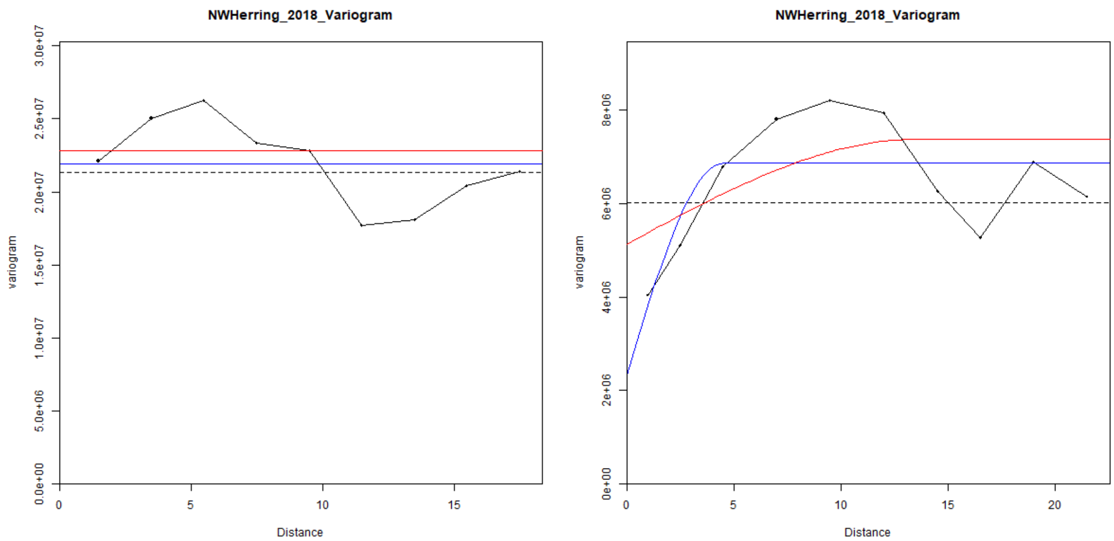

Figure 3.2.5.3. Acoustic survey of 6aS/7b, c. Variogram when n = 4 (left), and n = 16 (right) in Lough Swilly.

The variogram models are much improved when the number of transects is increased and there is a more even spread of mean sA values from individual transects (Figure 3.2.5.3).

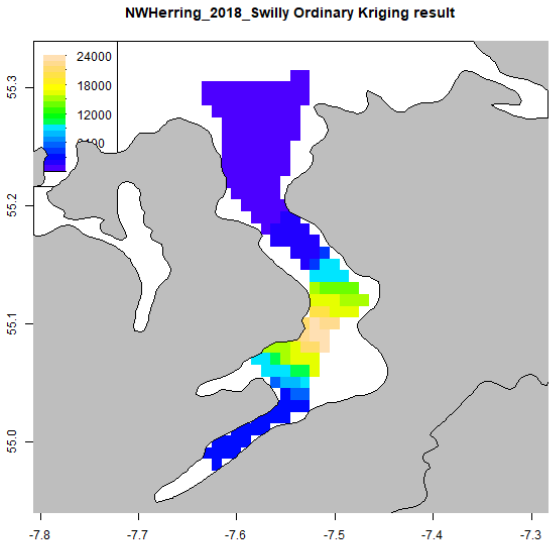

Figure 3.2.5.4. Acoustic survey of 6aS/7b, c. Results of kriging of the herring data within lough Swilly using simulated data (n = 16 transects and EDSU = 0.1nmi). A peak area of distribution is shown clearly.

Ordinary kriging results using Lough Swilly data (n = 16 transects) in 2018 show a clear peak in the distribution of herring within the lough (Figure 3.2.5.4). There are obvious issues with containment in this area because of the inshore distribution of the schools and the difficulty in designing a survey to deal with this is an on-going issue. The EDSU for this kriging was reduced to 0.1nmi to improve the resolution.

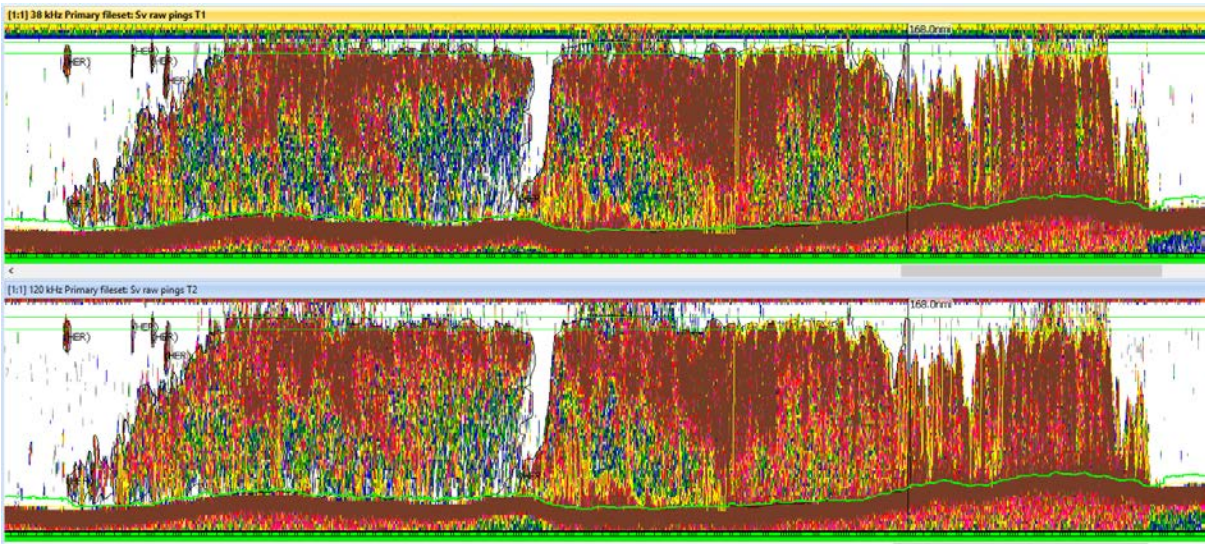

Figure 3.2.5.5. Acoustic survey of 6aS/7b, c. Very dense marks of herring in Lough Swilly in 2016.

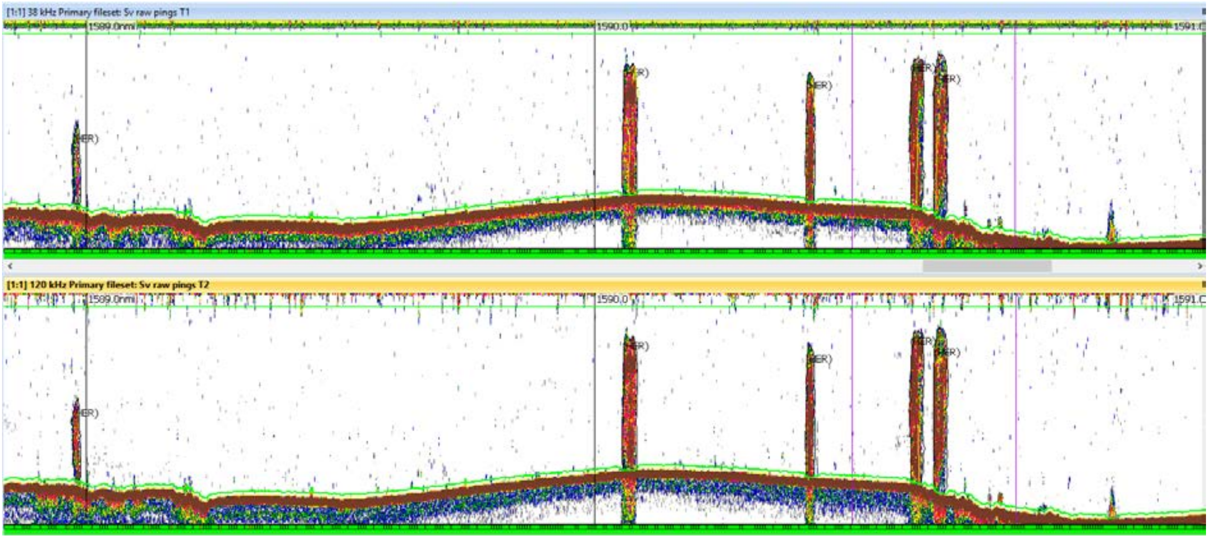

Figure 3.2.5.6. Acoustic survey of 6aS/7b, c. Dense marks of herring in Donegal Bay in 2016.

3.2.6 Future survey design

Biological precision of the number of samples taken during the survey is good, therefore this level of sampling will continue going forward for this survey. The investigations into CV, precision and variograms of the biomass estimates highlight some issues with the survey design in 2016-2018. The high CV on the estimates are not ideal and better survey deign should be developed to improve these results. More intense transect spacing would reduce the number of zero mean s_A estimates on transects. It is expected that more intense transects will be a feature of the survey design going forward, particularly in areas where high densities of herring are found inshore. Improving the CV on the abundance and biomass estimates is important, while ensuring that the stock is contained. These considerations need to be weighed up against the survey limits including time, cost, weather, and vessel availability. The herring stock in 6aS/7b, c tends to be hyper concentrated during this time (Nov/Dec) and there is good information coming from the fishery about spatial distribution which should also be considered annually. It is important that all areas where herring are known to occur are covered, and that the survey design for these areas ensures that the estimates of abundance and biomass are robust and can be used as an index in an assessment of the stock.

3.3 7a Chartered Herring acoustic survey

Targets in each 15-minute interval were allocated to species or species mixes by scrutinizing the echo charts together with acoustic records during trawling and maps of NASC values indicating location of trawls relative to school groups. In some cases, trawls with similar species and size composition are combined to give more robust estimate of population length composition. The single-species or mixed-species mean target strength (TS) is calculated from trawl data for each interval as 10 log {(Σs,l Ns,l.100.1.TSs,l) / Σs,l Ns,l } where Ns,l is the number of fish of species s in length class l. The values recommended by ICES for the parameters a and b of the length -TS relationship TS = a log (l) + b are used: a = 20 (all species); b = -71.2 (herring, sprat, horse mackerel), -84.9 (mackerel) and -67.5 (gadoids). Acoustic data should be backed up every 24 hrs and scrutinised using Echoview® (V 5) post-processing software Partitioning of data into the categories shown below is largely a subjective process back up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms. The NASC values from each region are allocated to one of five categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows: 1) Definitely herring: echotraces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echotraces directly, and on large marks which had the characteristics of “definite” herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in midwater and in the case of spawning shoals very dense aggregations in close proximity to the seabed). 2) Probably herring: attributed to smaller echotraces that had not been fished but which had the characteristic of “definite” herring traces.

Possibly herring: are attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite herring traces or similarities to historic observations. 4) Definite Clupeoid mixture: echotraces or traces were identified on the basis of capture of herring as part of a clupeoid mixture (mostly juvenile herring and sprat) from the fishing trawls which had sampled the echotraces directly, and on marks which had the characteristics of “definite Clupeoid mix” traces (i.e. scattered midwater targets inshore or normally round in shape and occurring in defined depth strata in offshore areas). 5) Probably Clupeoid mixture: attributed to smaller echotraces that had not been fished but which had the characteristic of “definite” Clupeoid mix traces. The RAW EK 60 data files are imported into Echoview for post-processing. The echograms are divided into transects using annotations and timestamps corresponding to the 15 minute survey intervals. Echotraces belonging one of the five categories above are identified visually and echo integration performed on the enclosed regions. The echograms are analysed at a threshold of -60 dB.

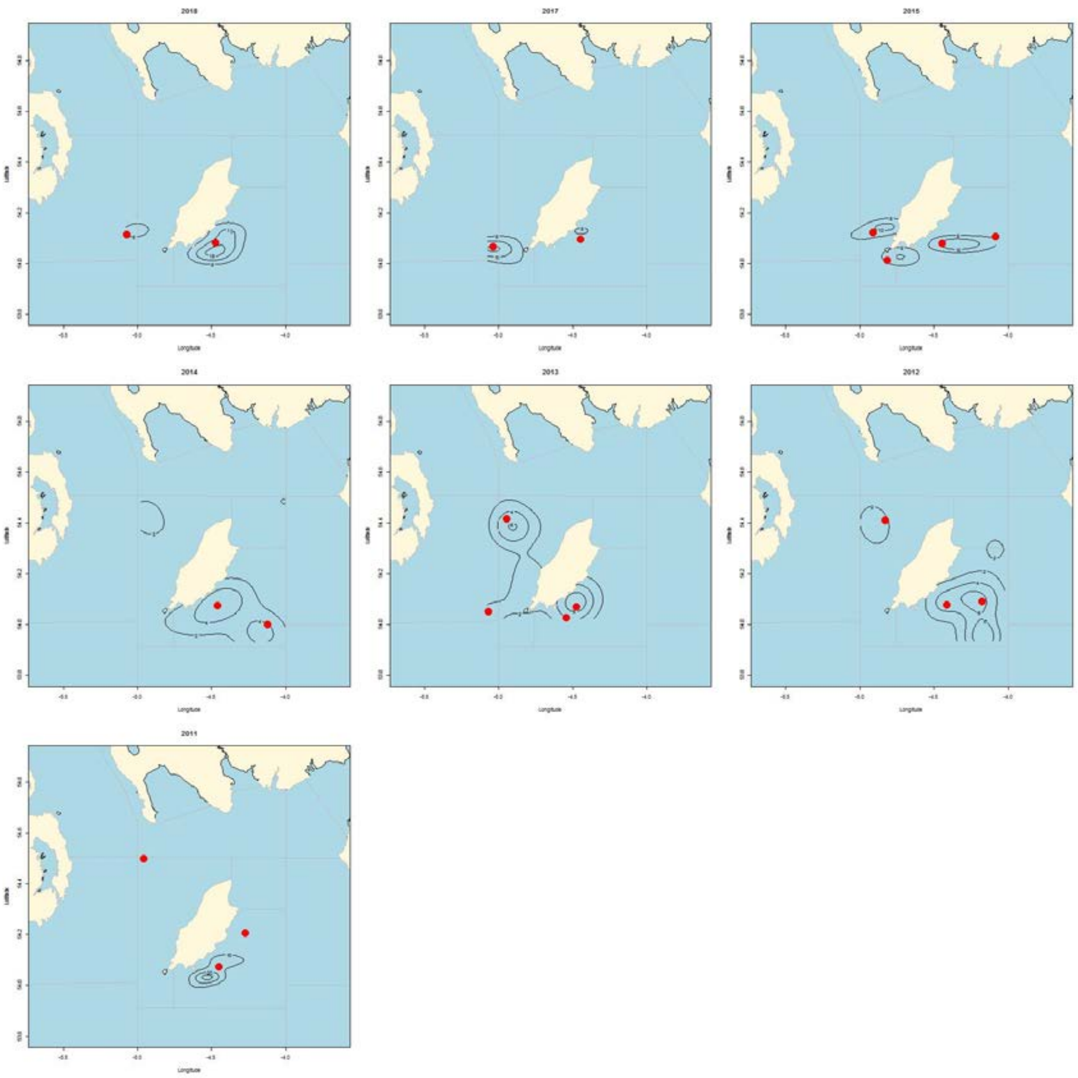

Figure 3.3.1 Kernel density analysis of herring NASC values showing the annual distribution of acoustically detected herring 2011 – 2018. The red dots sow the location of trawl samples used for biological information.

The weighted mean TS is applied to the NASC value to give numbers per square nautical mile. For herring, this is further decomposed into densities by age class according to the length frequencies in the relevant target-identification trawls and the survey age–length key. Age–length data from the commercial fishery are normally not used, in order to avoid spurious correlations between survey data and catch data in ICES assessment. Mean weights at age, calculated from length-weight parameters for the survey, and the ICES WG maturity ogives for 7a herring, are used to calculate spawning biomass of herring from the estimated numbers-at-age. The weighted mean fish density is estimated for each survey stratum using distance covered in each 15minute EDSU as weighting factors, and raised by stratum surface area. Coefficient of variation are computed for the biomass estimates based on the variation between EDSUs within strata. Variance components assume that EDSUs are statistically independent and are , the global CV is weighted by strata area.

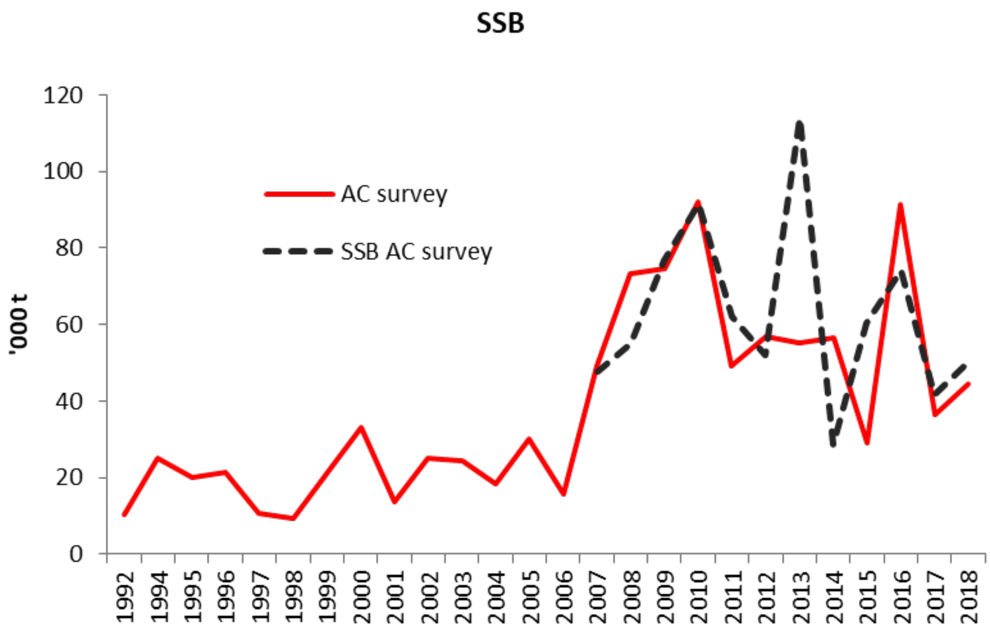

Figure 3.3.2 Comparison of Spawning Stock Biomass (SSB) estimates derived from ToR d

4 ToR c

ToRa reviewed the survey design and methods for herring spawning surveys and showed that both the 6aN and 6aS,7bc industry-led surveys are not yet in a position to be able to provide definitive survey manuals because they are still undergoing regular changes as they learn from testing different designs.

WKHASS recommends that the Irish Sea survey (7a) should be included in the SISP 9 manual for pelagic acoustic surveys

Experience from the Irish Sea spawning surveys (7a) was particularly helpful in thinking about future refinements that would help to provide a useful index of herring abundance during spawning time. Some changes are anticipated for industry survey in 6aN in 2020. The analyses of previous surveys that will be prepared for a forthcoming benchmark of 6a,7bc herring and to plan future surveys, will also take into consideration the discussion on the extent and stratification of survey areas and components of the herring stock (total mature herring and spawning ready only) to be included in the calculations of abundance indices.

The consensus of the members of WKHASS at the meeting in Vigo was that the acoustic survey in 6aS/7b,c was still in development, therefore was not yet ready to be considered as a candidate survey to be fully integrated into the WGIPS survey manual (SISP 9). The survey however will be reported on every year at WGIPS and included in the WGIPS report. There are a number of reasons why the acoustic survey in 6aS/7b, c is not fully fixed and established to the point that it could be included in the manual:

- Design changes. The design of the acoustic survey in 6aS/7b, c has changed over the period 2016 – 2019 and can still be considered a period of development for the survey. The overall area has changed slightly and there have been changes to the strata outlines and new strata added. More intense transect spacing has been used to good effect in 2019, and it is expected that this may be a feature of the survey design going forward, particularly in areas where high densities of herring are found inshore. All surveys are considered to have contained the stock, particularly off shore, however, there remains issues with the stock inshore when the schools are found in shallow water. The estimates of abundance and biomass can be considered minimum estimates from the surveys in 2016 – 2019.
- Method changes: The towed body has been used on 3 out of the 4 surveys so far (2016 – 2019), with ship’s hull mounted transducers used in 2016. Four different vessels have been used also. Calibration was not successful on the towed body in 2018 because of poor weather conditions, however it is not expected that this had a negative impact on the estimates in this year. Calibrations were successfully carried out on the hull mounted vessel in 2016, and on the towed body in 2017 and 2019 with minor updates to the beam model required on all occasions.
- Timing. The timing has shifted slightly in the years 2016 – 2019; the main reason has been the availability of vessels and other logistics to do the survey. Ideal timing is considered to be early November, however it was not always possible to get a vessel for this period.
- Funding. Funding for the survey has been uncertain, with many funding pathways used and considered. Until the survey is on a more permanent footing in terms of guaranteed ship time and funding, the negative impact on survey design, methods and timing will remain. There will be a benchmark on the assessment of the herring stock in 6a in the near future; it is hoped that this survey will be considered as a potential candidate as an index for the 6aS herring stock. If it was accepted as a useful index of the 6aS stock, then the funding would become easier to secure.

5 ToR d

Collection of acoustic data recorded from commercial vessels offers a huge and exciting possibility in terms of the spatial extent and durations of ecosystem observations, but it is not without its challenges. In the recent workshop on industry sciences initiative (WKSCINDI, ICES 2019b), Martin Pastoors and Sytse Ybema identified some of the challenges and innovations seeking to overcome them.

A major challenge in dealing with acoustic data from commercial vessels is coping with the logistics of fishing operations and the scale of the data that could be collected. The Oceanbox is designed to deal with this challenge and is designed to be a central data-hub on board of fishing vessels where different types of data could continuously be collected, processed and send to shore on a next-to-realtime basis. At the moment, it supports (broadband) Simrad echosounders, GPS sensors, catch sensors and weather stations but it can be expanded to other sensors and even forward looking sonars.

Not only is it using the latest technologies in acoustics, data processing and data infrastructure but also it takes into account the data ownership when it comes to the legal- and logistical challenges that brings along when sharing data to third parties.

The OceanBox consists of a combination of hardware and associated modular software that allows for continuous processing of sensor data. Automated procedures integrate (Simrad) acoustic data into NASC values by time-intervals and by depth layers. This summarised information, together with other sensor information is then sent to Microsoft Azure taking into account irregular and narrow satellite bandwidth and ownership of the data. From within MS Azure the data is accessible by a variety of reporting tools.

The system is currently being tested on five pelagic trawlers (including one operating in the South Pacific). Once proven successful, this system can be scaled up with relatively modest efforts to cover a substantial number of vessels in the pelagic fleet.

5.1 Additional information from 6aS/7ab Herring spawning acoustic survey.

5.1.1 Horse mackerel

Horse mackerel were widely distributed throughout the survey area in 6aS/7b, c during the surveys in 2016 – 2019 (e.g. Figure 5.1.1.1). This is also an important area for the Irish and Dutch horse mackerel fishery during this time. Although the survey does not contain the stock, indices from the survey area could still generate a useful index of abundance for this species for this area at this time.

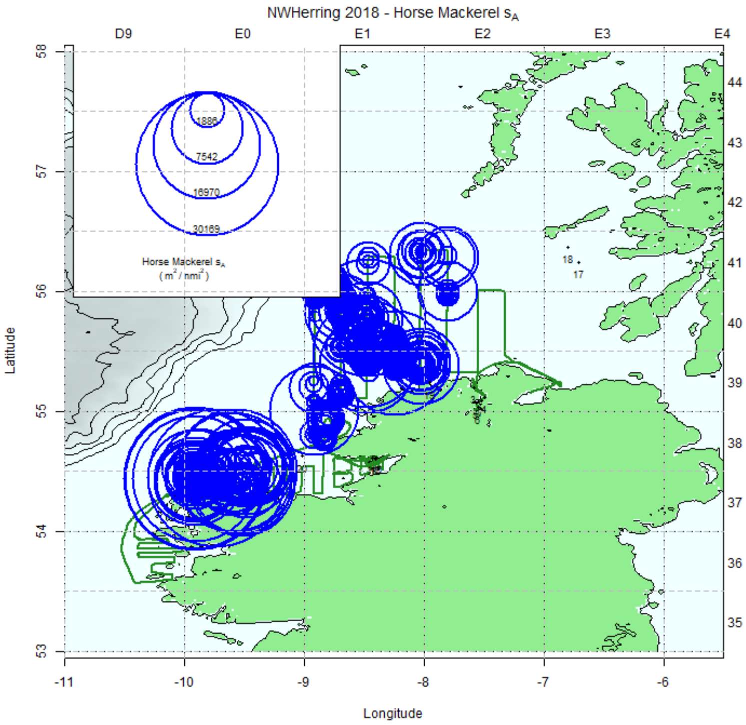

Figure 5.1.1.1. Acoustic survey in 6aS/7b, c. Distribution of horse mackerel s_A from the survey in 2018. Horse mackerel were distributed throughout the survey area.

The horse mackerel marks were widespread and easily identified during the surveys in 2016 – 2019 (e.g. Figure 5.1.1.2). The marks were also relatively easy to obtain samples from with trawling.

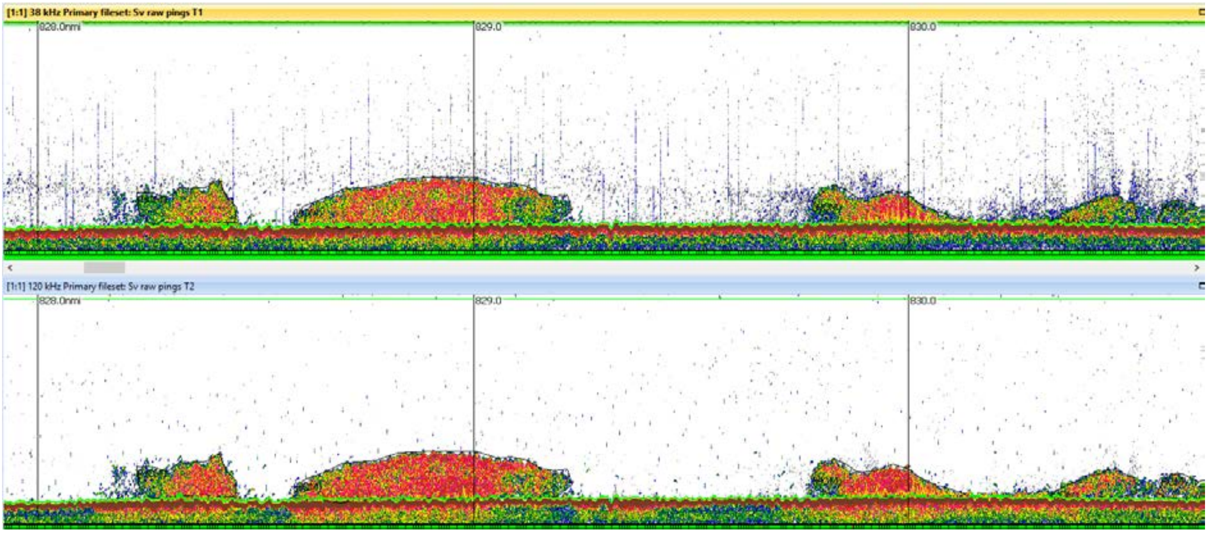

Figure 5.1.1.2. Acoustic survey in 6aS/7b, c. Horse mackerel marks on echograms from the survey in 2016.

Horse mackerel biomass was distributed across transects in 2018, with many transects containing fish, some with relatively high biomass (e.g. transect 10 in Figure 5.1.1.3).

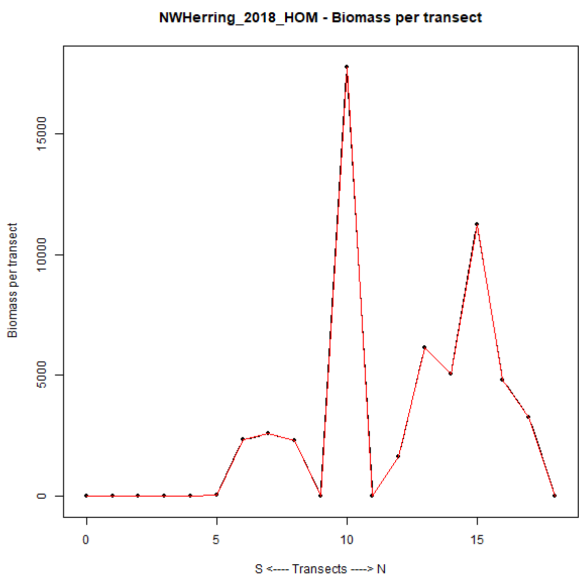

Figure 5.1.1.3. Acoustic survey in 6aS/7b, c. Horse mackerel biomass per transect in 2018.

The CV for the survey in 2018 was relatively good (0.32) and the relationship between CV and intertransect distance is within expected results for an acoustic survey (Figure 5.1.1.4).

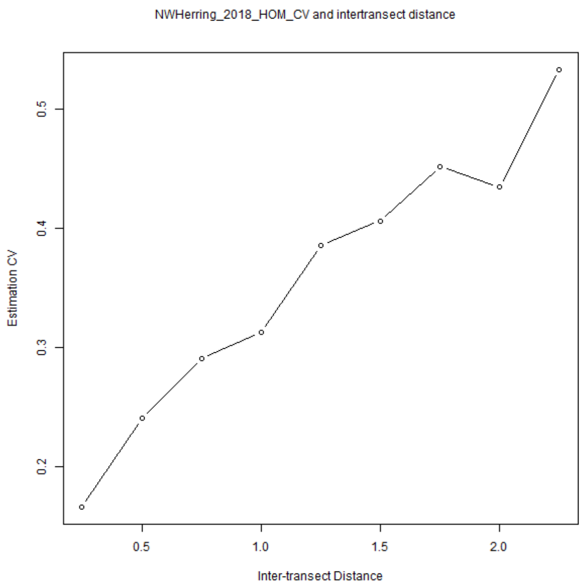

Figure 5.1.1.4. Acoustic survey in 6aS/7b, c. Relationship between CV and intertransect distance of horse mackerel from the survey in 2018.

The results from kriging using the topcut model (RGeostats package; Petitgas, 2017) show clearly the issue with containment in 2018 (Figure 5.1.1.5), with areas to the west and north containing fish on the edges of the survey area. It is not expected that this survey would contain such a widely distributed stock, however, an increase in the survey area out to the 200m contour would increase containment for this species at this time of the year.

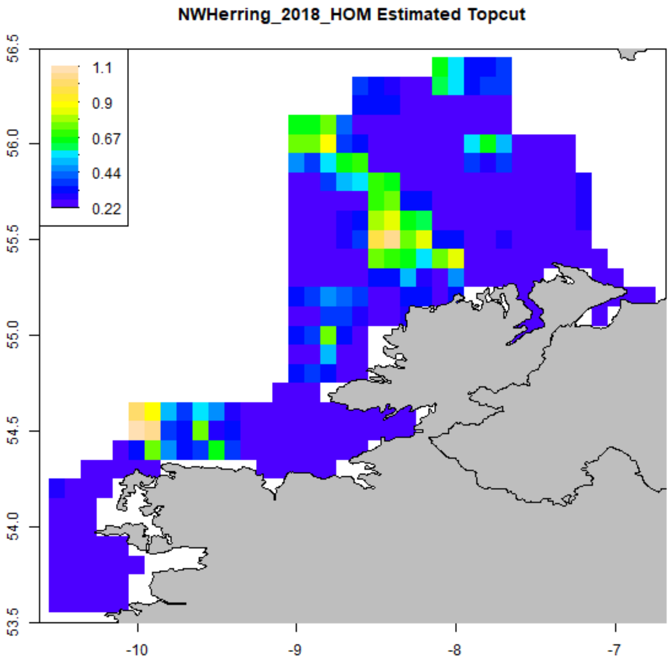

Figure 5.1.1.5. Acoustic survey in 6aS/7b, c. Estimated kriging using the topcut model of horse mackerel from the survey in 2018.

5.1.2 Sprat

Sprat were distributed in shallow water inshore in Donegal Bay in particular during the surveys in 2016 - 2019. The survey coincides with the inshore fishery for sprat in this area. There is no dedicated survey to sprat in this area, therefore this survey could be developed as an index for sprat in this area during this time.

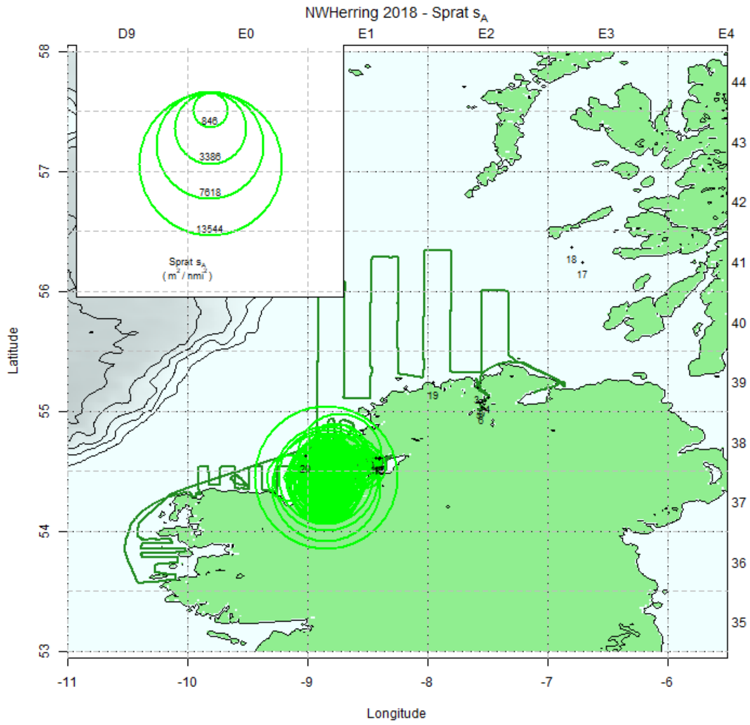

Figure 5.1.2.1. Acoustic survey in 6aS/7b, c. Distribution of sprat s_A from the survey in 2018. Sprat were distributed in a defined area in Donegal Bay.

Sprat marks were clear on the echosounder (Figure 5.1.2.2) and it is relatively easy to obtain samples using pelagic trawl.

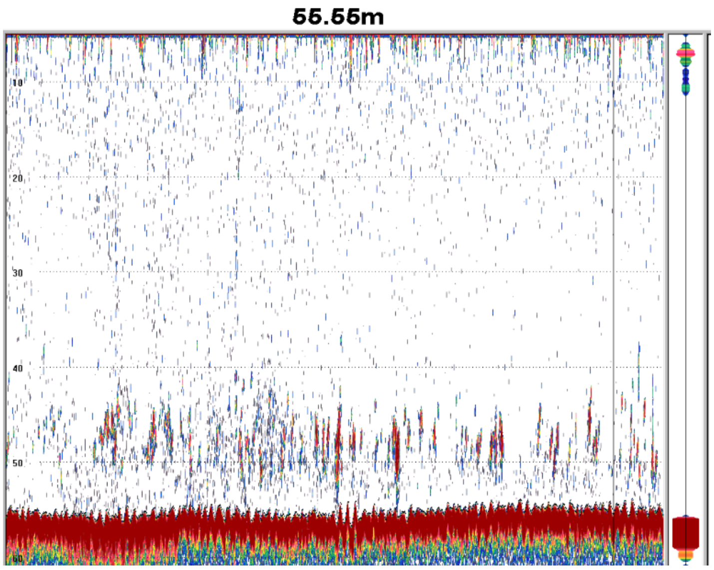

Figure 5.1.2.2. Acoustic survey in 6aS/7b, c. Sprat marks on echograms from the survey in 2018 in Donegal Bay.

5.1.3 Additional biological samples

Genetic and morphometric sampling is routinely conducted on the survey to assist with a project investigating the possibility of stock splitting through stock identification (e.g. ICES, 2010; EASME ongoing).

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Annex 1: List of participants

Name	Institute	Country (of institute)	Email
Pablo Carrera (Chair)	IEO (Spanish Institute of Oceanography)	Spain	pablo.carrera@ieo.es
Michael O´Malley	Marine Institute	Ireland	michael.omalley@marine.ie
Mathieu Lundy	Agri-food and Biosciences Institute	Northern Ireland	Mathieu.Lundy@afbini.gov.uk
Benoit Berges	Wageningen University & Research	Netherlands	Benoit.berges@wur.nl
Steven Mackinson	Scottish Pelagic Fishermen's Association	Scotland	steve.mackinson@scottishpelagic.co.uk
Steven O'Connell	Marine Scotland	Scotland	Steven.O'connell@gov.scot
Susan Mærsk Lusseau	Marine Scotland Science	Scotland	S.Lusseau@marlab.ac.uk

Annex 2: Resolution

WKHASS - Workshop on Herring Acoustic Spawning Surveys

2018/2/EOSG13 A **Workshop on Herring Acoustic Spawning Surveys (WKHASS)**, chaired by Pablo Carrera, Spain, will meet in Vigo, Spain, 15–17 October 2019 to:

a) Review survey design and acoustic data collection methods of ongoing surveys not previously reviewed by WGIPS (Irish Sea Spawning Survey and 6a Herring Industry Acoustic Spawning Surveys). The review should address survey design, timing, stock identification, containment, biological sampling and acoustic data collection methods;

b) Explore the estimation methods of indices, including sensitivity to trawl and biological sampling allocations and echogram scrutinisation. Review and document methods used to produce measures of uncertainty (CV) in abundance and biomass for the survey by strata and the overall survey area.

c) Fully document methods for inclusion in the Manual for International Pelagic Surveys (SISP 9) to ensure repeatability of the survey as reviewed, allow appropriate data quality checks and provide transparency of methodologies.

d) Consider the relevance of additional information that is collected or could be collected for ICES advisory or science products, particularly ecosystem over-views and integrated ecosystem assessments.

WKHASS will report by December 13th 2019 for the attention of ACOM, SCICOM.

Supporting information

Priority	The Irish Sea herring spawning survey has never been thoroughly reviewed by WGIPS, however, results from the survey are presented to the group annually. The survey index is currently used in the stock assessment for Irish Sea herring as an absolute estimate of abundance. There are also herring spawning surveys under development for herring in 6a in recent years that have never been thoroughly reviewed. These surveys are similar in design and objectives to the Irish Sea Spawning Survey. WGIPS requests a workshop to establish and agree on survey design and protocols for coordinating and conducting these surveys
Scientific justification	Surveys need to be designed to appropriately address issues including containment, stock identification, sampling and precision, etc. Design considerations for such surveys in general are objective dependent and may be different to survey designs currently reviewed by WGIPS. It is important that the survey design is fit for purpose and understood by WGIPS in order to review and conduct the QA-checks under the group. Scrutinisation procedures, including biological sampling and allocation of species to echotraces need to be reviewed for herring spawning acoustic surveys; procedures need to be evaluated and documented for a transparent evidence base and to ensure appropriate use in science and advice. The Manual for International Pelagic Surveys should be updated to include these surveys during this workshop. Currently there are no protocols in the manual on how to conduct these surveys.
Resource requirements	No additional resources are required from ICES. The research programmes which provide the main input to this Workshop are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this Workshop is negligible.

Participants	It is expected that this Workshop will be attended by 7-8 members of WGIPS and HAWG.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	HAWG
Linkages to other committees or groups	WGIPS, PGDATA
Linkages to other organizations	There are no obvious direct linkages to outside organisations.