VIP Report Acoustic Data Collection

"Implementation of the structural use of acoustic data from pelagic trawlers in scientific stock estimates (PelAcousticII)"

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Summary

This project describes the collection of acoustic data on pelagic freezer-trawlers during normal herring and blue whiting fishing operations over a period of three years. The progress contributed to the long term aim of utilising the potential of such data as a source of information for fisheries management. Using this method, a considerable amount of quantitative information on fish distribution and biomass could potentially be made available at negligible costs to strengthen the understanding about fish resources. In some cases, where information from research vessel surveys is absent due to lack of resources or the difficulties associated with widely distributed species, fishing vessel data could potentially become the only and most significant source of information.

Previous feasibility studies have shown that routine data collection by fishing vessels is possible, provided they are of the same or very similar quality as those collected on scientific research vessels. That means data need to be collected routinely, at the required quality, and in a standardised calibrated from. The aims of the project were therefore also primarily of a practical nature and focussed essentially on: (1) a continuation of the fishing vessel data collection started in 2012, and (2) the implementation of more independent vessel calibrations. This involved education of fishermen in independently performing calibrations aboard their own vessels. Special calibration material was built to facilitate the procedures and a training program was set up to provide guidance. If vessel crew could perform the calibrations themselves, the amount of usable information they could provide would be larger and cheaper. As these data are not collected in a systematic way, the results cannot be directly used for abundance estimation and development of more advanced analysis methods is necessary. Potential analysis methods to utilise the information for management were also explored. The project contributed to strengthening cooperation and mutual understanding between the pelagic fishing industry and scientists from relevant research institutes.

Results emphasised the need to further focus on data processing efficiency, especially if more vessels are considered. One week of fishing vessel data could be processed to extract fish density information within 8 hours by experienced scientists. Algorithms to detect fish schools and tackle data quality issues would speed up the process.
Due to lack of routine, self-calibration by vessel crew could not be achieved by all participants. Further continuation of regular (possibly assisted) calibrations on the freezer-trawlers is recommended to provide the vessel crew with more routine and confidence.
Measurement of echosounder performance by means of calibrations should be done at least once a year, preferably before the beginning of the fishing season. Additionally, “between-calibration” checks of the system is recommended.

Good correlations found in the simulation studies between relative abundance indices and true abundance for herring suggest that such an index is promising, but also that data collected from many more vessels operating simultaneously during a fishery will improve the precision of a resulting abundance index.
Use of geostatistics for analysis of fishing vessel data is highly promising due to the ability of these methods to deal with lack of structured sampling designs. Again, availability of data from many more vessels covering areas at the same time would improve such a method.

Vessel behaviour analysis in connection with acoustic fish detections can then facilitate the approach of treating the vessels as predators and infer resource abundance based on their behaviour pattern, in a similar way as previously done for marine bird foraging trips.

The methodology and guidelines developed in this project for fishing vessels could also be used to perform mini acoustic surveys with systematic survey transects. This applies especially if time to perform such surveys during fisheries is available and the resource distributed over a relatively small area.

Samenvatting

In dit project zijn akoestische gegevens op pelagische vissersschepen verzameld tijdens normale haring en blauwe wijting visserijactiviteiten gedurende een periode van drie jaar. Dit project heeft bijgedragen aan de lange termijn doelstelling van het potentieel gebruik van deze gegevens als een bron van informatie voor visserijbeheer. Met deze aanpak kan met minimale kosten een aanzienlijke hoeveelheid kwantitatieve informatie over vis distributie en biomassa ter beschikking worden gesteld om de kennis over visbestanden te versterken. In sommige gevallen waar waarnemingen van onderzoekschepen ontbreken, onder andere door gebrek aan middelen of omdat soorten wijd verspreid zijn, zal data van vissersschepen mogelijk de enige en meest belangrijke informatiebron kunnen worden.

Eerdere haalbaarheidsstudies hebben aangetoond dat routinematige gegevensverzameling door vissersschepen mogelijk is, mits ze van dezelfde of zeer vergelijkbare kwaliteit zijn als die verzameld op onderzoekschepen. Dat betekent dat dergelijke gegevens routinematig moeten worden verzameld met waarborging van de gewenste kwaliteit, en door kalibreren gestandaardiseerd moeten worden. De doelstellingen van het project waren dan ook vooral van praktische aard en voornamelijk gericht op: (1) de voortzetting van het verzamelen van data op vissersschepen begonnen in 2012, en (2) de uitvoering van meer onafhankelijke kalibraties op deze schepen. Dit behelsde de opleiding van vissers in het zelfstandig uitvoeren van kalibraties aan boord van hun eigen schepen. Speciaal kalibratiemateriaal werd gebouwd om de procedures te vergemakkelijken en een trainingsprogramma werd opgezet. Als de bemanning de kalibratieprocedures zelf kan uitvoeren, zal dat de hoeveelheid bruikbare informatie die ze kunnen leveren groter en goedkoper maken. Aangezien de gegevens niet op een systematische manier worden verzameld, kunnen de resultaten op dit moment niet direct worden gebruikt voor een bestandsschatting. Dit maakt de ontwikkeling van geavanceerde analysemethoden noodzakelijk. Potentiële analyse methoden om de informatie bruikbaar te maken voor beheer werden dan ook onderzocht. Het project heeft ook bijgedragen aan de versterking van de samenwerking en wederzijds begrip tussen de pelagische visserij en wetenschappers uit de relevante onderzoeksinstituten.

De resultaten benadrukten onder andere de noodzaak om verder te concentreren op een efficiëntere verwerking van de gegevens, met name als er meer schepen bij dataverzameling worden betrokken. Een week van vissersvaartuig gegevens kan binnen 8 uur door een ervaren akoesticus worden verwerkt om informatie over vis dichtheiden eruit te halen. Het ontwikkelen van algoritmen om scholen vis aan te tonen en datakwaliteit problemen aan te pakken zou het proces versnellen.

Voornamelijk wegens gebrek aan routine kon zelf-kalibratie door de scheepsbemanning niet door alle deelnemers worden gerealiseerd . Voortzetting van de reguliere (waar mogelijk geassisteerde) kalibraties van de echolood apparatuur op de vriestrawlers wordt aanbevolen om de bemanning van de schepen meer routine en vertrouwen te laten ontwikkelen in het op zelfstandig kalibreren.

Meting van de echolood prestaties door middel van kalibraties moeten ten minste eenmaal per jaar worden gedaan, bij voorkeur vóór het begin van het visseizoen. Bovendien wordt een "tussentijdige" controle van het systeem aanbevolen.

Goede correlaties in de simulatie studies tussen een relatieve abundantie index en de werkelijke hoeveelheid haring suggereren dat zo'n index veelbelovend is. Gegevens verzameld door nog meer vissersschepen die gelijktijdig in de zelfde visserij actief zijn, zal de precisie van een resulterende abundantie index verbeteren.

Gebruik van geostatistiek voor analyse van vissersvaartuig gegevens is veelbelovend omdat deze methoden de eigenschap hebben dat zij kunnen omgaan met het gebrek aan een gestructureerde steekproef opzet die inherent is aan het gebruik van data uit commerciële visserijactiviteiten. Ook zou de

beschikbaarheid van gegevens van veel meer schepen die tegelijkertijd gebieden afdekken de werkwijze van deze analysemethoden verbeteren.

De gecombineerde analyse van visserijgedrag in relatie tot akoestische vis detecties kan vervolgens worden gebruikt ter ondersteuning van de methodologische benadering, waarbij vissersschepen als predatoren worden gezien en visverspreiding op grond van hun gedragspatroon wordt afgeleid, op dezelfde manier als wordt toegepast bij foerageertochten van zeevogels.
De methodologie en richtlijnen ontwikkeld in dit project voor vissersvaartuigen kunnen ook worden toegepast om akoestische mini-surveys met systematische transecten uit te voeren. Dit geldt vooral als tijd beschikbaar is om dergelijke surveys tijdens het vissen uit te voeren en het visbestand over een relatief klein gebied verdeeld is.

1. Introduction

1.1. Background

The echosounder, an acoustic instrument used to detect fish schools based on reflected sound, is an essential tool in pelagic fishing. It is used by fishermen to locate fish and to help them make decisions about catch operations. Scientific pelagic surveys aimed at quantifying the biomass of a particular fish stock resource are also dependent on measuring acoustic reflections of fish using echosounders. Such dedicated scientific surveys usually only take place once a year due to practical and financial constraints. They can thus only obtain a snapshot of, for example, the size and distribution of a fish stock. The pelagic fleet on the other hand is present on the fishing grounds for a longer period of time and may provide additional information useful for scientific research over wider temporal scales.

A considerable amount of quantitative information on fish distribution and biomass could potentially be made available at negligible costs by simply recording acoustic data from these vessels during regular fishing trips. In addition to scientific monitoring surveys, such data may strengthen the understanding about fish resources. In some cases, information from research vessel surveys may even be absent due to lack of resources or the difficulties associated with widely distributed species (e.g. jack mackerel in the South Pacific). In such situations, fishing vessel data could possibly be the only and most significant source of information as a basis for management of fish stocks.

Several previous feasibility studies, including a project funded through 'Collectieve acties in de visketen', have investigated the possibilities of using acoustic data collected by pelagic trawlers to monitor fish stocks. Results from these studies show that it is feasible to use the data collected by fishing vessels, provided they are of the same or very similar quality as those collected on scientific research vessels. That means the data would need to be collected routinely, at the required quality, and in a standardised calibrated from. Data from non-calibrated equipment could not be used for quantitative purposes because they cannot be compared between different vessels.

Protocols for acoustic echosounder calibrations are well developed and frequently applied on scientific survey vessels. Nevertheless calibrations remain a somewhat complex process, in which a metal sphere (with known reflectivity properties) is put inside the acoustic beam under the ship and reflections from it measured by the echosounder. In order to make this procedure as efficient as possible on a freezer-trawler, specialised equipment and software needs to be developed. Despite the fact that fishermen are very familiar with the use of the echosounder itself, specific training and acquisition of necessary equipment will be necessary in order to execute echosounder calibrations.

The Dutch pelagic sector was particularly excited about realising this project because it fitted within their overall goal of having a more involved role in providing data for scientific research on fish stocks and the ecosystem they are part of. The industry was therefore willing to invest time and to make the necessary efforts to ensure that the quality of the data they collect would meet the required standards.

1.2. Aims of this project

The aims of the project are primarily of a practical nature and focus essentially on a continuation of the vessel data collection during the herring and blue whiting fishery started in 2012 (Brunel et al., 2013), and the implementation of more independent vessel calibrations. That entails to educate fishermen in independently performing calibrations aboard their own vessels. This will be done by building custom-made calibration material that facilitate calibration procedures; and by setting up a training program (theoretical and practical) to provide the skippers and crew with guidance (on board and/or remote) in the first period of the project. Thereafter the aim is to trial independent calibrations performed by the vessel crew.

During a previous project funded through ‘Collectieve acties in de visketen’ (Brunel et al., 2013) it was shown that calibration of echosounders on fishing vessels from the Dutch pelagic fleet, using an adaptation of standard scientific methods, was possible. In that project scientists from IMARES were on board to perform the calibrations. However, the use of scientific experts is costly and only a very limited number of ships could be calibrated. As a calibration should be performed each time the vessel changes a fishing area also meant that the collected acoustic data could only be used for a limited part of the fishing trip. The pelagic fishing industry takes an active stance with regards to the sustainability of the exploitation of resources, and the provision of the acoustic data collected during their regular fishing trips for scientific research is part of this. During the previous project it was realised that if vessel crew could perform the calibrations themselves, the amount of usable information they can provide would be much larger.

For these reasons, the current project focuses specifically on teaching fishermen how to calibrate their echosounders. If fishermen are able to independently calibrate their echosounders, their vessels will be more independent platforms for data collection. In that respect, costs associated with a potential cooperation in scientific data collection would be relatively lower. The applicability of such collected data could be diverse, ranging from input to stock size estimates, real-time species identification (which can help in preventing bycatch of unwanted species), and ecosystem monitoring (e.g. mapping of distribution areas of fish stocks or estimating zooplankton biomass). Therefore, the project aims to provide the basis so that the data quality and quantity required for these applications could be achieved. As these data are not collected in a systematic way, the results cannot be directly used for abundance estiumation and development of more advanced analysis methods. Therefore, apart from calibration focussed tasks, the project will also provide the opportunity to process the collected data and investigate potential analysis methods in order to utilise the information for management.

Apart from extending the collected data, giving fishermen the possibility to learn how to execute echosounder calibrations, and investigating how the information can be used for management, the project will contribute to strengthening cooperation and mutual understanding between the pelagic fishing industry and scientists from relevant research institutes.

1.3. Assignment

The originally proposed project contained the following specific practical tasks and activities:

Task 1: construction of calibration material
Echosounder calibration is performed by correctly positioning a metal sphere inside the acoustic beam under the keel of the ship, a few meters below the echosounder transducer. The sphere could be put in that position by hand-controlling the length of 3 lines to which the sphere is attached and suspend from 3 points on the side of the vessel. This is a rather labour-intensive method of lowering and positioning of the sphere. For this reason, a remotely-controlled prototype system was designed in a previous project to position the sphere by use of engine-controlled winches. Five more of these systems will have to be made and further developed, one for each of the ships taking part in the project.

Task 2: software development
During a calibration, the transmitted and received signal of the echosounder needs to be visualised on a computer for conducting the calibration properly, for further analysis, and estimating calibration parameters. The scientific version of the Simrad echosounder (i.e. EK60) used commonly on research vessels has a built-in calibration module in its software that is used to perform echosounder calibrations. This module is not contained in the commercial version of the echosounder (i.e. ES70) that is commonly available on the pelagic trawlers. Task 2 is focussing on developing a custom-made software module to facilitate calibrations with commercial echosounder versions that are available of the trawlers. The software remains available to the pelagic industry after completion of the project for use on different vessels in the future.

Task 3: calibration courses and practicals
Subtask 3.1: based on the experiences made during calibrations executed on pelagic vessels in a previous project in 2012, a theoretical course shall be developed. This course would consist of hands-on “dry runs” of the procedures on board when the fishing vessels are in harbour and given to relevant crew of each trawler participating in the project.
Subtask 3.2: one calibration per trawler will be done by scientists together with the crew during data collection trips on the fishing grounds. This will give a practical demonstration and aims to identify and resolve potential issues.
Subtask 3.3: after performing the first few calibrations a meeting should be organised to discuss results and possible problems.

Task 4: remote support
Trawler crew should start performing calibrations independently after completion of Task 3. Scientists will be available by phone to solve problems that may come up. After calibrations, the vessels will send a short report to the scientists in order for them to check whether the calibration process was a success.

Task 5: data storage, processing and analysis
Subtask 5.1: data will be recorded on external hard disks for every fishing trip on which calibrated acoustic data is collected.
Subtask 5.2: the data will be processed and analysed at IMARES to extract fish densities along the covered vessel tracks from the collected acoustic data. Ways to deduct useful information out of these data for comparison with scientific acoustic surveys will be explored.

All assignments were covered and completed as described except in the following cases:

Subtask 3.1: Theoretical courses were given on board the 5 trawlers selected to participate in the project at the beginning of the project period. However, due to changes in fishing patterns and vessel allocations, some of the vessels had to be exchanged and the “new” crew could therefore not participate in the whole educational process from the start.
Subtask 3.2: One calibration was performed together with the crew assisted by scientists on each participating trawler on the fishing grounds on the first data collection trips. However, as some skippers still did not feel comfortable doing their own calibrations afterwards, or because new trawlers without any previous experience had to join the project, additional assisted calibrations that were not planned had to be performed within the project. In the last project year, there were no more additional funds available for any more assisted calibrations, so data were collected and calibration values from the previous year were applied. That meant, data could only be collected in the last year from uncalibrated trawlers that had done a valid calibration in the previous year.

Subtask 3.3: Due to changes in vessels participating in the project and irregular overlaps in fishing trips between vessels it was actually impossible to have a dedicated meeting with all participating crew. Instead, feedback was taken on the different trawlers directly from the crew after individual trips.

Task 4: Sending of short calibration reports was only possible on the SCH6, which is equipped with the scientific Simrad echosounder. However, a quality check was built in the calibration software module designed for commercial echosounder versions. It gave an indication after an adequate amount of data points to estimate a calibration have been collected.

2. Materials and Methods

2.1. Data collection

Acoustic data were collected and recorded on the pelagic freezer-trawlers participating in the project during fishing trips between June 2013 and August 2015 targeting Northeast Atlantic blue whiting (*Micromesistius poutassou*) and North Sea herring (*Clupea harengus*) (Table 2.1). These fisheries were selected for a twofold reason. Firstly, in order to continue the data collection effort started on these fisheries in a previous project in 2012 (Brunel et al., 2013), hence extending the time series; and secondly, because scientific surveys existed for these stocks taking place at the time of the fishery. All the trawlers used were equipped with either the commercial Simrad ES70 or the scientific Simrad EK60 echosounders operated at 38 kHz, both of which can produce .raw output files containing the raw acoustic backscatter data. Prior to the respective fishing seasons, fleet managers were contacted to determine which of the project trawlers would be available for upcoming data collection.

During data collection trips, time- and GPS position-stamped raw acoustic data from the echosounders were recorded to external hard disks using the prescribed settings given in the calibration manual (see Appendix B). The hard disks were directly connected to the computers operating the echosounders prior to each individual fishing trip and collected after the trawlers returned to port. For operational reasons, echosounders were set to log data from the very beginning of the trip when leaving the home port until arrival back in port to prevent accidental data loss and to monitor the proper functioning of the echosounder during the whole recording period. During data collection, the prescribed echosounder settings such as pulse duration, input power and transceiver gain remained fixed.

Table 2.1. Overview of acoustic data collected by participating freezer-trawlers during the herring (red) and blue whiting (blue) fisheries in 2013-2015. Calibrations performed per trawler are given as green dots.

year:	2013							2014												2015							
month:	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
SCH24			red ●	red																							
SCH6	red	red ●		red				●				blue		red	red	red					●	blue	blue				
SCH81			red ●												red	red ●											
H171		red	red ●											red													
ROS785											blue ●	blue															
SCH72										blue		blue				●							blue	blue		red	red

2.2. Vessel calibration

Calibration of the acoustic equipment used for collection of acoustic data for scientific purposes is vital due to the following reasons:

1. to ensure correct functioning of the system,
2. to get an estimate of the stability of the recorded data, and
3. to adjust the uncompensated received signal amplitude relative to that of a reference target, and to gain insights into potential error sources in the resulting dataset.

At the start of the project, vessel crew of trawlers participating in acoustic data collection were provided with specific calibration equipment (Appendix A) and a manual (Appendix B). While vessels were in harbour, the necessary procedures were discussed and necessary instructions explained to the crew (Figure 2.1). Once out on the fishing grounds, crew members received assistance from scientists for the first calibrations (Figure 2.2). Thereafter, the plan was to have trawler crew execute calibrations of the echosounder themselves and scientists being available by phone if problems and questions arise.

For each calibration, the vessels either steamed into a sheltered bay close to the fishing grounds (e.g. SW Ireland or Scapa Flow, Scotland, UK), or remained in open water if conditions were calm, and followed the recommendations for common standard sphere calibrations of scientific split-beam echosounders (Demer et al., 2015; Simmonds and MacLennan, 2005). Calibrations were performed either directly before, during or adjacent to respective data collection fishing trips (Table 2.1). Thereby the calibration equipment created in the project were used and steps followed according to the developed manual and instruction procedures given. Each calibration was ideally performed with two spheres attached at least 3 m apart to enable verification of the measurements as well as adding additional weight to the setup to enhance the stability of the top sphere used for calibration measurements. The raw data recorded during the calibration procedure of the commercial Simrad ES70 echosounders were later replayed and visualised in the office in the calibration tool of the Simrad ER60 software (Andersen, 2001) to estimate the transceiver gain offsets. For the vessel where the EK60 system was available, the calibration was conducted completely using the ER60 software.

Figure 2.1. Impressions from an instruction and calibration procedure "dry run" session given to trawler crew in IJmuiden harbour.

Figure 2.2. Impressions from a first time calibration of the echosounder on a freezer-trawler in a sheltered location at sea close to the fishing grounds, where scientists assisted the vessel crew.

2.3. Data processing

The calibration results including updated transceiver gains and acoustic beam patterns were applied *a posteriori* during post-processing. The calibration closest in time to a particular trip was usually applied for further data analysis. Data collected by the Simrad ES70 echosounders contain an embedded systematic error component (Ryan and Kloser 2004). The error has the shape of a periodic triangular wave of approximately 1dB peak-to-peak amplitude with a period of exactly 2721 data points. Inspection of the wave showed that data points remain stable for 16 pings, after which there is a step over to the next level where the next stable group of 16 data points resides. The structure of the error wave can be identified from the transmit pulse section in the raw data header information and used as a basis for adjusting the entire echogram accordingly. A java applet ('ES60adjust') developed by scientists from the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to remove the triangular wave error (Keith et al., 2005). The wave-corrected acoustic raw data from the Simrad ES70, or the original raw data provided by the Simrad EK60 system, were post-processed and analysed using LSSS (Large Scale Survey System, marec, NO, www.marec.no). Implementation of the calibration results were applied through the KORONA module within LSSS. The resulting error-corrected and calibrated datasets were then used for scrutinising procedures, i.e. the data post-processing where acoustic volume backscatter values (s_V) of fish schools are allocated to species. The scrutinising process was based on a combination of expert judgement by scientists having covered the same areas and species with acoustic surveys, and the catch information available from trawl lists provided by the skippers.

To improve data quality before the scrutinising process, the following pre-processing steps were performed in LSSS (c.f. Korneliussen et al., 2009) (see Figure 2.3): (i) remove spike noise from other, non-synchronised acoustic instruments; (ii) replace any missing pings by interpolation; (iii) quantify the background noise, using the data in each ping; (iv) remove the noise from the dataset. After echogram scrutiny, LSSS was used to produce output reports containing mean date, time, position and acoustic area density values (Nautical Area Scattering Coefficient (NASC), sA; m2 nmi-2; MacLennan et al., 2002) at 38 kHz of the respective fish species per 1 nmi intervals along the track covered by the trawlers. The general data processing procedure used is shown in Figure 2.4.

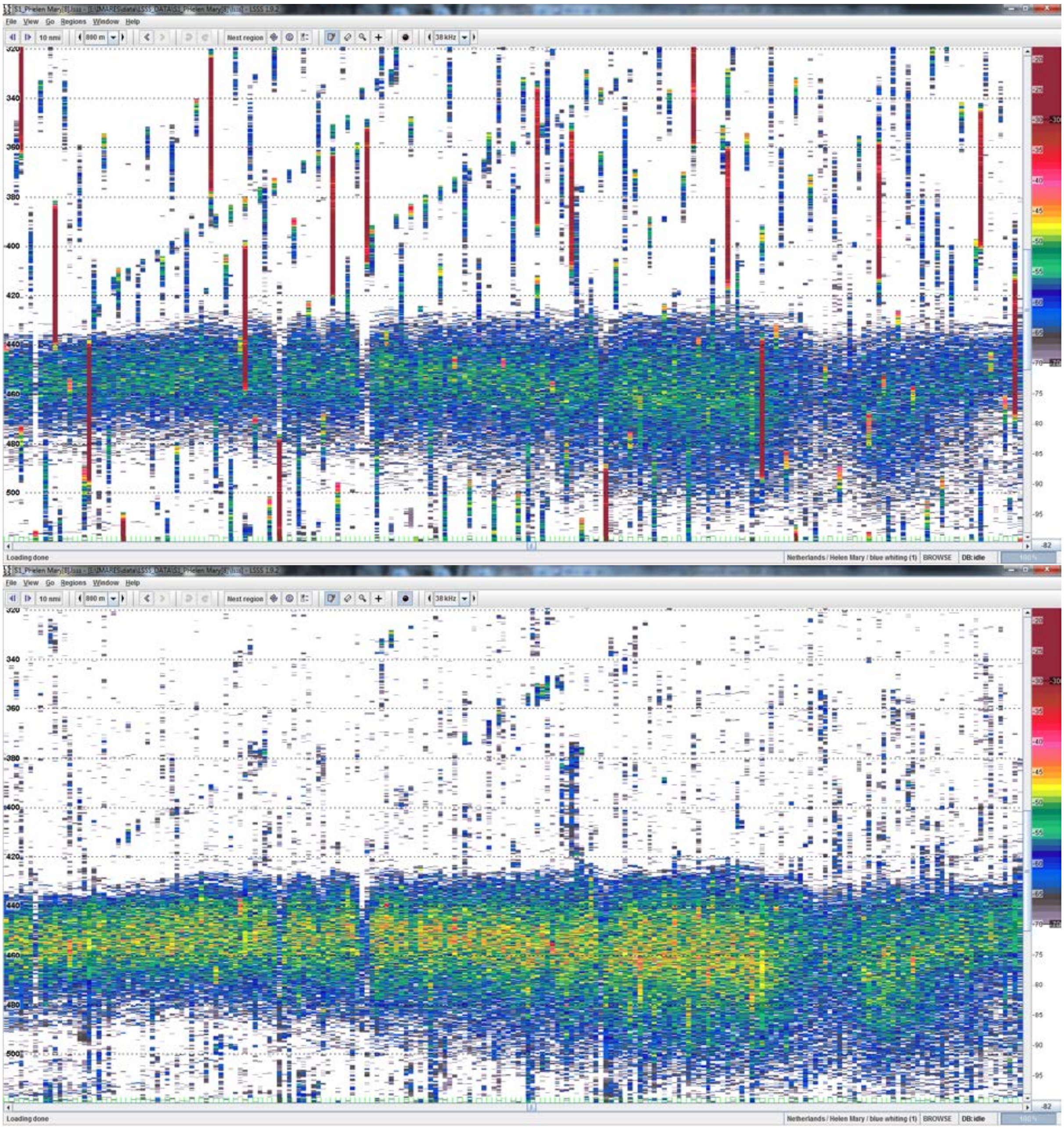

Figure 2.3. Processing example of blue whiting acoustic raw data collected on a freezer-trawler showing some extreme cases of interference noise contaminating the data. Top panel shows the uncalibrated and unprocessed raw data with strong (red-brown) noise stripes present, while the bottom panel shows the same situation after applying calibration values and data cleaning pre-processing steps.

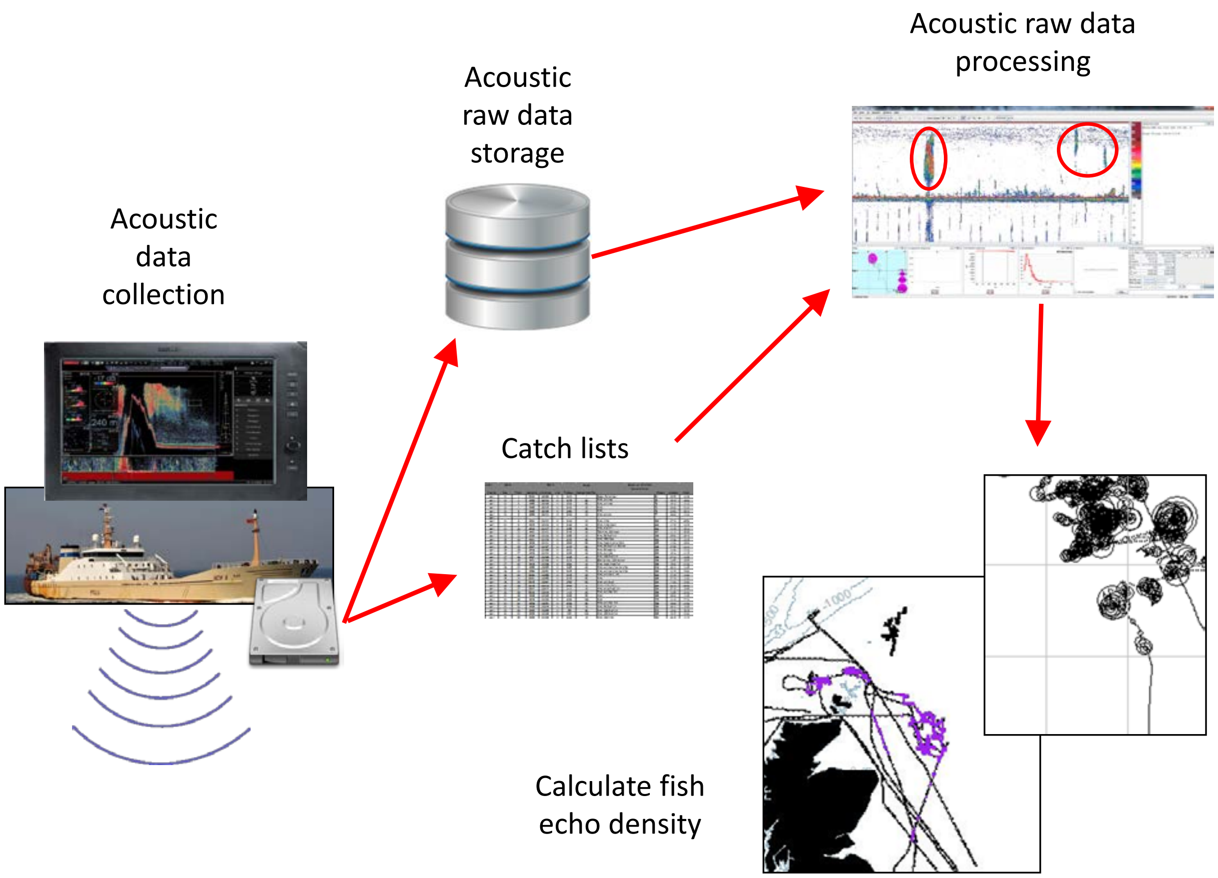

Figure 2.4. Schematic description of the data flow: collection of raw acoustic data on the freezer-trawlers during fishing trips, transfer and storage, processing, and conversion into fish densities along the vessel track.

2.4. Data storage

During fishing trips acoustic raw data were recorded and stored on external hard disks of type LaCie Rugged™ RAID with total storage capacity of 1TB. The specific type of hard disks provided additional protection against water, dust and increased mechanical movement. The storage capacity chosen was adequate to cover data volumes collected on a typical 3 week fishing trip. After completion of each trip, or in some situations several trips, the external hard disks were collected from on board and returned to IMARES where the data was transferred to local network storage devices (NAS drives). These are located in a fire-proof server room to provide additional protection against data loss. Additionally, data were backed up externally at a national Science data infrastructure.

2.5. Data analysis

The following sections provide an overview of different methods explored to further analyse the resulting fish densities along vessel tracks derived from the acoustic data collected on pelagic freezer-trawlers during their fishing activities.

2.6. Acoustic densities and vessel behaviour

In order to investigate the correlated patterns between fishing vessel behaviour and corresponding acoustic detections of fish densities, a selection of trips were processed more thoroughly to extract fish density data in combination with different vessel activities during the trip. Using the information provided by the skippers' logbooks available and experience of scientists familiar with acoustic data on herring and blue whiting, the acoustic intervals corresponding to the start and end times of a trawl haul were identified for these selected fishing trips. Only intervals between the start of the first and end of the last trawl were used. Acoustic data also contained the recorded speed of the vessels, and for every 1 nmi interval the average vessel speed was available. During data processing, intervals corresponding to stationary periods (e.g. after hauling or during catch processing) were identified based on low observed speed (below typical speeds observed during trawling: <~3 kts). Eventually, all intervals in these selected trips were allocated to three different activity periods: (1) 'stationary', corresponding to all intervals having low observed speed (<~3 kts); (2) 'fishing', corresponding to intervals within logbook recorded haul start and end times; and (3) 'searching', corresponding to intervals falling between 'fishing' and 'stationary'. Start and end times of the 1 nmi intervals were used to allocate a duration and mid-time to different intervals. The interval mid-time was equal to the time of the middle ping in each interval. As the trawl information was time referenced, the mean times of the 1 nmi fishing trip intervals were allocated to the nearest 15 minute time bin relative to the trawl start, i.e. the shooting of the trawl. Thereby, all intervals with a positive 15 minute time bin value (after trawl start) were only used if they also coincided with the activity 'fishing' of that respective trawl. By definition, negative time bins corresponded to activity 'searching' and started soonest after the end of the 'fishing' activity of the previous trawl or any subsequent 'stationary' activity. In that way, fish detection information of the recorded intervals could be related to time relative to trawling operations and compared between different trips.

2.7. Abundance indices

Three types of abundance indices, described and initiated in a similar previous project (Brunel et al., 2010 and 2013), were considered here.

- *Biomass estimate (absolute)*

First, the data collected by the fishing vessels may be treated as if it was survey data, and the same method can be used to compute absolute estimates of fish biomass. The acoustic density is averaged per ICES rectangle.

- *Average density (relative)*

Similar to a CPUE index, one can define an "acoustic detection per unit effort" index. This could be calculated by summing all the local estimates of fish density, and dividing by the total length of the track which comes down to computing the average fish density detected during the fishing trip.

- *Spatial occupation (relative, semi-quantitative)*

It was also interesting to consider which type of abundance indices could be computed in a situation where echosounders could not be calibrated. In this case, the data cannot be used quantitatively, and data collected from different vessels are not comparable. Hence acoustic data from non-calibrated echosounders only give presence-absence information. Two spatial indices were considered:

The *area* covered by the stock, represented by the total number of ICES rectangles where the fish were present.

The *surface occupation index*, computed as the proportion of the track (in nmi) covered by the vessels where fish was present. This index has been shown to be proportional to the abundance for the case of sardines in Chile (Castillo and Robotham 2004).

The values for the 4 indices were computed from the data recorded during the blue whiting and North Sea herring fishing trips collected during this project and the previous one.

2.7.1. Testing the accuracy of abundance indices using a "fisheries simulator" development

During the two previous projects, a fisheries simulator has been developed to investigate the potential use of commercial acoustic data for abundance estimation. The idea behind this approach, is to have a tool mimicking the behaviour of a fishing fleet exploiting a spatially distributed fish resource, and generating "virtual" acoustic data. The candidate abundance indices listed above can then be computed based on this data, and be compared to the abundance of fish in the model, which is known. In previous reports, simulations for the blue whiting fishery and the North Sea fishery were run, and a first investigation of the accuracy of potential abundance indices was presented. For a detailed description of the simulation see Brunel et al. (2013).
To be valid, this approach requires that the simulator is realistic enough, both in terms of fishing behaviour and in term of fish spatial distribution. Within the current project, the simulator presented in previous report was further developed to improve on those two aspects, still using the blue whiting and herring fisheries as case studies. First, the modelled distribution of herring was improved by extrapolating data from the whole North Sea herring survey (and not only the Dutch part of the survey, which covered only a limited part of the survey area as presented in the previous report). Secondly, effort was made to calibrate the simulator, i.e. set values for some of the parameters based on observations, rather than guessing them. Finally, posteriori "reality checks" were performed to compare the simulator with the reality.

<u>Herring abundance map</u>
In the same way as previously done for the blue whiting, spatial distribution maps were generated for the North Sea herring, based on interpolations from the herring acoustic survey. The survey data is first transferred to a grid of 1nmi resolution representing the North Sea. Then all the empty cells in the grid are filled by sampling from the 1nmi herring abundance values observed in the survey, using for each survey value a probability to be drawn equal to the inverse of the distance between the survey point and the grid cell to be filled. This method allows us to generate a gridded map of herring abundance in which the spatial structure observed in the survey is reproduced, and which values have a distribution similar to the survey data.
This interpolation was done for 4 different years, 2005, 2007, 2008 and 2010, selected to have a good contrast in the total herring biomass.
An example of the herring extrapolated abundance for 2005 is given in Figure 2.5 with a comparison with the original survey data.
Simulations on blue whiting were carried out on the grid map of abundances generated during the previous project (e.g. Fig 11 p29 in Brunel et al (2013)).

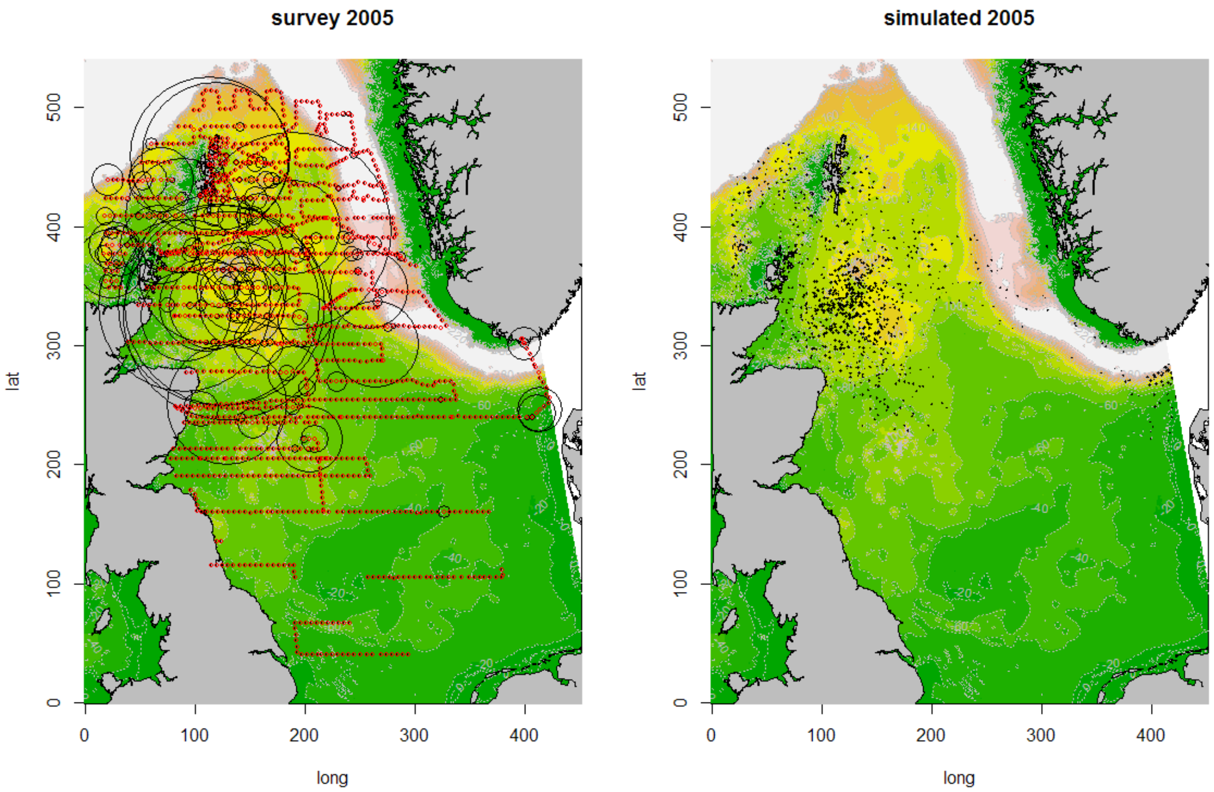

Figure 2.5. herring abundance from the 2005 acoustic survey for North Sea herring (left, survey track in red, circles proportional to the abundance) and interpolated abundance (right, black points represent the grid cell with herring) used for the simulations.

<u>Model calibration</u>

In order to give realistic values to a number of parameters in the simulator, two additional data sources where used: the acoustic data recorded during this project for a number of fishing trips, and the list of trawl haul provided by the skippers corresponding to these trips.

The list of trawl hauls was used to give a value for two parameters in the simulator: 1) the maximum catch per haul of a given species, and 2) the maximum duration of a haul. These two parameters are used in the model to decide when a vessel stops fishing and switches to the state “catch processing”.

Using the abundances estimated from the acoustic data collected during those trips, combined to the trawl haul list, two additional parameters were estimated. First, based on the analysis of the local densities observed by the vessel just before the gear is shoot (Fässler et al, 2015) it was possible to establish a threshold biomass which is used in the simulator as a criteria to decide if a vessel which sees in its sonar a fish biomass will decide to stop searching and start fishing, or will continue searching. Secondly, by identifying from the recorded acoustic data the location of each trawl haul, it is possible to compute an estimate of the biomass of fish present under the vessel during each haul. By dividing then the catch of each haul by the observed biomass, a catchability coefficient can be estimated. The mean value of this coefficient is then used in the simulation to compute the actual catch taken from the biomass present in each grid cell while fishing.

<u>Reality check</u>

Reality checks were run a posteriori, i.e. based on the output of the simulations, to compare some of the features of the simulated data with the real data available. The first comparison dealt with the resource for which tests were conducted to check that the total biomass of fish in the model was in agreement with the biomass estimated by the survey from which the modelled data was extrapolated. The frequency distribution of the modelled v.s. the observed fish densities were also compared. In order to assess the realism of the vessel behaviour in the simulator, the frequency of the changes in direction was computed, both for the simulation output and for the real fishing trip, and compared. Finally, the values of the catches per trawl haul in the model was compared with the reality.

2.8. Geostatistical modelling of fish abundance from fishing vessel data

By definition, data collected in this project did not follow any sampling design but were recorded opportunistically while trawlers performed normal fishing operations. Consequently, data can be expected to be clustered and preferentially collected since trawlers rely on historical experience, personal knowledge and technological means to find, follow and fish the densest aggregations in order to maximise economic profit. The spatial pattern of the fishing vessel observations are therefore different from those originating from systematic sampling (which are more representative of the true spatial pattern) and reveal a higher proportion of observations that are very intense. Coverage of vessels is also more repetitive on a temporal scale, but highly irregular and limited on a spatial scale (Niklitschek and Skaret, 2015). Evidently, the underlying assumptions that apply to design-based approaches to spatial resource estimation, such as those used by Jolly and Hampton (1990), are not valid. Even more liberal assumptions, such as the existence of random searching patterns (Aubry and Debouzie, 2000) are most probably violated (Niklitschek and Skaret, 2015). A possible approach that can handle spatial and temporal correlation together with the lack of a sampling design are geostatistical methods, which do not necessarily require probabilistic sampling designs.

Geostatistics can be used to model spatial structures of variables such as fish densities and then utilise that model to make predictions of variable values at given locations (e.g. from locations that were not sampled). The methods have been established and widely used for fisheries applications, such as fish survey analyses (Petitgas, 2001). Geostatistics methods were used here specifically to explore the spatial structure of the fish density data from the trawlers and attempt to combine them with data from research vessels that were synoptically collected in the same area and time in an attempt to merge two sources of information. The similarities in spatial structure between data sources were compared using cross-variograms. Eventually, the spatial datasets from the different platforms were mapped and modelled by geostatistical co-kriging (Georgakarakos and Kitsiou, 2008).

3. Results

3.1. Calibration

As part of the project, a total of 9 calibrations of the 38 kHz Simrad ES70 (commercial system) or EK60 (scientific system) installed on board the different pelagic freezer-trawlers were performed either directly before, during or adjacent to respective data collection fishing trips (Appendix C). These were the calibrations used to generate calibrated data values for further analyses in this project. Two additional calibrations were performed early in 2013 just before the project start with funding from individual fishing companies or through other projects.

An overview of relevant calibration values can be found in Tables 3.1 and 3.2. Comparison of measured transceiver gain values between calibrations collected at a particular set of echosounder settings can reveal information about system stability if there were no major changes to the hardware in the meantime (new transducer, new cable, etc.). Throughout the period of acoustic data collection projects, one trawler (SCH6) has performed several calibrations at the same echosounder settings (power & pulse duration), which allowed for an investigation of the system performance over a longer time period (Figure 3.1). The same trawler has also performed a series of three calibrations at a different set of settings.

Table 3.1. Summary of calibration results from participating freezer-trawlers throughout the project period.

Vessel	Day	Month	Year	Frequ. (kHz)	Gain (dB)	Sa Corr. (dB)	Pulse dur. (ms)	Power (W)
SCH24	15	August	2013	38	25.12	-0.61	1.024	2000
SCH6	23	February	2013	38	24.59	-0.85	0.512	2000
				70	27.37	-0.52	0.512	375
				120	26.79	-0.35	0.512	250
				200	27.05	-0.27	0.512	105
SCH6	12	July	2013	38	22.52	-0.24	0.512	2000
				70	26.18	-0.99	0.512	375
				120	24.70	-0.59	0.512	200
				200	24.80	-0.40	0.512	105
SCH6	21	January	2014	38	24.30	-0.88	0.512	2000
				70	26.91	-0.50	0.512	750
				120	26.68	-0.43	0.512	250
				200	26.69	-0.24	0.512	150
SCH6	08	February	2015	18	22.66	-0.35	2.048	2000
				38	24.58	-0.92	1.024	2000
				70	26.90	-0.17	0.512	750
				120	26.76	-0.25	0.256	250
				200	26.76	-0.14	1.024	150
SCH72	11	September	2014	38	23.29	-0.55	1.024	2000
SCH81	08	August	2013	38	26.17	-0.55	1.024	2000
SCH81	21	March	2013	38	24.67	-0.58	0.256	2000
SCH81	12	September	2014	38	26.23	-0.68	1.024	2000
H171	27	August	2013	38	26.65	-0.59	1.024	2000
ROS785	09	April	2014	38	23.86	-0.64	0.512	2000

Table 3.2. Results of calibrations of the 38 kHz transducer on freezer-trawlers participating data collection projects between 2012 and 2015. These values were used for subsequent analyses of the collected 38 kHz data.

Vessel	Day	Month	Year	Frequ. (kHz)	Gain (dB)	Sa Corr. (dB)	Pulse dur. (ms)	Power (W)
SCH24	15	August	2013	38	25.12	-0.61	1.024	2000
SCH6	10	March	2012	38	24.84	-0.60	1.024	1200
SCH6	02	August	2012	38	24.78	-0.67	1.024	2000
SCH6	23	February	2013	38	24.59	-0.85	0.512	2000
SCH6	12	July	2013	38	22.52	-0.24	0.512	2000
SCH6	21	January	2014	38	24.30	-0.88	0.512	2000
SCH6	08	February	2015	38	24.58	-0.92	1.024	2000
SCH72	11	March	2012	38	23.91	-0.54	1.024	1000
SCH72	11	September	2014	38	23.29	-0.55	1.024	2000
SCH81	23	August	2012	38	24.56	-0.52	0.256	2000
SCH81	08	August	2013	38	26.17	-0.55	1.024	2000
SCH81	21	March	2013	38	24.67	-0.58	0.256	2000
SCH81	12	September	2014	38	26.23	-0.68	1.024	2000
H171	27	August	2013	38	26.65	-0.59	1.024	2000
ROS785	09	April	2014	38	23.86	-0.64	0.512	2000

Apart from that, there was one other trawler (SCH81) with at least two different calibrations for a given settings (Figure 3.1).

The efficiency of the commonly used modern Simrad ES38B ceramic transducers, also applied in this project, is considerably higher than that of earlier nickel transducers. However, even with ceramic transducers a long-term variation of the measured transducer gain can sometimes be observed, which indicates an ageing effect, in some cases reducing the gain by 1.5 dB over five years (Knudsen, 2009). The reasons why some transducers exhibit an ageing effect while others do not, is not fully understood yet. However, it underpins the need for regular calibrations for monitoring of echosounder performance and stability. Especially in cases where vessels are in use almost continually throughout the year facing adverse weather conditions to which the transducers are exposed.

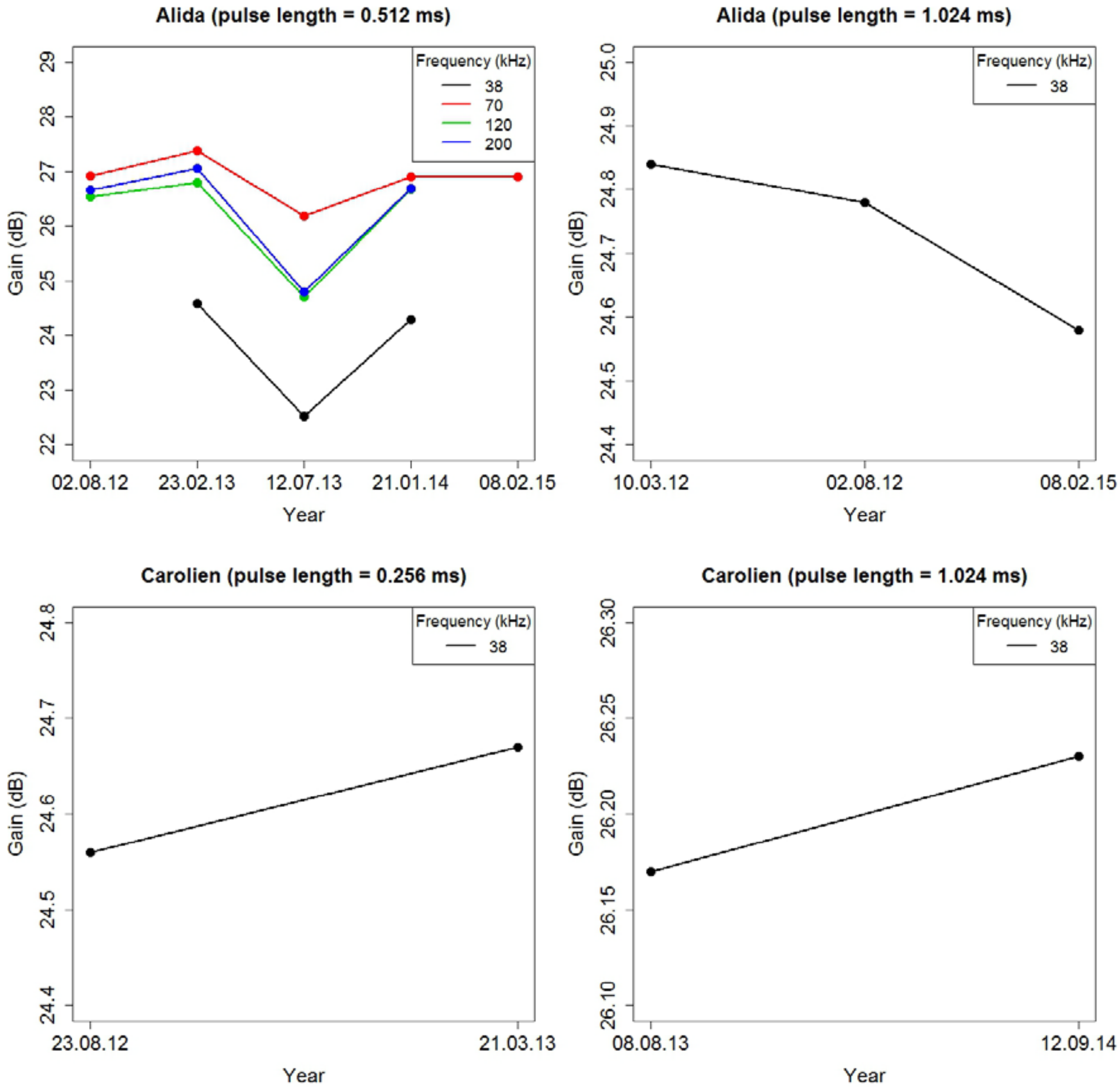

Figure 3.1. Time trends of calibrated transceiver gain values for a given set of echosounder settings (pulse duration & power) on different freezer-trawlers participating in the project.

The research vessel RV “G. O. Sars” had a drop keel installed in 1997. This made calibrations possible even in poor weather conditions, because the transducers could be lowered below the layer of wind-induced air bubbles that could cause variability in calibration values. Figure 3.2 shows a time-series of the transducer gain of the ES38B transducer on that vessel between January 1997 – November 2000 (Knudsen, 2009). The stability of calibrations improved a lot after installation of the drop keel and the variation over the time period was around 0.2 dB. In the case of freezer-trawlers, transducers are usually also at a more suitable water depth for calibration especially if the vessel is calibrated at the end of a fishing trip, when it is fully loaded with fish. Variation in observed transducer gains of freezer-trawlers, for which a time-series of calibrations at a given set of common echosounder settings (power & pulse duration) exist, were also in the range of 0.2-0.3 dB in this project (Table 3.2, Figure 3.1). However, there was one noteworthy exception: on 12.07.2013 the SCH6 performed their own self-calibration attempt at sea. While assuring that all procedures were followed correctly, extra care was taken not to lose any of the calibration spheres. The vessel crew therefore coated the sphere with an additional layer of meshing, which caused wrong calibration values.

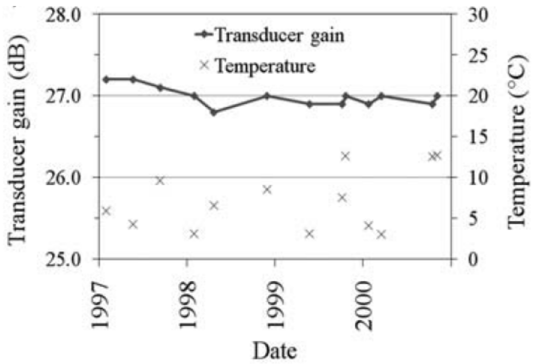

Figure 3.2. Time series of transducer gain and corresponding temperatures during calibrations on a research vessel ("G.O. Sars") over a time span of approximately 4 years. The variation of transducer gain values is <0.2 dB (source: Knudsen, 2009).

While the project successfully contributed to the delivery of suitable calibration material and instruction documents for a number of freezer-trawlers, and scientist assisted calibrations could be executed efficiently, the envisaged introduction of self-calibration routines did not work out as anticipated. Within the project, 7 out of the 9 calibrations were done with assistance from scientists, while there were only 5 assisted calibrations planned initially. Given that 5 vessels were selected and provided by the different PFA companies to participate in the project and collect data during 2 blue whiting and 3 herring fisheries, a total of 25 calibrations should have been performed if all vessels were available for data collection throughout the project. After evaluation of the data collection process and feedback from the trawler crew, a number of reasons can be mentioned for the lack of calibrations and additional need for assisted calibrations:

- Not all freezer-trawlers selected at the start of the project were available for all the fisheries used for data collection throughout the project duration.
- Given the nature of fishing operations, some of the initially selected trawlers had to be allocated to different areas/fisheries at times of the data collection fisheries in this project.
- In order to replace some of the trawlers initially thought to participate in the project but which became unavailable, new trawlers (with other crew) were brought into the project at intermediate stages.
- Calibration instructions and procedures were formally explained to vessel crew once at the beginning of the project during a dedicated "education period". If new trawlers with "inexperienced" crew had to join the project at a later stage unanticipatedly, this procedure was not repeated.

- Calibrations required the trawlers to steam to sheltered locations in an attempt to assure as calm as possible water conditions. While collection of data did not interfere with normal fishing operations, moving to calibration locations had a bigger impact on fishing operations and time was always limited.
- The intention of scientist assisted calibrations was primarily to guide crew through calibration procedures during an actual calibration. However, due to time pressure, crew was mostly involved with setting up hardware but the educational aspect usually got lower priority when it came to performing calibration data collection, which was then done by scientists.
- Not all vessels selected to participate in the project contributed during the data collection fisheries in the project. Fleet managers were requested prior to the respective fishing seasons to identify vessels that would be available for data collection. Sometimes vessels could not be named at that stage, presumably due to planning reasons, even though they were later present on the fishing grounds.
- The time between different calibrations was in some cases simply deemed too long by vessel crew for them to build up a routine and experience to execute calibrations independently. They would rather still rely on more experienced scientists to assists them or even perform the whole calibration in as little time as possible.
- In some cases, collected data were not stored on disks or lacked necessary auxiliary information important for analysis (e.g. GPS records) even though instructions were available in manuals provided. It is another aspect that may be linked to acoustic data collection not belonging to the usual year round procedures and routines done during fishing trips.
- Trawlers participating in the project did not get compensated for lost time needed for calibrations. Even though this was agreed with companies and vessel owners, it was unclear what the individual agreements about this were with vessel crew.
- Some unplanned additional assisted calibrations were performed within the available project resources, however, these were limited and therefore no additional assisted calibrations could be performed in the last year of the project. Data were then collected and calibration values from the previous year applied. That meant, data could only be collected in the last year from uncalibrated trawlers that had done a valid calibration in the previous year.

3.2. Fishing vessel data collection, processing and storage

Processing of the collected acoustic data was done for all the data collected during individual fishing trips in the project, amounting to a total of 132 days in 2013, 141 days in 2014, and 101 days in 2015. Throughout the project a wealth of experience could be developed by the analysing scientists, making processing of data, including noise cleaning, identifying, and producing acoustic density values per fish species, as efficient as possible. Individual fishing trips lasting approximately 3 weeks could on average be processed within a total effort of 24 hours. Most efficient processing was achieved by storing data from a whole trip of a particular trawler on an external hard disk and accessing it via a USB3 connection. Storage and backup of data was then done on a series of NAS drives available via network connection. An overview of the collected data can be found in Table 3.3. The amount of acoustic raw data collected on the trawlers throughout the project period was 2.2 TB.

During processing of the acoustic data, it was evident that quality issues that are common and typical for such type of fishing vessel data were present (Figure 3.3). Collected data should usually meet or exceed the quality level demanded by the project objectives. In this project, focus was primarily on the practical calibration aspects and data collection procedures, with the benefit of data collection during normal fishing operations. Effort was put in and recommendations made (Appendix B) to guarantee a high as possible data quality under the given conditions and circumstances, which was generally also achieved (Figure 3.4). Demands on data quality are higher if the objective is to eventually quantify biomass using the echo-integration method. Poor data quality can increase post-processing time greatly and may even result in failure to meet desired outcomes. Factors affecting the quality of the acoustic data collected in this project fall into the general categories: acoustical interference and sea state.

One of the most common problems encountered when collecting data from the vessels was acoustic interference from other installed echosounders and sonars. Vessels typically had a number of acoustic systems running, which normally operate independently of each other. This sometimes caused contamination of acoustic data on fish aggregations with noise spikes generated by interfering acoustic equipment operating at the same bandwidths. Even though methods were invented to limit these effects through data cleaning (see Figure 3.3), it is desirable to have as clean data as possible to prevent the need to alter raw information by means of data processing algorithms. Another, related issue concerns the existence of false seabed echoes especially during the blue whiting fisheries where water depths are more extensive. These could sometimes also cross over data from fish schools and interfere with the data.

Prevailing sea states resulting from wind-induced waves and swells can have significant impacts on the signals received by echosounders. Two factors combine to contribute to the degradation of the acoustic signal: vessel motion and air bubbles in the surface waters. When weather conditions are poor, hull-mounted echosounder transducers, such as those on the freezer-trawlers, especially when fish storage tanks are empty, are affected by aeration and noise caused by wind-generated air bubbles and bubbles trapped beneath the hull. These bubbles pass across the transducers and build a barrier between the water and the active transducer surfaces, thereby blocking transmitted and received signals for a period of time. Modern survey vessels are often equipped with protruding drop keels to limit those factors. The extent to which motion affects acoustic measurements depends on the sea state, swell, seagoing characteristics of the vessel, and target range. It is not possible to make reliable adjustments for large losses in signal. For now, the data collected in this project were not corrected for ping losses and resulting estimates may therefore be more conservative than those coming from data without ping losses. It is recommended that, whenever possible, commercial fishing vessels avoid surveying in winds greater than 10 ms^{-1} (Karp et al., 2007). An illustration of the common factors that affected data quality in this project are shown in Figure 3.3.

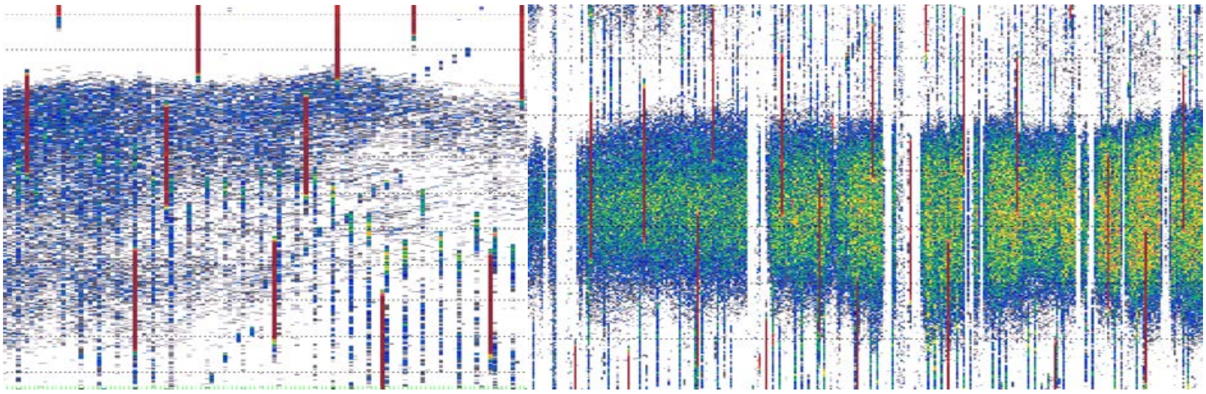

Figure 3.3. Echograms of data collected on freezer-trawlers indicating examples of some of the more extreme data quality-issue cases experienced: interference noise in the form of strong (brown) spikes is contaminating data of a blue whiting aggregation (left panel); and weather induced acoustic signal losses in the form of white stripes from pings containing no data information (right panel).

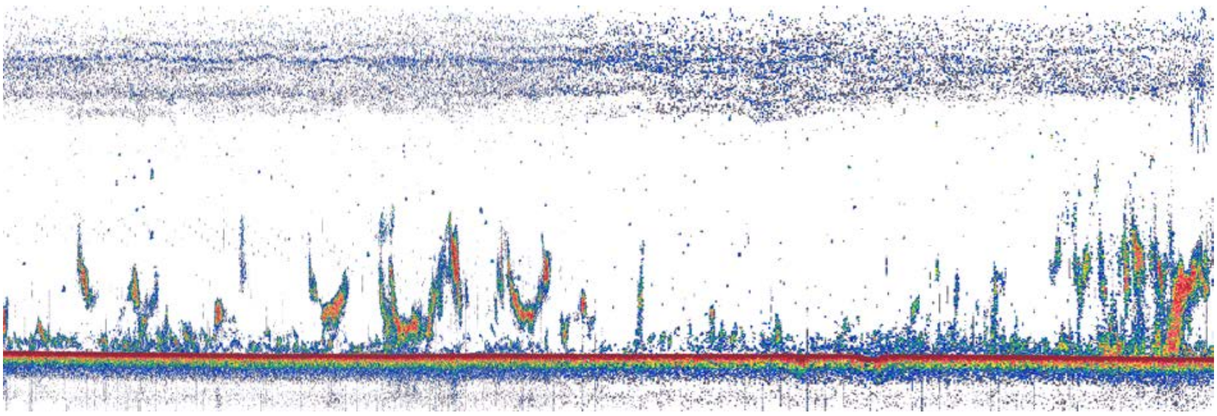

Figure 3.4. Example echogram of freezer-trawler data collected on herring aggregations in the North Sea indicating a good data quality situation.

Table 3.3. Overview of data collected on pelagic freezer-trawlers during North Sea herring (HER) and Atlantic blue whiting (WHB) fisheries between 2013 – 2015 in this project. Total amount of data =2.2TB.

Vessel	Species	Trip start	Trip stop	Nr files	Storage location (IMARES)	Size (GB)
SCH6	HER	22.06.2013	01.07.2013	236	S:\ALIDA_2013\2013\ES70\22_jun_-_14_jul_(2013)	25.8
SCH6	HER	02.07.2013	14.07.2013	492	S:\ALIDA_2013\2013\ES70\22_jun_-_14_jul_(2013)	-
SCH6	HER	17.07.2013	28.07.2013	505	S:\ALIDA_2013\2013\ES70\17_jul_-_28_jul_(2013)	14.8
SCH6	HER	06.09.2013	02.10.2013	5939	S:\ALIDA_2013\2013\ES70\6_sep_-_2_oct_(2013)	174.0
SCH81	WHB	09.03.2013	13.03.2013	313	R:\CAROLIEN\2013\EK60\corrected\9 mar - 21 mar	45.8
SCH81	WHB	13.03.2013	21.03.2013	627	R:\CAROLIEN\2013\EK60\corrected\9 mar - 21 mar	-
SCH81	HER	31.07.2013	11.08.2013	172	S:\CAROLIEN\2013\EK60\Raw	8.3
H171	WHB	06.03.2013	19.04.2013	597	R:\CORNELIS VROLIJK\2013\EK60	29.3
H171	HER	03.07.2013	03.09.2013	654	S:\CORNELIS_VROLIJK\2013\EK60\Raw	31.7
SCH24	HER	01.08.2013	19.08.2013	245	S:\AFRIKA 2013	49.5
SCH24	HER	26.08.2013	11.09.2013	215	S:\AFRIKA 2013	-
SCH24	HER	18.09.2013	27.09.2013	131	S:\AFRIKA 2013	-
SCH6	WHB	22.02.2014	13.03.2014	15231	T:\ALIDA 2014\SEAT_DATA\march\seat\data\raw	149.0
SCH6	WHB	20.03.2014	05.05.2014	22227	T:\ALIDA 2014\SEAT_DATA\april\seat\data\raw	217.0
SCH6	WHB	08.05.2014	27.05.2014	9207	T:\ALIDA 2014\SEAT_DATA\may\seat\data\raw	90.3
SCH6	HER	10.07.2014	13.07.2014	1368	T:\ALIDA 2014\SEAT_DATA\july\seat\data\raw	15.9
SCH6	HER	07.08.2014	11.09.2014	4087	T:\ALIDA 2014\SEAT_DATA\august september\seat\raw	119.0
SCH72	WHB	16.04.2014	23.04.2014	195	S:\BONEFAAS\2014\EK60\Raw\16_apr_-_23_apr	9.5
SCH72	WHB	19.02.2014	03.04.2014	1307	U:\BONEFAAS\2014\EK60\Raw\19_feb_-_3_apr_2014	62.6
SCH72	WHB	28.04.2014	28.05.2014	1254	U:\BONEFAAS\2014\EK60\Raw\28_apr_-_28_may_2014	61.1
H171	HER	14.07.2014	17.07.2014	41	T:\CORNELIS_VROLIJK\2014\EK60\Raw\14_jul_-_17_jul	2.0
H171	HER	24.07.2014	31.07.2014	86	T:\CORNELIS_VROLIJK\2014\EK60\Raw\24_jul_-_31_jul	4.1
ROS875	WHB	09.04.2014	24.04.2014	1324	T:\HELEN_MARY\2014\EK60\Raw\7_apr_-_24_apr	63.5
ROS875	WHB	28.04.2014	15.05.2014	1010	T:\HELEN_MARY\2014\EK60\Raw\28_apr_-_15_may	49.1
SCH81	HER	04.08.2014	08.09.2014	7955	U:\CAROLIEN\2014\EK60\Raw	389.0
SCH6	HER	20.02.2015	26.02.2015	91	B:\ES70 & SEAT data\Alida seat feb mar 2015\seat\data\raw	169.0
SCH6	WHB	13.03.2015	26.03.2015	66	B:\ES70 & SEAT data\Alida seat feb mar 2015\seat\data\raw	-
SCH6	WHB	04.04.2015	15.04.2015	50	B:\ES70 & SEAT data\Alida seat april mei 2015\Alida seat april 2015\raw	316.0
SCH6	WHB	17.04.2015	04.05.2015	99	B:\ES70 & SEAT data\Alida seat april mei 2015\Alida seat april 2015\raw	-
SCH72	WHB	02.04.2015	16.04.2015	526	B:\EK60 Data 38kc 2015 Frank Bonefaas\IMARES\2015\2015 reis 03 197	12.8
SCH72	WHB	18.04.2015	07.05.2015	1032	B:\EK60 Data 38kc 2015 Frank Bonefaas\IMARES\2015\2015 reis 04 198	25.2
SCH72	HER	18.06.2015	27.07.2015	697	B:\EK60 Data 38kc 2015 Frank Bonefaas\IMARES\2015\reis 2015 07	30.1
SCH72	HER	29.07.2015	08.08.2015	554	B:\EK60 Data 38kc 2015 Frank Bonefaas\IMARES\2015\reis 06 2015 200	13.5

3.3. Acoustic densities and vessel behaviour

Investigation of the correlated patterns between fishing vessel behaviour and corresponding acoustic fish densities from a selection of more thoroughly processed trips (where fish density data was combined with different vessel activities), showed different acoustic detection patterns between the target fisheries covered. Data collected on blue whiting trips covered areas along the continental shelf slope west of the British Isles and Ireland. The analysed herring fishing trip generally covered the northern North Sea around the Orkney and Shetland Islands (Figures 3.7-3.9).

The duration of different activity periods of the acoustic fish density interval data were compared by target species in the fishery. The highest proportion of time spent for activity 'fishing' was observed for the analysed blue whiting fishing trips (82%) while the time proportion allocated to 'fishing' activity was less (54%) for herring trips, where proportionally more time for 'searching' was used (Figure 3.5). Mean duration (±s.d.) of 1 nmi trip intervals allocated to 'fishing' were 15.5 (±6.4; herring), and 16.9 (±5.8; blue whiting) minutes. The observed mean speeds (±s.d.) for the 'fishing' & 'searching' activities were 3.8 (±1.1) & 10.5 (±2.5) for the herring, and 3.5 (±0.9) & 8.8 (±2.2) knots for the blue whiting trips, respectively.

Acoustic fish densities measured per interval on each fishing trip were bootstrapped to give means and s.d. per trip activity (Figure 3.5). All trips showed significant differences between mean densities recorded during 'fishing' and 'searching' (Student's t-test; herring: $t = 64.6$, $p < 0.001$; blue whiting: $t = 224.4$, $p < 0.001$). The mean fish density recorded during 'fishing' were higher on all trips, with the herring showing a 1.5x, and the blue whiting a 2.1x difference between 'fishing' and 'searching'. There were distinct differences in the magnitudes of observed absolute acoustic fish density values between the fisheries: mean values observed during blue whiting had magnitudes of $x10^3$ and those for herring had magnitudes of $x10^2$. For the herring fishing trip, the mean density per individual 15 minute time bins around the time at which the net of the closest trawl was shot showed an approximately Gaussian distribution pattern. A LOESS curve fitted through the values showed a gradual increase in observed mean sA per time bin from about three hours before the trawling process towards a peak around the shooting time, and a coherent decrease thereafter (Figure 3.6). To get a quantitative indication of expected density levels when detections are at a low level in areas away from the peak spots, the 5th percentile of all observed acoustic fish detections throughout the 'fishing' and 'searching' activity was taken. For herring, the 5th percentile of observed densities was low at just 18.3 m^2nm^{-2}. For blue whiting trips, a higher low-level fish detection was observed (5th percentile: 1595 m^2nm^{-2}). The LOESS curve fitted through the detections of blue whiting increased from 3.5 hours before trawling towards a peak around one hour before the shooting of the net and declined steadily thereafter (Figure 3.6).

In the data presented here, different acoustic detection patterns can be observed between the different target fisheries covered. Vessels involved in the blue whiting fishery were strongly confined to geographical features (shelf slope), as the resource is typically aggregating there in high densities. As a result, more constant acoustic detections could be observed when blue whiting was targeted, with less time spent for searching once the fishing grounds were reached. Clupeids such as herring on the other hand are typically more characterised by localised schooling behaviour with larger shoals or schools and aggregations occurring more sporadically, hence increasing the relative time spent searching for the trawlers. The observed magnitudes of fish densities in situations of low detection levels, typically away from fishing hotspots, were therefore relatively low for herring. An aspect that was not considered here but could have affected the nature of the observed data was the simultaneous use of acoustic equipment other than the echosounder. To detect and pursuit schools especially during the herring fishery the skippers make extensive use of omnidirectional sonars (Brehmer et al., 2006). With that additional aid, covering a larger volume of water, echosounder detections were not the only source of information available to influence fishing decisions. Recorded fish densities from the echosounder were therefore not solely affecting the duration of the 'searching' period, which may have otherwise been extended had there been less acoustic tools available. Such interactions will have to be considered when analysing acoustic fish detections in combination with the behaviour of the fishers and fish distribution patterns. Apart from the simple extraction of acoustic fish density values in 2D space, quantification of acoustic detection patterns in relation to fishing behaviour will indeed be an important step in the process of deriving useful characteristics from acoustic fishing vessel data.

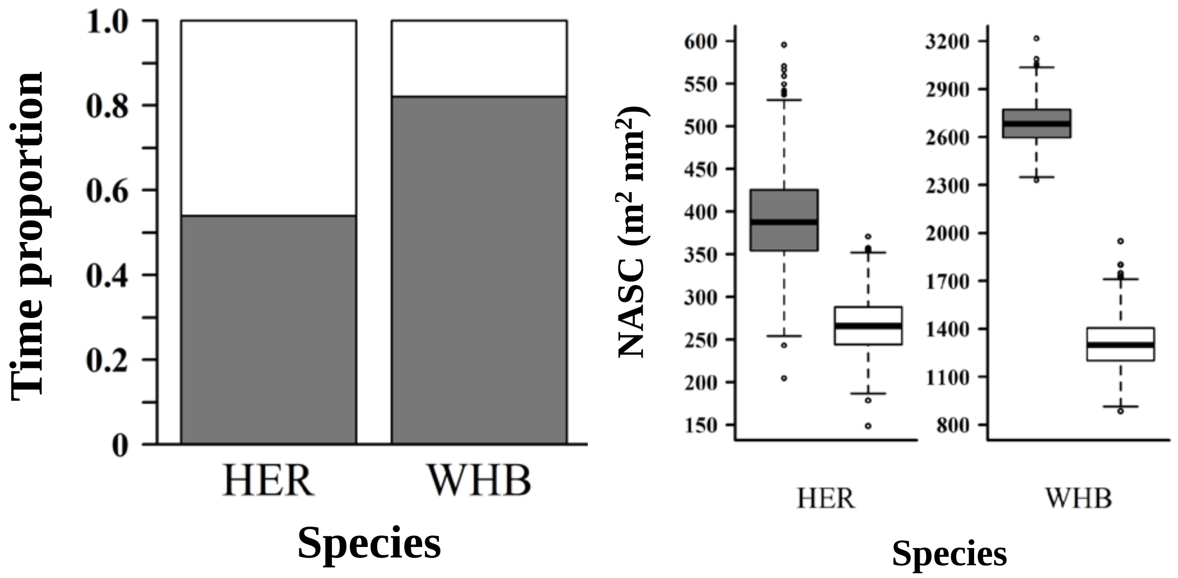

Figure 3.5. Relative proportion of time spent fishing (grey) and searching (white) after the vessels have reached the fishing grounds (HER: North Sea herring; WHB: Northeast Atlantic blue whiting), between starting the first and finishing the last trawl (left panel). Bootstrapped mean acoustic densities (n=1000) recorded on different fishing trips during fishing (grey) and searching (white) activities (right panel).

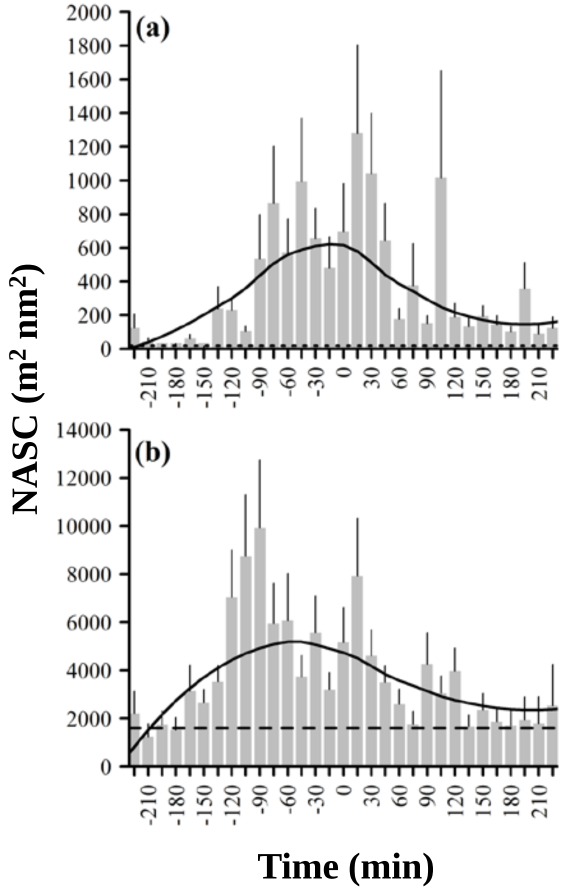

Figure 3.6. Mean (+S.E.) acoustic fish densities (NASC: nautical area scattering coefficient) per 15 minute time bins before (negative values; ‘searching’ period) and after (positive values; ‘fishing’ period) shooting the net (zero) during: a) the herring and b) blue whiting fisheries. LOESS curves (solid lines) were fitted to the mean values and 5th percentiles of fish densities observed during the ‘fishing’ and ‘searching’ periods are given (dashed lines).

3.4. Abundance Indices & simulations

3.4.1. Abundance indices calculations

The acoustic data collected on the pelagic trawlers now cover the years 2013 to 2015 for North Sea herring, and 2012 to 2015 for the blue whiting (Table 3.4). The number of vessels involved, the number of trips and the amount of data recorded varied substantially between years. For herring, the sampling effort was particularly high in 2013 compared to 2014 and 2015. For blue whiting, very few data were collected in 2013 compared to the other years.

The geographical and temporal coverage of the data also differed between years. For herring, the area around the Shetlands was covered in the earlier part of the fishing season in 2013 and 2015 but not in 2014 (in blue on figure 3.7). The middle part of the fishing season (in yellow) usually concentrate on the southeast of the Shetland, and is well covered in all 3 years. The area off the central coast of England was well covered at the end of the season (in red) in 2013, but there is only little coverage in 2014, and none in 2015. For blue whiting, the spatial coverage was also not consistent between years. During the early part of the fishing season, areas west of Ireland were consistently covered, but more southern areas, such as Celtic Sea and Northern Biscay are only occasionally (e.g. 2014) covered. The shelf-edge area between west Ireland and west Scotland was covered in the middle of the season in 2012 and 2015, but not during the two other years. Finally the area northwest of Scotland was covered in all years (except 2013) but not exactly at the same time.

Table 3.4. summary of the amount of data collected on North Sea hearing and blue whiting since 2012.

	Herring			Blue whiting		
	vessels	trips	Data[1]	vessels	trips	Data[1]
2012	1[2]	1[2]	2389 nmi[2]	2	3	3299 nmi
2013	4	11	15360 nmi	1	1	445 nmi
2014	3	7	3755 nmi	3	4	8924 nmi
2015	1	2	3923 nmi	2	5	5323 nmi

[1]: excluding steaming to the fishing grounds

[2]: no quantitative estimate could be calculated for this trip because the echosounder was not calibrated

For the indices to be representative of a stock, the data used has to correspond to the distribution area of this stock. Using data collected on the steaming route, outside of the distribution area of the stock, would introduce a bias in some of the candidate indices. Therefore, in order to compute abundance indices based on the acoustic data, the part of the steaming route from or towards the departure/arrival point was removed from the data. Practically, only the data collected between the first and the last acoustic detection of the species studied are used for computing the indices. The rest is considered not to be representative of the stock. The tracks with the steaming route depicted in black and the acoustic detection showed as red circles are given on Figure 3.8 and 3.9 for herring and blue whiting respectively.

Areas of high herring densities (Figure 3.9 and 3.10) were located off the central coast of England in 2013, and herring was also abundant in the southwest to southeast of the Shetland. In 2014, herring densities were higher than in 2013, especially in the area southeast of the Shetlands, while they were slightly lower off the central English coast. In the year 2015, densities were generally substantially lower, with the highest densities observed also in the southeast of the Shetlands.
The highest blue whiting densities were also found in different areas each year (figure 3.9 and 3.11). Most often, high densities are found in the west of Ireland but this was not the case in 2014. High densities were also recorded in the northwest of Scotland in 2014 and 2015, but not in 2012. In 2015, the highest density was observed in the west of Scotland/north of Ireland.

The 4 candidate abundance indices are shown on Figure 3.12, together with the SSB estimated by the stock assessment models (ICES 2015a,b). For herring, 3 out of 4 indices had similar variations, with an increase from 2013 to 2014 and a decrease from 2014 to 2015. However, overall, there was little agreement between the abundance indices and the stock assessment estimates of SSB. The stock assessment estimate was stable over the period 2013-2015, while the different indices showed up to a 3 fold variation.
For blue whiting, there was even less similarities among indices, or with the assessment. Here again the indices were much more variable than the assessment .

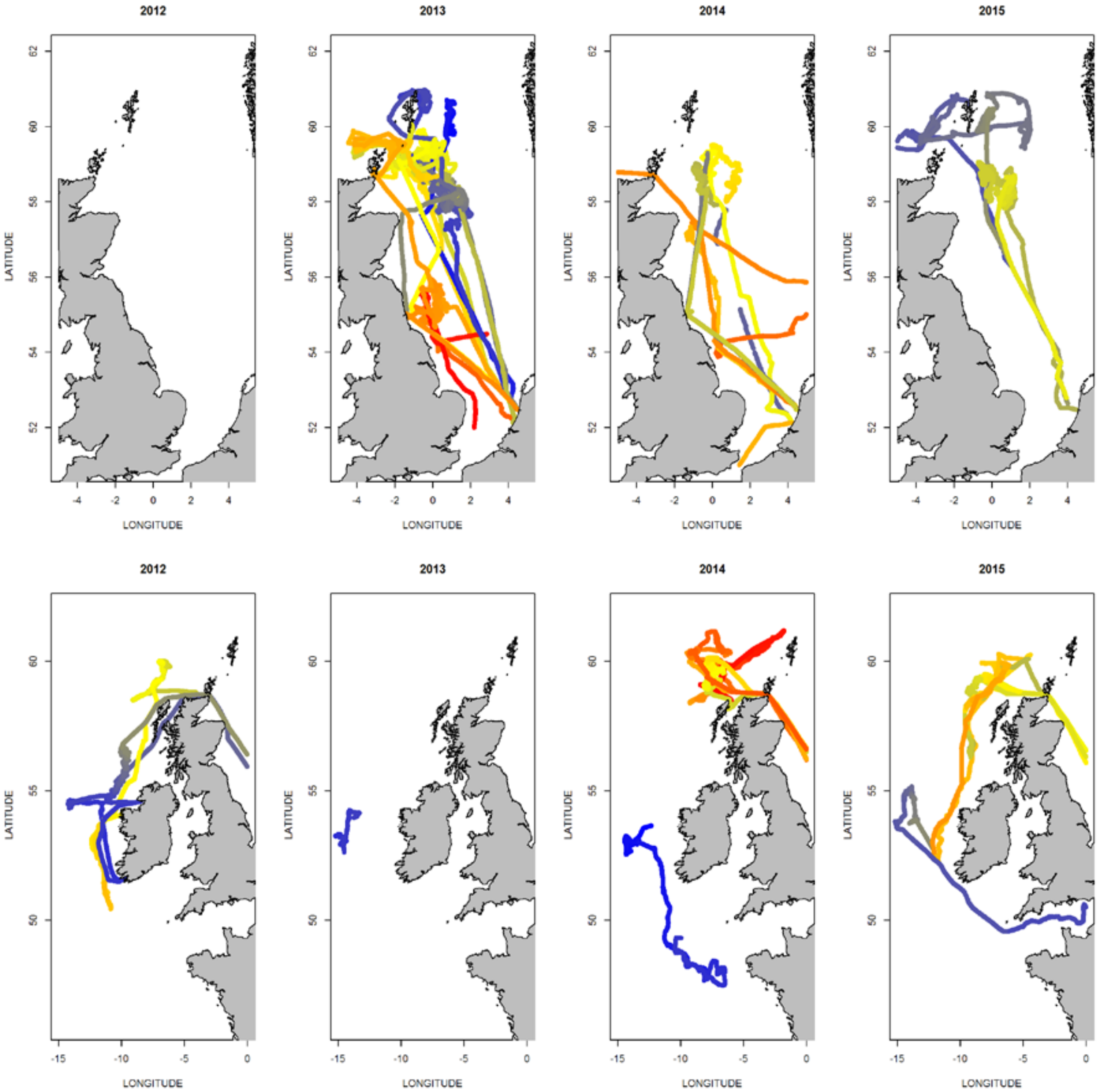

Figure 3.7. tracks of the fishing trips during which the data was collected from 2012-2015 with colouring representing the timeline of data collection (start in blue, end in red : North Sea herring 22 June to 28-september (top panels), blue whiting 3 March to 28 May (bottom panels)).

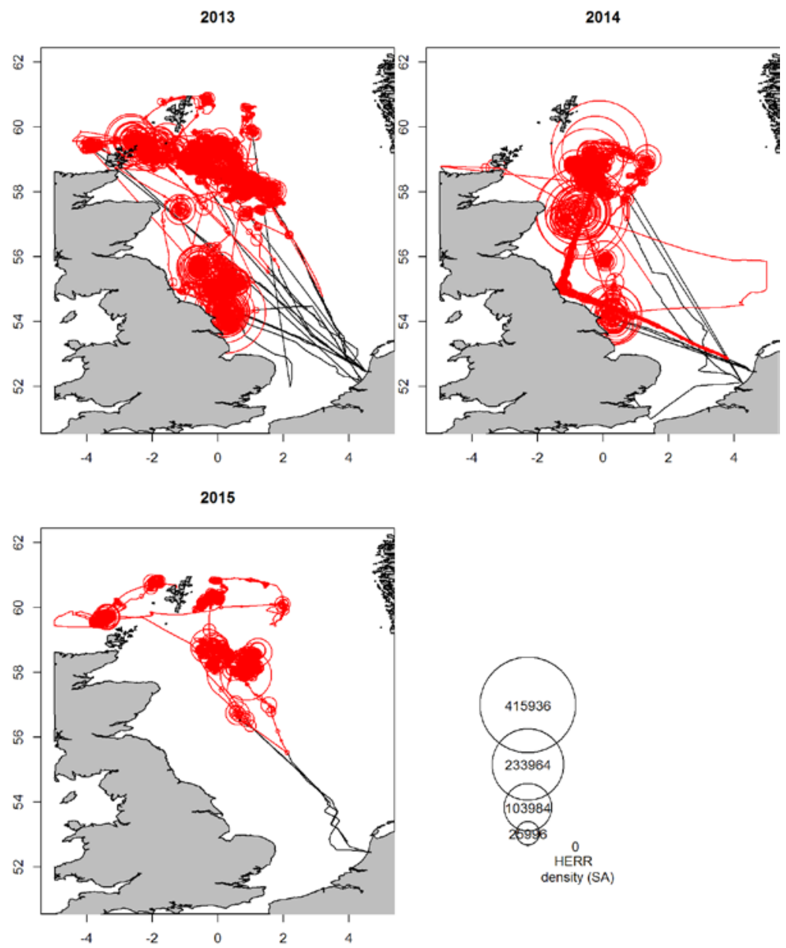

Figure 3.8. herring acoustic detection in the North Sea. Steaming routes are indicates in black and red bubbles represent acoustic fish densities where bubble size is proportional to the magnitude of detections.

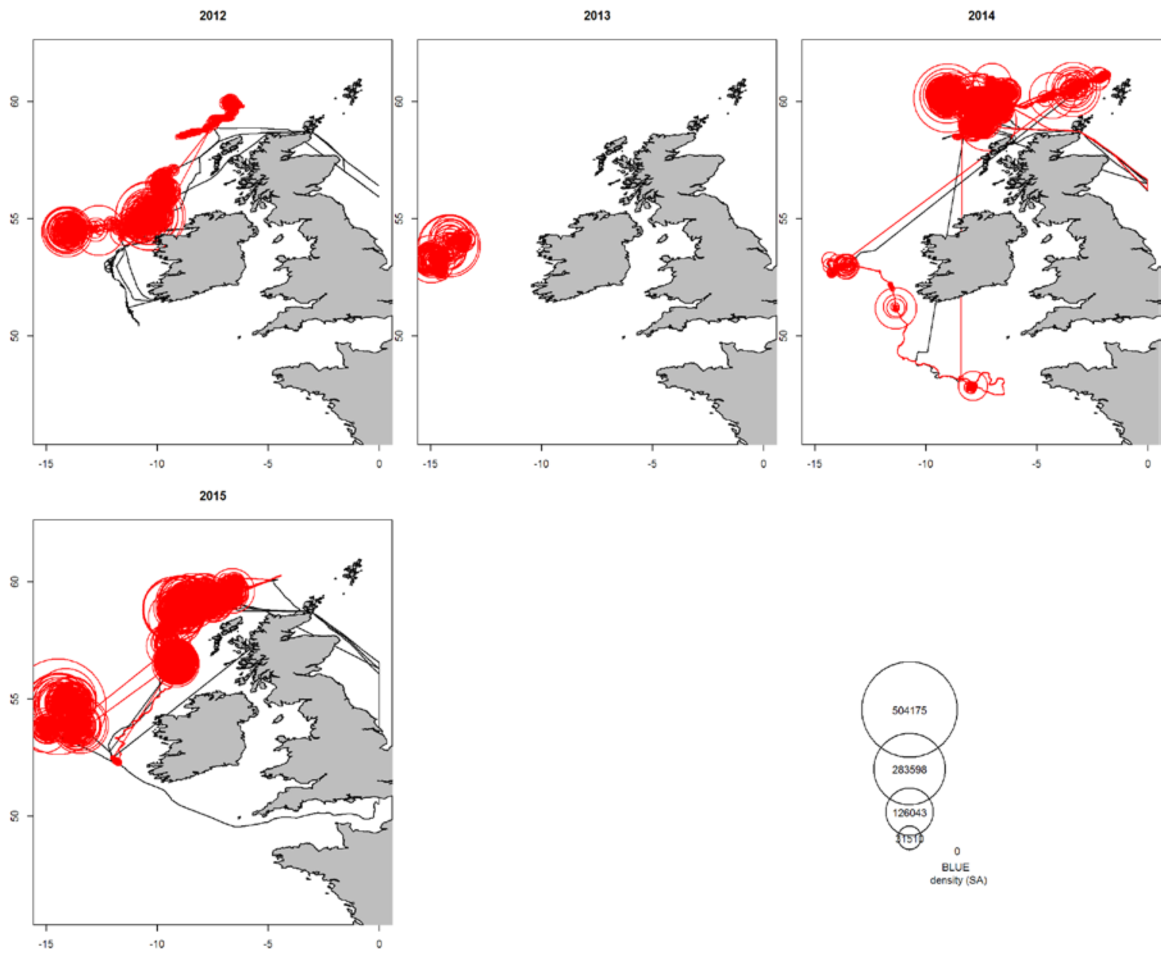

Figure 3.9. blue whiting acoustic detection. Steaming routes are indicates in black and red bubbles represent acoustic fish densities where bubble size is proportional to the magnitude of detections.

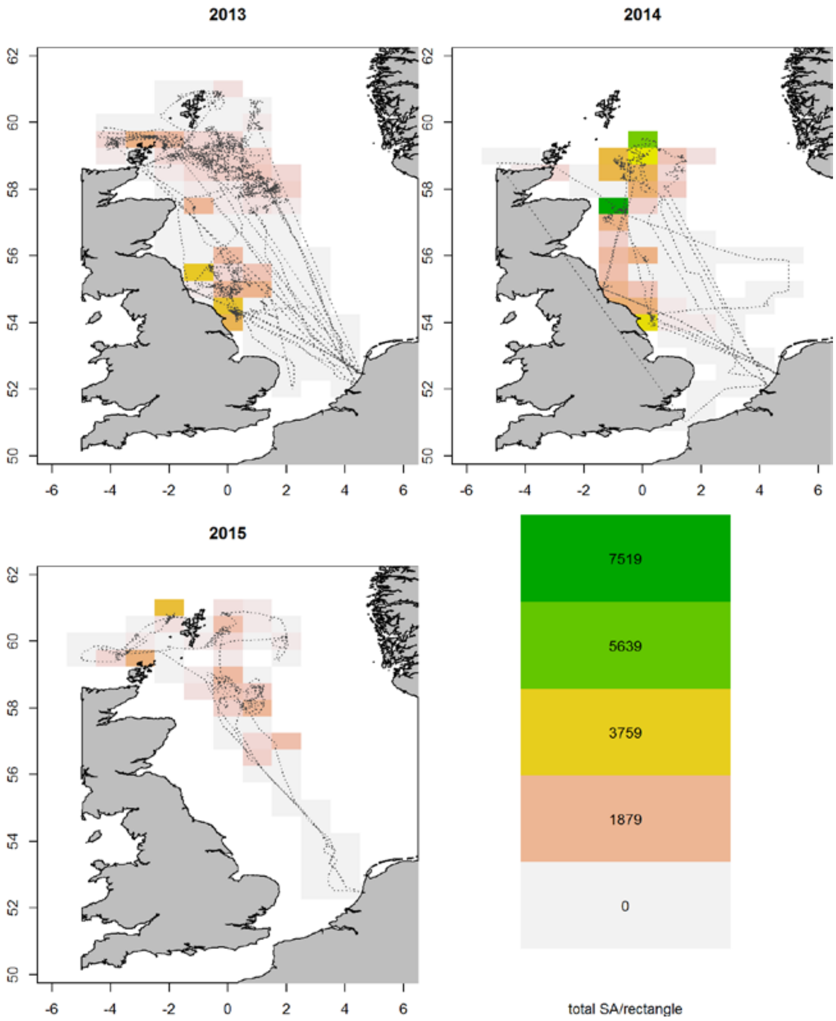

Figure 3.10. average herring acoustic density per ICES rectangle for the 3 years of data. Grey dashed line show the track along which the data was collected.

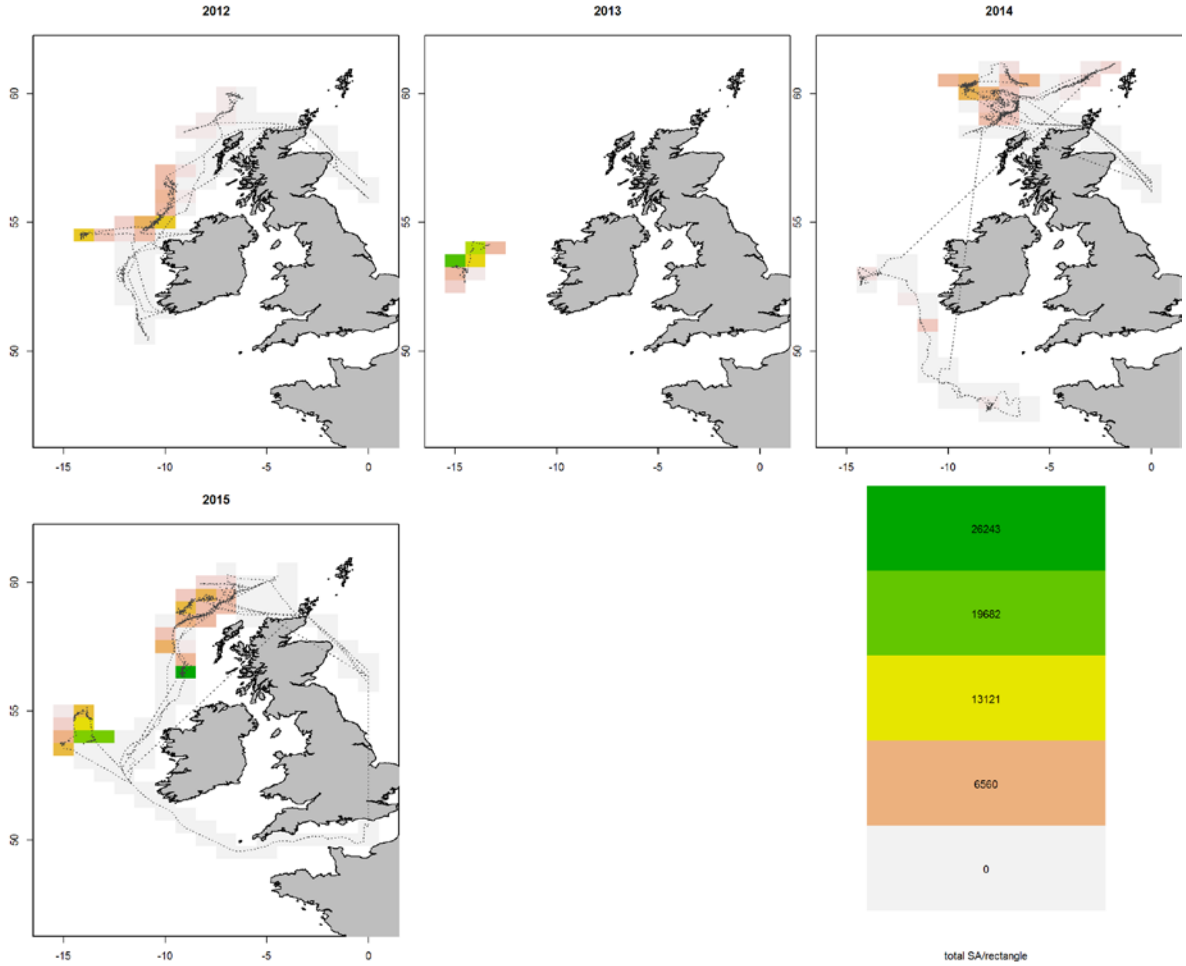

Figure 3.11. average blue whiting acoustic density per ICEs rectangle for the 4 years of data. Grey dashed line show the track along which the data was collected.

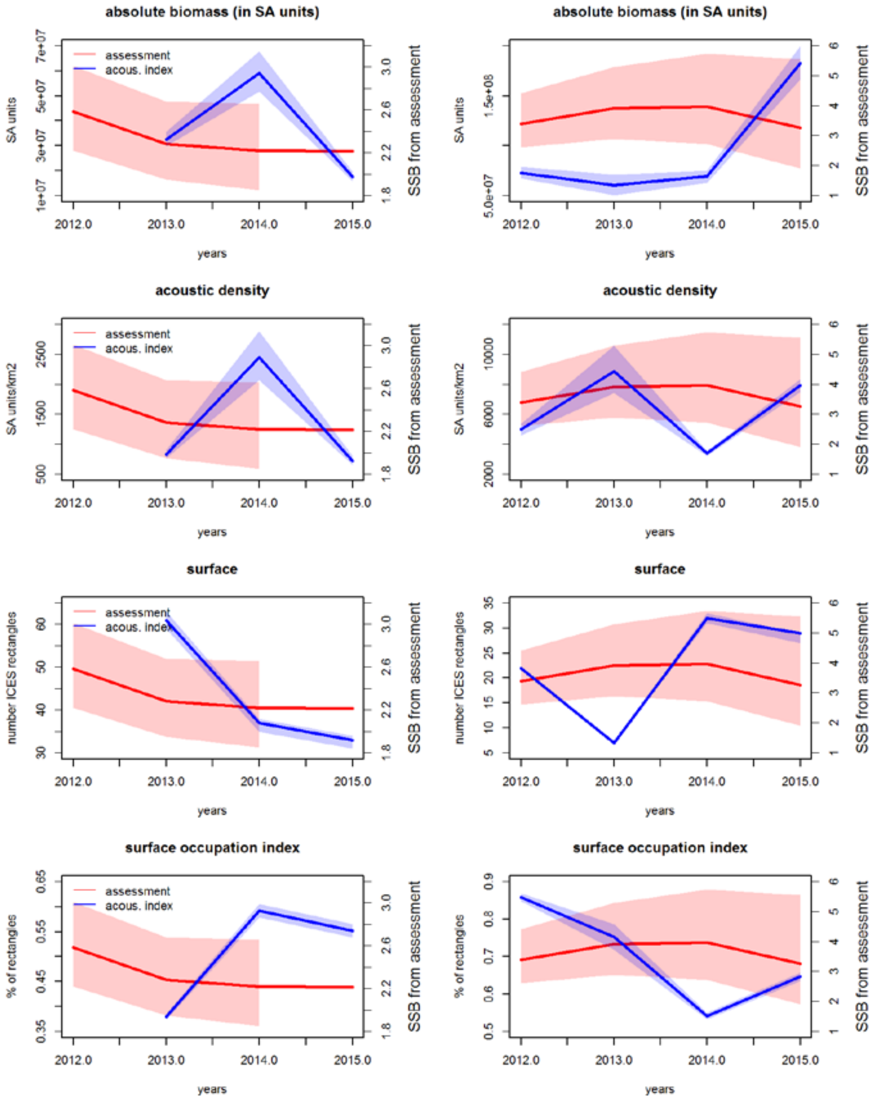

Figure 3.12. abundance indices derived from the acoustic data collected from the pelagic trawlers for North Sea herring (left panels) and blue whiting (right panels).

3.4.2. Investigations using the simulator

Reality checks

- The Resource

The herring and blue whiting stock abundance was calculated from the herring and blue whiting acoustic survey data and from the interpolated data for the 4 years using the same method. The local density values were first averaged within each ICES rectangle, and then multiplied by the surface of the rectangle to get the biomass per rectangle. The biomass was then summed across rectangles.

For both species there was good agreement between the stock abundance estimated by the survey and the total abundance from the grid map used for the simulations (Figure 3.13, upper part).

There was also a very good overlap in the frequency distribution of the 2011 survey and interpolated abundance values for the herring. For the blue whiting, there was a small difference in the frequency distribution with slightly more small and large values in the interpolated data, but overall, both density curves overlapped to a large extend.

This results indicate that the gridded map of fish abundances used in the simulations are in good agreement with the information on stock abundance given by the survey and that they give a realistic enough representation of the resource to carry out the simulations.

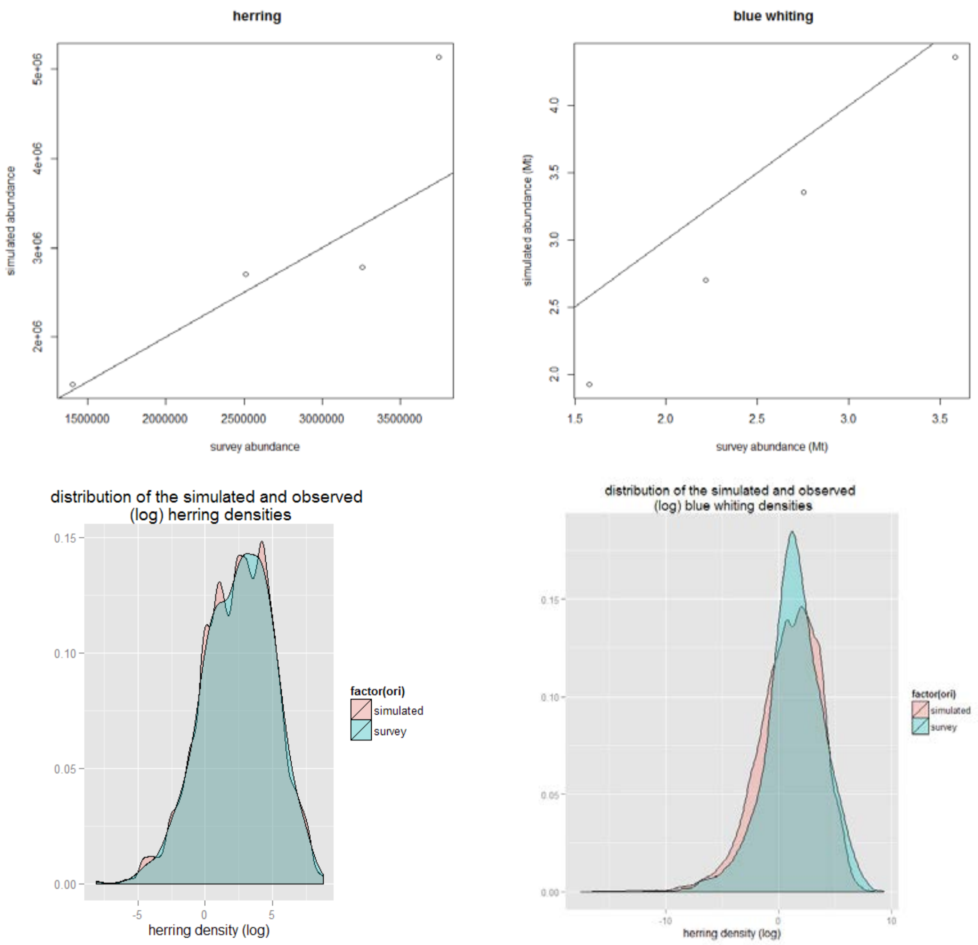

Figure 3.13. comparison of the original and interpolated abundance data for the herring (left) and blue whiting (right). Top panel : relationship between the total biomass estimated from the survey and the total biomass from the abundance map used in the simulator, bottom panel : distribution of the (log) abundance values from the survey and the interpolated data for the year 2011 (herring) and 2012 (blue whiting).

- Fishing behaviour

In a first attempt to compare the vessels behaviour in the simulation and in reality, a simple descriptor of the behaviour was investigated. The real data was first placed on the grid used for the simulations to have comparable units for both data sources. For both the real and simulated trips, the angle of the changes in direction between successive grid cells were calculated (NB : on a grid each cell is surrounded by 8 cells, so there are only 8 possible directions to go to). The frequency of the changes of direction between the two data source were then compared (Figure 3.14).
For both species there are small discrepancies between the simulated and real behaviours. In the simulations, the vessels tend to change direction slightly less frequently (roughly 10%) than the real

vessels, while the real vessels change direction by around 45° more often. However, overall the direction changes profile from the real and simulated data are broadly in agreement.

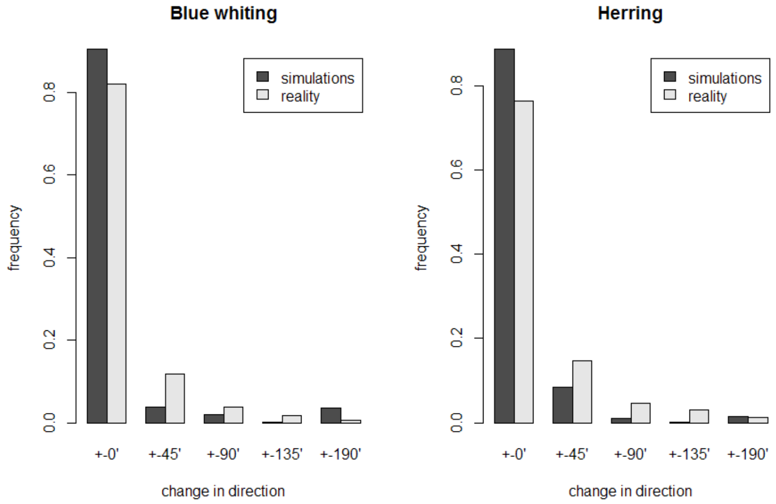

Figure 3.14. histograms of the changes of direction of the vessels calculated on a 1nmi resolution from the simulated and real trips on herring and blue whiting

- Catches per haul

Finally, the frequency distribution of the catches per haul was also compared (Figure 3.15). Here the discrepancies between the simulated and the real trips were larger. The maximum catch per haul in the simulator is the same, for both species, as the observed one in the vessels trawl haul lists. The simulations were indeed setup so that fishing would stop when this maximum observed catch is reached. For blue whiting, the real catches per haul are never smaller than 80 tonnes. In the simulations however, catches per haul smaller than 80 tonnes represent roughly 50% of the hauls. While very small catches are not frequent in the simulation, the mode of the distribution is at 80 tonnes, while it is at 110 tonnes in reality.
In the case of the herring, there is more similarities between the simulations and the real catch frequency, but here again, small catches are more frequent in the simulator than in the real fishery.

The reasons for this differences could not yet be investigated, but they may be linked to unappropriated modelling for either or both of the resource distribution or the vessels behaviour. This requires further investigation in order to improve the realism of the simulations.

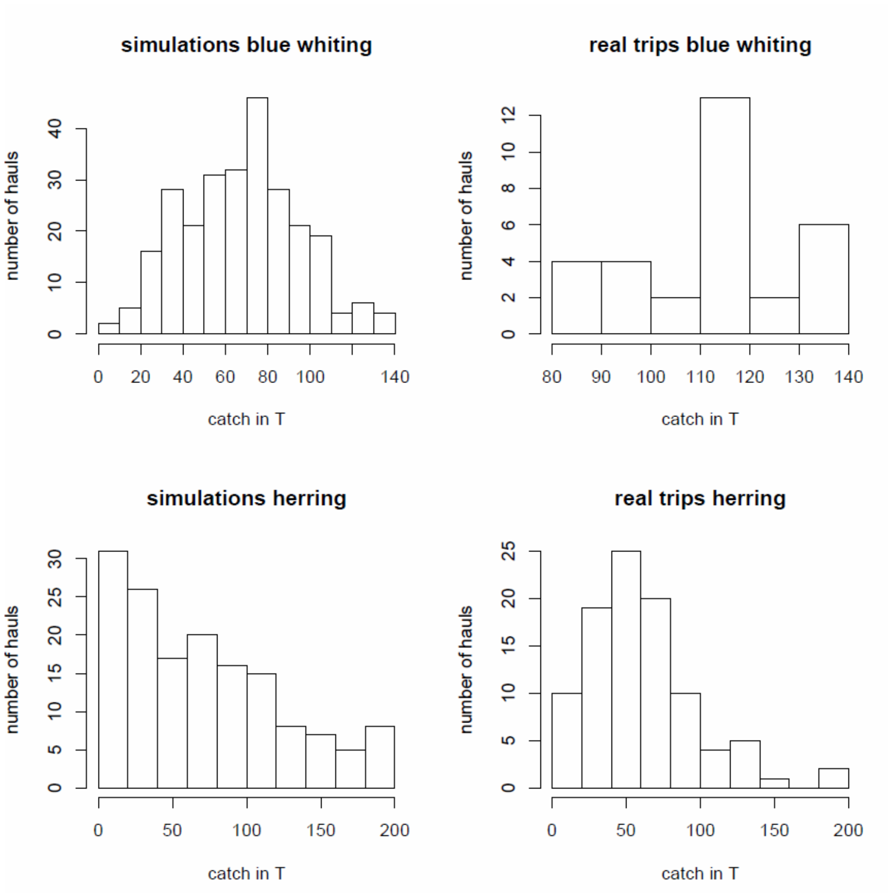

Figure 3.15. distribution of the values of the catches per trawl haul in the simulations and in the real fishing trips.

<u>Simulation results</u>

For each species, simulations were run for 4 years (with 10 replicates for each year to assess the variability of the process). Based on the output of these simulations ("virtual" acoustic data collected during the fishing trips), the four abundance indices described in section 3.4.1 were computed. The Figure 3.16. and 3.17. show the link between the resulting indices and the absolute fish abundance in the simulator for blue whiting and herring respectively.

In the case of blue whiting, most of the candidate indices do not correlate well with the true stock abundance. The best performing index is the absolute biomass estimate, which reflected well the low and high abundance years, but did not pick up well the difference between year 2005 and 2012, with intermediate biomasses. In addition, the uncertainty in this index was quite large, sometimes larger than the interannual differences (e.g. 2005 vs. 2012).

For the herring, both the biomass index and the density index correlated well to the true biomass. The uncertainty of these two indices was usually small, expect for the 2010, corresponding to the highest true biomass. The two indices based on spatial distribution, however, did not correlate at all with the stock biomass.

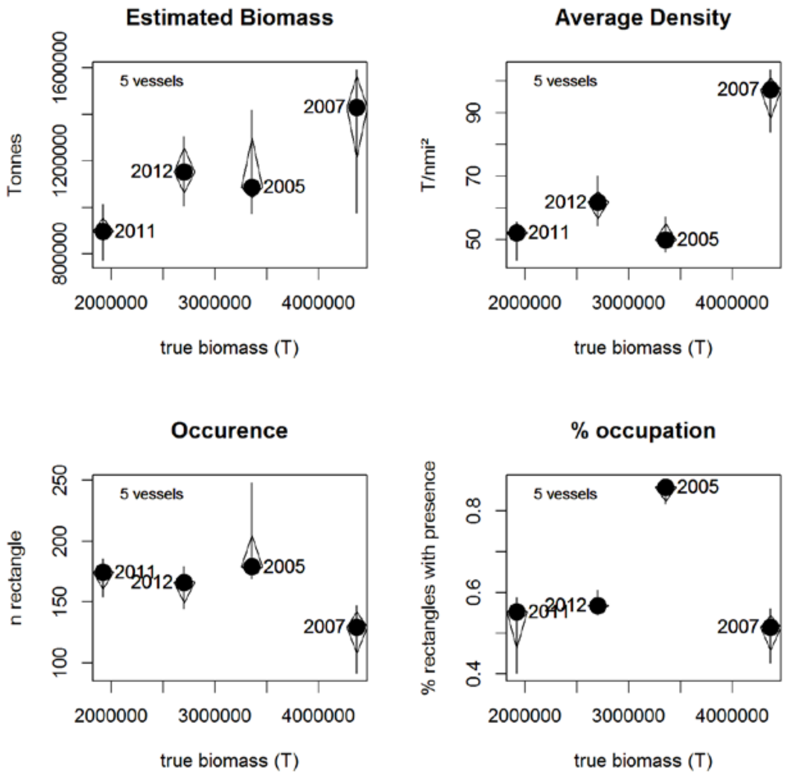

Figure 3.16. relationship between the “true” blue whiting abundance in the simulator and the abundance estimates calculated from the “virtual” acoustic data. The vertical bars show the variability in the index values among the 10 replicates.

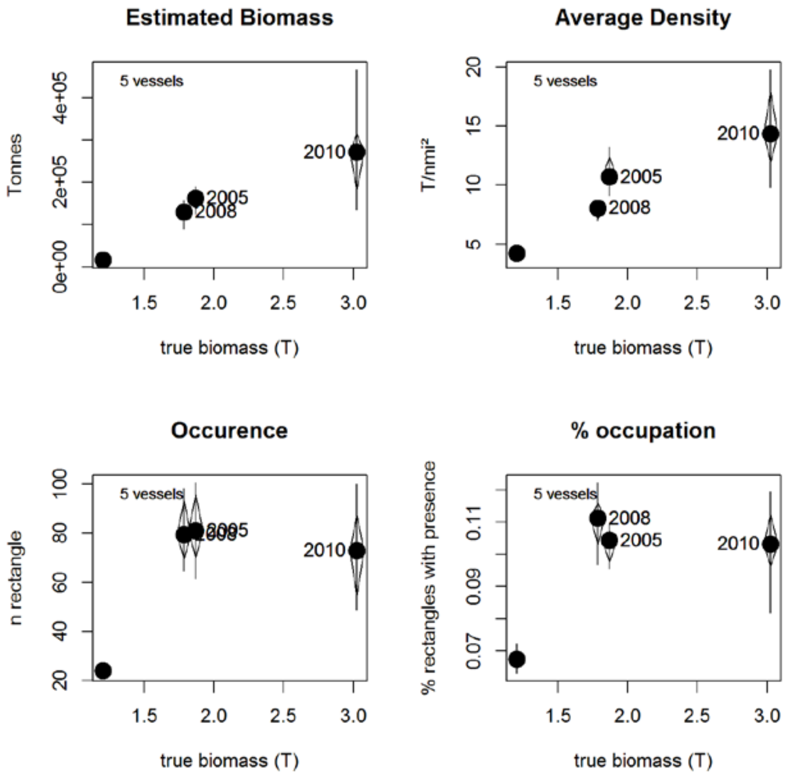

Figure 3.17. relationship between the “true” herring abundance in the simulator and the abundance estimates calculated from the “virtual” acoustic data. The vertical bars show the variability in the index values among the 10 replicates.

3.5. Geostatistical modelling

A possible way to use the potential of geostatistics with the type of acoustic data described here is the use of co-kriging to combine different spatial datasets like those from fishing vessels and scientific surveys (Petitgas, 2001). In so doing, it is however important that these data come from areas that were covered synoptically by both survey and fishing vessel platforms in order to avoid bias due to fish movement and variations in their aggregative behaviour (Figure 3.18). Apart from the need to have both data sets at the same spatial variance structure for the joint modelling, the added value of fishing vessel data to identify “hotspots” (c.f. Petitgas et al., 2015) and spatial movement patterns over longer time periods can be demonstrated (Figure 3.19).

Research surveys for fish stocks are undertaken to monitor the distribution and abundance of fish stocks, and usually distinct areas of very high fish concentration values are encountered. These denote so-called “hotspots of interest”, but statistically, they are responsible for important uncertainty in the estimation (Petitgas et al., 2015). Thus understanding the spatial predictability of these “hotspots” and their surroundings is expected to reduce such uncertainty. The geostatistical tools that are currently available could facilitate the use of the additional information provided by fishing vessel data for improving estimation of hotspot habitat maps and their variability. These are key information for the spatial management of fish stocks. However, in this approach it is important to better understand the factors governing fishing behaviour. High fish abundance is an important driver of the fishing process but it is not the only one. Fish length, schooling at small scale, amounts of species mixes, distance to harbour (less critical for freezer-trawlers), selling price at a particular harbour, fleet and social behaviour are other factors that make fishermen select some hotspots rather than others. A further step may then be the incorporation of a model that takes into account the temporal change of the fish population, especially since the fishing vessel data covers an extensive time range. The co-kriging approach explored here and improvement of knowledge on “hotspots” would however clearly benefit from the availability of data from all possible fishing vessels covering the area and time period together with any available research survey data. In that way, chances are bigger to have simultaneous complementing data available that describes the fish resource patterns within the same time and spatial limits.

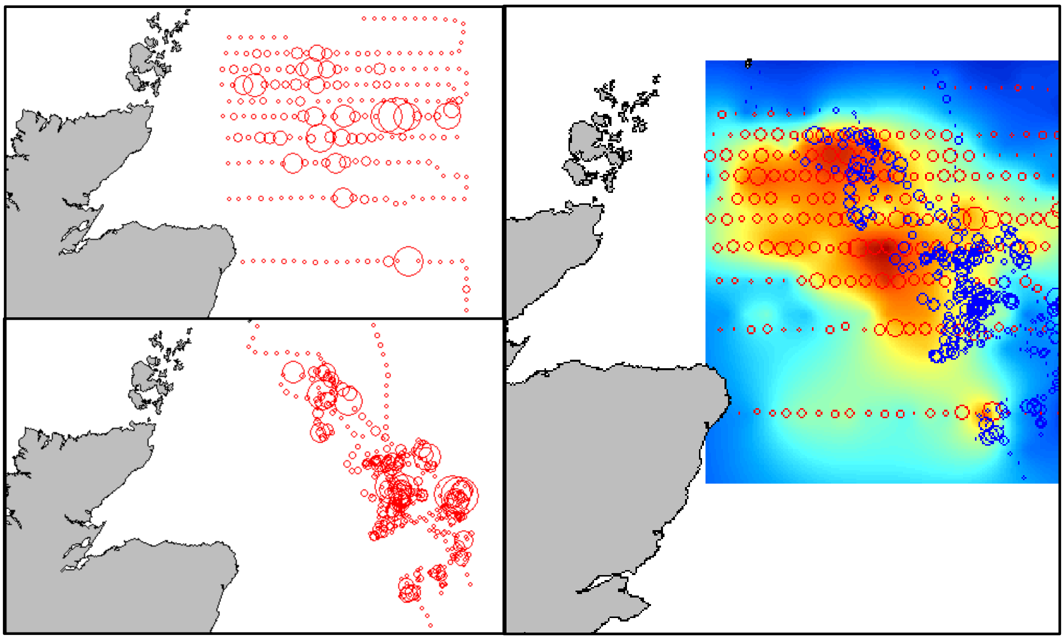

Figure 3.18. Example acoustic data of herring densities from the same area collected by two different platforms within the same 2 week time period: research vessel (top left panel) and one fishing vessel fulfilling these requirements (bottom left panel). The data sets were combined by means of geostatistical co-kriging (right panel) to make simultaneous use of the two information sources to predict the herring distribution.

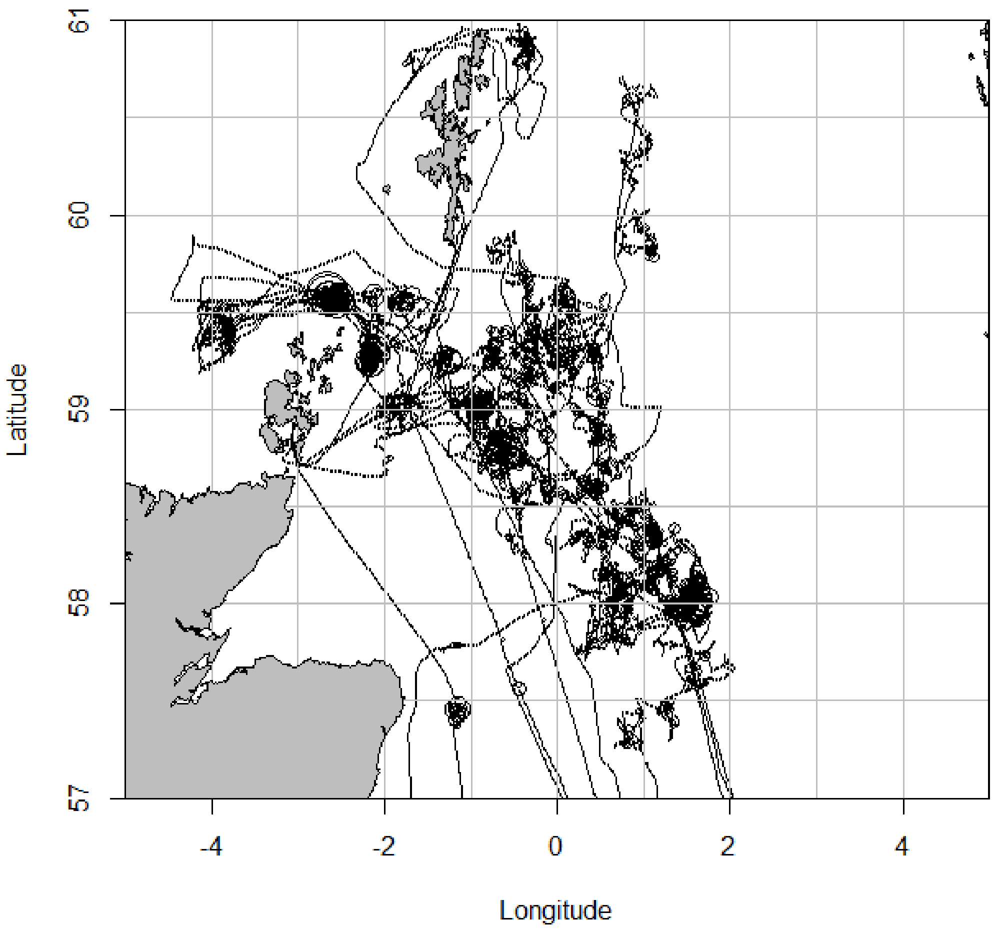

Figure 3.19. Example acoustic data collected by freezer-trawlers in this project during a herring fishing season from June – September in the northern North Sea.

3.6. Dissemination and publication

Results and progress of the project were disseminated and communicated at various intermediate stages to different audiences. Audiences ranged from project participant fishing industry stakeholder, to scientists, NGOs and ministry members. A brief overview is given here with additional information in the Appendix of this report.

- ICES WORKING GROUP ON FISHERIES, ACOUSTICS, SCIENCE AND TECHNOLOGY (WGFAST) meeting, Aquarium Donostia-San Sebastián (April 2013). Presentation entitled: “First insights from echosounder data collected on commercial vessels during different fisheries throughout an annual cycle” (Appendix D). Audience: fisheries acoustic scientists.
- ICES Annual Science Conference, Reykjavik, Iceland (September 2013). Presentation entitled: “Using acoustic data from pelagic fishing vessels to monitor pelagic fish stocks and their ecosystem” (Appendix D). Audience: fisheries scientists, fisheries managers, NGOs, industry representatives.

- Northern Pelagic Working Group meeting, Schiphol, Netherlands (June 2015). Presentation entitled: "PelAcoustic II: collecting acoustic data from pelagic freezer-trawlers" (Appendices D and E). Audience: fisheries acoustics scientists, NGOs, industry representatives, vessel owners, fleet managers, skippers.
- ICES Annual Science Conference, Copenhagen, Denmark (September 2015). Presentation entitled: "Complementary acoustic data from fishing and research vessels for enhanced ecosystem understanding" (Appendix D). Audience: fisheries scientists, fisheries managers, NGOs, industry representatives.
- WORKSHOP OF THE SPRFMO TASK GROUP ON "FISHING VESSELS AS SCIENTIFIC PLATFORMS", Lima, Peru (September 2015). Workshop participation and contribution to a report on fishing vessel calibration recommendations (Appendix E). Audience: fisheries acoustics scientists, engineers, industry representatives, vessel owners.
- Pelagic AC Executive Committee meeting, Edinburgh, Scotland (October 2015). Presentation entitled: "PelAcoustic II: collecting acoustic data from freezer-trawlers" (Appendix D). Audience: fisheries scientists, NGOs, industry representatives, government ministry & EU representatives.
- Dutch Bioacoustics Day, IMARES, IJmuiden, Netherlands (November 2015). Presentation entitled: "Echosounder data collection from fishing vessels for improved ecosystem understanding". Audience: bioacoustic scientists, industry representatives, government ministry representatives.
- Peer-reviewed paper accepted for a special issue on "Using fishing Vessels as Scientific Platforms" in the scientific Journal 'Fisheries Research'. Paper title: "Acoustic data collected on pelagic fishing vessels throughout an annual cycle: operational framework, interpretation of observations, and future perspectives" (Appendix F)

4. Discussion and Conclusions

4.1. Technical achievements & identified issues

The project has successfully demonstrated the potential for implementing routine acoustic data collection and processing protocols on pelagic freezer-trawlers. The project pilot fleet of up to 6 vessels was not fully utilised during every fishery for aforementioned reasons (see section 3.1), however, up to 3 vessels were on average available to deliver data. While collection of data is less resource demanding and mostly associated with correctly following guidelines to assure quality, the next steps in the data processing sequence are more affected by time constraints. While time required for analysis of scientific survey data can be considerable, the data amount resulting from weeks' worth of acoustic recordings from several fishing vessels is yet an order of magnitude bigger. Based on the required data analysis time of experienced scientists and methods used in this project, it took on average 8 hours to process the data collected by a fishing vessel over one whole week. Continuous streaming of data during fishing trips may help spreading out the workload as the data could be processed in smaller chunks at a time, however, the total time required for the task will remain the same. A potential solution could be automation of some of the data processing steps to assist for example with identifying and detecting of fish schools on the echograms. Additionally, such approaches could also tackle some of the data quality issues observed. Advances in methods for automatic school recognition, bottom-tracking correction, and identification of areas where records are contaminated with noise by weather, acoustic interference, or electrical interference, hold promise and may well be useful for preliminary review of acoustic data collected aboard commercial vessels to speed up the process, as already suggested by Karp et al. (2007). Advances like that are worth investigating in the future, especially if more vessels are added to the data collection pilot fleet (which is beneficial for some analysis methods like "hotspot identification" and relative indices). Such approaches may especially become applicable in cases where data were collected at more than one acoustic frequency or even over a wide bandwidth. Fishing vessels are continuously upgrading their acoustic systems and some already collect data at several frequencies. Such techniques have already been used successfully for many years in scientific surveys to aid discrimination between groups of fish, micronekton and zooplankton and also for discrimination between biological targets and physical phenomena such as bubbles (Horne, 2000; Korneliussen and Ona, 2002). With further advances in acoustic technology such as broadband systems (Stanton et al., 2011), identification of scattering groups or even individual species will likely be much improved and allow for more objective and automated, therefore efficient data processing approaches. At least for now and for the foreseeable future, fully automated processing of acoustic data is not possible and the human analyst is still required to assure the required quality.

Calibration of the echosounders on freezer-trawlers could be achieved with acceptable results. This was especially true for the calibration sessions on the fishing grounds that were assisted by scientists and could be completed within a reasonable amount of time that was comparable with research vessel calibrations. Nonetheless, the envisaged introduction of a routine of more independent calibrations primarily conducted by vessel crew was not successful for aforementioned reasons (see section 3.1). The solution to still achieve that, however, could most likely simply be the continuation of calibrations on the freezer-trawlers to provide the vessel crew with more routine and confidence. Evidence for this comes from the example of one trawler (SCH6) which has been participating in several projects involving echosounder calibrations. Even though they are using the same protocol and hardware also available to other trawlers, the crew of that particular trawler have independently been performing calibrations of their echosounder on a regular basis since 2014. Given adequate protocols and quality assurance by scientists, independent calibrations allow a much more flexible use of such trawlers as data gathering platforms.

Apart from achieving good calibrations, acoustic recordings and resulting data can still be contaminated or biased by various noise sources (see section 3.2). Knowledge of the overall noise signature of the vessel, and specifically the noise detectable by the transducer, is of the greatest importance. It is only a partial achievement to maintain a high precision in echosounder performance, if the trawler itself causes bias in acoustic measurements. Therefore, it is crucial to comply with general recommendations regarding noise reduction (mechanic, electrical, and acoustic interference noise) onboard to achieve data of the highest possible quality. Within the frame and available resources of this project, noise reduction has only partially been tackled, mostly at the data processing step in the form of data cleaning. There have been positive achievements on some of the vessels in similar projects involving PFA freezer-trawlers collecting acoustic data, however, that issue should be covered more thoroughly in similar projects in the future.

Both echosounder technology and calibration methods itself have gradually improved during the past three decades (Knudsen, 2009). The precision of echosounders and post-processing systems, at the frequencies most commonly used for biomass abundance assessments (mainly 38 kHz), can be maintained within 3% over several years. The accuracy of the calibration depends on how good the estimate of the equivalent beam angle is (Simmonds, 1990). If data is collected regularly from fishing vessels, it is essential to measure echosounder performance by means of calibrations at frequent intervals, because the transducers are especially vulnerable to mechanical damage and ageing effects, or a combination of both. Calibration methods are standard protocols and it is also essential that they can be done routinely and that the procedure gives comparable results, independent of personnel and location. The shape of freezer-trawlers as used in this project also aid calibration precision, especially if the vessel is fully loaded with fish, because the transducers can be lowered below any air bubbles generated by strong winds at the calibration site.

The experiences made in this project also helped contribute to international initiatives, primarily in the ICES and SPRFMO network, that are currently underway to improve and facilitate data collection on fishing vessels. From workshops and meetings, a few recommendations can already be concluded in terms of best practise for calibrations and achieving good data quality:

- No major difficulties exist for the calibration of fishing vessels provided they are using SIMRAD split-beam systems, which is the case for the trawlers used in this project and most other pelagic fishing vessels. The quality of acoustic data collected aboard fishing vessels, once calibrated, is therefore acknowledged by the scientific community and comparable to that of research vessels.
- It is recommended that a complete calibration of the echosounder be performed at least once a year, preferably before the beginning of the fishing season. Modern echosounder systems are relatively stable in their performances are unlikely to drift severely from the standard values.
- Nevertheless, annual calibrations presents a drawback: if a failure event occurs (e.g. mechanical damage, loss of a quadrant of the split-beam transducer through cabling failure, etc.) this would not be recognised immediately and all the data collected after the last calibration will be worthless, which could represent up to one year of data.
- In order to reduce this period and to insure that the data are of good quality, a “between-calibration” analysis of the behaviour of the system is recommended to be performed. That way, the stability of the echosounder could be monitored on a more regular basis.
- After analysis of possible solution, it appeared that only 2 of the methods for “between-calibration” checks would be feasible for fishing vessels: 1) monitoring of the bottom reflection and 2) ringdown zone. More details on these methods are provided further below. Other methods either are requiring particular scientific equipment or complex scientific methodology that could not be easily implemented aboard a fishing vessel.

- Ringdown zone: Under particular conditions, the data collected at very short distance from the transducer allow to evaluate its characteristics. The continuous observation of these data allow to evaluate whether the system is working properly and in case of any event changing its acoustic characteristics, to know precisely when this event occurred, therefore to discard doubtful data.
- Bottom reflection: Another approach is to monitor the reflective properties of a constant section of seabed over time. Fishing vessels often tie-up at a specific location of a wharf for unloading and/or mooring. Assuming the small section of bottom under the vessel is relatively consistent acoustically then recording the echosounder data while it is stationary and in the almost exact same place should provide a mechanism for comparing backscatter between trips. While there will be some variability due to slight differences in positioning of the vessel and bottom variability, it should be possible to establish a range of acceptable mean backscatter values of the seabed. If major difference are observed then further investigation of the system outputs should be undertaken to ensure that the calibration remains valid, and if not when the problem began during the previous trip.

4.2. Progress on analysis of opportunistically recorded acoustic data

Once data collection protocols have been designed, tested, and can be utilised by many fishing vessels, gathering of extensive data sets with a high sampling potential will be possible. Consequently, the establishment of a novel data source for assessments will be a major benefit of such an approach. So far, however, the application and utilisation of acoustic data collected on fishing vessels over extended periods of time during their normal fishing operations has not been widely addressed. The primary reasons for this are, apart from large data volumes and the lack of system calibrations, the absence of a predetermined sampling design. This is challenging and calls for novel and innovative statistical and/or modelling approaches that first need to be developed. The primary aims of this project were related to practicalities associated with the data collection process and the vessel calibrations. Consequently, less resources have so far been available for developing methods to extract useful information out of the data products. Nonetheless, several approaches were investigated and a few conclusions can be drawn in light of developing further steps to utilise acoustic fishing vessel data for ecosystem understanding.

4.2.1. Relative indices

Simulator approach

Using real data to calibrate and further develop the “fisheries simulator” (described in section 2.7.1), which was created in a previous project (Brunel et al., 2013), has improved its realism and hence strengthened the ability of this approach to evaluate relative indices derived from fishing vessel data. While most of the simulator tests showed good agreement with real data from fishing vessels, others point towards potential lack of realism, which deserve some improvement in the future. These were related for example to the timing of when and where the decision of starting a fishing action is taken. Small catches per haul were more frequently made in the simulator than in reality, which may be explained by the fact that simulated vessels often start fishing in areas where average fish density was not particularly high, but where at least a density above an observed threshold was encountered. Also, the spatial coverage was larger in the simulation than in reality, which might be explained by the fact that fishers use historical knowledge of suitable fishing grounds, and that there is no such knowledge in the simulator to guide the vessels. Nonetheless, such shortcomings can still be overcome. The availability of more data from different vessels will further improve the realism of the simulator and consequently its use to demonstrate the robustness of relative indices from fishing vessel data for assessments.

Optimistic results could be found from the simulation exercises in the case for herring, where the biomass index and the density index correlated well with the true biomass. The uncertainty of these two indices was also small, suggesting their usefulness as a potential index candidate for assessments. The two spatial distribution indices, however, did not correlate at all with stock biomass. In the case of blue whiting, most of the candidate indices did perform less well when compared to the herring case. The best performing index was the absolute biomass estimate, which reflected well the low and high abundance years. The observations suggest that these relative indices are more suitable for species that form more heterogeneous aggregation patterns (e.g. herring) with distinct schooling hotspots and therefore more empty water in-between detections. Other species that form more homogenous layers and can more predictively be linked to geographical features (e.g. blue whiting at shelf edge) may not give useful relative biomass indices from the fishing vessel data. Nonetheless, these data could still be used to provide (localised) absolute biomass estimates or to indicate aggregation areas.

Abundance indices

The different candidate abundance indices (section 2.7: absolute biomass, relative average density, spatial occupation) calculated based on the data collected from the pelagic trawlers showed little correlation with the assessment based SSB estimates for both herring and blue whiting. However, it is evident that the time series are still very short and cover a period over which both stocks have been quite stable according to the assessments. On the other hand, there was a notable increasing trend observed in the North Sea herring acoustic survey from 2013-2014, similarly as in the biomass and density indices from the trawler data reported here. Unfortunately, however, these are the only 2 years where these data series overlap so far. At this time, it is therefore still difficult to evaluate the robustness of these indices based on comparison with the stock assessment output or indices from surveys. There is still a need for more data years and ideally some more changes in SSB levels over time to delineate any correlated trends better.

As the indices calculated here show variations during this period of relative stock stability it is likely that they may be affected by various sources of uncertainty, just like other indices from conventional research surveys. Still, the variations observed so far appear to be relatively high since up to 4 folds differences were evident for some of the indices over the time period. The degree of variability can likely be linked to the small amounts of trawlers (sample size) used to produce these indices during this early development stage so far.

Another aspect to improve the precision of the derived indices is related to the fact that acoustic density was used and not actual fish density. To convert acoustic density into fish density, it is necessary to know the average length and weight of the fish detected on the echograms. Such data is routinely collected in acoustic surveys by performing regular trawl hauls along the transect. However, even though fish samples are also taken on pelagic trawlers, the relevant biological information was not available at the required resolution (length-frequency and weight samples per trawl). The bias introduced should be small if there is no large differences in the average size of the fish in the different years. The data collected during the 4 years were also quite heterogeneous in terms of coverage, which is likely to have affected the accuracy of the resulting abundance estimates. As described in section 4.3, there were large differences in sampling effort, geographical coverage and timing of data collection between years. For instance, index values corresponding to the years in which data has not been collected in some potentially important fishing areas (i.e. off central UK coast for herring in 2015, or west of Scotland for blue whiting in 2013) are likely to be biased. Again, these issues related to coverage in time and space can be tackled in the future by collecting data from more trawlers to achieve a more realistic representation of the true species distribution.

The use of more vessels to deliver data over a short period of time to increase precision of resulting indices is supported and emphasised by the simulation runs, which predicted good correlations between indices and true abundance, especially so for herring. Simulations could be run with a much higher sampling effort (12500 nmi covered each year) than the real data (around 3500 nmi). In addition, in the simulations, all data were collected within the time frame of a single fishing trip (carried out simultaneously by 5 vessels) while the real data was collected over a 3 months period, during which the resource has probably moved between different areas. Nonetheless, by use of more trawlers it will also be possible to produce estimates of indices for several consecutive short periods of time and thereby reduce bias caused by fish migration.

4.2.2. Other explored analysis methods

Mapping fish densities

A promising approach to spatially analyse and model absolute fish densities from fishing vessel acoustic data, due to the ability to take into account the spatial and temporal sampling peculiarities, are geostatistical methods. Possible ways to use the potential of geostatistics with the type of acoustic data described here may include use of co-kriging to combine different spatial datasets like fishing vessel, scientific survey or environmental parameter data (Petitgas, 2001) (see section 3.5). Georgakarakos and Kitsiou (2008) used that approach to model the spatial distribution of small pelagic fish. They especially highlighted the significant reduction of the overall estimation error and its effect on subsequent stock assessment and management. As previously mentioned (section 3.5), there may also be potential in adding the acoustic information from fishing vessels usually collected in high density areas with those collected by survey vessels that follow a systematic design. Naturally, these data would have to be from areas that were covered synoptically by both survey and fishing vessel platforms in order to avoid bias due to fish movement and variations in their aggregative behaviour (Petitgas, 2001). Increase of the number of fishing vessels providing data would naturally improve that approach. A further step may then be the incorporation of a model that takes into account the temporal change of the fish population, especially since the fishing vessel data covers an extensive time range (e.g. Zhou, 1998). In any case, ignoring the particular preferential sampling pattern of these data can lead to serious misleading geostatistical inferences (Diggle et al., 2010).

Combining acoustic data and vessel behaviour

Measured acoustic densities represent an important proxy for fish abundance. These recorded densities may thus easily be translated to fairly accurate biomass levels representative for the locations of the different fish hotspot areas within the time window covered by the fishing vessels. More importantly, however, for these data to be useful for ecosystem management they need to be representative of the wider stock distribution and abundance over the wider time scales covered. The results showed that information on distribution patterns could indeed be derived from the data and that these differed between species (see section 3.3). Given that some important species like herring show no population size-dependent effect on observed acoustic densities per fish school (Beare et al., 2002), it may be valid to link observations from hotspot areas to stock abundance. However, due to the effect of vessel behaviour the validity and sensitivity of such an approach still has to be further verified with data over a few more years. The fishing behaviour-governed acoustic detection characteristics together with knowledge about distribution patterns of different target species may for instance be used in developing individual based models (IBM), such as the “fisheries simulator” (section 2.7.1), to verify analysis methods and derive robust and representative relative abundance indices (Bastardie et al., 2010). Similarly, irrespective of the specific aggregation behaviour of different species, fish searching time may also be affected by both stock biomass and/or stock area extension, and these factors including their interactions would have to be quantified in order to draw any useful conclusions.

A fruitful approach is also the combination of analysis tools that were developed and used for VMS data, which are typically applied to effectively classify the different fishing trip activities (Lee et al., 2010), together with acoustic fish density recordings collected on the same trips. Recorded acoustic data provide a spatial history record of the fishing trip, however at a much higher resolution, since data points are typically collected at an interval of one second. A whole suite of such existing analysis tools could therefore be applied to the very high resolution time-space acoustic data to supply a more accurate picture of fishing behaviour in addition to the synoptic collection of pelagic fish densities. A possible approach may then be to investigate if the combined spatial pattern and fish density information could be used to infer fish densities. The idea behind that is to treat the vessels as predators and derive resource abundance based on their behaviour pattern. Such methods have been demonstrated on investigations into the predation pattern of marine birds using GPS trackers (Pinaud and Weimerskirch, 2005; Weimerskirch et al., 2007). In a patchy environment, predators are expected to increase turning rate and start a so-called area-restricted search when prey have been encountered. By improving the understanding about these processes it becomes possible to link behavioural decisions to scale-dependent processes and therefore spatial resource distribution. For albatrosses for example, it was shown that after prey capture the birds return to a circling behaviour similar to that before immediate prey encounter, to increase search effort to find other prey near the prey caught. Use of straight movement over long distances appeared to be particularly efficient for finding prey and areas worth more restricted searches (Figure 4.1).

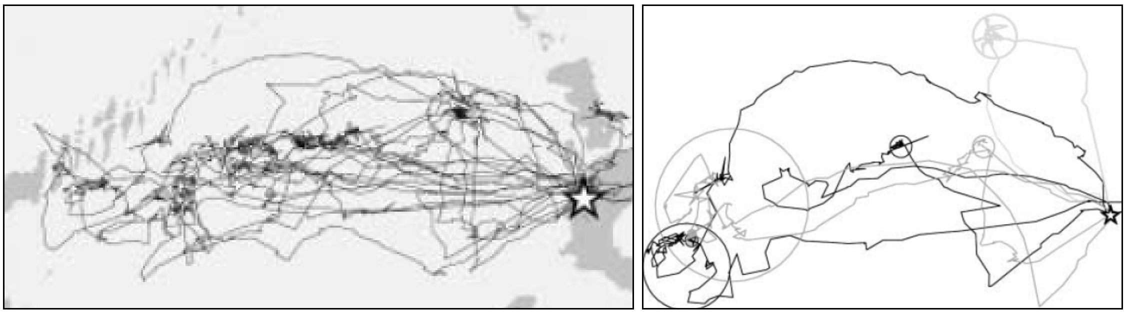

Figure 4.1. Foraging tracks of marine birds (left) with a few more detailed examples of individual trips and locations of area-restricted searches indicated with circles (right) (source: Pinaud and Weimerskirch, 2005).

4.3. Potential future approaches

4.3.1. Data analysis: Hotspot identification and geostatistical approaches

In fisheries, hotspots usually refer to areas of high local productivity due to particularly favourable environmental conditions. The identification of such hotspots is a fundamental aspect of pelagic fisheries, but these are also responsible for determining uncertainty in survey estimates. The idea behind quantifying the properties of hotspots is to apply a threshold to differentiate hotspot from non-hot areas. Such a threshold is usually set subjectively and based on the distribution of survey data. Petitgas et al. (2015) described a method where a local rule defines hotspots based on a non-linear geostatistical approach. The advantages of doing so are that the cut-off defining hotspots is based on locally observed transition probabilities that can and will vary across years with global abundance and do not need to be fixed. This provides insight into the uncertainty when mapping hotspot habitats due to inter-annual variability. Data from fishing vessels could be used in this approach described by Petitgas et al. (2015) to increase the knowledge about local fish hotspots and therefore reduce uncertainty in survey estimates due to improved power in predicting high concentration values spatially.

Acoustic data recorded during fishing activities poses challenges for analytical analysis for purpose of biomass estimation as it represents the vessel's approach of describing fish distribution in relation to catch operations. The observations are likely biased and the challenge is to extract unbiased estimates of fish distribution and abundance (Melvin et al., 2015). However, once data of such unbiased estimates can be extracted, they can provide information on the distribution of fish or aggregation sizes. Estimates of fish density or biomass in these situations have been made using a random selection of track segments, geostatistics, or spatial analysis within a polygon defined by the vessel track (Bez, 2002; Petitgas,2001; Barbeaux et al., 2013). These analyses provide a point estimate in time of the fish present within the limited covered area. This information can be used to describe what was observed, as a minimum biomass, and to estimate exploitation rates on the aggregation (Surette et al., 2015) (Figure 4.2). An as complete coverage of the situation (e.g. distribution of fish population or aggregation) as possible is very important, and multiple vessels operating in the same area will improve the available coverage and reduce the error associated with the mean estimate. This is especially true because such data cannot be extrapolated to estimates of fish biomass or biological targets in areas or time periods that were not actually covered by vessels, due to the dynamics of pelagic fish (Melvin et al., 2015).

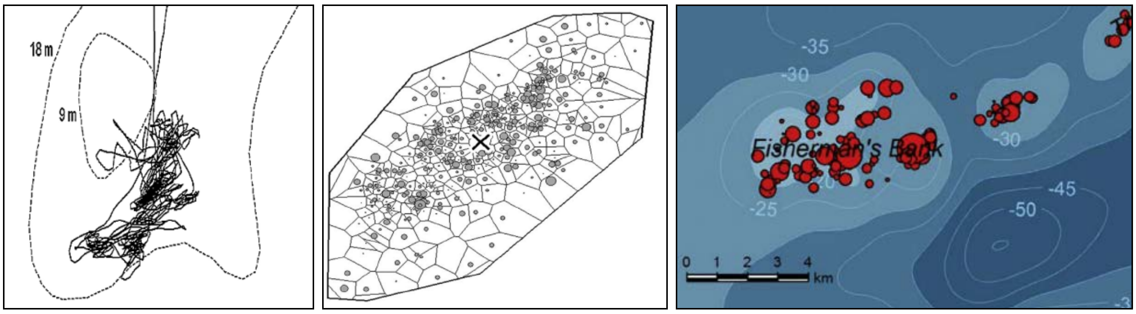

Figure 4.2. Fishing vessel track showing the location of more intense searching and fishing activities (left); fish detections collected on the vessel tracks were then split into Voronoi polygons for further processing of the acoustic data (middle); to produce averaged and spatially representative fish biomass estimates (right) (source: Surette et al., 2015).

Geostatistics provide promising analysis approaches due to the ability to handle spatial and temporal correlation together with the lack of a sampling design (Watkins et al., 2015). The analysis of acoustic data collected during fishing activities presents particular problems because the track of the vessel is determined by the requirement to find fish aggregations of certain densities. Even core assumptions of model-based analysis approaches like random search patterns are most likely violated as omnidirectional sonars are often used to aid search operations. Likelihood-based geostatistics in particular have been used to address these data limitations and to estimate mean organism density from acoustic data collected by commercial vessels conducting normal fishing operations (Figure 4.3) (Niklitschek and Skaret, 2015). This would also be a possible approach for the future to derive densities and biomass estimates from fishing vessel data like those collected in this project on freezer-trawlers.

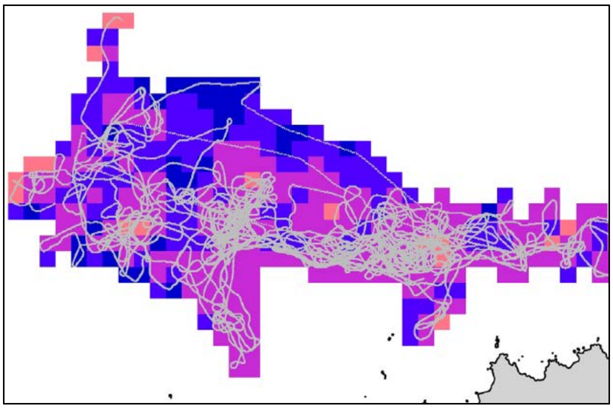

Figure 4.3. Estimates of the mean acoustic densities by spatial cell over one month period. Colder colours indicate low values while warmer colours indicate higher values. Fishing vessel tracks used to derive the estimates are shown in grey. Density values at non-observed locations were predicted using simple kriging. (source: Niklitschek and Skaret, 2015).

4.3.2. Data collection: Mini-surveys

The data collection routines and processing steps developed and applied in this project essentially provide freezer-trawlers with scientific data gathering capabilities. Given the available advanced equipment and the numbers of fishing vessels present, these represent a serious acoustic sampling platform potential. Consequently, they have been utilised by scientists in the straightforward case of acoustic survey vessels (Honkalehto et al. 2011; Hordyk et al. 2011; Karp 2007; Ressler et al. 2009). In Eastern Canada for instance, near real-time management decisions about the herring fishery are taken on the basis of such industry vessel based surveys (Melvin et al., 2001). However, this approach uses a systematic sampling design and therefore would only be possible if fishing vessels are actually available to plan and perform such surveys and the related costs and loss of income still have to be covered. In that respect, attempts have also been made to combine data collection and fishing activity, for example by using spare time during regular fishing trips to perform mini-surveys (O'Driscoll and Macaulay, 2005). But unfortunately that is only practicable when such time is available (e.g. during processing of the catch on a factory vessels) and if the fish resource is distributed over a restricted area (e.g. deep sea fish over sea mounts or coastal spawning aggregations) (Figure 4.4). Nonetheless, the freezer-trawlers used here would of course have the capabilities to apply the data gathering methodology and guidelines developed in this project to be used for utilisation of mini acoustic surveys.

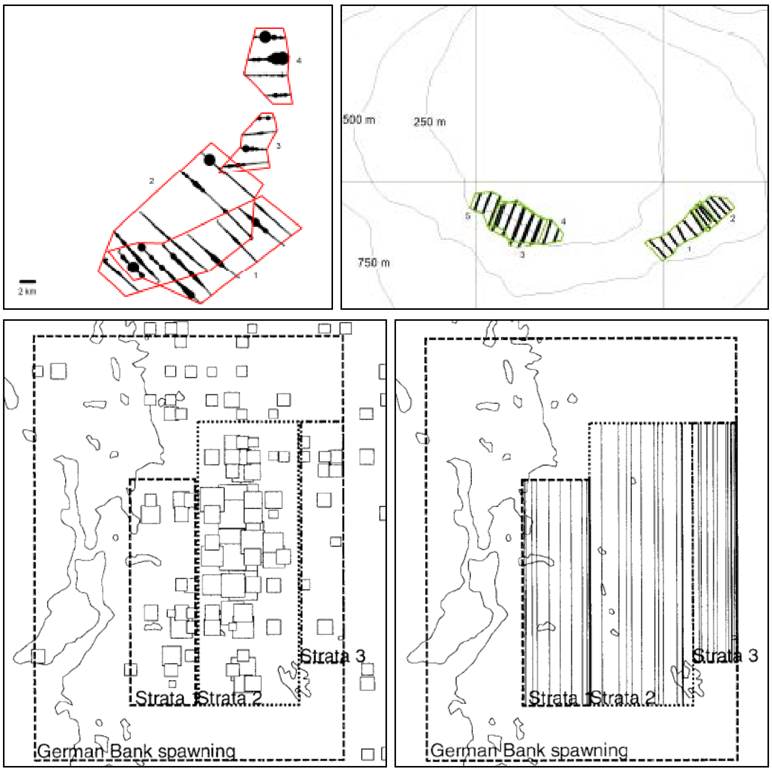

Figure 4.4. Examples of areas covered with systematic transects by fishing vessels having available spare time during southern blue whiting fisheries (top panels; source: O'Driscoll, 2011); and proposed areas to be covered by systematic fishing vessel surveys based on observed spawning aggregations (bottom panels; source: Melvin and Power, 1999)

5. Recommendations

- Future acoustic fishing vessel data collection, especially if more vessels are considered, should investigate automation of data processing steps. This will assist with detecting fish schools and also tackle data quality issues to speed up the process.
- To achieve more independent calibrations, continuation of regular (possibly assisted) calibrations on the freezer-trawlers is recommended to provide the vessel crew with more routine and confidence.
- The overall noise signature of individual vessels should be more thoroughly quantified. It is only a partial achievement to maintain a high precision in echosounder performance through calibrations, if the trawler itself causes bias in acoustic measurements.
- It is essential to measure echosounder performance by means of calibrations at frequent intervals, because the transducers are especially vulnerable to mechanical damage and ageing effects, or a combination of both.
- A complete calibration of the echosounder should be performed at least once a year, preferably before the beginning of the fishing season. However, if a failure event occurs this would then not be recognised immediately and all the data collected after the last calibration would be worthless.
- In order to reduce the period between performance checks, a "between-calibration" analysis of the behaviour of the system is recommended: possible approaches are monitoring of the bottom reflection and the echosounder ringdown zone.
- Observations from hotspot areas covered by vessels can be linked to localised fish abundance and in some cases to the wider stock size. Use of geostatistics for analysis of such fishing vessel data is highly promising due to the ability to deal with lack of structured sampling designs. Likelihood-based geostatistics in particular have recently been used to address these data limitations and to estimate mean organism density from acoustic data collected by commercial vessels. Data from more vessels covering areas at the same time would improve such a method.
- Methods currently used for analysing VMS data can also be applied to acoustic fish density recordings to aid area based data analysis of fishing trip data. This can then facilitate the approach of treating the vessels as predators and infer resource abundance based on their behaviour pattern, in a similar way as previously done for marine bird foraging trips.
- The good correlations found in the simulation studies between abundance indices and true abundance for herring suggest that data collected from many more vessels operating simultaneously during a fishery will improve the precision of a resulting abundance index. This is because a more realistic coverage of the resource in time and space can be achieved if more vessels are available for data collection.
- The data gathering methodology and guidelines developed in this project for fishing vessels can be used to perform mini acoustic surveys using a systematic survey design to derive abundance estimates. This would be applicable if time to perform such surveys is available and the resource distributed over a relatively small area.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

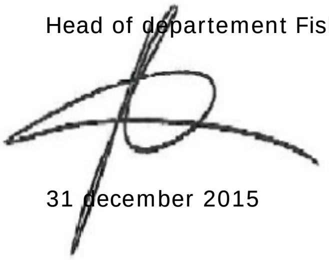
Approved: Thomas Brunel
researcher

Signature:

Date: 31 december 2015

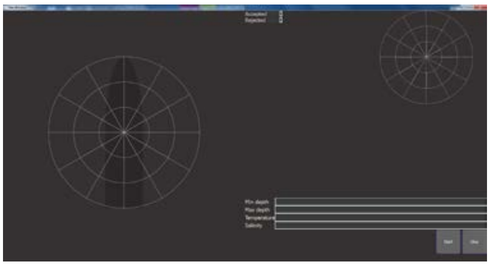
Approved: Nathalie Steins
Head of departement Fisheries

Signature:



Date: 31 december 2015

Appendix A. developed calibration material

IMARES kalibratie software	
5 X 3 kalibratie hengels met servo winch motoren	
5 x Control box	
10 x 38.1mm kalibratie wolfraam sphere's	

5 x afstands bediening

Appendix B. calibration manual

Kalibratie van akoestische apparatuur en data log protocollen voor commerciële visserij vaartuigen

Versie: 3.0
Datum: 14/06/2013

Europees Visserijfonds: Investering in duurzame visserij

Inhoudsopgave

1 Samenvatting: Echosounder systeem vereisten & data opslag

Hardware

Vaartuig moeten minimaal een SIMRAD ES70 systeem met een splitbeam 38kHz transducer aangesloten aan een gps, en een systeem voor het loggen van de .raw data.

Software

De meest recente ES70 software (of ER60 bij EK-systemen) moet geïnstalleerd zijn op de echosounder computer.

Opslag echosounder data

Voorafgaand aan de reis, de echosounder settings die instelbaar zijn (puls lengte, power, opslag, etc) moeten ingesteld zijn volgens de aangegeven waarden (zie sectie 2). Tijdens de reis moet de ruwe data altijd opgeslagen worden; start met opnemen in de haven vertrek tot en met het einde van de reis terug in de haven.

Vermijd ongewenste storing en ruis

Storing en ruis bronnen moeten geminimaliseerd worden. Conventionele visserij echosounders en andere akoestische instrumenten met dezelfde of dicht in de buurt van de 38 kHz, moeten gesynchroniseerd worden, of uitgeschakeld, tijdens de data registratie.

Controleer de data opslag

Top prioriteit: de persoon die zorg draagt voor de akoestische data opslag, moet regelmatig controleren of de ES70/ER60 goed werkt en of er problemen zijn met de data opslag naar de harde schijf (zie sectie 3).

Kort na vertrek, moeten wetenschappers via TeamViewer controleren of alles goed is ingesteld.

Potentiele problemen (b.v. Echosounder uit, geen gps, storing in het signaal, niet opslaan van ruwe data, harddisk vol....) moeten direct verholpen worden.

Kalibratie

Direct voor, tijdens of na de data registratie, moet het akoestische systeem gekalibreerd worden met een wolfraam sphere(zie sectie 4). Voor de locatie van de echosounders levert de rederij of schipper van het schip de tekening met de exacte plaatsing van de echosounder, dit is nodig voor de planning van de kalibratie.

Data backup

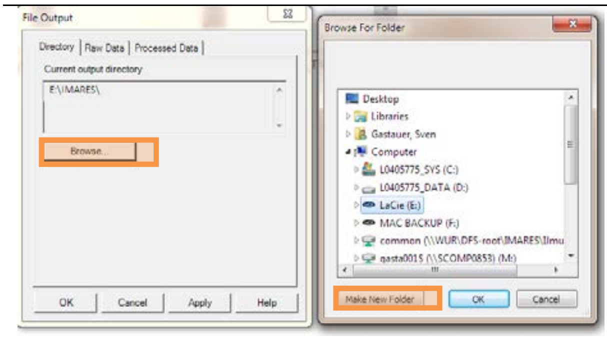
Aan het einde van de reis moet de opgeslagen data overgezet worden naar een hard disk van Imares.

2 START VAN DE REIS: Hard disk aansluiten, instellingen & data opslag

2.1 ES70

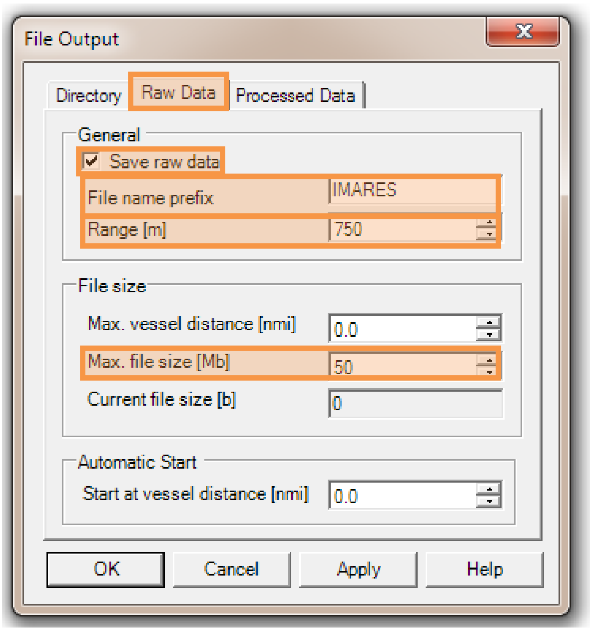
Sluit de externe harddisk (>500Gb) aan op de ES70 computer. configureer de data opslag en kies de echosounder instellingen in de ES70:

Operation → File output



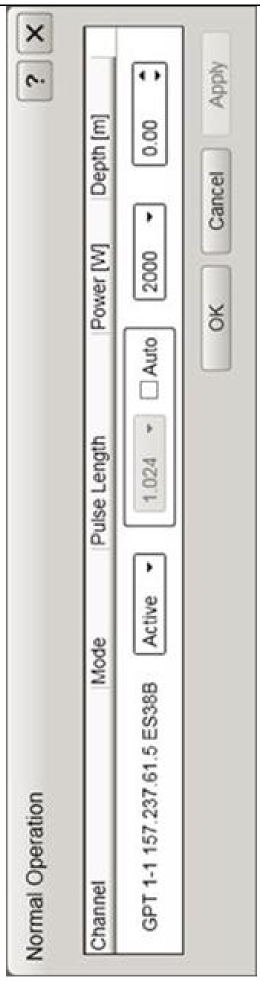
Maak een 'destination folder' aan

Directory → Browse → Make New Folder -> bijvoorbeeld: E:\IMARES\data



Selecteer de file size en range

- Selecteer RawData Tab
- check het finkje bij “Save raw data”: ☑
- geef een file name prefix (b.v. “IMARES”)
- stel de Range [m] op: 750
- stel de Max. file size [Mb] op: 50



Eenmalig de PulsLengte en Power instellen:

(niet veranderen tijdens de reis!!!)

Operation → Normal Operation

Mode → Active

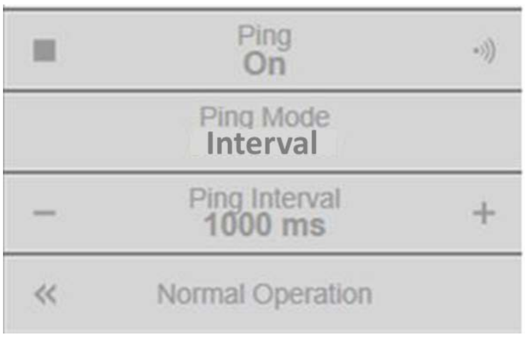
Pulse Length → 1.024 (niet op ‘Auto’!!!!!)

Power [W] Settings

(met de volgende waarden):

38 kHz → Max = 2000W

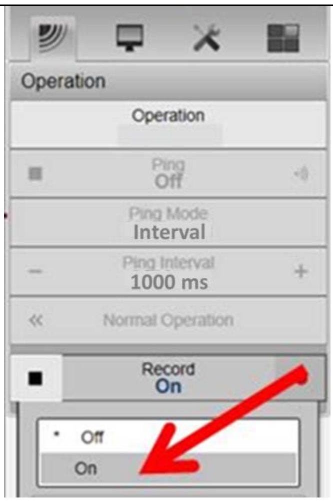
(70 kHz → Max = 750W
120 kHz → Max = 250W
200 kHz → Max = 110W)



Stel de ping interval in op 1 per seconde:

OPERATION → PING MODE: "INTERVAL".

OPERATION → PING INTERVAL: select 1000 ms.

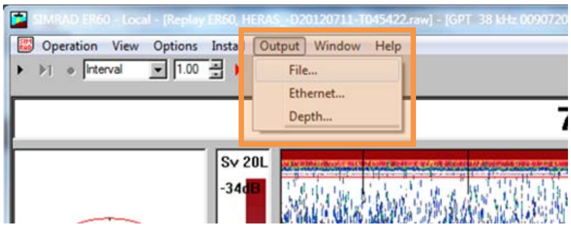


Activeer de ruwe data opslag van de echosounder

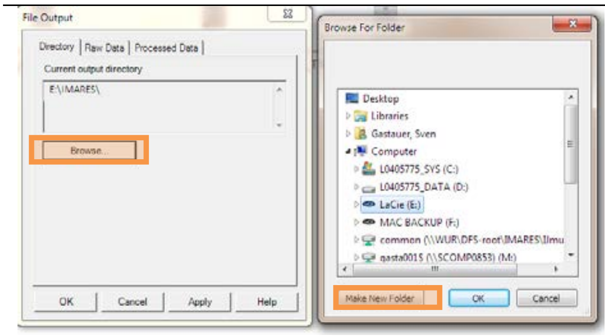
Operation → Record: "On"

2.2 ER60

Sluit de externe harddisk (>500Gb) aan op de ER60 computer. configureer de data opslag en kies de echosounder instellingen in de ER60:

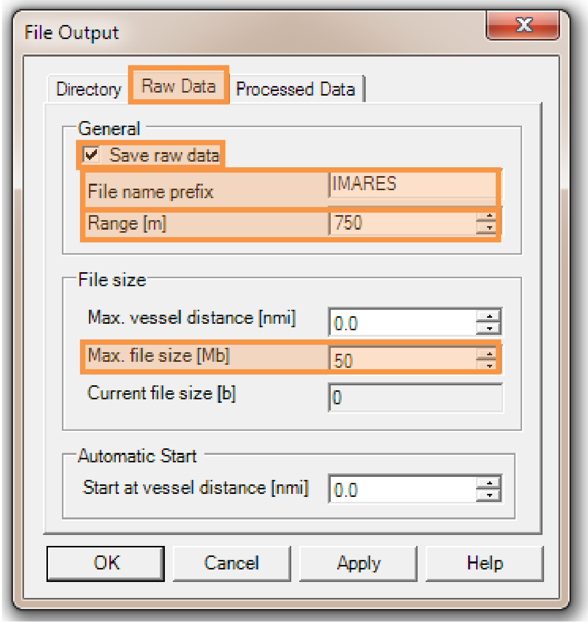


Output → File...



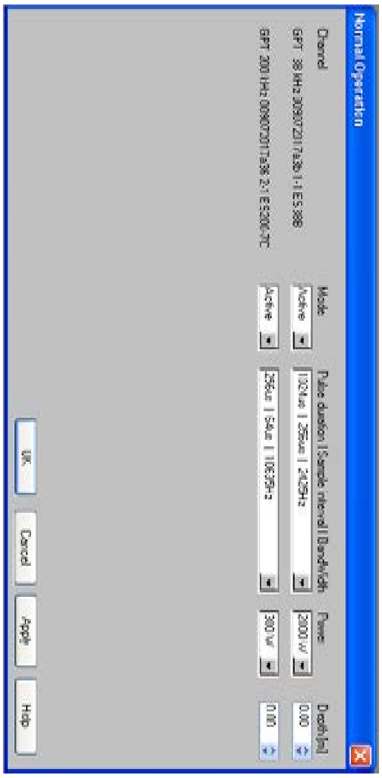
Maak een 'destination folder' aan

Directory → Browse → Make New Folder -> bijvoorbeeld: E:\IMARES\data



Selecteer de file size en range

- Selecteer 'Raw Data' tab
- check het finkje bij "Save raw data": ☑
- geef een file name prefix (b.v. "ALIDA_")
- stel de Range [m] op: 750
- stel de Max. file size [Mb] op: 50
- "OK"

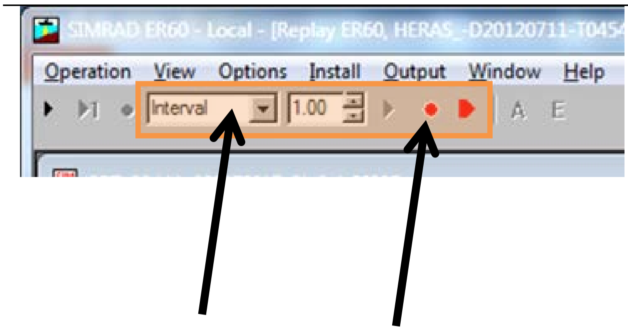


Eenmalig de 'Pulse duration' en 'Power' instellen:
(niet veranderen tijdens de hele reis!!!)

Operation → Normal...

Mode → Active
Pulse duration → 512μs (of 1024μs)
(tijdens kalibratie de zelfde waarde gebruiken!)

Power [W] Settings
(met de volgende waarden):
38 kHz = 2000W
70 kHz = 375W
120 kHz = 250W
200 kHz = 105W



Stel de ping interval in op 1 per seconde:

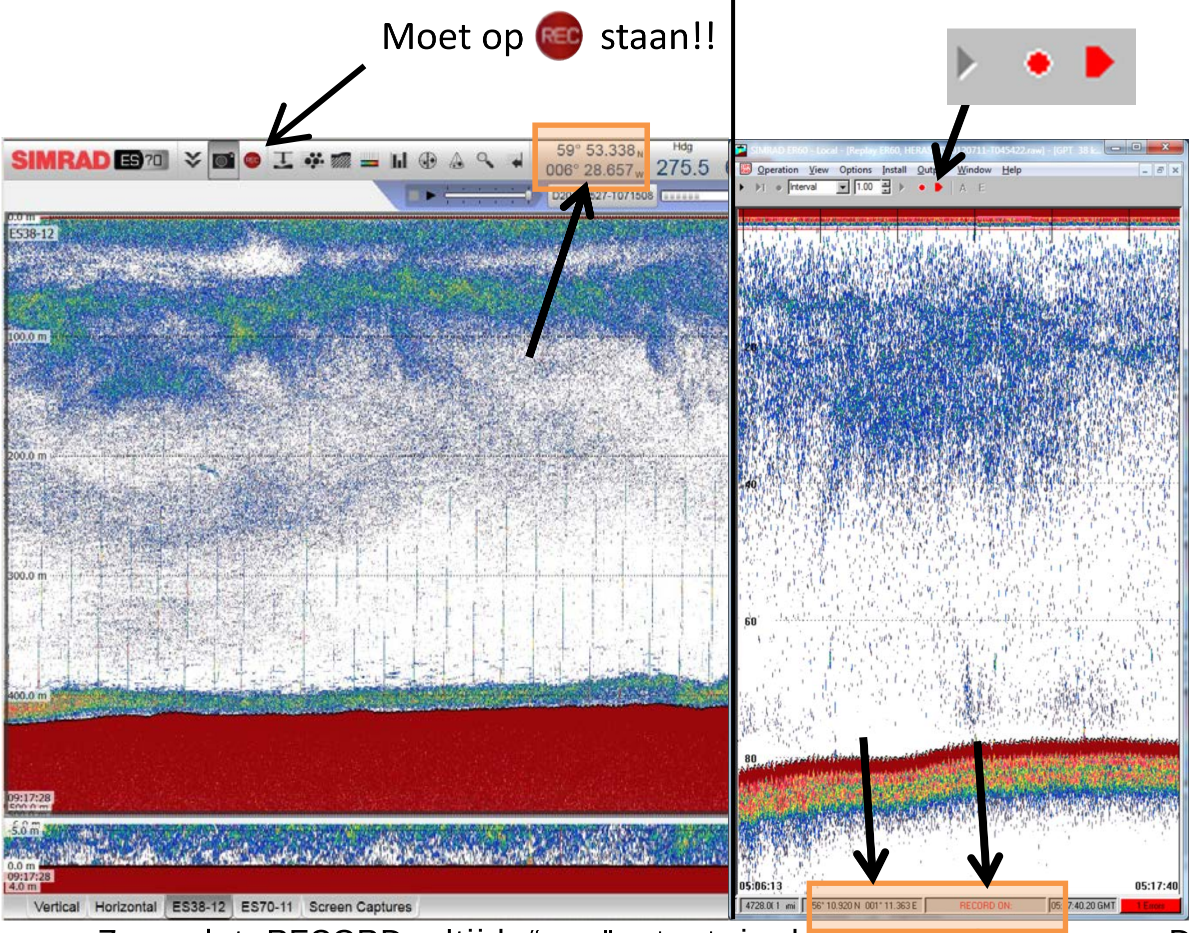
- OPERATION → PING CONTROL: "INTERVAL".
- 1.00 (een ping per seconde; in de Noordzee kan het ook sneller, b.v.: 0.50 – maar niet te snel, i.v.m. foute bodem detectie en storing te voorkomen).

Controleer ruwe data opslag van de echosounder

- De RECORD button moet rood zijn.

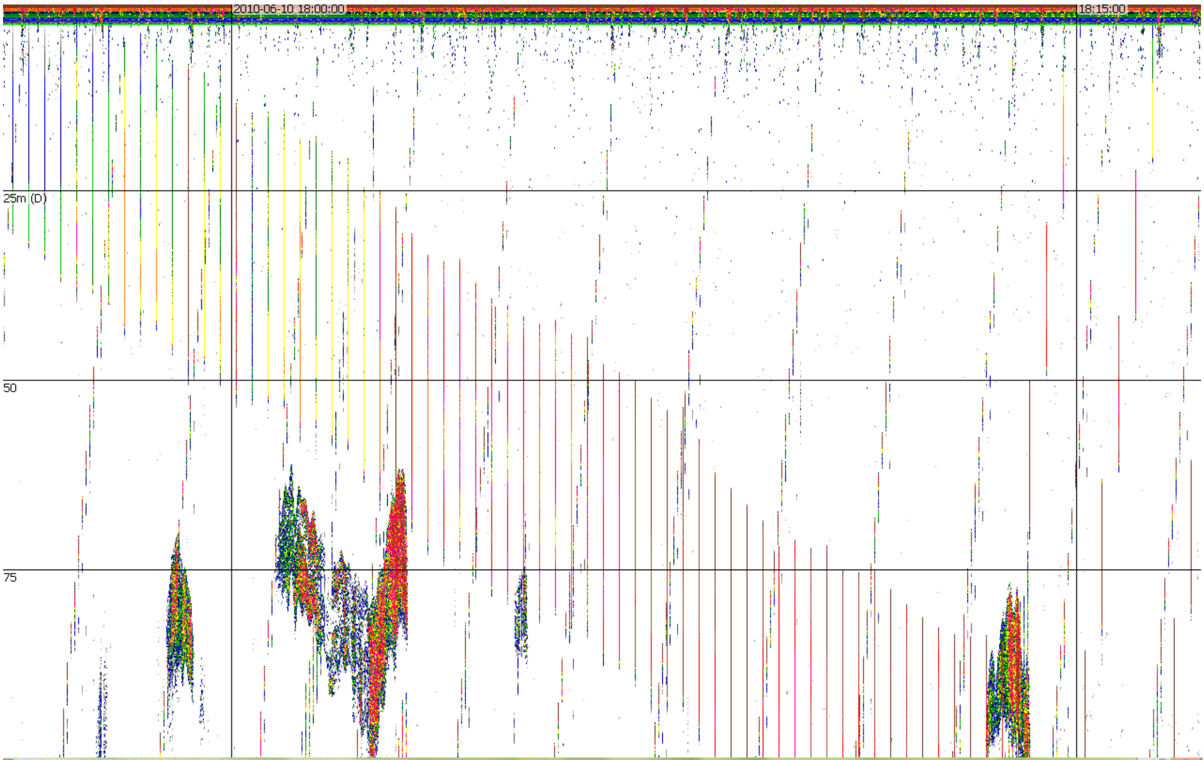
3. TIJDENS DE REIS: controleer de data opslag & echosounder werking

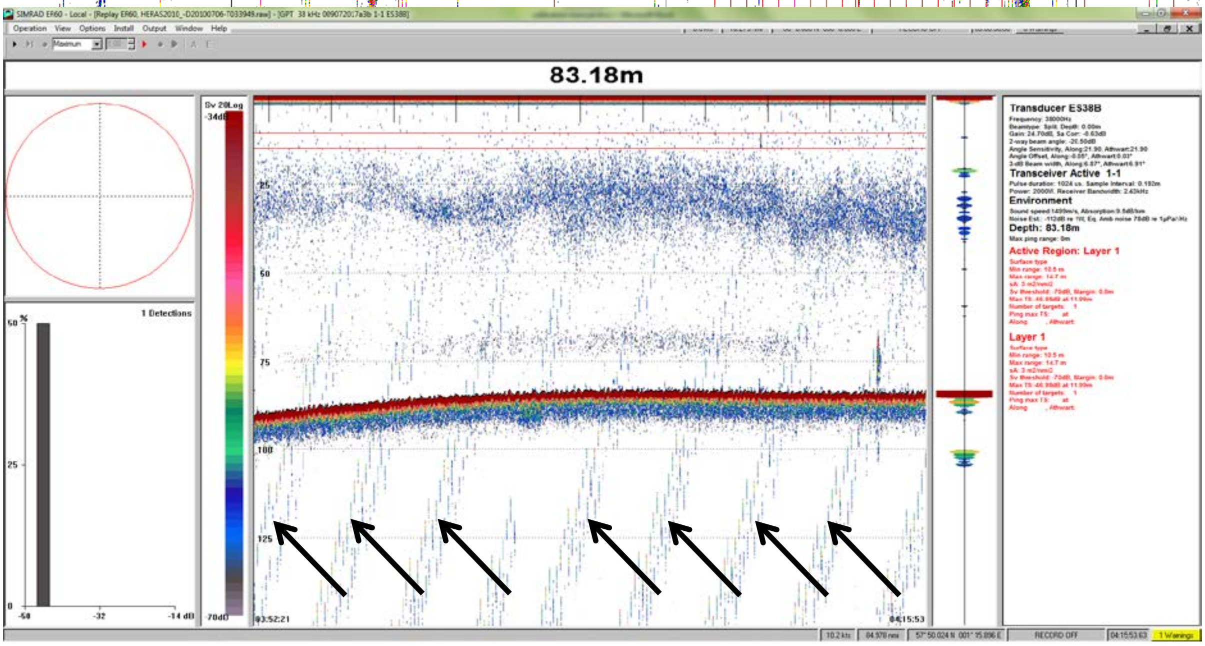
ES70: **ER60:**



- Zorg dat RECORD altijd “aan” staat in het Operation menu. De RECORD Button (ES70) moet altijd **rood** zijn: REC
- Mocht de ES70 of ER60 opnieuw gestart worden, dan **niet de factory settings kiezen**, maar de “Most Recent State”. Anders zijn de settings niet juist en wordt de ruwe data niet (of alleen maar naar de C-schijf) opgeslagen.
- Tijdens de reis af en toe controleren of de **GPS informatie** op de ES70/ER60 binnenkomt, en de **record button rood** is, en de data files (extensions .raw) naar de externe schijf geschreven wordt: bij voorbeeld op “E:\Imares\data”
- Let op tekening van storing door interferentie van een andere transducer in het echogram (zie scherm hieronder). Als dit zichtbaar is dan de andere transducer uitschakelen. Valse bodem echo's (=storing) kunnen ontstaan als de ping interval te hoog is ingesteld.

Echogrammen die storing vertonen in zoals hieronder getoond, laten interferentie zien veroorzaakt door een andere echosounder:





4. KALIBRATIE

voorbereiding

- De kalibratie kan gedaan worden wanneer dit het beste uitkomt aan het begin, tijdens of aan het einde van de reis.
- Het wordt aanbevolen de kalibratie verankerd uit te voeren. Kalme weersomstandigheden en diep water (>20-30m onder het schip!!) zijn nodig. Vermijd gebieden met grote verschillen in getij hoogte of dicht bij rivier mondingen.

Aanbevolen Kalibratie Locaties

Bantry Bay (IRELAND):	51°41'11.8"N, 9°32'57.0"W
Dunmanus Bay (IRELAND):	51°34'49.7"N, 9°38'13.5"W
Scapa Flow (SCOTLAND):	58°55'15"N, 3°02'11"W
Penzanze Bay (ENGLAND):	50°5'59.6"N, 5°31'4.4"W
Douarnenez Bay (FRANCE):	48°11'56.6"N, 4°29'30.1"W

- De positie van de echosounder(s) moet bekend zijn voordat er met kalibratie begonnen wordt, dit beperkt de tijd van het zoeken naar de sphere in de beam van de echosounder. Kalibratie neemt normaal gesproken 4 – 6 uur in beslag(plus de stoomtijd naar de geschikte kalibratie locatie).
- De hoofd motor moet als mogelijk uitgeschakeld worden tijdens de kalibratie.
- Zorg dat er weinig tot geen individuele vissen aanwezig zijn in de waterkolom onder de echosounder. Bij daglicht is de kans op vis minimaal, kalibratie s'nachts is moeilijk doordat er vis aanwezig is aan de oppervlakte.

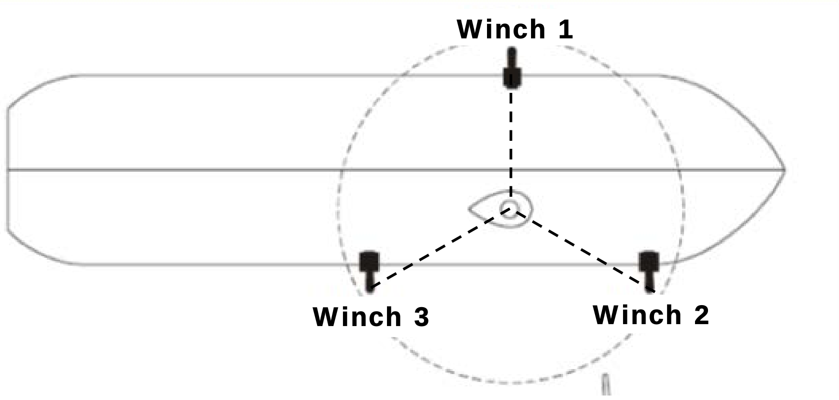
4.1 Procedure

a) CTD meting

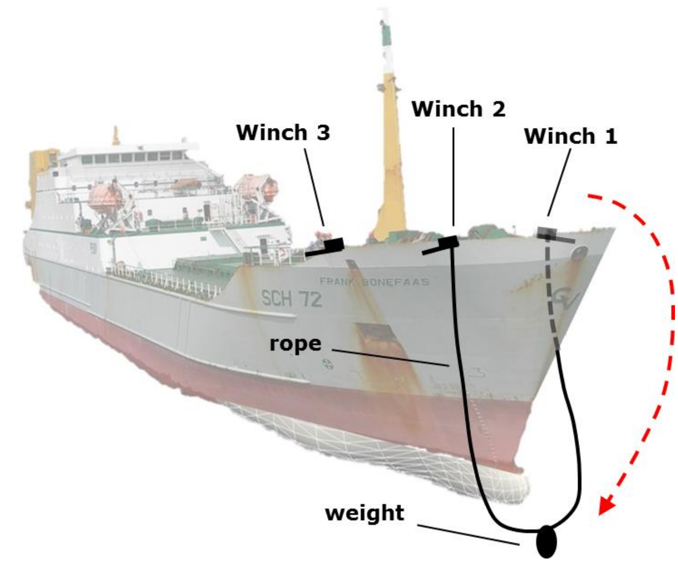
Het meten van de saliniteit en de temperatuur van het water op de kalibratie locatie is nodig om de geluidsnelheid door het water te berekenen, en de geluidsdemping van het water.
Note down the values! These will later be entered in the calibration software on the ES70 computer.

b) Kalibrate kit opstelling

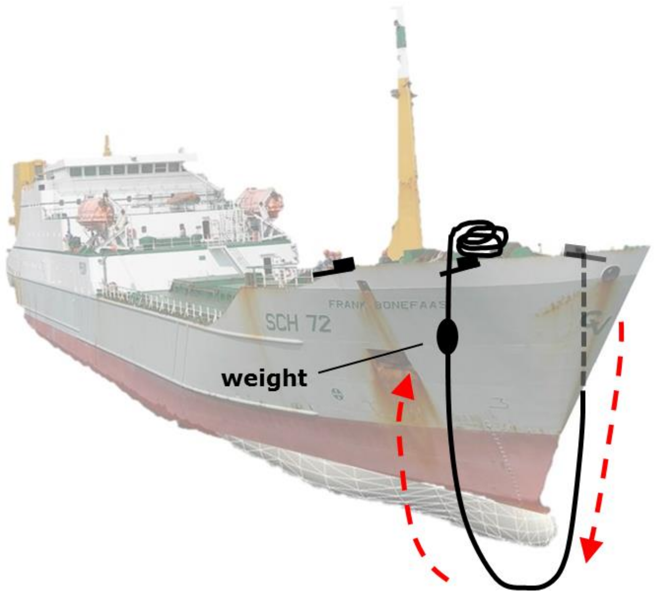
Voordat het anker neergelaten wordt!!: Zet de drie hengels met elektrische lier op de aangegeven locaties (gecentreerd rondom de transducer), en stel deze zonodig bij zodat de sphere het beste in de beam gepositioneerd kan worden:



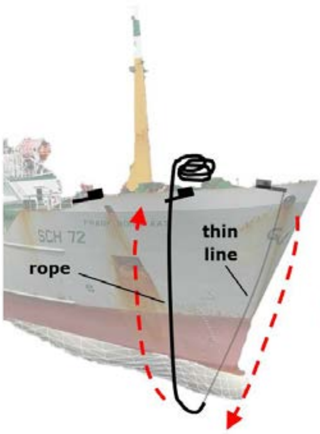
c) De kalibratie sphere in positie brengen onder het scheep

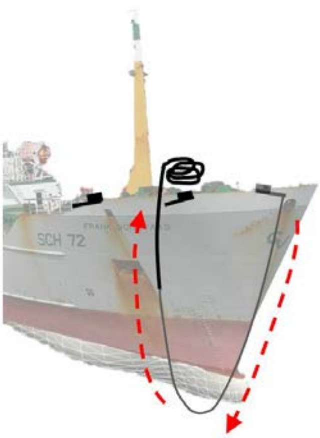
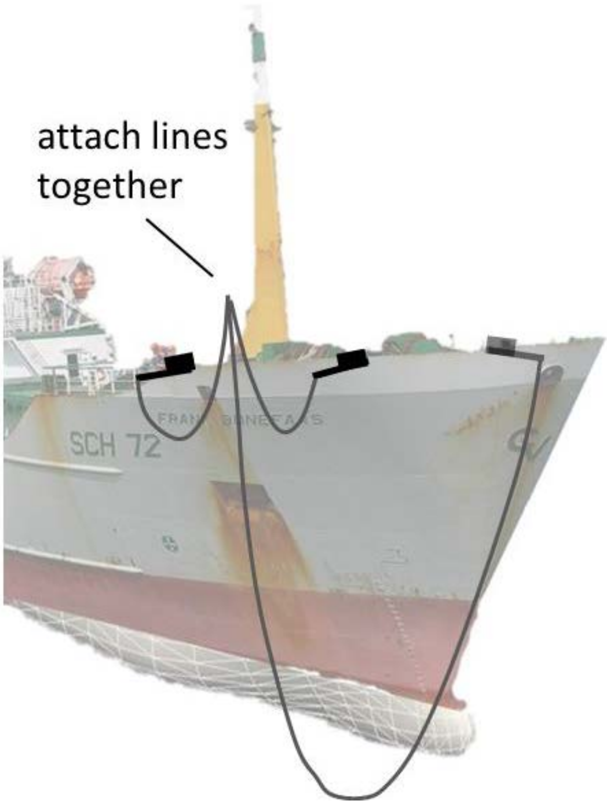


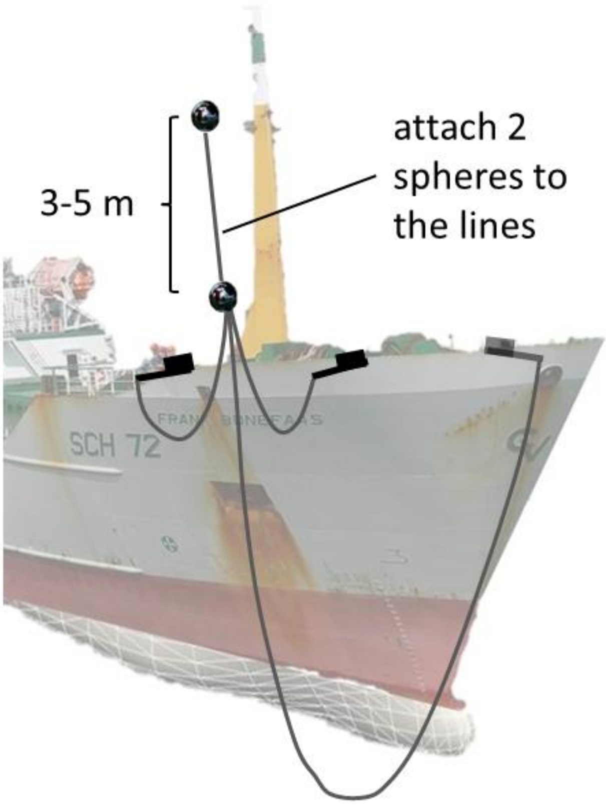
Laat een touw (8mm-10mm) met een man aan bakboord, een aan stuurboord, en een man in het midden het touw met genoeg lengte en een gewicht over de boeg werpen, zodanig dat het touw voorbij de bulb onder het schip komt. Het touw moet lang genoeg zijn om uitsteeksel zoals de sonar kop vrij te houden.



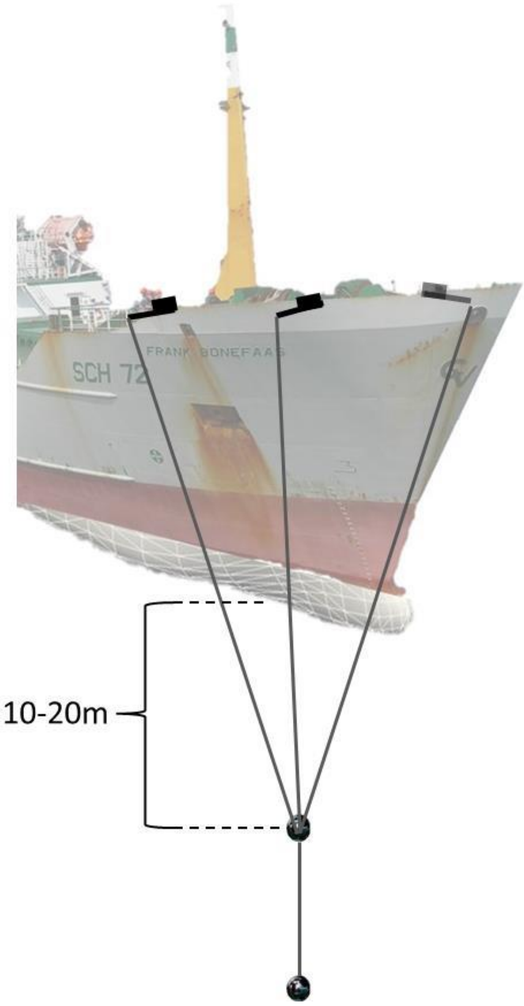
Loop met de beide uiteinden van het touw tot beide gelijk zijn aan de positie van winch 1 (de ene aan bakboord). Geef aan de bakboord zijde lijn, en haal deze in aan stuurboord zijde, zover dat het gewicht er af genomen kan worden. Neem dan het gewicht af van het touw.

<table>
<tr>
<td>

</td>
<td>Knoop de vislijn van de bakboord winch1 aan het touw, en vier daarna de bakboord winch uit, terwijl aan stuurboord het touw wordt ingenomen, waarbij er genoeg ruimte blijft om de vislijn van de huid van het schip af te houden, i.v.m. scherpe uitsteeksels die de vislijn kunnen snijden.</td>
</tr>
<tr>
<td>
</td>
<td>Als de vislijn van bakboord aan de stuurboord verschansing komt wordt het touw verwijderd, en worden de drie vislijnen aan elkaar gekoppeld. Pas hierna kan het schip voor anker gaan.</td>
</tr>
</table>

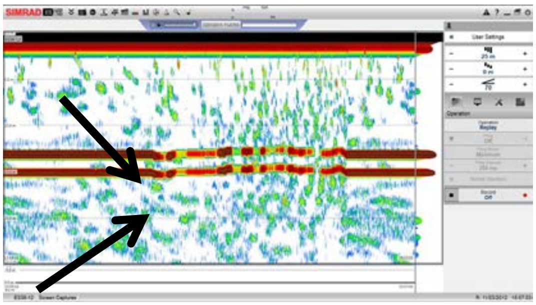
	Dompel de schone en droge kalibratie sphere's in een emmer of bakje water met afwasmiddel (b.v, ‘dreft’). Dit om te voorkomen dat de sphere microbubbles van lucht vasthoud en een foute echo waarde geeft.
	Verbind de sphere aan het punt waar de drie monofilament vislijnen aan elkaar gekoppeld zijn. Verbind de tweede sphere, 3 tot 5 meter onder de eerste, sphere, deze werkt als stabilisator gewicht. De lijn heeft een lengte indicatie door middel van een kleur aanduiding, elke tien meter heeft een andere kleur, en elke 1 meter en 5 meter is er een kleur indicator. Op deze wijze is er een goed inzicht hoeveel lijn elke winch uitgevierd heeft, en ze op gelijke lengte te positioneren.

De spheres moeten nu voorzichtig overboord gezet worden, hierbij moet kontakt van de spheres met het schip vermeden worden.

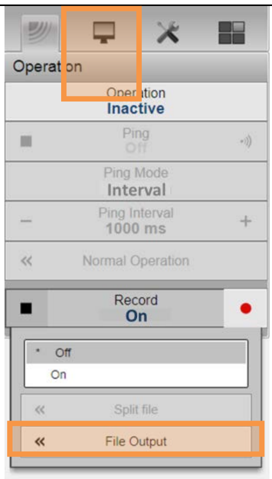


Vier zoveel lijn uit dat ze alle drie dezelfde lijnlengte hebben, een 10 tot 20 meter onder de transducer, zodat die sphere's in de beam van de transducer komen te hangen.

d) De kalibratie op de brug uitvoeren (ES70)

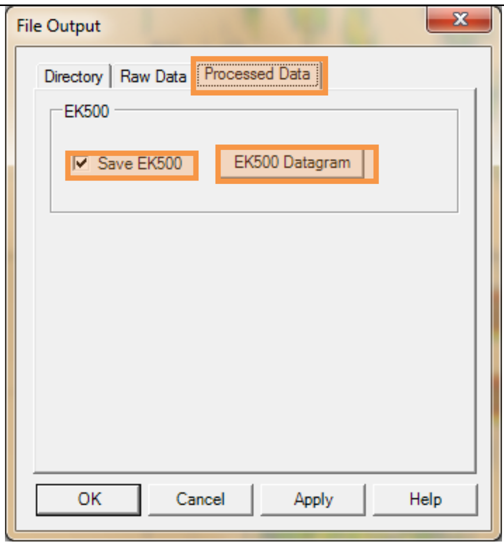


Zoek in het echogram de echo's van de twee sphere's op (deze zijn te zien als twee donkere lijnen). Vier de lijnen van de winches, met de remote control, uit tot ze zichtbaar zijn op het ES70 scherm (maar let op dat er niet zoveel lijn uitgevierd wordt dat de onderste de bodem raakt...). De bovenste sphere moet tussen de 10 tot 20 meter onder de transducer hangen!!

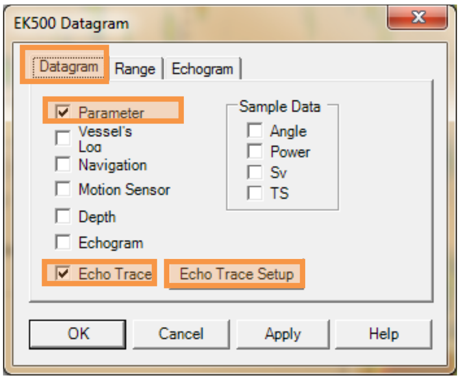


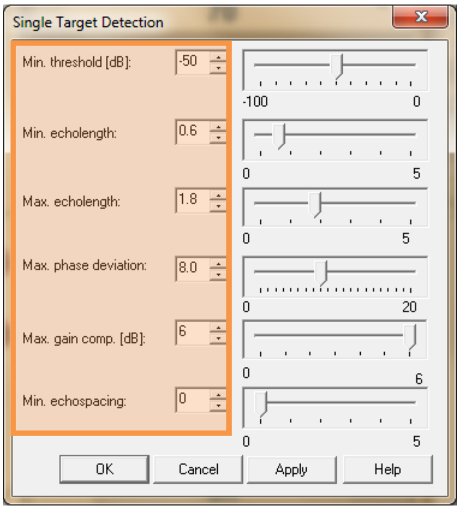
Sla de single target data op de harde schijf tijdens de kalibratie.

Operation → File output



- Selecteer ‘Processed Data’ van het tab menu
- Zet een vinkje in de box “Save EK500”: ☑
- Selecteer de tab “EK500 Datagram”

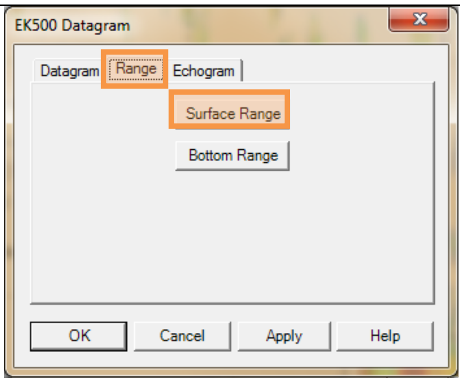


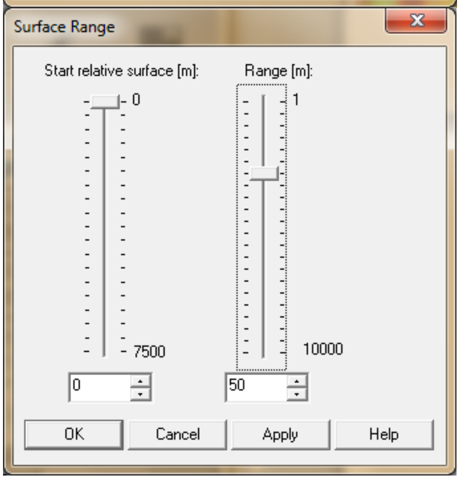


- Selecteer ‘Datagram’ van het tab menu
- Zet vinkjes in de box
  “Parameter”: ☑
  en
  “Echo Trace”: ☑
- Selecteer de tab “Echo Trace Setup”

Target Detectie Settings

- Min. threshold [dB]: -50
- Min. echolength: 0.6
- Max. echolength: 1.8
- Max. phase deviation: 8.0
- Max. gain comp. [dB]: 6
- Min. echospacing: 0



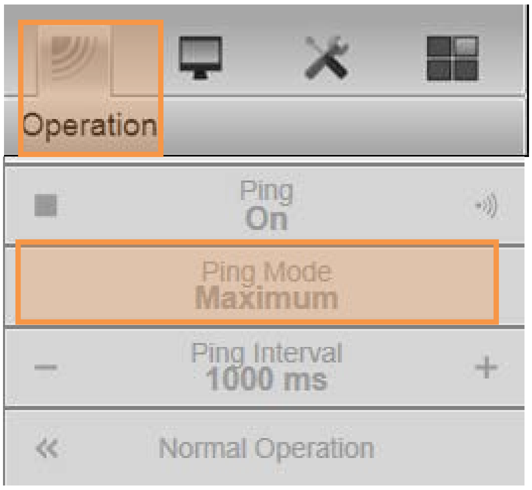


- Selecteer ‘Range’ van de tab menu
- Selecteer de tab “Surface Range”

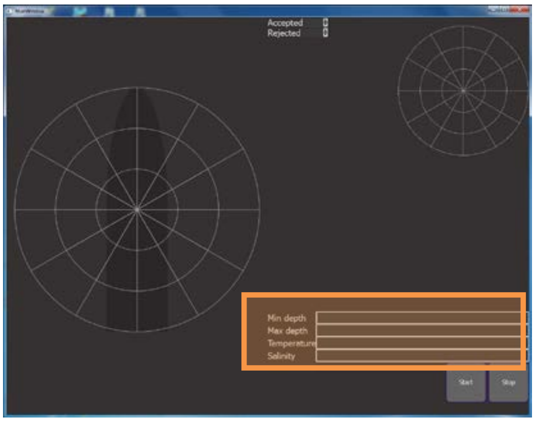
Surface Range Settings

- Start relative surface [m]:
  0
- Range [m]:
  50

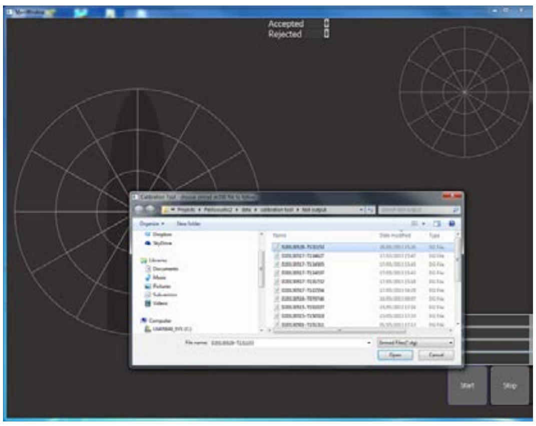
sluit het scherm met “OK”



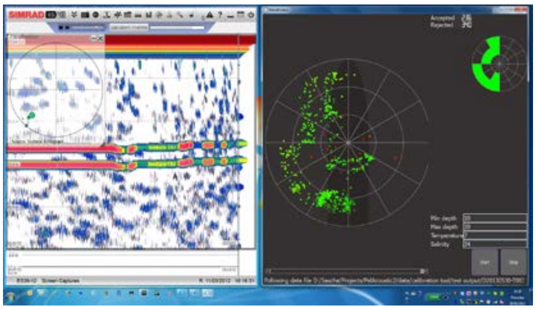
Zet de Ping interval op Maximum alleen tijdens de calibratie:
OPERATION → PING MODE: “MAXIMUM”.



Start de Imares Calibration Tool. Stel de diepte limieten in op +/- 2.5 meter van de bovenste sphere zichtbaar in het echogram en voer deze in de Imares Calibration Tool.
Bijvoorbeeld, als de bovenste sphere op 15 diepte is:
Min depth = 12.5 and
Max depth = 17.5
Voer ook de gemeten waarden voor saliniteit en temperatuur in.

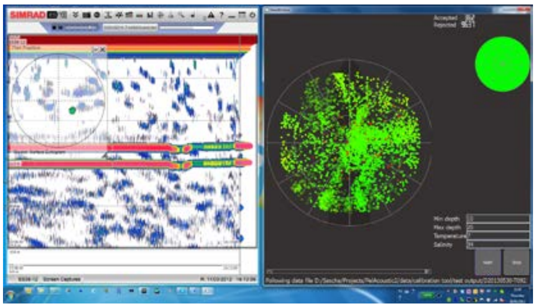


Click op de ‘Start’ button. Selecteer de meest recente file eindigend op .dg in de data folder op de externe harddisk (b.v. “E:\Imares\data”).
→ click: OPEN



Met de remote control wordt de sphere rustig door de akoestische beam gemanouvreerd – de gedetecteerde data punten worden zichtbaar in het Imares Calibration Tool scherm.

Zorg dat er genoeg data punten worden gedetecteerd gelijk verdeeld over de akoestische bundel. Als de sphere door de bundel gemanoeuvreerd wordt let dan op de diepte van de sphere in het ES70 scherm, zodanig dat de sphere binnen de in de Imares Calibration Tool gestelde diepte limieten blijft.



Als er genoeg data punten gedetecteerd zijn, en alle segment in het ‘target window’ rechts boven in de Imares Calibration Tool groen oplichten, kan de kalibratie gestopt worden. Click op de ‘Stop’ button.

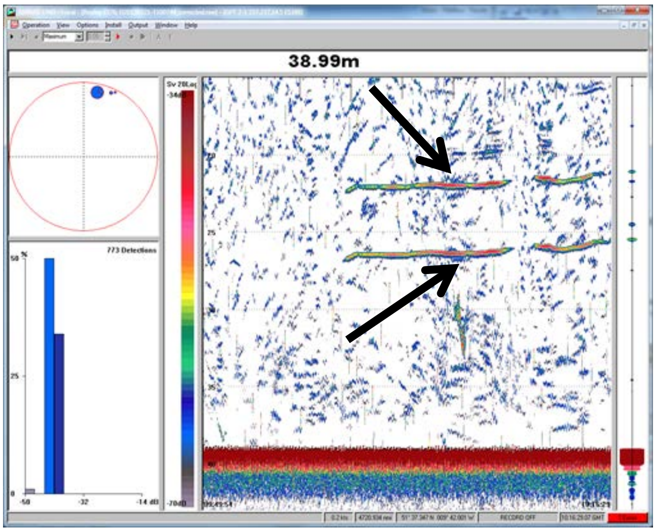
Na de kalibratie moeten de instellingen van de ES70 terug gezet worden:

- Operation → File output → Processed Data: de box afvinken
  “Save EK500”: ☐
- OPERATION → PING MODE: “INTERVAL”.
- OPERATION → PING INTERVAL: select 1000 ms.

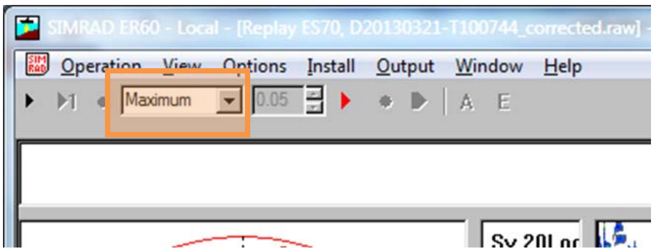
Na de kalibratie:

- Haal de sphere's binnen zonder de huid van het schip te raken.
- Ontmantel de kalibratie equipment.
- Spoel de sphere's af in warm zoet water, en droog ze goed af met een doek, en bewaar ze droog in de doos met schuimrubber uitsparingen.

e) De kalibratie op de brug uitvoeren (ER60)

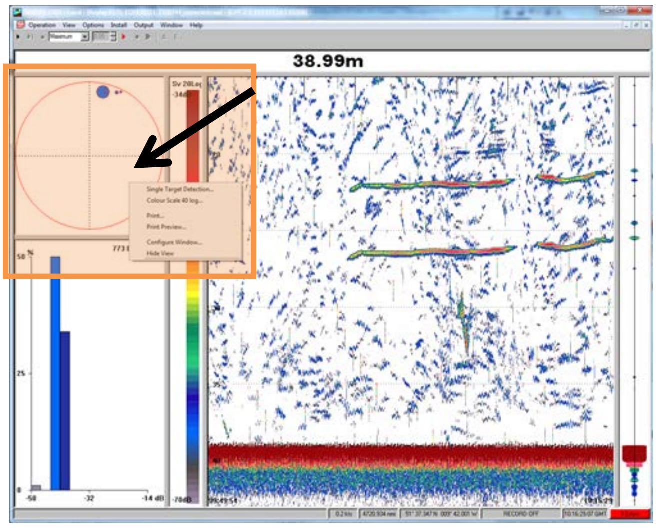


Zoek in het echogram van de frequentie die je wil kalibreren de echo's van de twee sphere's op (deze zijn te zien als twee donkere lijnen). Vier de lijnen van de winches, met de remote control, uit tot de sphere's zichtbaar zijn op het ER60 scherm (maar let op dat er niet zoveel lijn uitgevierd wordt dat de onderste de bodem raakt...). <u>De bovenste sphere moet tussen de 10 tot 20 meter onder de transducer hangen!!</u>



Zet de Ping interval op Maximum alleen tijdens de calibratie:

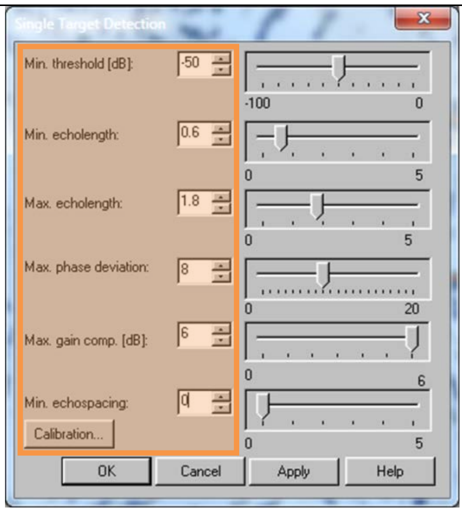
OPERATION → PING CONTROL: “MAXIMUM”



Start het SIMRAD kalibratie tool.

‘Single Target Position’ scherm (links boven) → rechter muis click

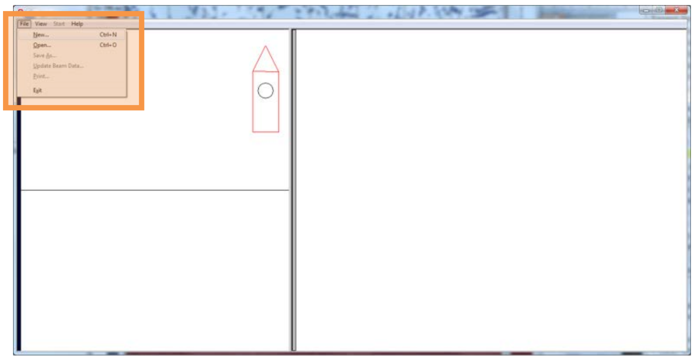
- Selecteer ‘Single Target Detection…’



Target Detectie Settings

- Min. threshold [dB]: -50
- Min. echolength: 0.6
- Max. echolength: 1.8
- Max. phase deviation: 8.0
- Max. gain comp. [dB]: 6
- Min. echospacing: 0

- Selecteer daarna de tab “Calibration…”



In het SIMRAD kalibratie tool. File → New…

Kalibratie Settings

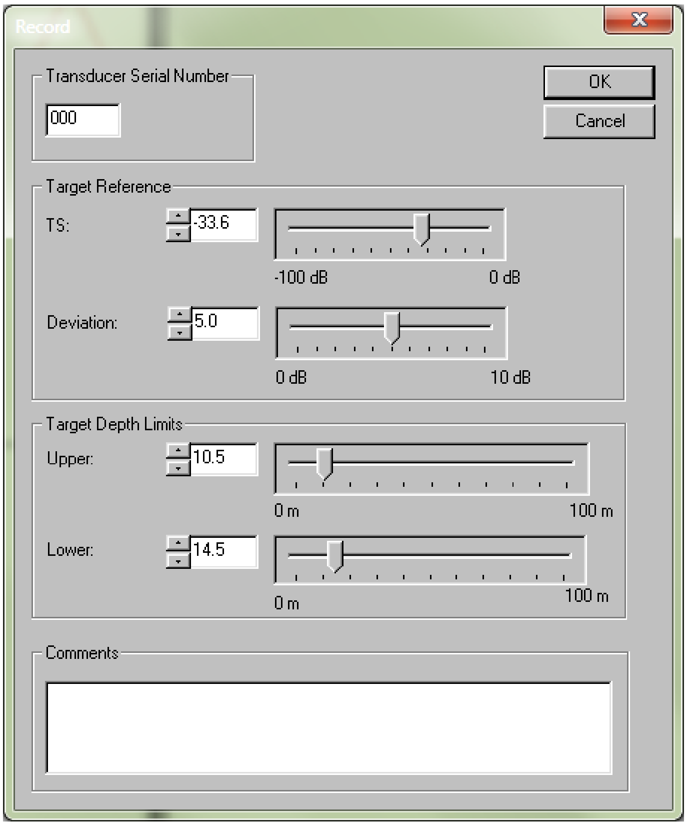
Target Reference

(bij ‘pulse duration’ van 512µs of 1024µs)
voor **38 kHz**, TS: -42.2
voor **70 kHz**, TS: -41.2
voor **120 kHz**, TS: -39.5
voor **200 kHz**, TS: -39.2

Deviation: 5.0

Target Depth Limits

Stel de diepte limieten in op

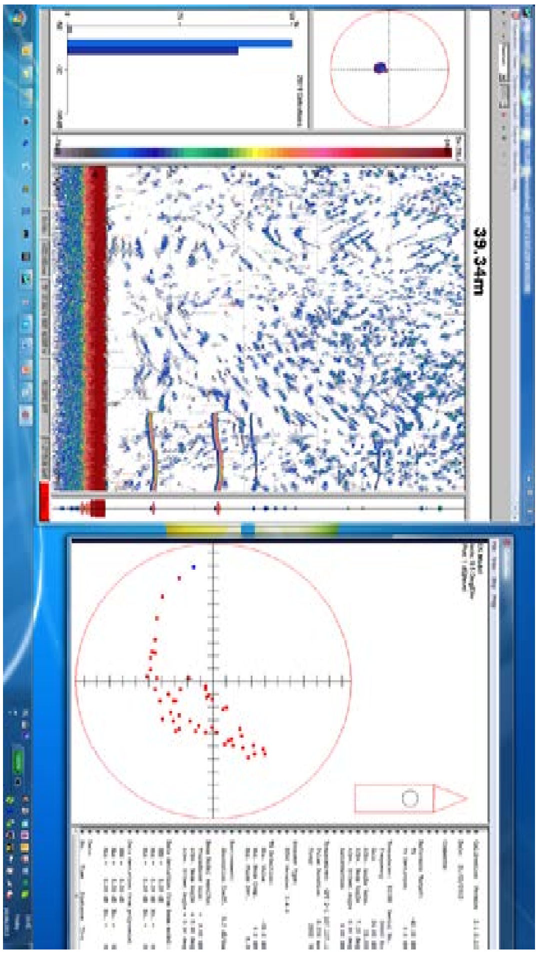


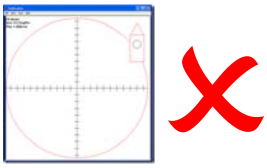
2.5 meter boven de bovenste sphere en 2.5 meter onder de onderste sphere zichtbaar in het echogram.

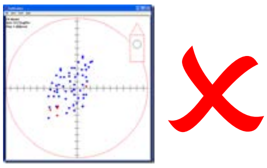
Bijvoorbeeld, als de bovenste sphere op 15m en de onderste sphere op 18m diepte is:

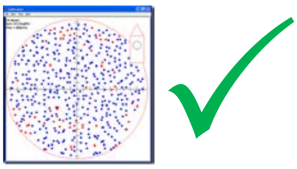
Upper: 12.5

Lower: 20.5





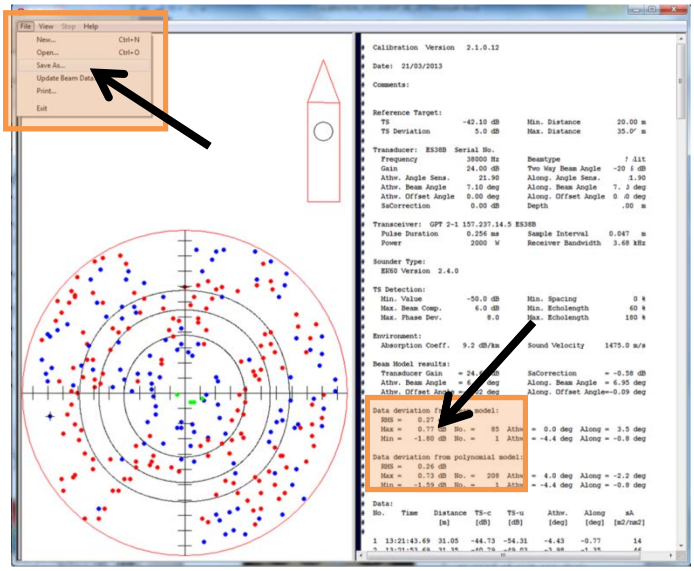




- Met de remote control wordt de sphere rustig door de akoestische beam gemanouvreerd – de gedetecteerde data punten worden zichtbaar in het Target Detection scheerm van het SIMRAD kalibratie tool (zie voorbeeld links).

- Zorg dat er genoeg data punten (>200-250) worden gedetecteerd gelijk verdeeld over de akoestische bundel (zie voorbeeld links).

- Als de sphere door de bundel gemanoeuvreerd wordt let dan op de diepte van de sphere in het ER60 scherm, zodanig dat de sphere binnen de in het SIMRAD kalibratie tool gestelde diepte limieten blijft.



Als er genoeg data punten gedetecteerd zijn (>200-250), het kalibratie file opslaan:
File → Save as…

Kies een ‘File name’ die het datum, scheep en akoestische frequentie omvat: b.v. ‘ALIDA_14062013_38kHz.txt’
Sla de file op in de data folder op de externe harde schijf (b.v. “E:\IMARES\data”).

Kontroleer de kalibratie getallen in het SIMRAD kalibratie tool (aan de rechter kant):
Data deviation from beam model: RMS < 0.40 dB
Data deviation from polynomial model:
RMS < 0.40 dB

Na de kalibratie kan het SIMRAD kalibratie tool worden beëindigd (File → Exit) en moet de ping interval van de ER60 terug gezet worden:

- OPERATION → PING CONTROL: “INTERVAL”.
- 1.00 (een ping per seconde)

	Na de kalibratie: • Haal de sphere's binnen zonder de huid van het scheep te raken. • Ontmantel de kalibratie equipment. • Spoel de sphere's af in warm zoet water, en droog ze goed af met een doek, en bewaar ze droog in de doos met schuimrubber uitsparingen.

Appendix C. calibration results

Vessel: SCH6 (Alida)
Date: 23.02.2013
Location: English Channel
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  23/02/2013
#
#  Comments:
#    test
#
#  Reference Target:
#    TS                   -42.30 dB       Min. Distance         10.00 m
#    TS Deviation           5.0 dB        Max. Distance         14.00 m
#
#  Transducer:  ES38B  Serial No.   38
#    Frequency             38000 Hz       Beamtype                Split
#    Gain                  26.00 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90        Along. Angle Sens.      21.90
#    Athw. Beam Angle      7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle    0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection           0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT  38 kHz 00907205b62e 1-1 ES38B
#    Pulse Duration        0.512 ms       Sample Interval     0.096   m
#    Power                  2000  W       Receiver Bandwidth   3.28 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value            -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.         6.0 dB       Min. Echolength          60 %
#    Max. Phase Dev.           8.0        Max. Echolength         220 %
#
#  Environment:
#    Absorption Coeff.  15.3 dB/km       Sound Velocity     1504.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 24.59 dB       SaCorrection       = -0.85 dB
#    Athw. Beam Angle   = 6.88 deg       Along. Beam Angle  = 6.95 deg
#    Athw. Offset Angle = 0.02 deg       Along. Offset Angle= 0.04 deg
#
#  Data deviation from beam model:
#    RMS =    0.20 dB
#    Max =    0.65 dB  No. =   242  Athw. =  3.9 deg  Along =  3.3 deg
#    Min =   -0.64 dB  No. =   232  Athw. = -0.4 deg  Along =  4.7 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.14 dB
#    Max =    0.48 dB  No. =   242  Athw. =  3.9 deg  Along =  3.3 deg
#    Min =   -0.52 dB  No. =   232  Athw. = -0.4 deg  Along =  4.7 deg
```

Vessel: SCH6 (Alida)

Date: 12.07.2013

Location: North Sea

Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  12/07/2013
#
#  Comments:
#    Reis 8 12072013 38khz
#
#  Reference Target:
#    TS                  -40.00 dB       Min. Distance         10.00 m
#    TS Deviation           6.0 dB       Max. Distance         15.00 m
#
#  Transducer:  ES38B  Serial No.   38
#    Frequency             38000 Hz       Beamtype                  Split
#    Gain                  23.40 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.        21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle      7.02 deg       Along. Beam Angle    6.99 deg
#    Athw. Offset Angle  -0.01 deg       Along. Offset Angle  0.03 deg
#    SaCorrection          -0.75 dB       Depth                 0.00  m
#
#  Transceiver:  GPT  38 kHz 00907205b62e 1-1 ES38B
#    Pulse Duration       0.512 ms       Sample Interval     0.096   m
#    Power                  2000  W       Receiver Bandwidth   3.28 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing                0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength            60 %
#    Max. Phase Dev.           8.0       Max. Echolength           180 %
#
#  Environment:
#    Absorption Coeff.   9.5 dB/km       Sound Velocity     1492.7 m/s
#
#  Beam Model results:
#    Transducer Gain    = 22.52 dB       SaCorrection       = -0.99 dB
#    Athw. Beam Angle   = 6.99 deg       Along. Beam Angle  = 6.95 deg
#    Athw. Offset Angle =-0.01 deg       Along. Offset Angle= 0.06 deg
#
#  Data deviation from beam model:
#    RMS =    0.34 dB
#    Max =    1.16 dB  No. =   301  Athw. =  2.8 deg  Along =  3.1 deg
#    Min =   -1.89 dB  No. =   279  Athw. =  3.7 deg  Along = -2.4 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.31 dB
#    Max =    0.84 dB  No. =   212  Athw. = -3.2 deg  Along = -3.8 deg
#    Min =   -1.60 dB  No. =   279  Athw. =  3.7 deg  Along = -2.4 deg
```

Vessel: SCH6 (Alida)
Date: 21.01.2014
Location: Channel
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  21/01/2014
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.20 dB       Min. Distance         11.00 m
#    TS Deviation           5.0 dB       Max. Distance         13.00 m
#
#  Transducer:  ES38B  Serial No.
#    Frequency            38000 Hz       Beamtype                Split
#    Gain                 26.00 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT  38 kHz 00907205b62e 2-1 ES38B
#    Pulse Duration       0.512 ms       Sample Interval     0.096   m
#    Power                 2000  W       Receiver Bandwidth   3.28 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.3
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing              0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          60 %
#    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    = 24.30 dB       SaCorrection       = -0.88 dB
#    Athw. Beam Angle   = 7.16 deg       Along. Beam Angle  = 7.02 deg
#    Athw. Offset Angle =-0.05 deg       Along. Offset Angle= 0.02 deg
#
#  Data deviation from beam model:
#    RMS =    0.15 dB
#    Max =    0.48 dB  No. =    23  Athw. = -2.4 deg  Along = -3.3 deg
#    Min =   -0.52 dB  No. =   305  Athw. =  1.6 deg  Along = -4.7 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.12 dB
#    Max =    0.31 dB  No. =   298  Athw. = -0.3 deg  Along = -3.5 deg
#    Min =   -0.35 dB  No. =   304  Athw. =  1.9 deg  Along = -3.2 deg
```

Vessel: SCH6 (Alida)
Date: 08.02.2015
Location: west of Ireland
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  8-2-2015
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.20 dB       Min. Distance          9.50 m
#    TS Deviation          5.0 dB        Max. Distance         15.50 m
#
#  Transducer:  ES38B  Serial No.   38
#    Frequency           38000 Hz        Beamtype               Split
#    Gain                26.50 dB        Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.      21.90        Along. Angle Sens.     21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT  38 kHz 00907205b62e 3-1 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.190   m
#    Power                 2000  W       Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.3
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing               0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength           60 %
#    Max. Phase Dev.           8.0       Max. Echolength          180 %
#
#  Environment:
#    Absorption Coeff.   9.8 dB/km       Sound Velocity     1485.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 24.58 dB       SaCorrection       = -0.92 dB
#    Athw. Beam Angle   = 6.93 deg       Along. Beam Angle  = 7.03 deg
#    Athw. Offset Angle =-0.01 deg       Along. Offset Angle=-0.01 deg
#
#  Data deviation from beam model:
#    RMS =    0.10 dB
#    Max =    0.21 dB  No. =    81  Athw. =  1.9 deg  Along =  2.9 deg
#    Min =   -0.35 dB  No. =   126  Athw. =  2.2 deg  Along =  3.7 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.07 dB
#    Max =    0.22 dB  No. =    77  Athw. = -4.8 deg  Along = -1.1 deg
#    Min =   -0.46 dB  No. =   126  Athw. =  2.2 deg  Along =  3.7 deg
```

Vessel: SCH24 (Afrika)

Date: 15.08.2013

Location: Scapa Flow

Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  15/08/2013
#
#  Comments:
#
#
#  Reference Target:
#    TS                   -42.20 dB       Min. Distance         10.00 m
#    TS Deviation           5.0 dB       Max. Distance         15.00 m
#
#  Transducer:  ES38B  Serial No.
#    Frequency            38000 Hz       Beamtype                Split
#    Gain                 26.50 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 1-1 157.237.14.6 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.192   m
#    Power                 2000  W       Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing              0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          60 %
#    Max. Phase Dev.           8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   9.7 dB/km       Sound Velocity     1500.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 25.12 dB       SaCorrection       = -0.61 dB
#    Athw. Beam Angle   = 6.80 deg       Along. Beam Angle  = 6.88 deg
#    Athw. Offset Angle = 0.00 deg       Along. Offset Angle=-0.01 deg
#
#  Data deviation from beam model:
#    RMS =    0.19 dB
#    Max =    0.55 dB  No. =   264  Athw. =  3.5 deg  Along =  1.2 deg
#    Min =   -0.57 dB  No. =   217  Athw. =  4.0 deg  Along =  3.3 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.16 dB
#    Max =    0.53 dB  No. =   258  Athw. = -4.9 deg  Along = -0.3 deg
#    Min =   -0.47 dB  No. =   172  Athw. =  1.5 deg  Along =  3.3 deg
```

Vessel: SCH72 (Frank Bonefaas)
Date: 11.09.2014
Location: North Sea
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  11/09/2014
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.20 dB       Min. Distance         12.00 m
#    TS Deviation          10.0 dB       Max. Distance         20.00 m
#
#  Transducer:  ES38B  Serial No.
#    Frequency            38000 Hz       Beamtype                 Split
#    Gain                 26.50 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 1-1 157.237.14.5 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.192   m
#    Power                 2000  W       Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing              0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          30 %
#    Max. Phase Dev.           8.0       Max. Echolength         210 %
#
#  Environment:
#    Absorption Coeff.   9.7 dB/km       Sound Velocity     1500.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 23.29 dB       SaCorrection       = -0.55 dB
#    Athw. Beam Angle   = 6.99 deg       Along. Beam Angle  = 7.17 deg
#    Athw. Offset Angle = 0.00 deg       Along. Offset Angle=-0.14 deg
#
#  Data deviation from beam model:
#    RMS =    0.38 dB
#    Max =    1.44 dB  No. =   242  Athw. =  2.4 deg  Along = -4.4 deg
#    Min =   -0.97 dB  No. =   231  Athw. =  1.2 deg  Along = -4.8 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.34 dB
#    Max =    1.08 dB  No. =   242  Athw. =  2.4 deg  Along = -4.4 deg
#    Min =   -1.12 dB  No. =   186  Athw. =  2.3 deg  Along = -4.2 deg
```

Vessel: SCH81 (Carolien)
Date: 21.03.2013
Location: Bantry Bay
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  21/03/2013
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.10 dB       Min. Distance         20.00 m
#    TS Deviation           5.0 dB       Max. Distance         35.00 m
#
#  Transducer:  ES38B  Serial No.   38
#    Frequency            38000 Hz       Beamtype                Split
#    Gain                 24.00 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 2-1 157.237.14.5 ES38B
#    Pulse Duration       0.256 ms       Sample Interval     0.047   m
#    Power                 2000  W       Receiver Bandwidth   3.68 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          60 %
#    Max. Phase Dev.           8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   9.2 dB/km       Sound Velocity     1475.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 24.67 dB       SaCorrection       = -0.58 dB
#    Athw. Beam Angle   = 6.89 deg       Along. Beam Angle  = 7.00 deg
#    Athw. Offset Angle =-0.03 deg       Along. Offset Angle=-0.11 deg
#
#  Data deviation from beam model:
#    RMS =    0.25 dB
#    Max =    0.70 dB  No. =   152  Athw. = -2.1 deg  Along =  2.5 deg
#    Min =   -1.80 dB  No. =     1  Athw. = -4.4 deg  Along = -0.8 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.23 dB
#    Max =    0.65 dB  No. =   162  Athw. = -0.1 deg  Along = -4.3 deg
#    Min =   -1.60 dB  No. =     1  Athw. = -4.4 deg  Along = -0.8 deg
```

Vessel: SCH81 (Carolien)
Date: 08.08.2013
Location: Scapa Flow
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  08/08/2013
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.20 dB       Min. Distance         11.00 m
#    TS Deviation           5.0 dB       Max. Distance         15.20 m
#
#  Transducer:  ES38B  Serial No.
#    Frequency            38000 Hz       Beamtype                  Split
#    Gain                 26.50 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 3-1 157.237.14.5 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.192   m
#    Power                 2000  W       Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing              0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          60 %
#    Max. Phase Dev.           8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   9.7 dB/km       Sound Velocity     1500.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 26.17 dB       SaCorrection       = -0.55 dB
#    Athw. Beam Angle   = 7.29 deg       Along. Beam Angle  = 7.26 deg
#    Athw. Offset Angle =-0.07 deg       Along. Offset Angle=-0.12 deg
#
#  Data deviation from beam model:
#    RMS =    0.46 dB
#    Max =    1.23 dB  No. =   328  Athw. = -2.8 deg  Along = -4.2 deg
#    Min =   -1.98 dB  No. =    48  Athw. =  3.6 deg  Along = -1.9 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.43 dB
#    Max =    1.23 dB  No. =   328  Athw. = -2.8 deg  Along = -4.2 deg
#    Min =   -1.69 dB  No. =    48  Athw. =  3.6 deg  Along = -1.9 deg
```

Vessel: SCH81 (Carolien)
Date: 12.09.2014
Location: North Sea
Calibration results:

```
#  Calibration  Version   2.1.0.12
#
#  Date:  12/09/2014
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.20 dB       Min. Distance          9.00 m
#    TS Deviation           5.0 dB       Max. Distance         13.00 m
#
#  Transducer:  ES38B  Serial No.
#    Frequency            38000 Hz       Beamtype                Split
#    Gain                 26.50 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 3-1 157.237.14.5 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.192   m
#    Power                 2000  W       Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing              0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          60 %
#    Max. Phase Dev.           8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   9.7 dB/km       Sound Velocity     1500.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 26.23 dB       SaCorrection       = -0.68 dB
#    Athw. Beam Angle   = 6.85 deg       Along. Beam Angle  = 6.92 deg
#    Athw. Offset Angle =-0.13 deg       Along. Offset Angle=-0.18 deg
#
#  Data deviation from beam model:
#    RMS =    0.26 dB
#    Max =    1.78 dB  No. =    28  Athw. = -2.6 deg  Along =  0.6 deg
#    Min =   -1.64 dB  No. =    29  Athw. = -2.6 deg  Along =  0.8 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.25 dB
#    Max =    1.81 dB  No. =    28  Athw. = -2.6 deg  Along =  0.6 deg
#    Min =   -1.61 dB  No. =    29  Athw. = -2.6 deg  Along =  0.8 deg
```

Vessel: H171 (Cornelis Vrolijk)
Date: 27.08.2013
Location: Scapa Flow
Calibration results:

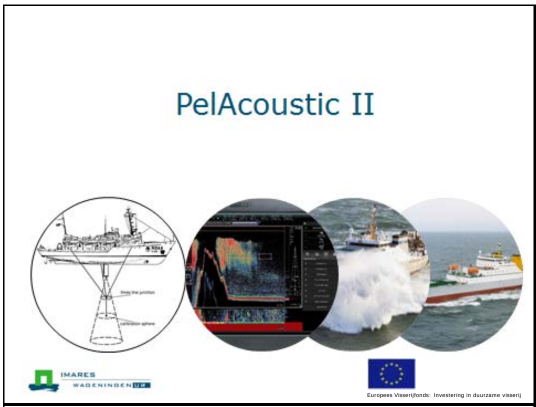
```
#  Calibration  Version   2.1.0.12
#
#  Date:  27/08/2013
#
#  Comments:
#
#
#  Reference Target:
#    TS                  -42.20 dB       Min. Distance         10.00 m
#    TS Deviation           5.0 dB       Max. Distance         14.50 m
#
#  Transducer:  ES38B  Serial No.   38
#    Frequency            38000 Hz       Beamtype                Split
#    Gain                 26.50 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg       Along. Beam Angle     7.10 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 1-1 157.237.14.20 ES38B
#    Pulse Duration       1.024 ms       Sample Interval     0.192   m
#    Power                 2000  W       Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing              0 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          60 %
#    Max. Phase Dev.           8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   9.7 dB/km       Sound Velocity     1500.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 25.65 dB       SaCorrection       = -0.59 dB
#    Athw. Beam Angle   = 6.98 deg       Along. Beam Angle  = 7.00 deg
#    Athw. Offset Angle =-0.04 deg       Along. Offset Angle=-0.03 deg
#
#  Data deviation from beam model:
#    RMS =    0.24 dB
#    Max =    1.14 dB  No. =   376  Athw. =  3.0 deg  Along = -4.2 deg
#    Min =   -1.26 dB  No. =   343  Athw. =  3.7 deg  Along =  1.1 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.22 dB
#    Max =    0.93 dB  No. =   376  Athw. =  3.0 deg  Along = -4.2 deg
#    Min =   -1.27 dB  No. =   343  Athw. =  3.7 deg  Along =  1.1 deg
```

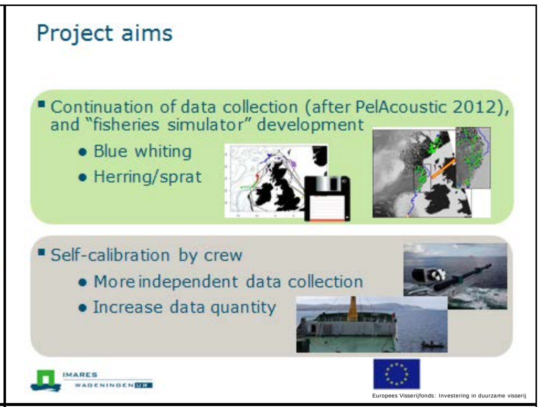
Vessel: ROS785 (Helen Mary)
Date: 09.04.2014
Location: Stornoway
Calibration results:

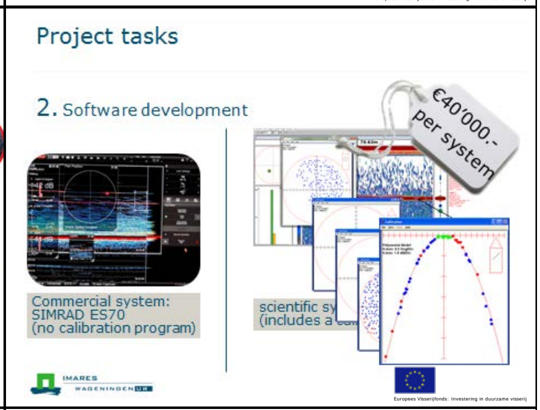
```
#  Calibration  Version   2.1.0.12
#
#  Date:  09/04/2014
#
#  Comments:
#
#
#  Reference Target:
#    TS                 -42.30 dB       Min. Distance         10.00 m
#    TS Deviation          5.0 dB       Max. Distance         13.80 m
#
#  Transducer:  ES38B  Serial No.
#    Frequency           38000 Hz       Beamtype                Split
#    Gain                26.00 dB       Two Way Beam Angle   -20.6 dB
#    Athw. Angle Sens.      21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.10 deg      Along. Beam Angle    7.10 deg
#    Athw. Offset Angle   0.00 deg      Along. Offset Angle  0.00 deg
#    SaCorrection         0.00 dB       Depth                 0.00  m
#
#  Transceiver:  GPT 1-1 157.237.14.5 ES38B
#    Pulse Duration       0.512 ms      Sample Interval     0.096   m
#    Power                 2000  W      Receiver Bandwidth   3.28 kHz
#
#  Sounder Type:
#    EK60 Version  2.4.3
#
#  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.   9.7 dB/km      Sound Velocity     1500.0 m/s
#
#  Beam Model results:
#    Transducer Gain    = 23.86 dB      SaCorrection       = -0.64 dB
#    Athw. Beam Angle   = 7.05 deg      Along. Beam Angle  = 7.02 deg
#    Athw. Offset Angle = 0.04 deg      Along. Offset Angle=-0.03 deg
#
#  Data deviation from beam model:
#    RMS =    0.18 dB
#    Max =    0.67 dB  No. =    92  Athw. = -3.9 deg  Along =  2.8 deg
#    Min =   -0.37 dB  No. =   230  Athw. =  4.9 deg  Along = -0.8 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.13 dB
#    Max =    0.59 dB  No. =   146  Athw. = -2.4 deg  Along = -2.9 deg
#    Min =   -0.40 dB  No. =    54  Athw. = -3.1 deg  Along =  3.5 deg
```

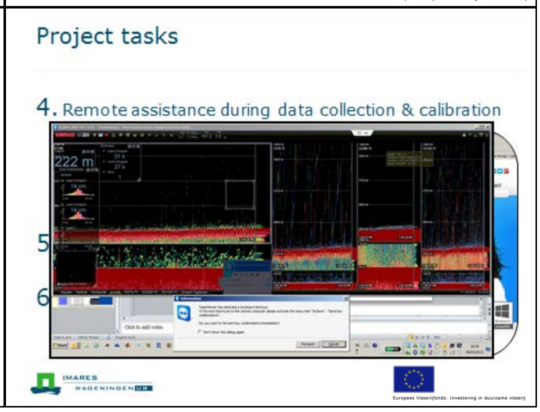
Appendix D. presentations

Project kick-off meeting, March 2013

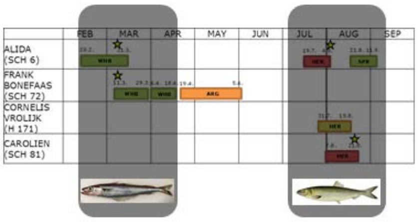




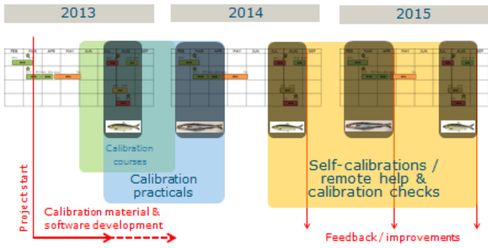




Fishing seasons

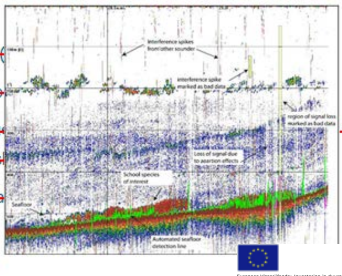


Total project timeline



Identified problems from PelAcoustic 2012

- Data quality issues (signal loss & interference of other equipment)
- ~~Loss of data (~~
- ~~Lack of perso~~
- ~~Logistics to g~~
  ~~locations at s~~
- ~~Need for data~~



Questions / discussion

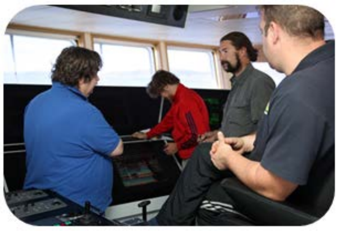
- Calibration courses: who / when??
  - 2-3 people per ship to keep it focussed & effective
  - 1-2 weeks before trip start, on ship in harbour (preferable) or at Imares or fishing company
- Which ships??
  - Budget can cover 5 ships (=5 equipment sets & 5 courses/ practical's).
  - When is annual planning known?
- Remote assistance: how ??
  - Internet access (for TeamViewer)

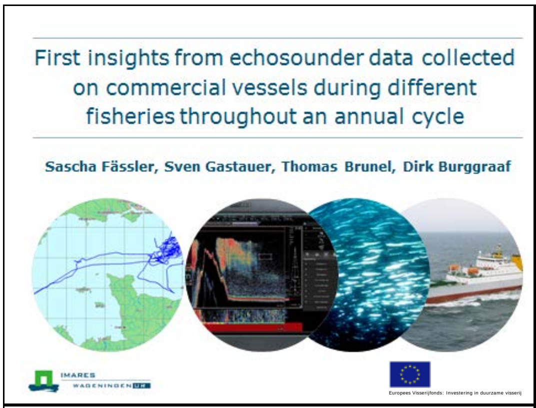
Questions / discussion

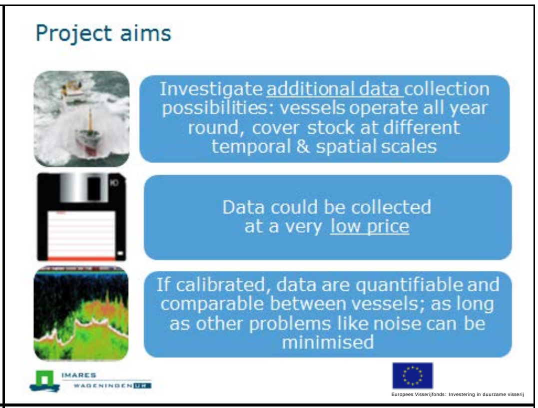
- Some proposed dates for this year:
  - Begin May: identify ships/crew for herring fishery
  - June/July: calibration courses for "herring crew"
  - August/September: calibration exercises on herring trips

➢ Any other questions/ideas/concerns?

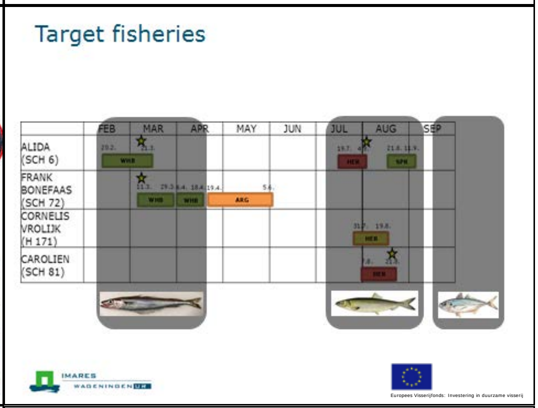
Thanks!

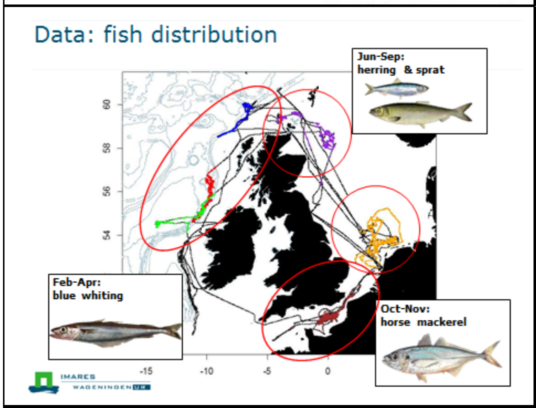


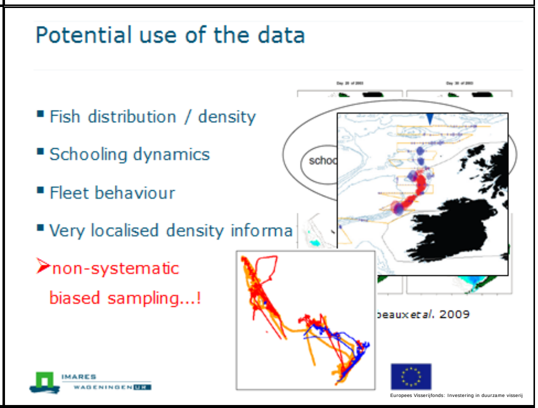

First insights from echosounder data collected on commercial vessels during different fisheries throughout an annual cycle
Sascha Fässler, Sven Gastauer, Thomas Brunel, Dirk Burggraaf
IMARES WAGENINGEN UR

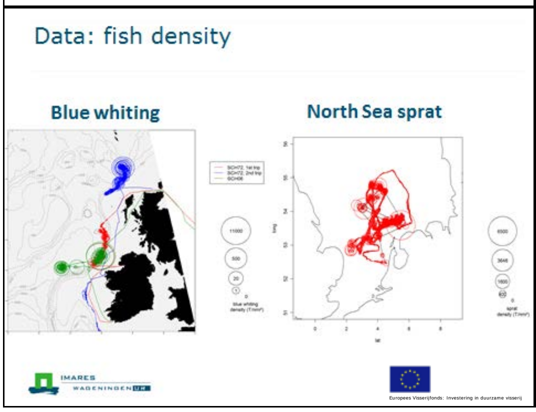

Project aims
Investigate additional data collection possibilities: vessels operate all year round, cover stock at different temporal & spatial scales
Data could be collected at a very low price
If calibrated, data are quantifiable and comparable between vessels; as long as other problems like noise can be minimised
IMARES WAGENINGEN UR

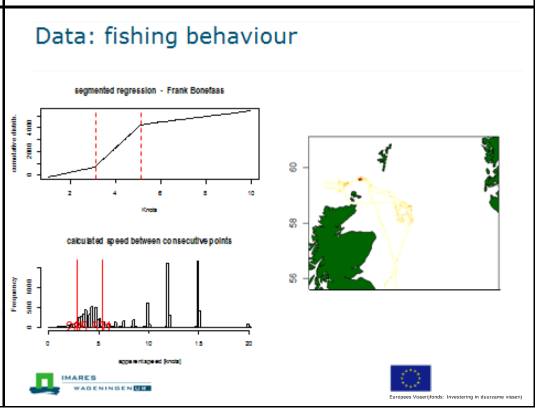

Calibration
113m

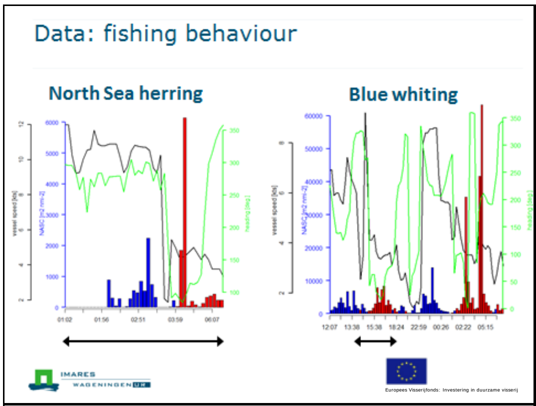

Target fisheries
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
ALIDA (SCH 6)
FRANK BONEFAAS (SCH 72)
CORNELIS VROLIJK (H 171)
CAROLIEN (SCH 81)
IMARES WAGENINGEN UR

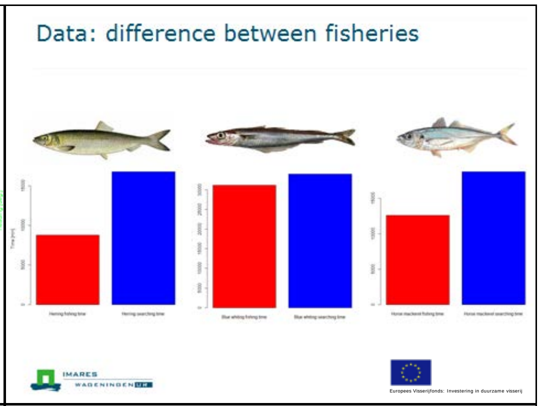

Data: fish distribution
Jun-Sep: herring & sprat
Feb-Apr: blue whiting
Oct-Nov: horse mackerel
60
58
56
54
-15
-10
-5
0
IMARES WAGENINGEN UR

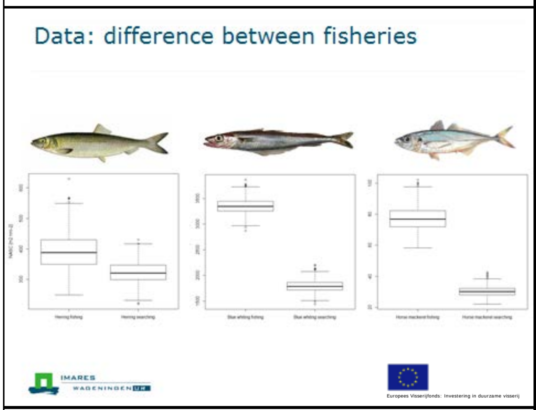

Potential use of the data
Fish distribution / density
Schooling dynamics
Fleet behaviour
Very localised density informa
non-systematic biased sampling...!
beaux et al. 2009
IMARES WAGENINGEN UR

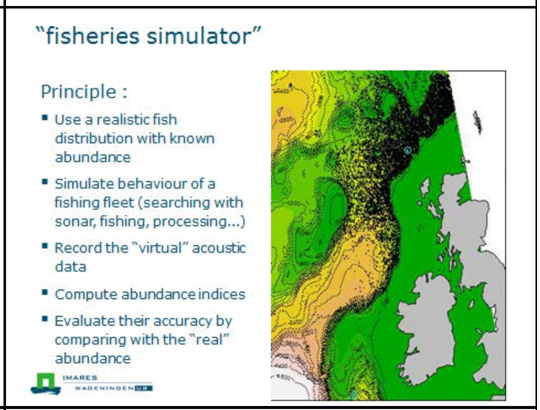

Data: fish density
Blue whiting
North Sea sprat
IMARES WAGENINGEN UR

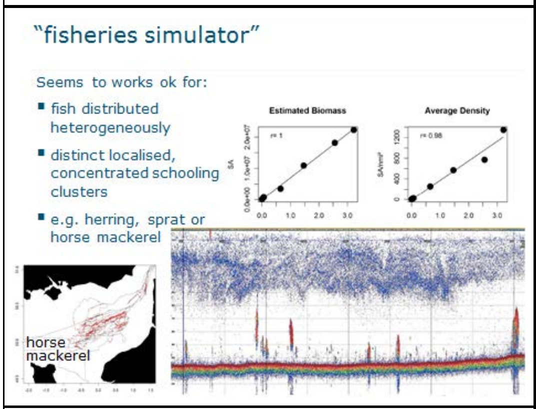

Data: fishing behaviour
segmented regression - Frank Bonefaas
calculated speed between consecutive points
IMARES WAGENINGEN UR

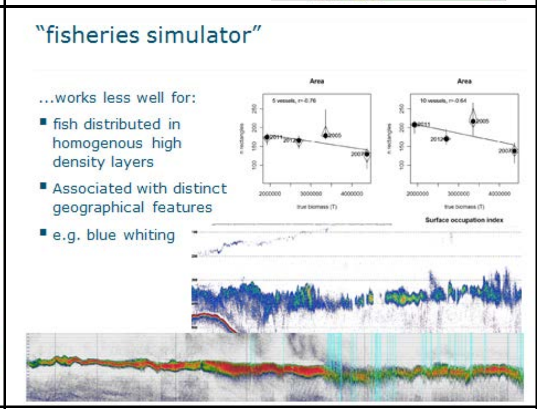

Data: fishing behaviour
North Sea herring
Blue whiting
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

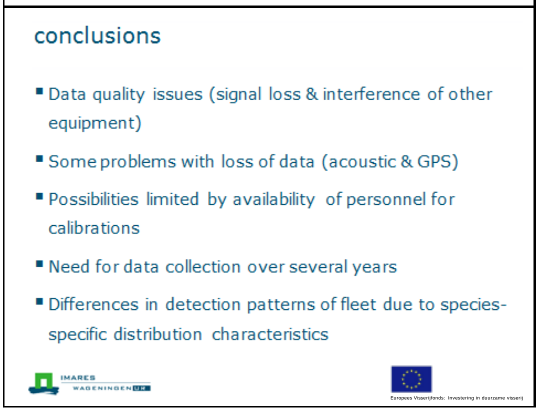

Data: difference between fisheries
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

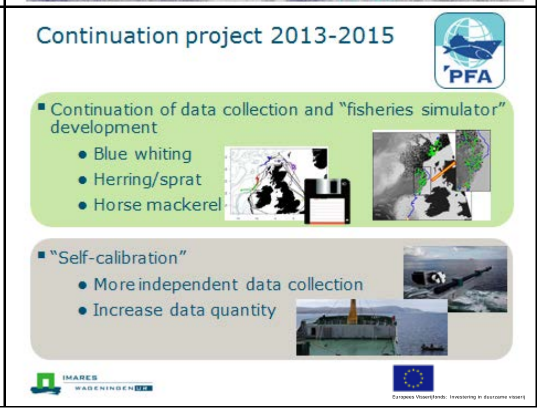

Data: difference between fisheries
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

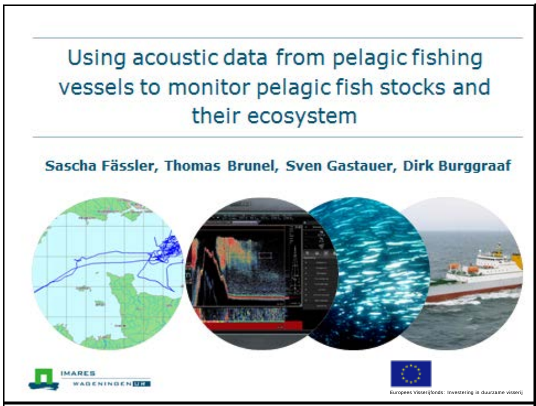

"fisheries simulator"
Principle :
Use a realistic fish distribution with known abundance
Simulate behaviour of a fishing fleet (searching with sonar, fishing, processing...)
Record the "virtual" acoustic data
Compute abundance indices
Evaluate their accuracy by comparing with the "real" abundance
IMARES
WAGENINGEN UR

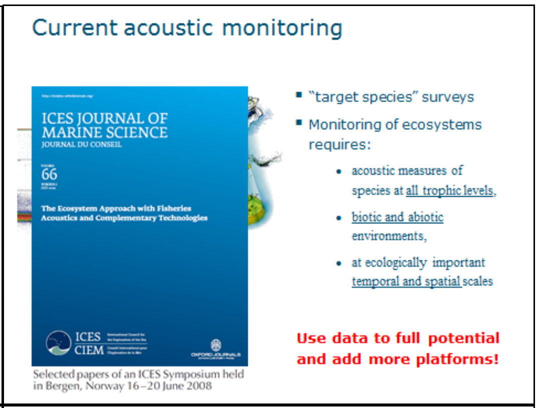

"fisheries simulator"
Seems to works ok for:
fish distributed heterogeneously
distinct localised, concentrated schooling clusters
e.g. herring, sprat or horse mackerel
Estimated Biomass
Average Density
horse mackerel


"fisheries simulator"
...works less well for:
fish distributed in homogenous high density layers
Associated with distinct geographical features
e.g. blue whiting
Area
Surface occupation index

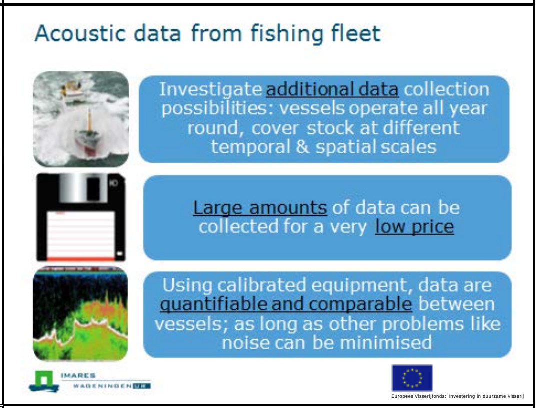

conclusions
Data quality issues (signal loss & interference of other equipment)
Some problems with loss of data (acoustic & GPS)
Possibilities limited by availability of personnel for calibrations
Need for data collection over several years
Differences in detection patterns of fleet due to species-specific distribution characteristics
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

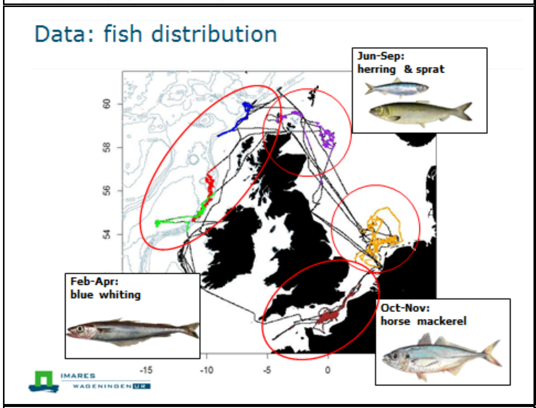

Continuation project 2013-2015
PFA
Continuation of data collection and "fisheries simulator" development
Blue whiting
Herring/sprat
Horse mackerel
"Self-calibration"
More independent data collection
Increase data quantity
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

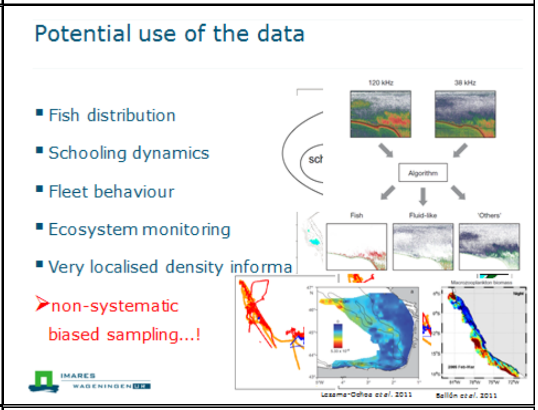

Using acoustic data from pelagic fishing vessels to monitor pelagic fish stocks and their ecosystem
Sascha Fässler, Thomas Brunel, Sven Gastauer, Dirk Burggraaf
IMARES
WAGENINGEN UR

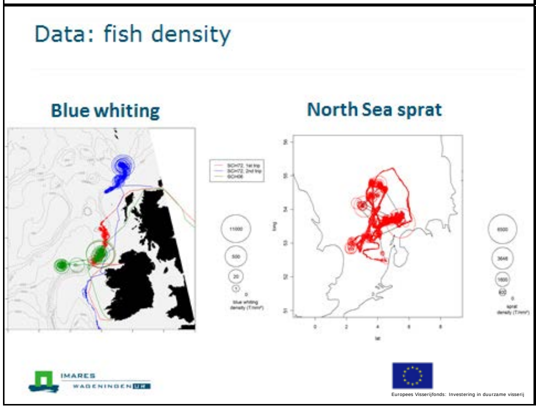

Current acoustic monitoring
ICES JOURNAL OF MARINE SCIENCE
JOURNAL DU CONSEIL
66
The Ecosystem Approach with Fisheries Acoustics and Complementary Technologies
ICES CIEM
Selected papers of an ICES Symposium held in Bergen, Norway 16–20 June 2008
"target species" surveys
Monitoring of ecosystems requires:
acoustic measures of species at all trophic levels,
biotic and abiotic environments,
at ecologically important temporal and spatial scales
Use data to full potential and add more platforms!

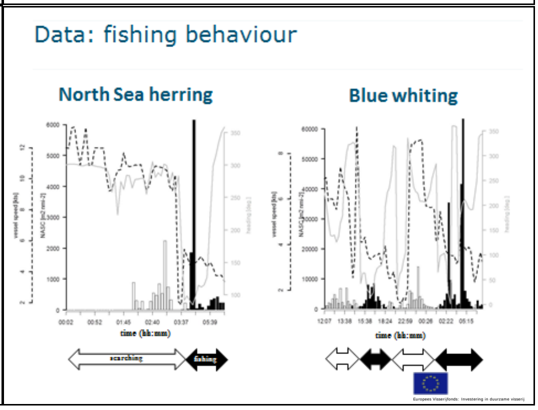

Acoustic data from fishing fleet
PFA

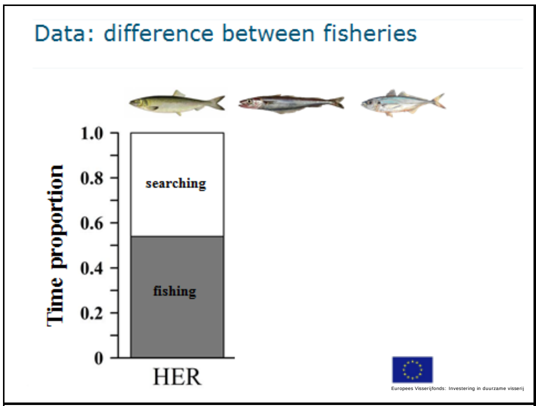

Acoustic data from fishing fleet
Investigate additional data collection possibilities: vessels operate all year round, cover stock at different temporal & spatial scales
Large amounts of data can be collected for a very low price
Using calibrated equipment, data are quantifiable and comparable between vessels; as long as other problems like noise can be minimised
IMARES
WAGENINGEN UR

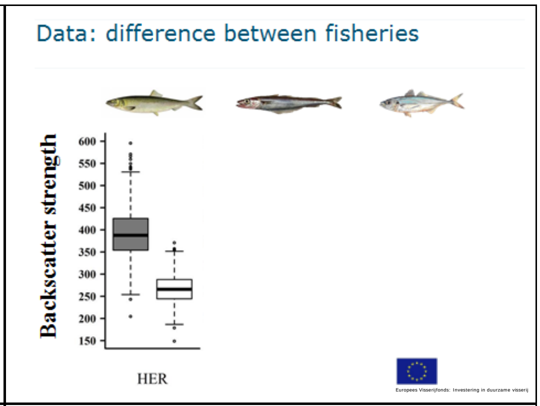

Data: fish distribution
Jun-Sep: herring & sprat
Feb-Apr: blue whiting
Oct-Nov: horse mackerel
60
58
56
54
-15
-10
-5
0
IMARES
WAGENINGEN UR

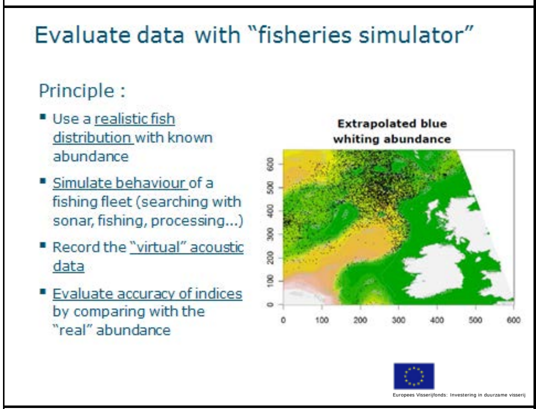

Potential use of the data
Fish distribution
Schooling dynamics
Fleet behaviour
Ecosystem monitoring
Very localised density informa
non-systematic biased sampling...!
120 kHz
38 kHz
Algorithm
Fish
Fluid-like
'Others'
IMARES
WAGENINGEN UR

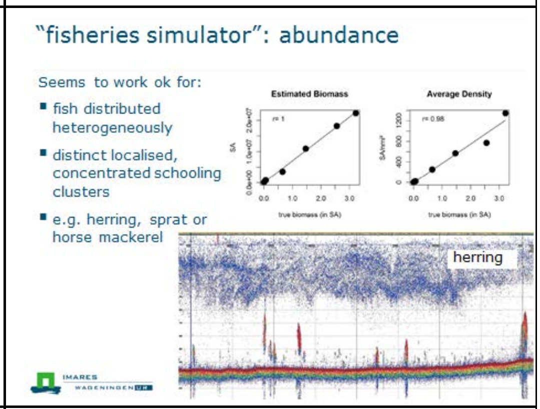

Data: fish density
Blue whiting
North Sea sprat
IMARES
WAGENINGEN UR

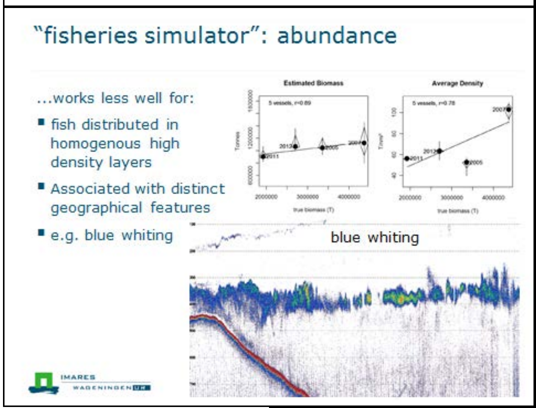

Data: fishing behaviour
North Sea herring
Blue whiting
time (hh:mm)
searching
fishing





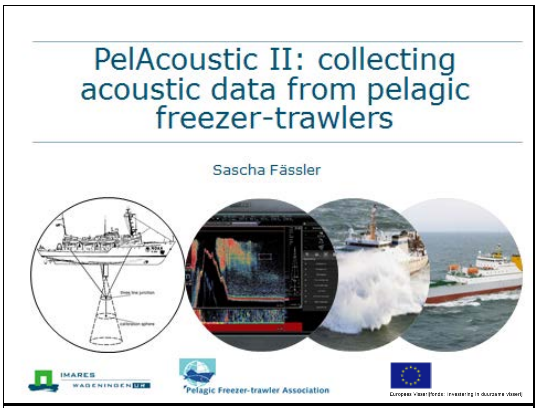


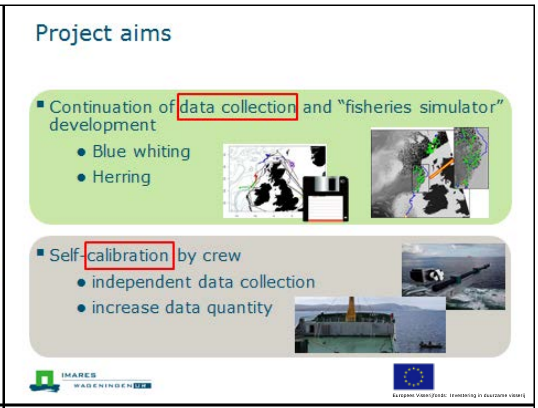


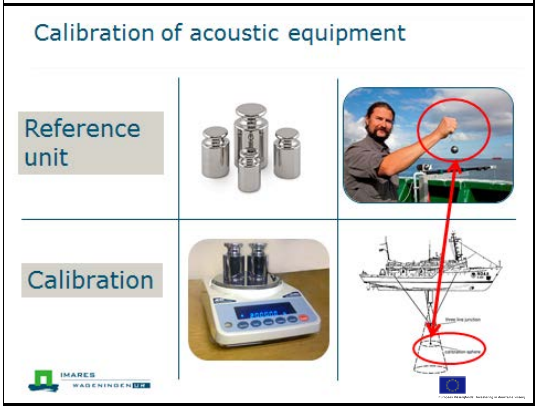


A few points to note

- Lots of additional "cheap" data, but time for analysis needed (~20h for one 3 week fishing trip)
- Data quality issues (signal loss & interference of other equipment), and loss of data (GPS..)
- Differences in detection patterns of fleet due to species-specific distribution characteristics
- Need for data collection over several years
- Next: Spatial data analysis approaches & other indices!

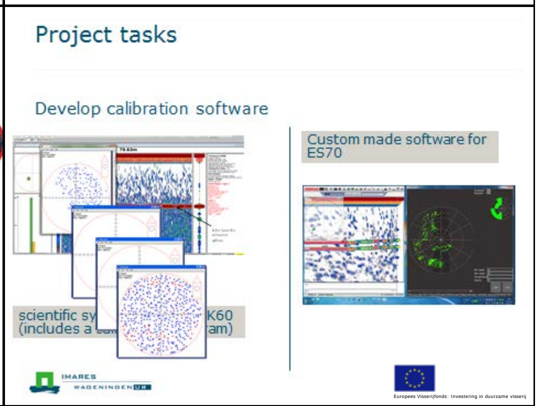

PelAcoustic II: collecting acoustic data from pelagic freezer-trawlers
Sascha Fässler
IMARES WAGENINGEN UR
Pelagic Freezer-trawler Association


Project aims
Continuation of data collection and "fisheries simulator" development
Blue whiting
Herring
Self-calibration by crew
independent data collection
increase data quantity
IMARES WAGENINGEN UR


Calibration of acoustic equipment
Reference unit
Calibration
IMARES WAGENINGEN UR

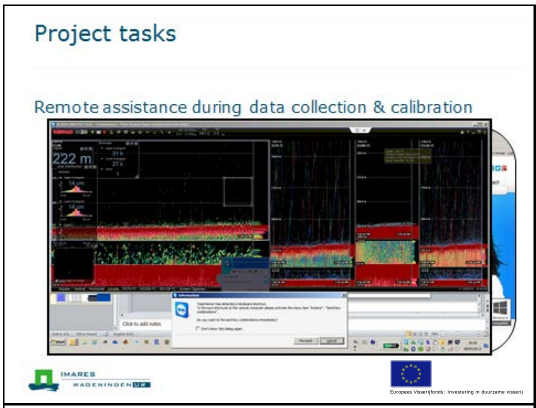

Calibration of acoustic equipment
113m

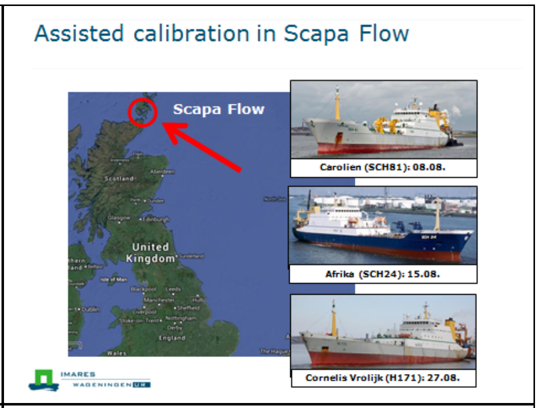

Project tasks
Build calibration sets for 5 trawlers

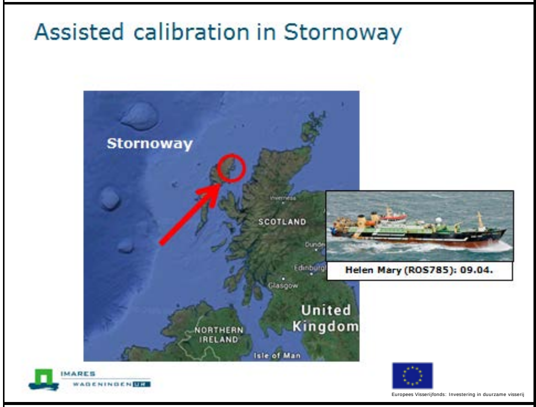

Project tasks
Develop calibration software
Custom made software for ES70
IMARES WAGENINGEN UR

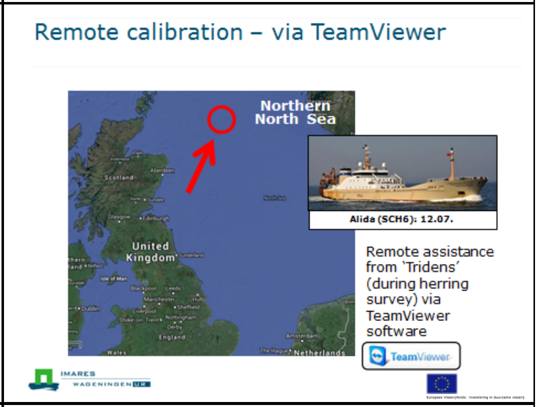

Project tasks
calibration courses / practicals

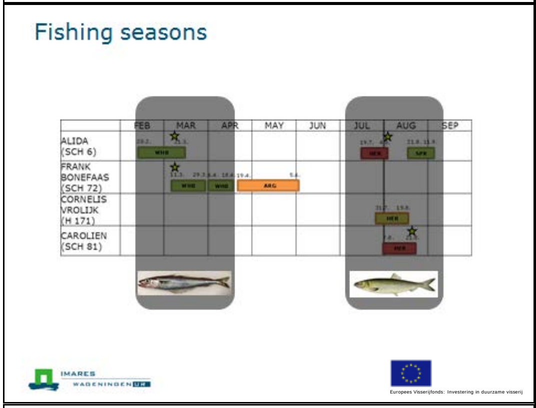

Project tasks
calibration courses / practicals
IMARES WAGENINGEN UR

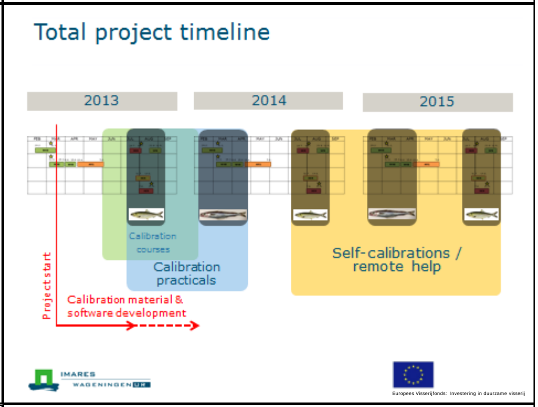

Project tasks
Remote assistance during data collection & calibration
IMARES WAGENINGEN UR

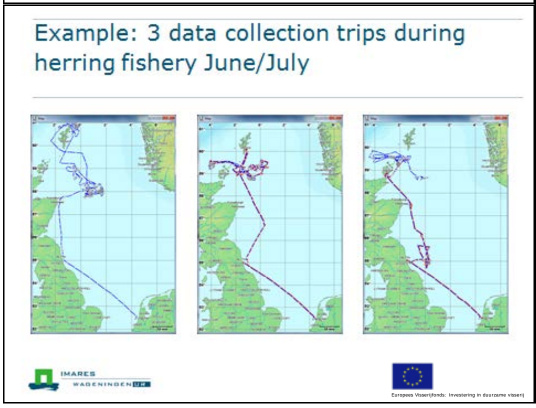

Assisted calibration in Scapa Flow
Scapa Flow
United Kingdom
Carolien (SCH81): 08.08.
Afrika (SCH24): 15.08.
Cornelis Vrolijk (H171): 27.08.
IMARES WAGENINGEN UR

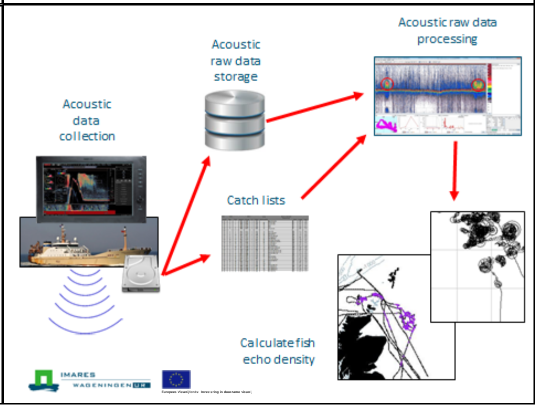

Assisted calibration in Stornoway
Stornoway
SCOTLAND
Helen Mary (ROS785): 09.04.
United Kingdom
NORTHERN IRELAND
Isle of Man
IMARES WAGENINGEN UR

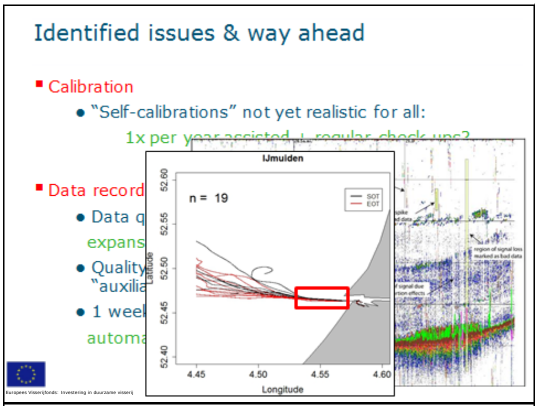

Remote calibration – via TeamViewer
Northern North Sea
Alida (SCH6): 12.07.
United Kingdom
Remote assistance from 'Tridens' (during herring survey) via TeamViewer software
TeamViewer
IMARES WAGENINGEN UR


Fishing seasons
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
ALIDA (SCH 6)
FRANK BONEFAAS (SCH 72)
CORNELIS VROLIJK (H 171)
CAROLIEN (SCH 81)
IMARES WAGENINGEN UR


Total project timeline
2013
2014
2015
Calibration courses
Calibration practicals
Self-calibrations / remote help
Project start
Calibration material & software development
IMARES WAGENINGEN UR


Example: 3 data collection trips during herring fishery June/July
IMARES WAGENINGEN UR


Acoustic data collection
Acoustic raw data storage
Acoustic raw data processing
Catch lists
Calculate fish echo density
IMARES WAGENINGEN UR


Identified issues & way ahead
Calibration
"Self-calibrations" not yet realistic for all:
1x per
Data record
Data q
expans
Quality
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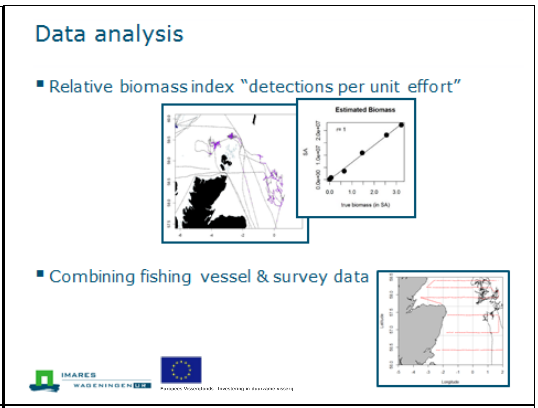
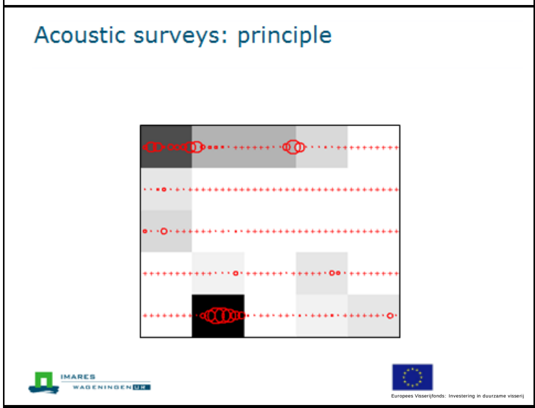
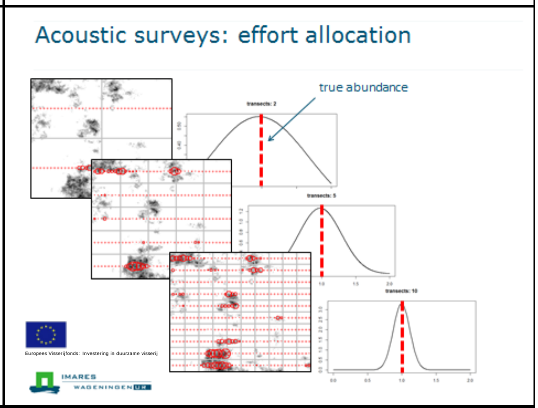
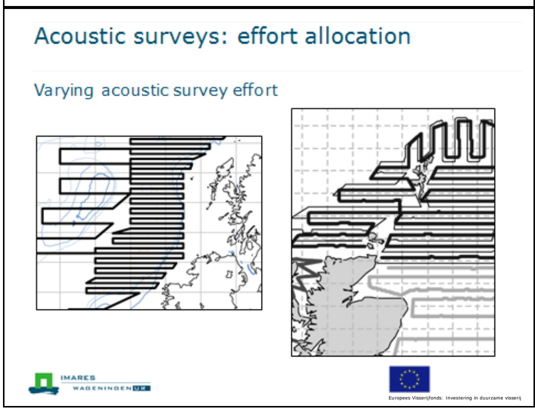
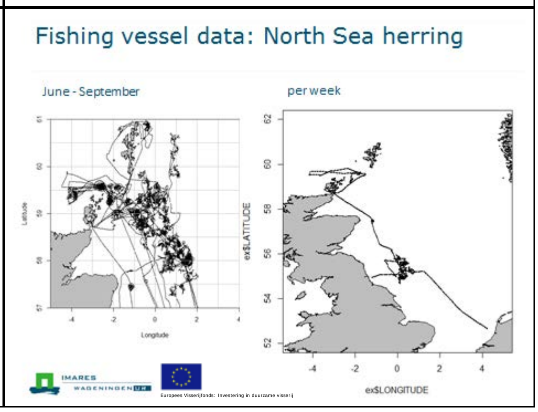
automa
IJmuiden
n = 19
Latitude
Longitude
Europees Visserijfonds: Investering in duurzame visserij

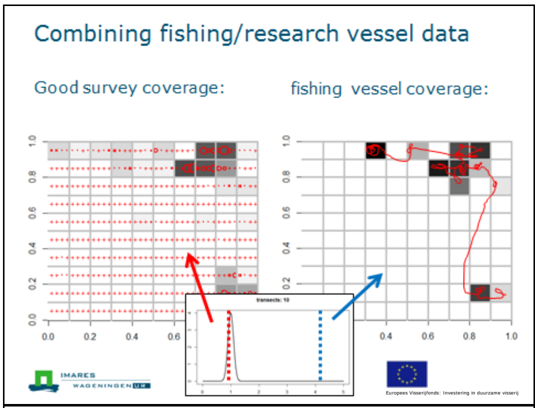

Data analysis
Relative biomass index "detections per unit effort"
Estimated Biomass
true biomass (in SA)
Combining fishing vessel & survey data
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

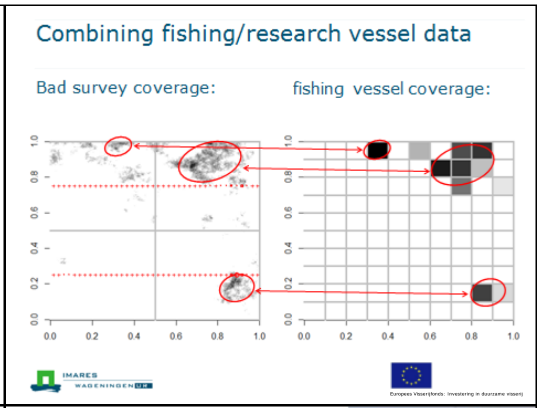

Acoustic surveys: principle
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

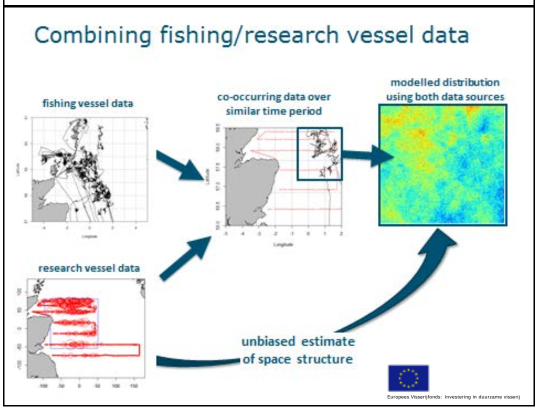

Acoustic surveys: effort allocation
true abundance
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij


Acoustic surveys: effort allocation
Varying acoustic survey effort
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

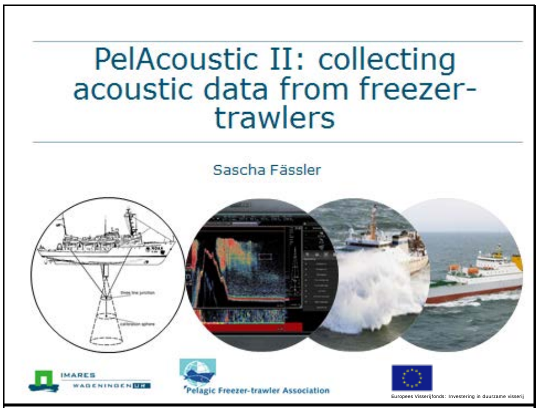

Fishing vessel data: North Sea herring
June - September
per week
Latitude
Longitude
ex$LATITUDE
ex$LONGITUDE
IMARES
WAGENINGEN UR
Europees Visserijfonds: Investering in duurzame visserij

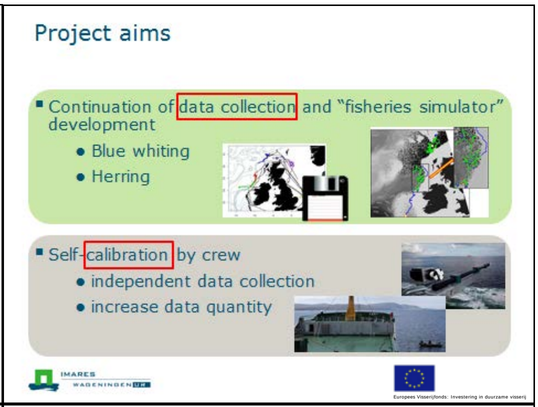

Combining fishing/research vessel data
Good survey coverage:
fishing vessel coverage:
IMARES
WAGENINGEN UR


Combining fishing/research vessel data
Bad survey coverage:
fishing vessel coverage:
IMARES
WAGENINGEN UR


Combining fishing/research vessel data
fishing vessel data
co-occurring data over similar time period
modelled distribution using both data sources
research vessel data
unbiased estimate of space structure


Thanks!
PFA
Europees Visserijfonds: Investering in duurzame visserij


PelAcoustic II: collecting acoustic data from freezer-trawlers
Sascha Fässler
IMARES WAGENINGEN UR
Pelagic Freezer-trawler Association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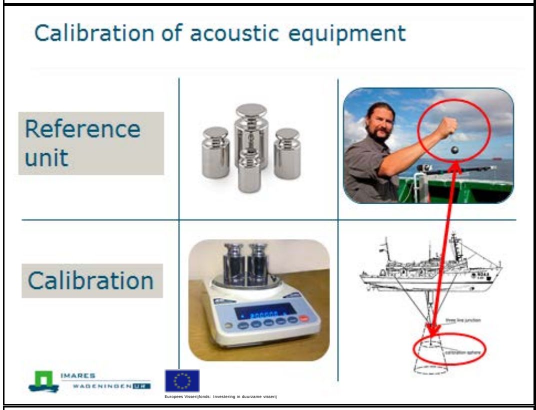
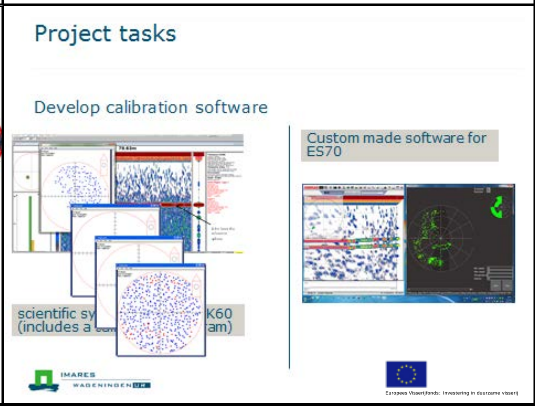
Continuation of data collection and "fisheries simulator" development
Blue whiting
Herring
Self-calibration by crew
independent data collection
increase data quantity
IMARES WAGENINGEN UR


Calibration of acoustic equipment
Reference unit
Calibration
IMARES WAGENINGEN UR

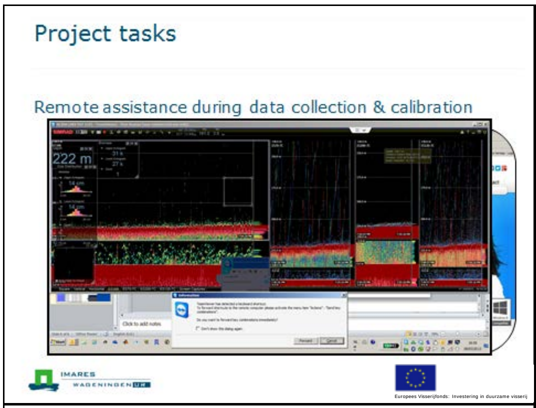

Calibration of acoustic equipment
113m

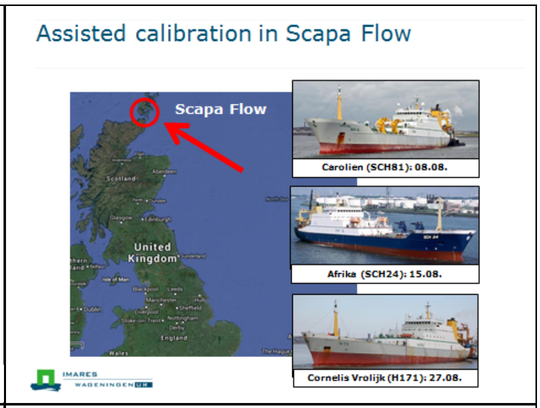

Project tasks
Build calibration sets for 5 trawlers


Project tasks
Develop calibration software
Custom made software for ES70
IMARES WAGENINGEN UR


Project tasks
calibration courses / practicals
Kalibratie van akoestische apparatuur en data log protocollen voor commerciële visserij vaartuigen


Project tasks
calibration courses / practicals
IMARES WAGENINGEN UR


Project tasks
Remote assistance during data collection & calibration
222 m


Assisted calibration in Scapa Flow
Scapa Flow
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Carolien (SCH81): 08.08.
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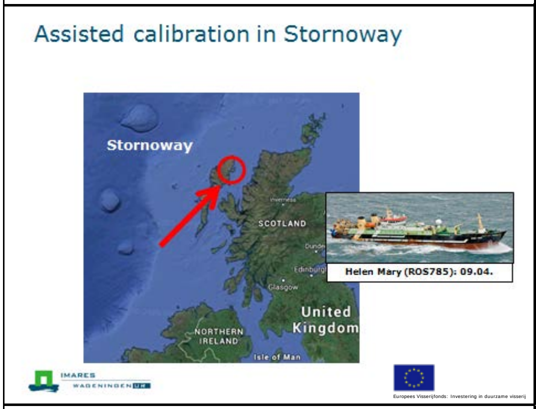
Assisted calibration in Stornoway
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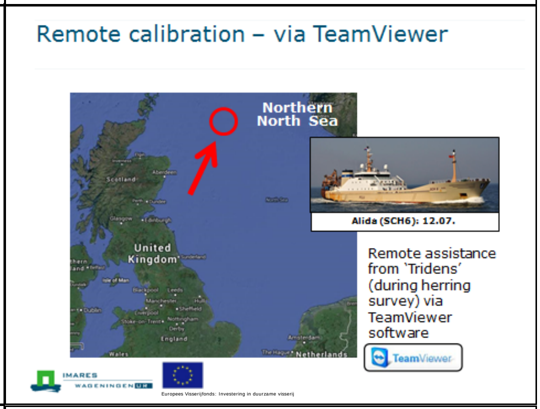
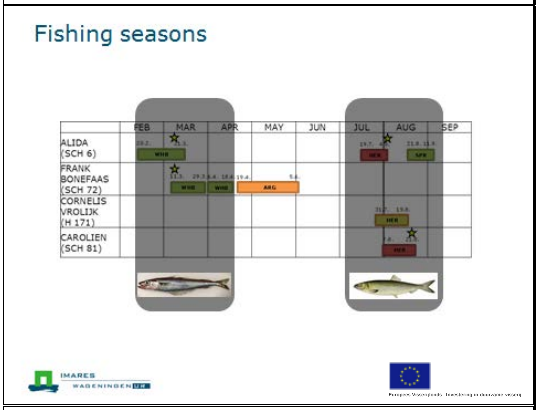
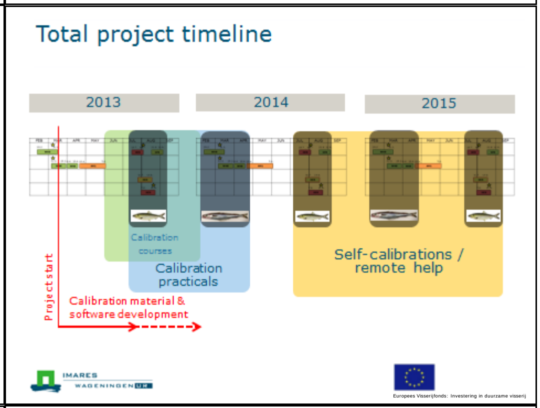
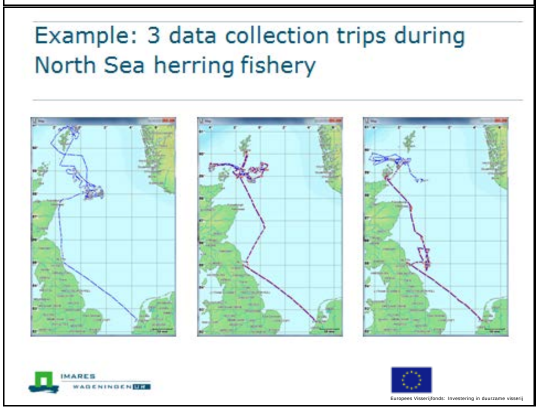
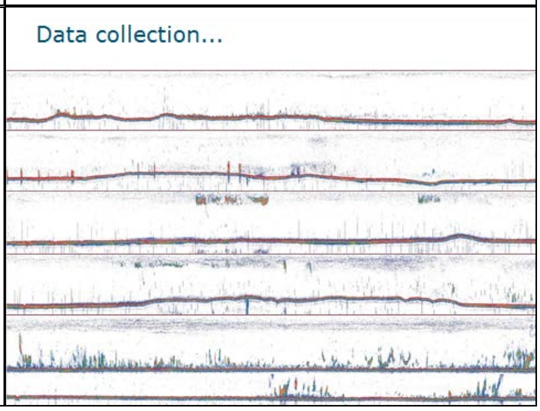
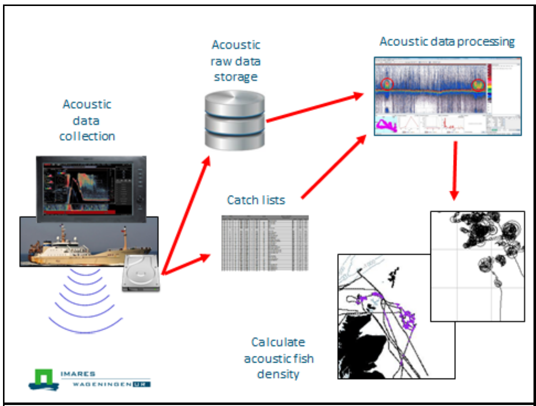

Remote calibration – via TeamViewer
Northern North Sea
Alida (SCH6): 12.07.
United Kingdom
Remote assistance from 'Tridens' (during herring survey) via TeamViewer software
TeamViewer

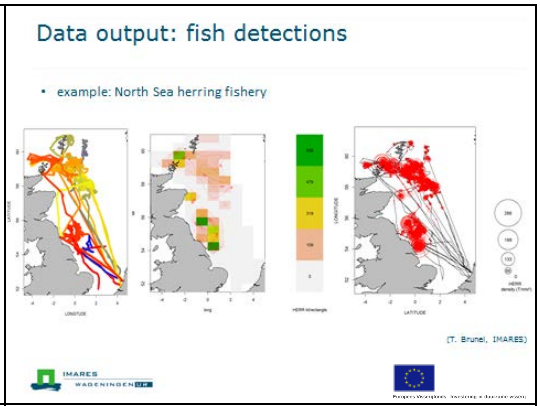

Fishing seasons
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
ALIDA (SCH 6)
FRANK BONEFAAS (SCH 72)
CORNELIS VROLIJK (H 171)
CAROLIEN (SCH 81)

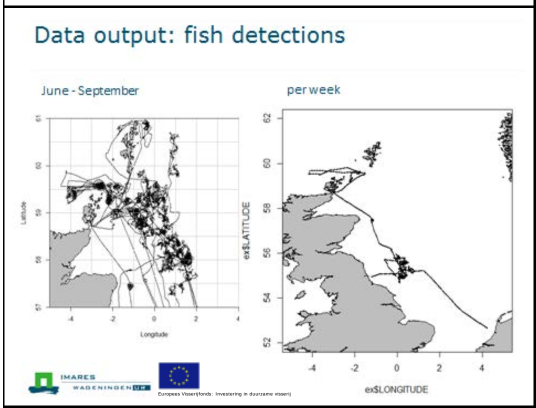

Total project timeline
2013
2014
2015
Calibration courses
Calibration practicals
Self-calibrations / remote help
Project start
Calibration material & software development

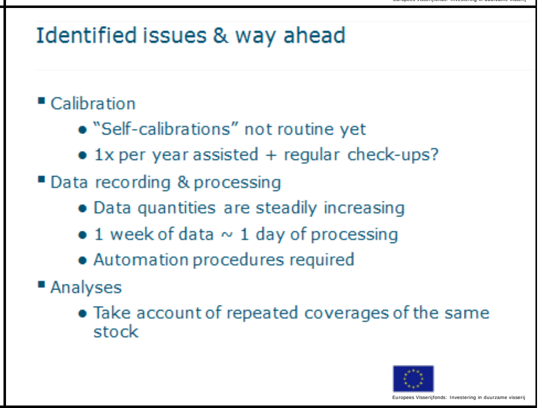

Example: 3 data collection trips during North Sea herring fishery

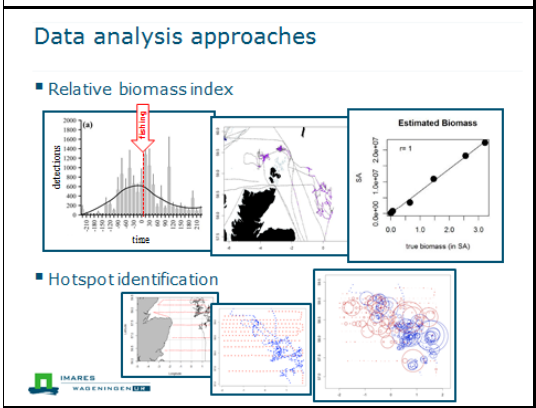

Data collection…

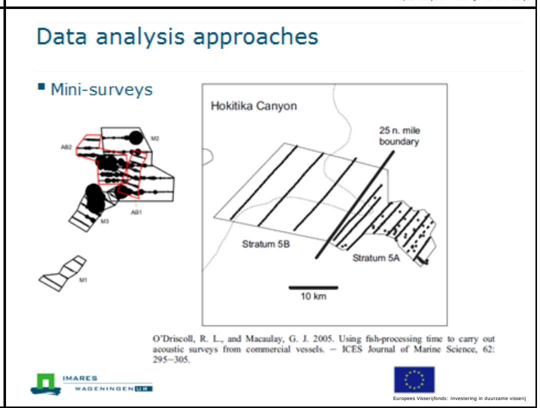

Acoustic data collection
Acoustic raw data storage
Acoustic data processing
Catch lists
Calculate acoustic fish density
IMARES WAGENINGEN UR

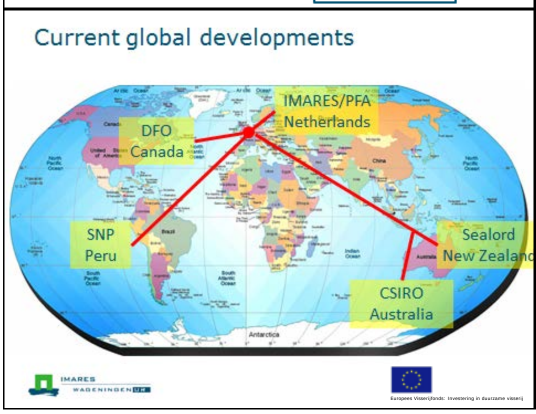

Data output: fish detections
• example: North Sea herring fishery
[T. Brunel, IMARES]
IMARES WAGENINGEN UR

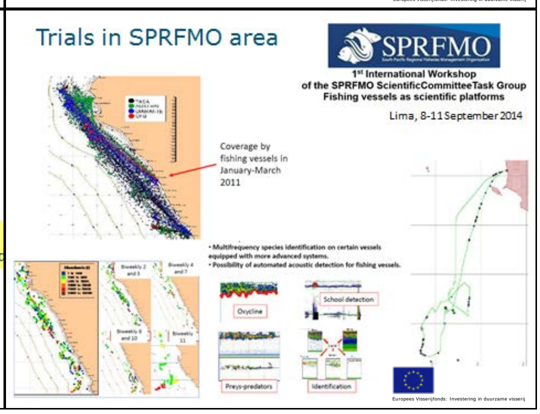

Data output: fish detections
June - September
per week
Latitude
Longitude
ex$LATITUDE
ex$LONGITUDE
IMARES WAGENINGEN UR

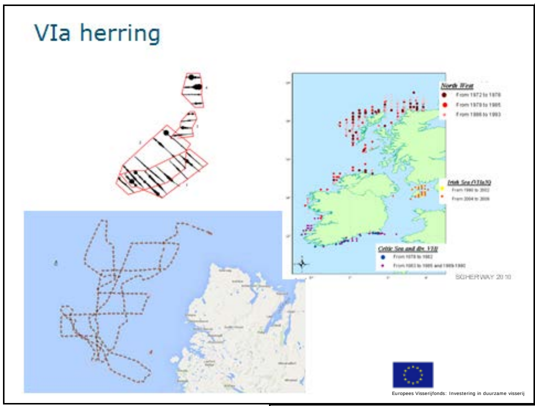

Identified issues & way ahead
▪ Calibration
• "Self-calibrations" not routine yet
• 1x per year assisted + regular check-ups?
▪ Data recording & processing
• Data quantities are steadily increasing
• 1 week of data ~ 1 day of processing
• Automation procedures required
▪ Analyses
• Take account of repeated coverages of the same stock

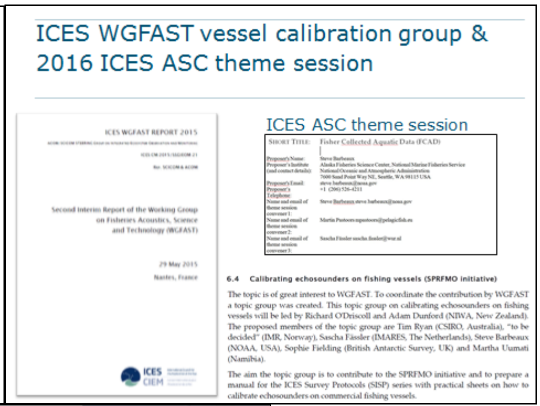

Data analysis approaches
▪ Relative biomass index
detections
time
fishing
Estimated Biomass
true biomass (in SA)
▪ Hotspot identification
IMARES WAGENINGEN UR


Data analysis approaches
▪ Mini-surveys
Hokitika Canyon
25 n. mile boundary
Stratum 5B
Stratum 5A
10 km
O'Driscoll, R. L., and Macaulay, G. J. 2005. Using fish-processing time to carry out acoustic surveys from commercial vessels. – ICES Journal of Marine Science, 62: 295–305.
IMARES WAGENINGEN UR


Current global developments
IMARES/PFA Netherlands
DFO Canada
SNP Peru
Sealord New Zealand
CSIRO Australia
IMARES WAGENINGEN UR


Trials in SPRFMO area
SPRFMO
1st International Workshop of the SPRFMO ScientificCommitteeTask Group Fishing vessels as scientific platforms
Lima, 8-11 September 2014
Coverage by fishing vessels in January-March 2011
• Multifrequency species identification on certain vessels equipped with more advanced systems.
• Possibility of automated acoustic detection for fishing vessels.
Oxycline
School detection
Preys-predators
Identification


VIa herring
SCHERWAY 2010
Europees Visserijfonds: Investering in duurzame visserij


ICES WGFAST vessel calibration group & 2016 ICES ASC theme session
ICES WGFAST REPORT 2015
Second Interim Report of the Working Group on Fisheries Acoustics, Science and Technology (WGFAST)
29 May 2015
Nantes, France
ICES ASC theme session
SHORT TITLE: Fisher Collected Aquatic Data (FCAD)
6.4 Calibrating echosounders on fishing vessels (SPRFMO initiative)
The topic is of great interest to WGFAST. To coordinate the contribution by WGFAST a topic group was created. This topic group on calibrating echosounders on fishing vessels will be led by Richard O'Driscoll and Adam Dunford (NIWA, New Zealand). The proposed members of the topic group are Tim Ryan (CSIRO, Australia), "to be decided" (IMR, Norway), Sascha Fässler (IMARES, The Netherlands), Steve Barbeaux (NOAA, USA), Sophie Fielding (British Antarctic Survey, UK) and Martha Uumati (Namibia).
The aim the topic group is to contribute to the SPRFMO initiative and to prepare a manual for the ICES Survey Protocols (SISP) series with practical sheets on how to calibrate echosounders on commercial fishing vessels.


Thanks!
The European Fisheries Fund
Investing in Sustainable Fisheries
Pelagic Freezer-trawler Association

Europees Visserijfonds: Investering in duurzame visserij

Report on the international workshop on the use of acoustic data from fishing vessels

Schiphol airport, Exchange avenue Friday 12 June 2015

Introduction

The use of acoustic information from commercial vessels for research purposes has been discussed frequently, but in the EU progress has been limited so far. With the EFF funded research project PelAcoustics, IMARES and PFA have initiated first steps in collecting and analyzing acoustic information from commercial vessels. Globally, there are many more initiatives in using vessel acoustics (e.g. New Zealand, Australia, Canada, Peru).

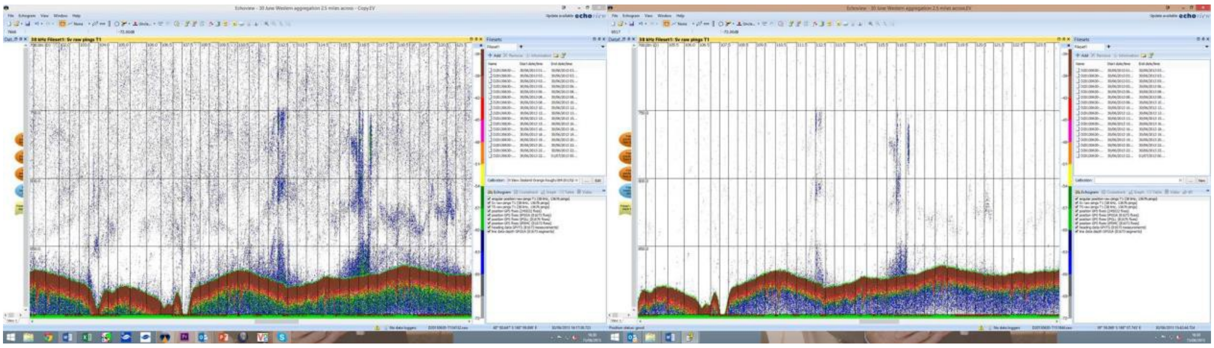
The international workshop on the use of acoustic data from fishing vessels, was organized under the auspices of the Northern Pelagic Working Group (NPWG), and brought together the global expertise on the application of vessel acoustics for research. The overarching ambition was to improve the collection, analysis and application of industry acoustic data for improved understanding of stocks and ecosystems in the EU and other areas that we are fishing in.

Participants

The list of participants is shown as an annex to the report. We were fortunate to the have the participations of many active skippers in the pelagic fishery and many scientists working on acoustics in different parts of the world.

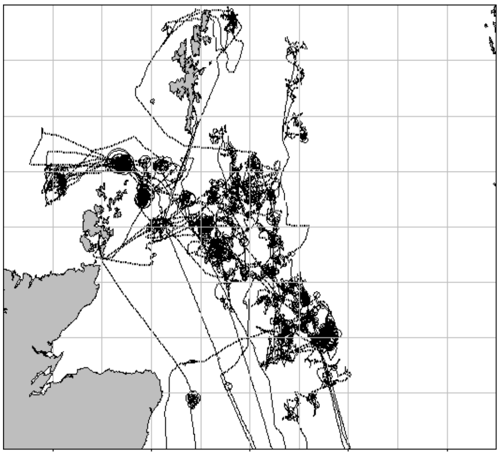
Presentations

Graham Patchell (Resource manager, Sealord, New Zealand) presented via Webex and explained the approach for their fisheries where they are collecting acoustic data during dedicated surveys and during transits to fishing grounds. Graham stressed the need for calibrating the echosounders, both for science and for the fishery, because with a calibrated echosounder “you see more fish” (see example below).



Left: calibrated echosounder (effect of the transducer sensitivity decrease taken into account). Right uncalibrated echosounder sees less fish.

Gary Melvin (DFO, Canada) explained the Canadian experience with the involvement of fishing vessels in the 4WX herring management, already since the early 2000s. This has clearly demonstrated that commercial fishing vessels can be used for scientific data collection. So far, the focus has been on stock assessment data. There are many opportunities for future cooperation and collaboration between the private and public sectors, especially in the ecosystem context (.e.g distribution and abundance of organisms in the water column, behavioural studies, sea bed mapping and classification, habitat utilization, ecosystem Production of fish and plankton, predator prey interactions like bluefin tuna and herring, etc.



Sascha Fässler (IMARES, Netherlands) discussed the approach and results of the Dutch PelAcoustics project, working with the PFA vessels. Guided calibration of echosounders is one of the elements of the project that has had mixed success so far. But according to one of the skippers this should not be a major problem in the future. In terms of analysis Sascha showed some of the current results and also highlighted the potential for combined scientific acoustic surveys with fishing industry data and for fishing vessel data with inbuilt 'mini-surveys'. In the discussion, Francois Gerlotto mentioned that it would be interesting to make use of the typical 'predator' behaviour of fishing vessels (compare to 'Levy flight' theory) instead of treating it as a nuisance parameter: "there are no predators that operate standardized transects when searching. There must be information in that".

Thomas Brunel (IMARES, Netherlands) presented a simulation model to assess the capability of fishing vessel data to track the abundance of aggregating species. He demonstrated that the methodology could work fine for less aggregated species like herring and horse mackerel where substantial searching time is involved. For highly aggregated species like blue whiting it would still be a challenge to prevent bias due to overrepresentation.

Sven Gastauer (Curtin University, Australia) took us to the world of a relatively small demersal fishery in the Northwest of Australia where he works with fishers to improve their understanding of the available resources, in an area where scientific surveys are very difficult or even impossible. Calibration of the echosounders was successful and acoustic data of good quality has been collected. Target strength measurements were successfully done with the aid of a commercial vessel.

Francois Gerlotto (IREA/SNP, Peru) gave us a very informative overview of the acoustic data collection by the Peru fishing fleets. He showed us some of the struggles in getting the data from commercial vessels accepted in SPRFMO (for Jack mackerel) but also how the fishing companies have embraced the acoustic information which they analyse for their own purposes (better fishing). Several workshops have been held already to analyse the acoustic information collectively. The future is to use fishing vessels more and more as monitors of the oceans. Especially in areas where traditional scientific surveys are no longer feasible, such as in the South Pacific, that is just too large to carry out regular surveys. Fisheries organizations of Peru, Ecuador and Chili have initiated a programme to make sure that all data collected by fishing vessels could be used to the scientific fishery research and to assess impacts of climate change in oceans. All other fisheries are invited to join the initiative.

Conclusions

Many different topics were discussed during the workshop, all showcasing the great potential of using industry data for different purposes but especially in those areas where standard scientific surveys are weak or simply not feasible. A number of strong conclusions can be drawn from the workshop as follows:

1. The acoustic data from fishing vessels could broadly be used for two different purposes: quantitative data directed at stock estimation and stock assessment, and qualitative data on overall trends and distributions within marine ecosystems. The overall driver could be to collect data where traditional research activities cannot reach (e.g. remote areas, rough weather, many vessels at the same time).

2. Regular calibration of acoustic echosounders is a key requirement for the potential uptake of commercial acoustics for stock assessment purposes. Calibration would need to be done at least once a year with additional quick-checks to see if the instruments are working as expected.

While the task of calibrating echosounders may seem daunting to the industry, one of the skippers who has been doing this for some year said: “you don’t have to be einstein to calibrate an echosounder”. We need investing in improving the capacity to carry out calibrations of echosounders in the industry but dedicated training and learning from best practices. The calibration workshop in Peru (8-11 september) will be a useful stepping stone in this development.

3. In the short term, we should investigate the potential contribution of the fishing industry to regular surveys (e.g. blue whiting) or in areas where acoustic surveys are lacking (e.g. horse mackerel). This could be carried out in the same way as the joint efforts on the mackerel egg survey where the industry is looking to put in ship time for survey purposes. Close coordination with ICES survey working groups will be required.

4. The initiative by the ICES Working Group on Fisheries Acoustics Science and Technology (WGFAST) to set up a dedicated subgroup on fishing vessel acoustics should be fully utilized to develop and agree protocols on the use of vessel acoustics for research. This group could map out the conditions for the uptake of vessel acoustics for research and make sure that data collected according to the protocols are appropriate and robust.

5. Acoustics data capture from calibrated fishing vessels can already already start today, if sufficient protocols are in place for recording and storing the information by the fishing companies. This can even start in the absence of a specific analytical approach or programme, because at least the data will be available for future analysis and a time- series can be derived from the data collected. Big data techniques are rapidly developing. This could provide wonderful opportunities of handling the big amounts of data that could be generated by the industry.

6. It is important to develop close and trusting relationships between industry and science. Together, we can improve the understanding of marine ecosystems and knowledge base for marine management. Developing a joint acoustic programme for the EU pelagic industry together with science is a feasible and rewarding step to take at this moment in time (maybe through H2020 or EMFF?).

We would like to thank all presenters for sharing their insights in the use of vessel acoustics for research and all participants for their active contributions to the workshop. We look forward to taking this issue (quickly) forward in the EU context.

Martin Pastoors (on behalf of NPWG) 16/6/2017

Europees Visserijfonds: Investering in duurzame visserij

Extract of the Report of the 1st WORKSHOP OF THE SPRFMO TASK GROUP ON "FISHING VESSELS AS SCIENTIFIC PLATFORMS"

Lima, Peru, 8-11 September 2015

Special focus on calibration of acoustic equipment of fishing vessels.

Dirk Burggraaf (IMARES)

The workshop of the Task group was held in Lima, 8th - 11th September, 2015. It was organized by the National Fisheries Society of Peru (SNP) and the Institute of Aquatic resources (IREA) with the support of TNC, WWF, PRODUCE (etc).

Following the terms of reference, three themes were considered during the workshop:
1. Calibration procedure for acoustic devices aboard fishing vessels;
2. Establishment of a standardized procedure for "between-calibration" analysis of the acoustic data collected aboard fishing vessels;
3. Definition of the priorities for the following activities of the Task Group.

The output of the workshop is a document describing the calibration procedures and protocols adapted to fishing vessels.

Dirk Burggraaf (IMARES) participated in the workshop with financial support from the PFA. Below, he addresses a number of specific questions by PFA regarding echosounder calibration of trawlers
1. Introduce/share our calibration experiences made so far in Pelacoustic projects. Are they useful? Where not? Why not?

The information was useful, but the recent ICES report CCR326 (about acoustic calibrations) provided the base information. Typically the practical items like how to put the lines under the ship was informative, using 4 rods instead of 3. The PFA manual is a very practical point to point manual, the SPRFMO manual has more theoretical background included.

2. during the meeting, discuss with other participants and come up with suggestions for an operational setup of calibrations throughout the year (how can the quality of calibration results be assessed?, what are the recommended possibilities of using fixed location calibrations e.g. the seabed, how often, when, and by whom would calibrations be ideally done?).

Other calibrations instead of the sphere under the ship, are second order. They are good checks to see if the system is not damaged or malfunctioning, but no substitute for a sphere calibration. The scientists present agreed that the calibration interval should not be more than one year. The stability of the equipment is not the problem, but the changing environment (temperature & salinity) introduce bigger offsets.

Instead of steaming over the seabed, the location in the harbour (if deep enough) could also provide relative information about the equipment. The open sea measurements are less stable compared to harbour measurements.

A valuable tool to keep quality control over the equipment would be an electronical monitoring device between the GPT and transducer, to check the coils inside the transducer. Experience shows that if the calibration interval is one year and at some point in time a problem occurs in the cabling or transducer, which

would not be noticed by the skipper in the echosounder software, then long time series of valuable acoustic data could be corrupted and not usable for analysis.
On the other hand, having such an electronic monitoring check continuously running, immediate steps could be taken to solve problems when they occur.

3. get details on recommended calibration procedures for using the seabed integration approach (steaming over the same stretch of seabed at different times of the year to check calibration results/echosounder performance)

Seabed integration has limited use as a second order calibration. It gives some information, but it could give large variances and sometimes even wrong information.
An alternative (but still not replacement of real calibrations) would be measuring of the echo in the harbour, when the ship returns to the same location at the dock. Many measurements averaged may give qualitative information/check of the echosounder performance.
To measure the environmental circumstances could give more input, if you measure temp and salinity the sound velocity and absorption is known and this can provide information for the different types of fisheries and experienced changes through the year. The acoustic equipment is pretty stable by itself, so validating and making sure the equipment is working properly , you could rely on the stable hardware and take account for the variations in temp and salinity, which have a more severe effect on the measured data than the change in the equipment (assuming the hardware setup doesn't change dramatically for various reasons).

4. Talk with Australian/New Zealand participants about their experiences with calibration agreements/procedures of the NZL/AUS fishing fleet. How do they do it? How does it work? Apparently they have an agreement for AUS scientists to calibrate vessels when they are in Australia, and NZL scientists to calibrate vessels when they are in NZL. Maybe an idea to do something like this also in Europe?

The guys from NZL every now and then calibrate AUS fishing vessels, when they (AUS) are in NZL waters doing acoustic surveys. The acoustic survey is a commercial thing and the calibration needs to be done by certified people, so the AUS fishing vessel ask if it is possible for the NZL calibrating crew to have a person available to do the calibration. Only one man is necessary, usually the crew on the fishing ship has done it before. The NZL crew is paid for the work: about 20 hours. Without the calibration, the survey on the commercial fishing vessel is worthless, so the commercial trawler crew understand the importance: no calibration, no pay.
The other way is not likely, but it happens, a NZL fishing vessel asks for calibration assistance from the AUS scientists in AUS waters.
As far as I can see it is more an economical choice to choose the calibrating assistance close by, otherwise crew has to fly in from AUS.
The NZL has a team of about six men who are able to perform the calibrations, three scientist biologist and three engineers, but only one man is doing the actual calibration on board.
Mainly they do drifting calibrations, no anchors used. New vessels with unknown echosounder locations have a diver present during the calibration to look for the location under the ship, and the sphere is guided into the beam.

5. Talk about how long it takes to calibrate, what are the expectations/recommendations of how long vessels need to spend for calibrations? When implementing routine calibrations, what kind of routine will be necessary to achieve self-calibrations by the crew? What we have seen, this needs to be more than just 1-2 times a year for the crew to get familiar/confident.

The Peru scientist crew can do the calibration in about one day. The 120kHz is the main frequency, some have 38kHz, but only one transducer is available per vessel. The actual calibration after setting up the rods and sphere rigging, per given setting of the acoustic equipment(frequency, pulse length, power etc) will take about 30 minutes.
They go for a calibration trip to a known location, with 2 -3 calibrators, use echoview (echo analysing software) for estimating calibration values of the ES60/70 systems from the acoustic data collected during calibration.
Now they are not able to do self-calibrations , but after education and learning it should be possible in the end, but might be difficult. This is a sensitive subject as it is unsure whether they will really be able to do a

good quality calibration if they do it only once a year. The long time in between calibrations will degrade the sharpness and loss of details in the procedure.

For the dutch freezer trawlers there is an opportunity, if the fish tanks are full, and when the weather condition allow an open sea calibration, the time can be used to do a calibration more regularly, without spending time to go to a bay.

6. Discuss how calibration values change over time: what difference in calibration values is to be expected between different seasons in the same year? General recommendation by us is to do it per fishing season/situation as the vessels are in at different times in different areas. But if these differences are not too bad, it could be possible to keep the number of required calibrations per year lower. What are the experiences of others in other fisheries? How often do they recommend to calibrate? And when? And where?

The experience is in the acoustic equipment it does not change much over time, if no damage is done to the transducer or cabling inside the vessel is damaged due to the vibrations and movement of the vessel. This last thing should be solved by a good quality installation of the equipment, but the installation quality seems not always to be as good as expected.

It would be a good thing to have a tool to diagnose the system (on a continuous basis) to see if it works correctly (see comment above), and give a warning to do a check in the form of an extra calibration. So that way it could be noticed something is wrong at an early stage, not at the next scheduled calibration with chance of corrupted data over a whole year.

7. Inquire about the role of the sonar in South Pacific fisheries. Is it even suitable/enough to just rely on echosounder recordings alone to get a good picture of fish distribution? Or will we miss a lot of information by not considering sonar? Some Dutch skippers indicated that most of the Jack mackerel they detect on the sonar, not the echosounder. What are the experiences of others?

Chile is using the sonar for the purse seiners, for fish finding it is more important than the echosounder. NZL vessels are not using sonars much , only one vessel has one, and the fleet will follow this vessel. The Peru seiner fleet is also using sonars, more important for searching and deciding what to catch than the echosounder.

Appendix F. publications

This article was published in Fisheries Research: Fässler, S.M.M., et al., Acoustic data collected on pelagic fishing vessels throughout an annual cycle: Operational framework, interpretation of observations, and future perspectives. Fish. Res. (2015), http://dx.doi.org/10.1016/j.fishres.2015.10.020, Copyright Elsevier (2015).

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Full length article

Acoustic data collected on pelagic fishing vessels throughout an annual cycle: Operational framework, interpretation of observations, and future perspectives

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ABSTRACT

Acoustic data collection trials on pelagic freezer-trawlers were realised in 2012 during several fishing trips targeting blue whiting west of the British Isles in spring, North Sea herring in summer, and horse mackerel in the English Channel and Celtic Sea in autumn. Echosounders were calibrated and time- and position-stamped data logged along the path covered by the vessels. The acoustic detections recorded during different types of trawler activity within a fishing trip ('searching', 'stationary', and 'fishing') were compared between target species. The highest proportion of time spent for activity 'fishing' was observed in the blue whiting fishery (82%), while that value was lower in the horse mackerel and herring fishery (68% and 54%). In all fisheries the quantified mean fish densities recorded were significantly higher during 'fishing' than during 'searching'. Changes in recorded fish density magnitudes over time before and after trawling also showed different patterns between fisheries. The quantified peculiarities exhibited by the specific fishing trip data is discussed in light of incorporating them in monitoring programs and analysis methods that can advance ecosystem understanding. Potential future approaches for analysis methods of opportunistically recorded acoustic fishing vessel data are discussed.

1. Introduction

Sustainable management of marine resources and services is increasingly being based on an ecosystem approach (Bianchi and Skjoldal, 2008; Levin et al., 2009; McLeod and Leslie, 2009; Link, 2010; Katsanevakis et al., 2011; Kruse et al., 2012). Apart from a holistic understanding about how human activities impact on the system, such an approach requires quantitative knowledge about fundamental ecosystem processes (Curtin and Prellezo, 2010). To develop this knowledge, information on the distribution, abundance and productivity of different biological ecosystem components are required (Demer et al., 2009; Handegard et al., 2013). However, the specific monitoring and sampling programmes currently in place are largely designed to assess individual ecosystem components. Available data therefore often do not satisfy the requirements of advanced ecosystem models (Fulton, 2010; Rose et al., 2010). The latter are designed to enhance our ecosystem process understanding and to make predictions based on biological and physical characteristics of the ecosystem over extended spatio-temporal scales.

Scientific acoustic surveys are an essential source of information for current stock assessments of widely distributed pelagic fish populations, which show distinct migration patterns throughout their life cycles (e.g. Iversen, 2002). Echosounders are used to continuously collect fish density data along systematic survey transects. The acoustic intensity reflected by the fish can subsequently be converted into average fish density-per-area values inside the covered area. A survey age-structured biomass index for the targeted stock can then be derived from the acoustic data in combination with collected biological samples. However, scientific surveys are limited by practical and financial constraints and the resulting coverage often provides only a snapshot view of the stock abundance at a very particular point in time. Furthermore, many commercial stocks cannot be sufficiently covered by a directed acoustic survey due to resource limitations or survey practicalities. The resulting lack of spatially resolved abundance information for many species severely constrains the parameterisation and prediction capabilities of advanced ecosystem models needed to serve as a foundation for ecosystem-based management.

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