Living Resources Committee

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REPORT OF THE

Planning Group on Aerial and Acoustic Surveys for Mackerel

Lisbon
6–9 April 2003

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

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1 INTRODUCTION

1.1 Terms of Reference

The Planning Group on Aerial and Acoustic Surveys for Mackerel [PGAAM] (Chair E. Shamray, Russia) met in Lisbon, Portugal from 6–9 April 2003 to:

a) collate and evaluate the data collected by the aerial surveys, fishing- and research vessels in the Norwegian Sea during the late summer and autumn 2002;
b) combine the summer 2002 aerial surveys data with vessels data of distribution of mackerel in the Norwegian Sea;
c) identify participants to contribute to the aerial surveys for mackerel in the Norwegian Sea and coordinate vessels collaboration;
d) combine the October-November 2002 survey data of abundance and distribution of mackerel within the North Sea-Shetland area;
e) coordinate acoustic surveys within the North Sea-Shetland area to ensure full coverage and appropriate areas and timings;
f) coordinate the timing and area allocation and methodologies for acoustic and aerial surveys for mackerel in the NEA;
g) consider the latest findings from the SIMFAMI project;
h) coordinate acoustic surveys in Divisions VIII and IX. Seek survey time for northern extension of these surveys;
i) identify surveys which are not targeted at mackerel, but which may have potential use for the estimation of mackerel distribution and abundance;
j) develop protocols and criteria to ensure standardization of all sampling tools and survey gears.

PGAAM will report by 22 April 2003 for the attention of ACFM, Fishing Technology Committee and to the Living Resources Committee who will parent the Group.

1.2 Participants

Ciaran O'Donnell	Ireland
Paul Fernandes	U. K. (Scotland)
Jan Arge Jacobsen	Faroe Islands
Ciaran Kelly	Ireland
Rolf Korneliussen	Norway
Vitor Marques	Portugal
Alexandre Morais	Portugal
David Reid	U. K. (Scotland)
Evgeny Shamray (Chair)	Russia
Dankert Skagen	Norway
Vladimir Zabavnikov	Russia

1.3 Background information

The mackerel widely distributed in the North-East Atlantic. According to long years total commercial mackerel catches taken during 1977-2001 mackerel is caught from the Iberian Peninsula in southern Europe up to around 73° N in the north. The distribution of catches is likely to vary from year to year due to environmental factors, stock size, and quota limitations for the participating nations. The distribution of commercial catches by quarter that in details described annually in the report of the WGMHSA should therefore be interpreted with caution. An example some countries cannot to fish in the different national EEZ or they have the quota limitation. So, the commercial data are meant to show only the wide are where mackerel is caught in the Northeast Atlantic, and the quarterly changes in the distribution of the fishery.

Various research surveys by different countries have verified an even wider distribution of mackerel than shown here by the commercial fisheries.

The assessment of the NEA mackerel stock complex is currently dependent on a single fishery independent estimate of biomass, derived from the ICES Triennial Mackerel and Horse Mackerel Egg Surveys. This is only available once every three years and makes the assessment increasingly insecure with elapsed time since the last survey. The results from the egg surveys also take a significant time to prepare (almost 1 year). While it is prohibitively expensive to carry out more frequent egg surveys, it may be possible to use other survey methods to provide data in the intermediate years.

At the same time, a number of different surveys have been carried out by a number of countries in recent years. All surveys have the potential to deliver information on the distribution and abundance of mackerel. However, the surveys covered only part of the known distribution area and consequently have not been able to deliver a valid stock estimate or complete distribution map. The aim of this Planning Group is to identify the deficiencies in area and timing of these surveys and to remedy these deficiencies.

PGAAM met for the first time in February 2002 to coordinate vessels from appropriate countries which can collaborate with the Russian aerial surveys in the Norwegian Sea, to coordinate Scottish and Norwegian acoustic surveys in the Viking Bank area, to coordinate Spanish, Portuguese and French acoustic surveys, utilize the findings of the EU SIMFAMI project to provide a universally applicable mackerel target strength. During the first PGAAM meeting it was possible to provide coordination for some of these surveys. (Anon. 2002). The some results of these surveys were reported to the WGMHSA (Anon. 2003).

Details results of that collaboration were discussed during second PGAAM meeting at and some next steps were find.

2 MACKEREL TARGET STRENGTH

Mackerel do not possess a swim bladder. As a result, they are poor reflectors of sound and have a low target strength (TS) at 38 kHz. The backscattering mechanisms are still not completely understood, although some TS modelling has been done in Norway (to be presented at the FAST WG in Bergen in 2003). The TS measured in Norway indicate a relationship of the form: $TS = 20 \log_{10}(\text{Length}_{(\text{in cm})}) - 86.0$. However, until the backscattering mechanisms are understood better we do not recommend changing the TS relationship used currently (below).

In 2002, PGAAM recommended that the common TS/L relationship, at the agreed integrating frequency (38 kHz) should be:

$$TS = 20 \log_{10}(\text{Length}_{(\text{in cm})}) - 84.9 \quad \text{(Edwards et al. 1984)}$$

It is still unsure as to which acoustic frequency is most appropriate for echo integration; until further notice it is recommended to continue using 38 kHz, integrating at a threshold of –82 dB. Provisional modelling studies indicate that for a single-sized mackerel, a “jump frequency” exists somewhere between 100 and 200 kHz, where the TS may increase rapidly. The exact frequency will depend on the size of the mackerel. Figure 2.1 illustrates how $TS=10\log_{10}(\sigma_{bs})$ may change, but there is still some uncertainty about this. This will be tested during the Norwegian mackerel survey in 2003 (Table 6.2.1) provided the 400 kHz transducer is available on the EK60 echosounder.

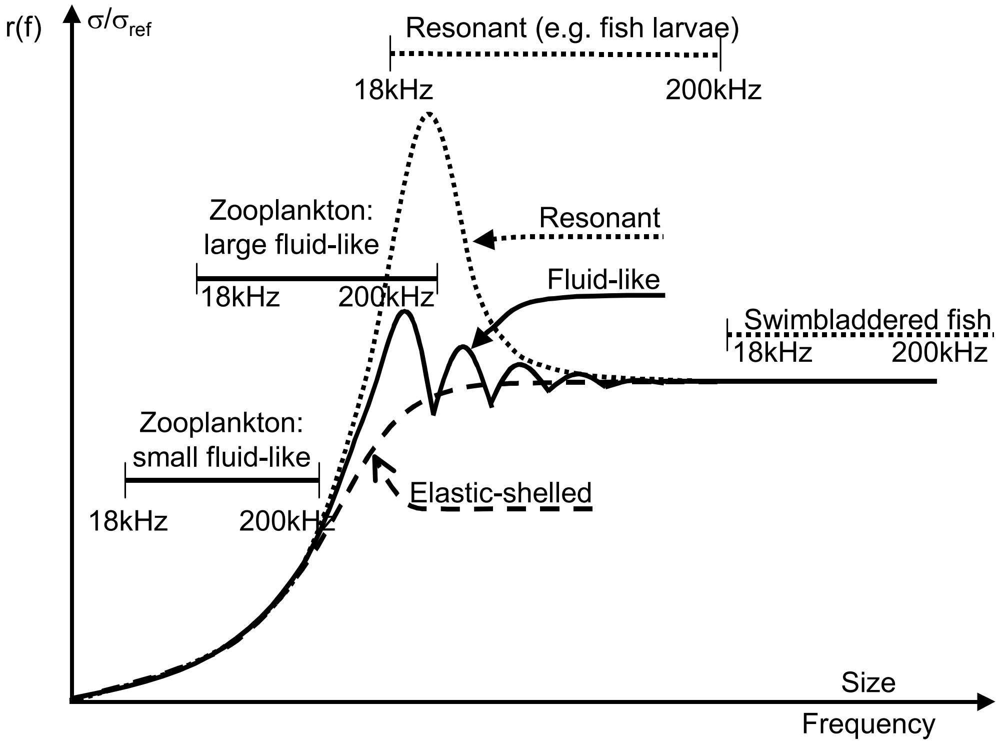

Figure 2.1a. General schematic description of the relative frequency response, r(f). The typical position in the figure for selected acoustic categories when measured in the frequency range 18–200 kHz are indicated. (Figure from Korneliussen and Ona, 2003).

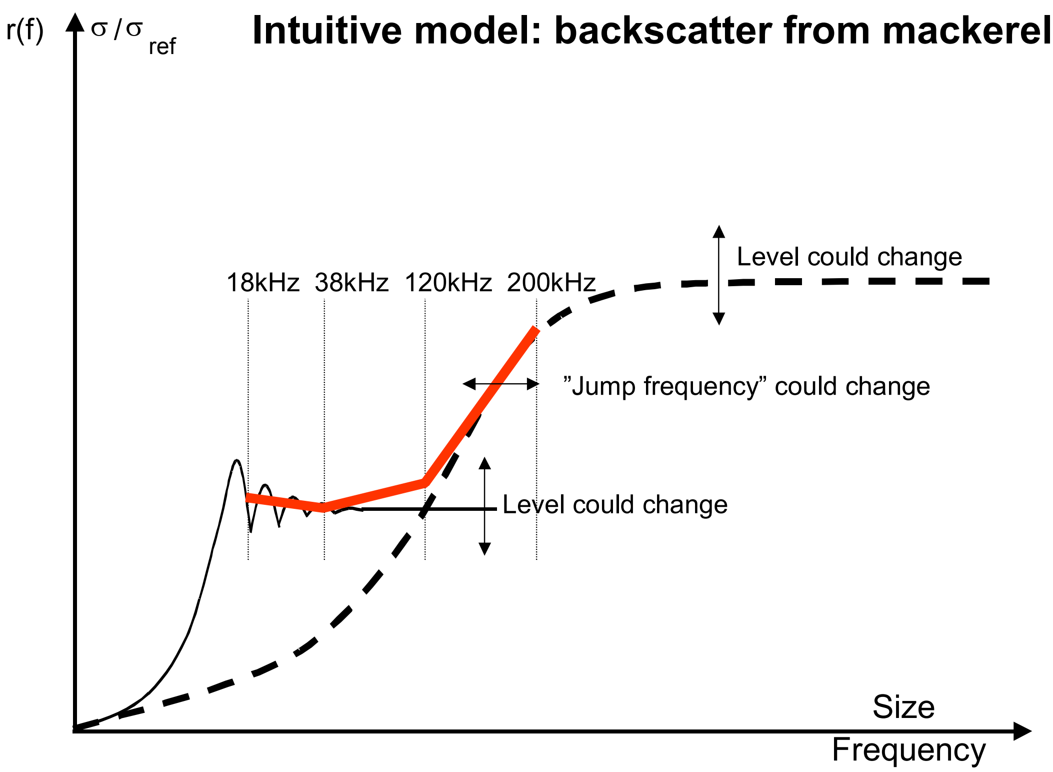

Figure 2.1b. Intuitive model of backscattering mechanisms from mackerel.

3 ACOUSTIC SURVEY PROCEDURES

Protocols and criteria to ensure standardization of all sampling tools and survey gears.

The acoustic surveys carried out under the auspices of this Planning Group are currently under development as are many of the tools and protocols . The planning group feels that this is, therefore, not the appropriate time for the setting of standards. This is particularly the case for methods of echogram scrutiny and pre-processing of the acoustic data. Survey designs are planned following the paradigm of the herring acoustic survey in the North Sea, but with modifications for the specific circumstances in particular areas and seasons. Until protocols specifically for mackerel acoustic surveys are fully researched and validated, cruise leaders are advised to use the general rules set out in the "Manual for herring acoustic surveys in ICES divisions III, IV and VIa" (Annex I). Where the procedures for mackerel surveys deviate significantly the text in **bold and underlined** outlines advice to be considered for these cases.

This manual and modifications are intended for use in new or existing acoustic surveys specifically targeted on mackerel, and carried out under the auspices of this Planning Group. For other surveys, where mackerel is a secondary objective, the manual and modifications should be regarded as advisory only.

4 THE SIMFAMI PROJECT

4.1 SIMFAMI project progress

SIMFAMI (Species Identification Methods From Acoustic Multi-frequency Information) is a three-year project, started in January 2002, funded by the European Commission. The project aims to apply modern multi-frequency acoustic techniques, in addition to the single-frequency methods available previously, to establish methods for acoustic identification of echo traces that are applicable to routine survey procedures. A website for the project has been constructed at http://simfami.marlab.ac.uk. The website has a simple description of the project objectives and background and details on project participants, timetable, a bibliography, a page from which to download relevant documentation (e.g. reports) and the database.

The project is still in its infancy and in the first year, as one might expect, much has been focused on the infrastructure through development of the database and provisional investigations into algorithm development. The database provides centralised access to data for the development of algorithms. It consists of information about short section of acoustic data that has been ground truthed (sampled with an appropriate trawl). Much has been learned about how algorithms should be constructed, how they should be described and what the shortcomings are with regard to validation. These concepts will need further development in the coming year.

A web-based (online) database has been constructed by IEO. This contains database tables describing: the survey; the acoustic data; a polygon identifying the relevant piece of acoustic data; the associated trawl haul; the catch (either fish or plankton); an image of the echogram (acoustic data); and provision for hydrographic (CTD) data. A substantial document was prepared describing protocols for the collection of multifrequency data: this deals with calibration; noise removal; spatial comparability; sampling volume; and sound speed. An additional document examined some of the errors associated with the spatial dislocation of transducers which, for many partners, is difficult to overcome: suggestions for amelioration were made.

Algorithms to identify fish species are being developed. The work done on extracted parameters based on school echo traces, has indicated that for fish with swim-bladders at least, the distinction between species may not be as great as that between size. This may, nonetheless, prove useful to distinguish for example, adult herring from Norway pout. In the case of fish without swim-bladders, algorithms have been developed for mackerel (using the 'frequency response' and the 'dB difference'). The principles of these algorithms are quite similar in that they rely on scattering from fish without swim-bladders (mackerel and sandeel) to be higher at higher frequencies whereas that of fish with swim-bladders (herring and blue whiting) to be lower at high frequencies. A detailed description of the frequency response algorithm is provided in WD Kornelliusen 2003. Algorithms to separate fish from plankton are also being developed and in some cases are being implemented in routine surveys. A bifrequency algorithm (using 38 and 120 kHz) has been developed which is based on a plankton scattering model and can be implemented through available software. Combined algorithms are already being considered: an algorithm for the identification of sandeel, for example, includes a plankton extraction component.

There were some delays in the construction of the database due to a significant alteration in personnel associated with WP1 (database construction). This was meant to be led by Mr. Pablo Carrera at IEO in A Coruna, Spain, but he resigned from his post in May 2002. IEO were eventually able to find a suitable replacement to undertake Mr. Carrera's duties but this inevitably resulted in some delays to the construction of the database. It should be stressed, however, that IEO put significant efforts into redressing the delays and a satisfactory working database is now available online. Any delays have only affected input to the database and not had any lasting effects on the project overall.

There have also been some problems in the transfer of acoustic data. There is simply too much data for the acoustic data to be stored in the database. The database will therefore store survey information and acoustic data filenames. The acoustic data files can then be retrieved from their home institute on request. The original intention was to store the data in a common data exchange format known as HAC. This has, however, proved problematic as there were insufficient translators for participants to convert their data into the HAC format. Participants have, therefore, spent some effort in writing translators to enable their data to be stored in HAC format to enable database access. This is now largely complete although some small problems still remain in the translation of one format (Echoview) to HAC; these are in the process of being addressed.

The results from the project are already filtering through to the user community in acoustic surveying procedures. One of the plankton separation algorithms is being implemented in the Orkney-Shetland herring acoustic survey where it serves to simplify the scrutinisation process. The mackerel identification algorithm is being used by IMR in a survey for mackerel in the North Sea and this has incited FRS to join IMR in that survey. It is possible if the algorithm proves robust and successful that this survey may provide an alternative index for mackerel which is a much needed parameter for the assessment of this valuable species.

4.2 IMR mackerel identification algorithm

The algorithm used by Norway is described in the Working Document Korneliussen, 2003 and illustrated by Figure 4.2.1. The starting relation of the relative frequency response $r(f)=s_v(f)/s_v(38kHz)$ is approximately 1.0 : 1.0 : 1.0 : 3.5 at 18, 38, 120 and 200 kHz respectively, allowing 35% uncertainty at each frequency in Stage-1. Note that the average r (200kHz) of the measured data was slightly less than 4.0 1999-2001, but was less than 3.0 in 2002.

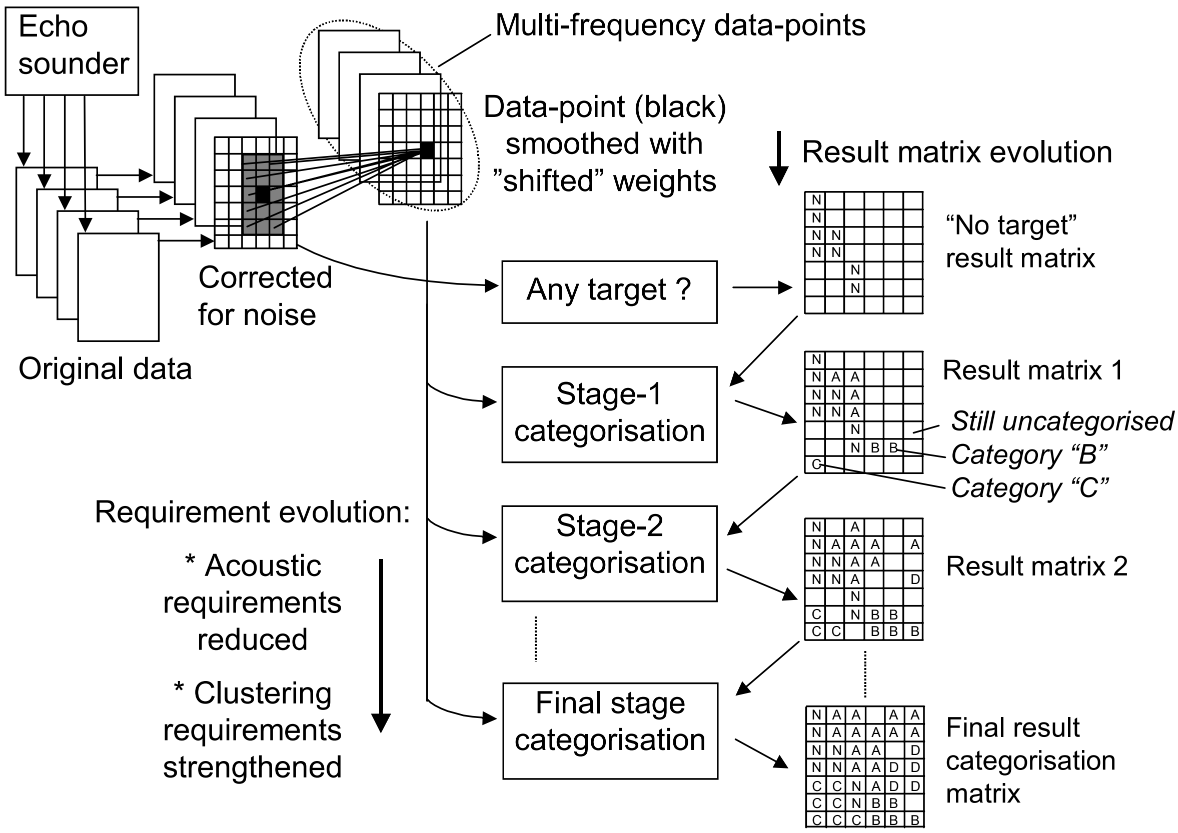

Figure 4.2.1. (Essentially from Korneliussen and Ona, 2002). Data flow through the categorisation system. The smoothed multi-frequency data-points are used to discriminate between the target classes. If the default weights are used on data with 0.3 m vertical resolution, the smoothed point is generated from the indicated 15 points with the filter weights reduced from 0.18 in the centre to 0.025 in the corners. In Stage-1 categorisation, strong model-based or

empirical requirements must be fulfilled by a multi-frequency data-point in order to put the corresponding volume segment into one of the specific acoustic target categories. The requirements on the data-point become weaker for each of the categorisation stages that follow but results from the previous categorisation stage are also used as new input.

4.3 FRS mackerel identification algorithm

FRS are in the process of developing a multifrequency algorithm for the identification of mackerel echo traces. Currently this consists of firstly applying a three-frequency plankton filter using data collected at 38, 120 and 200 kHz and then a dB difference echogram is created using plankton filtered 38 and 200 kHz data (38 minus 200 kHz) on a pixel by pixel basis. The dB difference echogram is color coded (blue for negative values; red for positive) and inspected for consistent echotraces with a strong negative dB difference. The algorithm then applies a threshold to extract only negative values from the dB difference algorithm. Some image processing is then applied to enhance and smooth the echotraces and to filter out small spurious marks. The image processed image is then used as a mask on the original 38 kHz data to isolate echotraces as potential candidates for mackerel. The final selection is based on a user operator selection of potential mackerel candidates from this mask. The user can employ the schools detection module in Echoview to draw regions around selected echotraces. These are then classified as 'mackerel' or 'possibly mackerel' according to inspection of the dB difference echogram.

5 AERIAL SURVEYS

5.1 Aerial surveys in the Norwegian Sea in 2002

Russian annual airborne research of feeding mackerel in the Norwegian Sea was continued in the summer 2002. These works were carried out as planned during PGAAM meeting 2002 (Anon. 2002). But some corrections were made due to the current oceanographic, biologic and meteorological conditions only.

The Russian aerial survey carried out onboard research aircraft An-26 "Arktika" (Zabavnikov et al. 1997, Anon. 2002) as in the previous years and was made during 20 July – 17 August (Figure 5.1.1.).

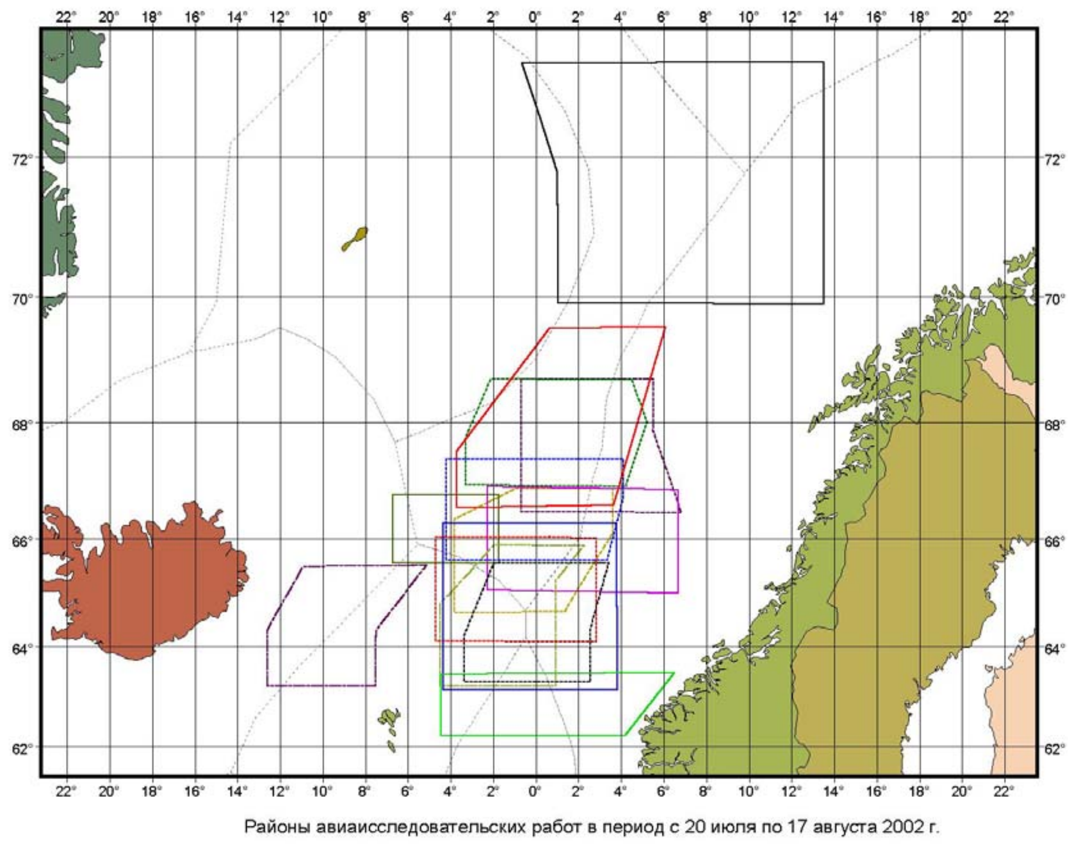

Figure 5.1.1 Area covered by the Russian aerial survey carried out onboard research aircraft An-26 "Arktika" during 20 July – 17 August 2002.

Methodology of the Russian aerial surveys described early in details (Zabavnikov et al. 1997, Anon. 2002). In 2002 for the first time were applied some elements of ecosystem approach, i.e. different type of information such as distribution of biological objects (marine mammals, fish, birds etc.) as well as oceanographic conditions collected, analysed, interpreted and mapped simultaneously in GIS presentation.

Polarizable aviation LIDAR (PAL-1) was used more efficiency, reliably and quality in comparing with previous years in considered aerial surveys. It was made due to the great modernization in autumn 2001 – spring 2002, including software and mathematics ensuring, that allowed to increase reliability and quality of mackerel schools identification, and also extend opportunity of PAL-1 using. In considered surveys LIDAR used not only for feeding mackerel schools, depth picnocline bedding discovering and identification, including transparency determination traditionally, and also for definition of zones with greater initial biological concentration (the first, phytoplankton). Also after each flight had opportunity to get mackerel schools images like echosounders echograms, that allow to determine size and density of each mackerel school objectively. This task was solved after creation of special software, which allows to process and accumulate several consecutive LIDAR mackerel schools signals. Example of this present on Figure 5.1.2.

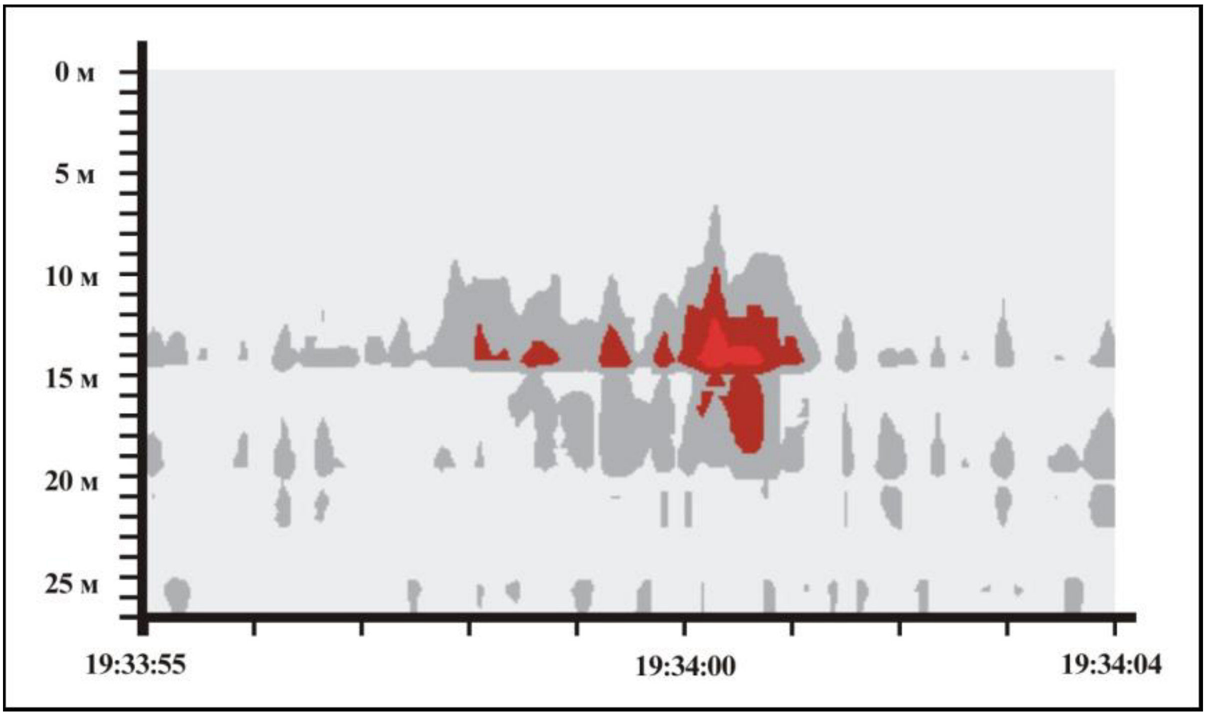

Figure 5.1.2. Example of process and accumulate several consecutive LIDAR mackerel schools signals. Vertical structure of mackerel school (LIDAR survey 23.07.2002, Russia)

According to the results of Russian airborne research the most meeting of feeding mackerel schools was registered in the Southern part of aerial surveys area, and also several local feeding mackerel schools registrations were made in the North or Northwest of Lofoten.

Norway performed aerial surveys in the Norwegian Sea were made in the period 15 – 23 July. A hired aircraft ”Aerocommander” and a LIDAR equipment hired from NOAA Environmental Technology Laboratory (NOAA ETL) with assistance James Churnside from NOAA ETL were used. 8 flights were made in the Norwegian Sea at latitudes from 62° N to 70°15’ N, from the Norwegan coast westwards to between 2° E and 1° W. The survey was mostly considered as a learning exercise, with emphasis on mackerel registrations in the conditions prevailing in the Norwegian Sea in the summer. Several algorithms for treating the data were explored, but definition of biomass estimate was not made.

In LIDAR was a Nd:YAG laser operating at 532 nm. The processing included two alternative means of removing noise due to plankton and other background scattering. These were a linear processing, which basically assumes that the plankton has a more homogenous horizontal distribution than the schools of mackerel, and a median procession, where the assumption is that the vertical plankton distribution is more homogenous than the schools.

The LIDAR works best when there are large, clearly outlined schools and no other sources of backscattering. In the summer conditions in the Norwegian sea, where mackerel is feeding on the plankton, this not the case. These two methods gave somewhat diverging interpretations of some of the signals, which were either rejected as plankton layers (according to the median algorithm) or interpreted as wide-spread aggregations of mackerel (according to the linear algorithm). Clearly, much work remains to get a signal processing system for reliable identification of the registrations.

Most of the mackerel was found together with plankton at 10-20 meters depth. As an example, Figure 5.1.3 shows the distribution of signals at 15-20 meters depth for teh northbound coverage, using the median algorithm. Most mackerel was found in the Southern part of the area. In addition, some registrations were made North of Lofoten.

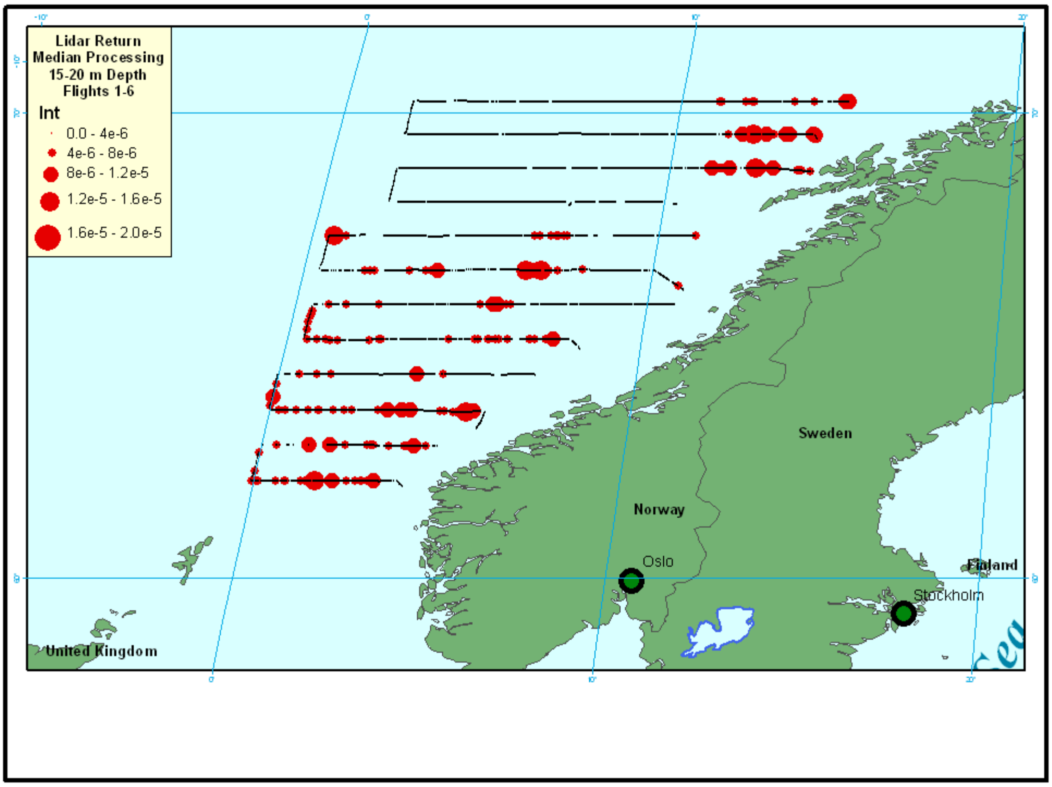

Figure 5.1.3. Registrations assumed to represent mackerel, according to the median processing algorithm, for the Northbound part of the Norwegian aerial survey 15 – 21 July 2002, at depths 15 – 20 meters.

Two hired commercial purse seiners/trawlers were operating in the area in the same period, one covering the area from North to South, the other from South to North (Godoe et al. 2002). Both were trawling in designated positions with the trawl operating at the surface, i.e. covering largely the depth range 5 – 40 meters. Because both the aircraft and the vessels were operating on relatively fixed schedules, simultaneous observations of the same area was not practically possible. Thus, a direct verification of the LIDAR registrations was not possible. Figure 5.1.4 shows the amounts caught by the two vessels in designated hauls. The area with the largest catches coincides grossly with the area where most mackerel was observed on the LIDAR as onboard of ”Aerocomander” as ”Arktika”. However, only small catches were made North of Lofoten.

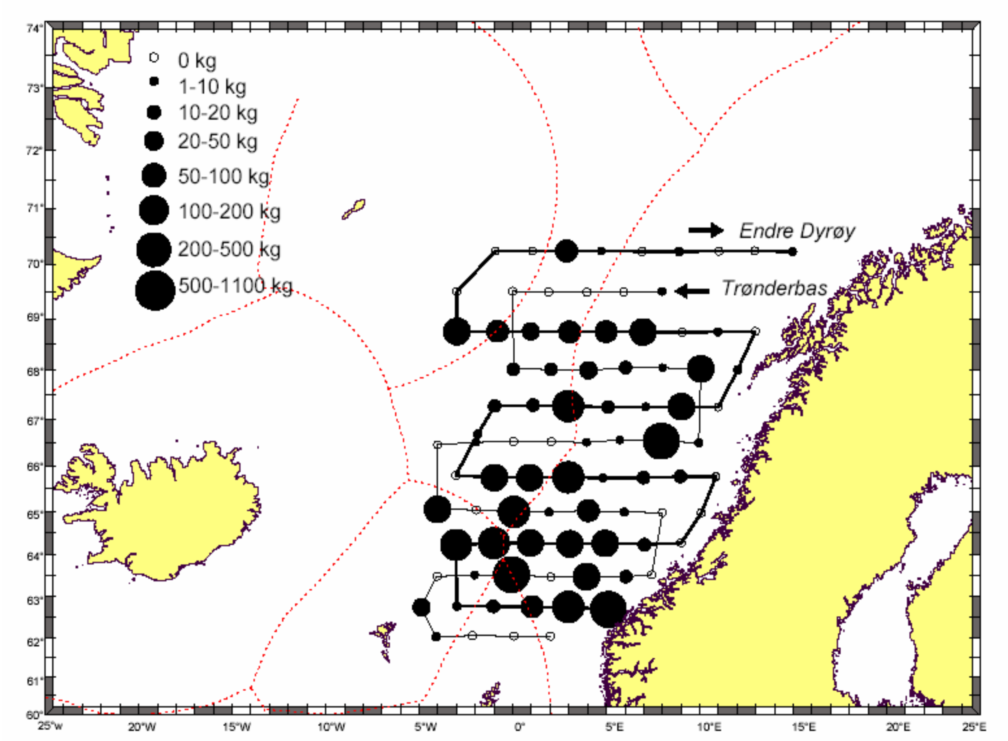

Figure 5.1.4. Trawl catches in designated hauls by two commercial purse seiners/trawlers 'Endre Dyrøy' and 'Trønderbas' in the period 15 – 27 July 2002. The trawl covered the depth range 5 – 40 meters. (Figure from Godø & al, 2003).

Besides, own airborne research of each country was made joint aerial survey in 23 July along two tracks 62° 45' and 62°00' N between 01°00' W - 04°00' E (Russian research flight tracks was some longer to westward to 04°00' W). Russian aerial survey was made on flight altitude from 200 m, and Norwegian from 300 m, with difference between each flight about 4 hours. It was requirement of Norwegian Aviation Safety Service. The preliminary results of this joint research were discussed during meeting PINRO and IMR scientists.

Under solutions of PGAAM meeting in 2002 were carried out joint research between "Arktika" from one side, Russian research vessel "Fridtjof Nansen" and Norwegian commercial vessel "Troenderbas" from other side. Joint research An-26 – R/V "Fridtjof Nansen" was carried out July 22-24. This research showed a good correlation between aircraft remote sensing data and vessel (in situ) data as in comparing of oceanographic data (SST, depth of picnocline bedding, transparency) as mackerel schools discovering. Several (not all) aircraft mackerel schools discovering was confirmed by vessel acoustic system, which were closest for R/V "Fridtjof Nansen". Unfortunately, on vessel technical problems R/V "Fridtjof Nansen"could not catch discovered mackerel schools.

The joint work between aircraft-laboratory "Arktika" and F/S "Troenderbas" was carried out during planned research flight in July 25. The regular telephone and e-mail connection between aircraft and "Troenderbas" scientific leaders were made during July 22-24. Joint work was made along aircraft and vessel common tracks, which were along 63°30' N between 02°00' W – 03°00' W. Unfortunately, exactly come to "Troenderbas" did not success, as abruptly and greatly worsted visibility and other weather conditions. Nevertheless "Arktika" located as close as possible to the "Troenderbas". Likely joint research with R/V "Fridtjof Nansen" this research showed a good correlation between aircraft remote sensing data and vessel (in situ) data. In the closely area of "Troenderbas" position mackerel schools did not observe and register of "Arktika". The same result noted of "Troenderbas" acoustic systems (look Figure 5.1.4).

During the PGAAM 2002 meeting it was planned to carry out joint research with Faroese research vessel which was ready for that in August 3-8 2002. The area for this work was located inside Faroese EFZ. Unfortunately, due to the strong and dense fog which occupied more than 80% of that area the joint research did not succeed, because the efficiency of the research aircraft in those weather conditions is very poor. The weather conditions for aerial surveys after 8 August were good but the Faroese vessel could not to be in the sea after 8. August. Nevertheless, during indicated time both sides had regular connection by e-mail and telephone with the purpose of information and consultations exchange.

Under above carried out research were defined more precisely some aspects of feeding mackerel distribution, got and accumulated new data, including LIDAR systems of PAL-1 and NOAA ETL, that can extend knowledge about feeding mackerel distribution, migration and behaviour. In the future, this information for the mackerel biomass calculation can be used.

Figure 5.1.5. is show overlaping area during separate and joint aerborne investigations in July 2002 conducted by Russia and Norway.

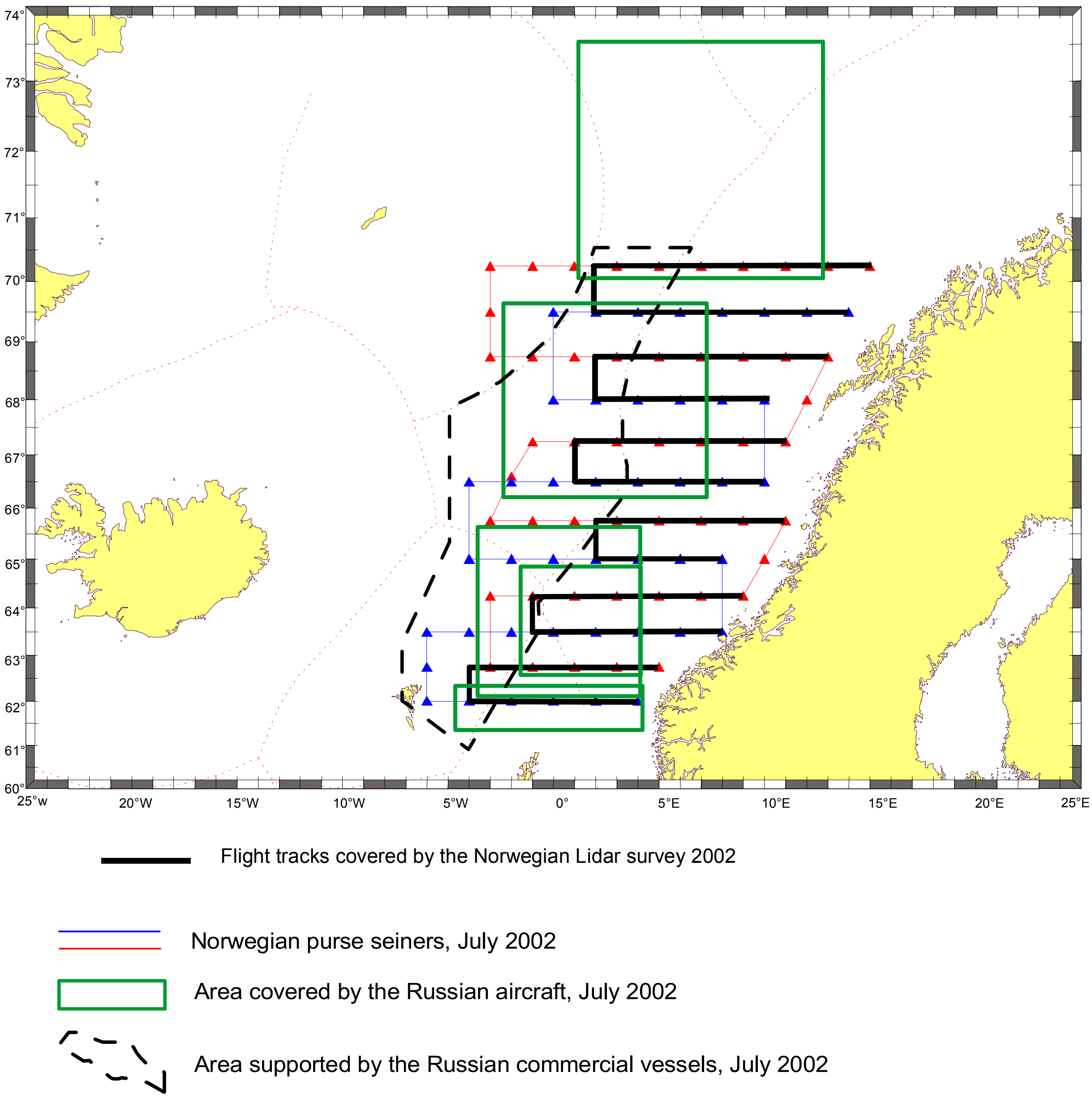

Figure. 5.1.5. Tracks by the Norwegian purse seiners and airplane, and areas covered by the Russian airplane and commercial vessels. July 2002.

5.2 Aerial surveys in the Norwegian Sea in 2003

Russia plans to carry out of feeding mackerel complex aerial surveys in the Norwegian Sea as in previous years. Airborne research will be carry out onboard of research aircraft An-26 “Arktika”, which is equipped by remote sensing instruments, working in the difference of electromagnetic wavelength ranges (Zabavnikov et al. 1997, Anon. 2002).

Norway will not perform aerial surveys in 2003. Work is in progress to build a new LIDAR in Norway, and this is scheduled to be ready for 2004.

Russia plans to carry out airborne research in the volume about 120 flight hours during the end of June – beginning of August. Planned area of aerial survey as the same last year. The main part of research flights will be carried out in the International waters and closest area inside of different National EEZ. However airborne research period and area can be exchanged dependent on development of oceanographic, meteorological and hydrobiological processes in the Norwegian Sea and closest area of the North Atlantic.

Plans that several nations will support airborne research by their research and commercial vessels as the same last year. The areas covered by Russian aircraft and vessels are given in Figure 5.2.

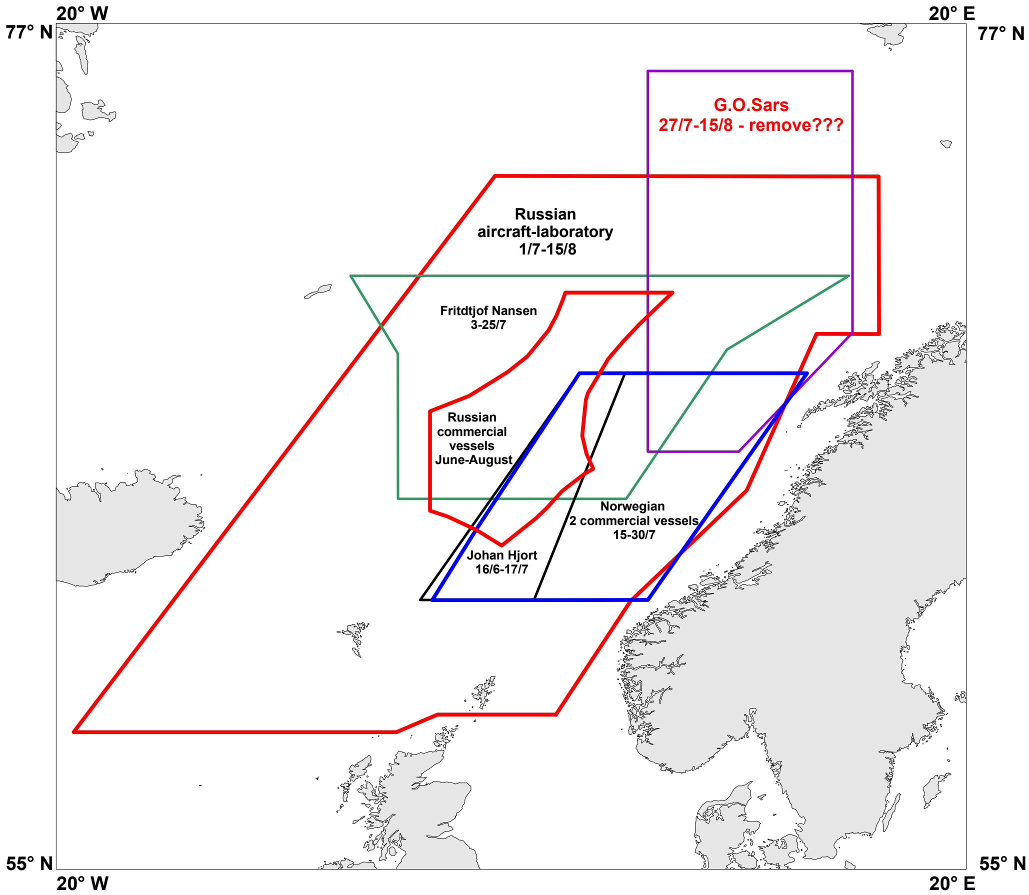

Figure 5.2. Russian Aerial survey July-August 2003 and research/commercial vessels which can to collaborate with aircraft-laboratory.

Russian research and several commercial vessels will work/fish in the International waters in June-August and will be able to identify observations made by "Arktika".

Norway will conduct a vessel survey in the Norwegian Sea in 16 June – 7 July with the R/V "Johan Hjort". This survey is directed at outlining the distribution of post-smolt and its association with mackerel, plankton and currents. Also Norway will have two purse seiners/trawlers operating in the Norwegian Sea for the period 15 – 30 July in 2003. These will follow designated cruise tracks and fish by trawling close to the surface in designated positions, similar to the procedure in 2002. The gear will be standardised, and echo-sounder and sonar registrations will be logged for subsequent processing. Both these surveys should be able to report to those performing Russian aerial surveys.

Detailed plans for the joint airborne remote sensing and vessels surveys will be exchanged by correspondence and agreed before July. The Russian and Norwegian contact persons for the joint research will be Vladimir Zabavnikov (ltei@pinro.ru copy inter@pinro.ru) and Dankert Skagen (dankert@imr.no) respectively.

The aerial surveys will also, if possible, be assisted by a Faroese commercial vessel working particularly in the Faroese EEZ the last week of July or first week of August. Aspects and possibilities of this cooperation will be agreed by correspondence in spring 2003. The Faroese contact person is Jan Arge Jacobsen (janarge@frs.fo).

The Russian aerial surveys in the end of July – beginning of August 2003 will also co-operate with Icelandic Marine Research Institute on pelagic fish stock distribution and abundance in the western area.

6 ACOUSTIC SURVEYS IN THE NORTHERN AREA

6.1 Acoustic surveys for mackerel in autumn 2002

6.1.1 Norwegian survey

The Norwegian acoustic survey in the North Sea took place form 15 October to 3 November with the R/V G. O. Sars. The area covered and the cruise track is shown in Figure 6.1.1. The first part of the survey, the cruise track was interlaced with that of R/V Scotia. This was followed by an intercalibration across the areas with the largest registrations. The second part of the survey covered a somewhat larger area, as well as the core area on the Viking Bank. Parts of the planned coverage in the second part had to be abandoned due to bad weather conditions.

The overall design of the survey was similar to that in previous years. As before, sampling by trawling was problematic, with both precludes a proper validation of the acoustic registrations, and may lead to underestimation of the mean length. These problems may to a large extent be due to the weak engine power of the G. O. Sars, allowing a towing speed of only 3.5 – 4 knots, and also to the lack of appropriate trawl doors. New doors were mounted after the first part of the survey, and performed much better.

The identification of mackerel was largely based on the frequency response. Thus, only distinct schools with the typical frequency response. The registrations are outlined in Figure 6.1.1. As in previous years, most of the mackerel was found 30 – 50 nautical miles to the west of the edge of the Norwegian deep, with occasional registrations further to the west. The biomass estimate, using the agreed target strength of 20logL - 84.9, was 493 000 tonnes for the first coverage, 488 000 tonnes for the second coverage, and 535 000 tonnes when the observations from the whole survey were taken together. This is in line with the results from 2000 and 2001.

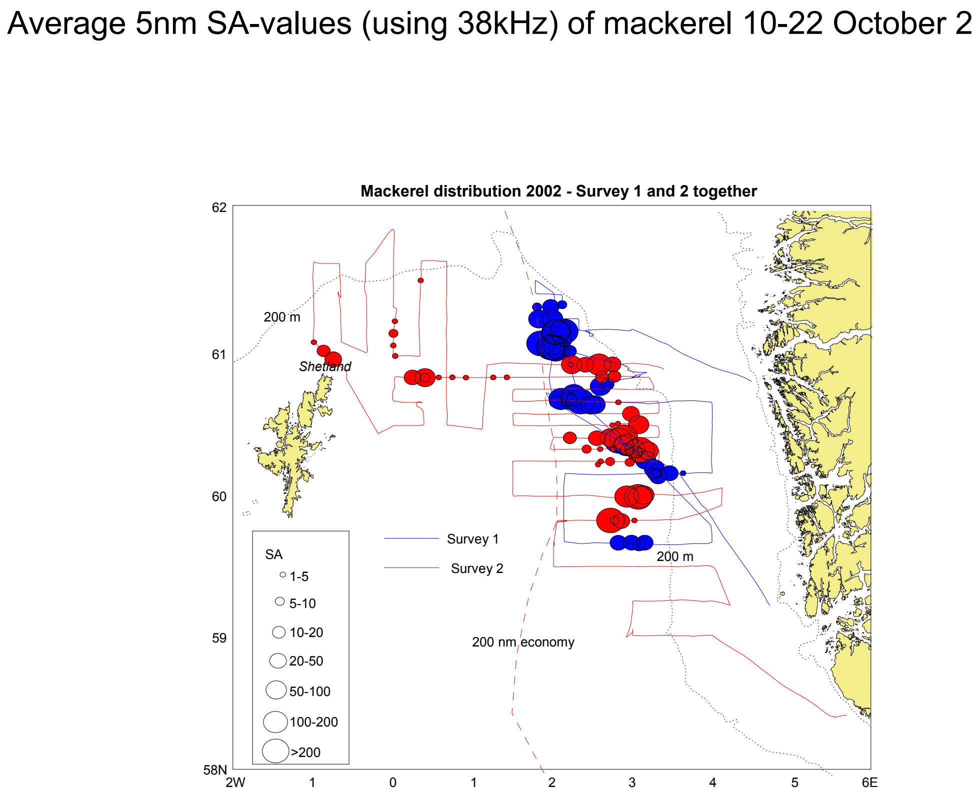

Figure 6.1.1. Cruise track and registrations of mackerel in the Norwegian survey with G.O. Sars. First coverage blue, second coverage red.

6.1.2 Scottish survey

The survey

The survey commenced in poor weather, north of the Minch, at 20:22 on 11 October. Zig-zag transects at various spacings were adopted crossing the continental slope, progressing towards the north of Shetland. At this stage, the survey was severely hampered by gale force winds and the transect design was altered as a result. On reaching the northerly limit of the survey area, the weather improved and transects progressed southward along lines of latitude, at spacings of 30 or 15 nautical miles (n.mi.) as planned. The first fishing trawl was carried out on 14 October on the most northerly transect. On 16 October, the vessel rendezvoused with the Norwegian FRV G.O. Sars as planned and the two ships carried out an interlaced survey in the Norwegian sector: transect spacing for each vessel was 30 n.mi. giving a combined effective spacing of 15 n.mi. When this was complete, the two vessels undertook an intercalibration exercise passing over areas where mackerel had been detected in the interlaced survey area. This lasted for approximately 115 n.mi. with each vessel taking the lead alternatively on three occasions. The intercalibration was completed at 23:00. The survey continued in the UK EEZ, east of Shetland. Calibration was carried out successfully on the 21st in a bay south of Fetla. After dropping off a crew member, the vessel resumed surveying at 15:34 on 21 October. The survey then continued with breaks for bad weather until the evening of the 24th October.

Results

The total mileage surveyed was approximately 2130 n.mi. with 851 acoustic log intervals recorded. The cruise track is presented in Fig 6.1.2.1. Successful calibrations were carried out of the three principal acoustic frequencies (38, 120 and 200 kHz); the 18 kHz was also calibrated. Calibration data are provided in table 6.1.2.1. Echo traces from mackerel were distinguished on the basis of the difference in acoustic return between the 38 and 200 kHz frequencies (see section 4.1). Most of the mackerel were detected close to the border between EU and Norwegian waters, in the centre of the survey area, south of Viking Bank, and area bounded approximately by 60° to 61° 30’N and 2 – 4° E. Some problems were encountered in fishing. 16 trawl hauls were carried out. Mackerel were caught on only one occasion, mixed with herring close to the seabed. On four occasions, echo traces thought to be mackerel were fished by line and reasonable quantities of mackerel were caught. In total, 201 of 222 mackerel were sampled for weight, sex, maturity and age; of these, 168 were obtained by hand line. In addition, over 10,000 herring were caught and 1,973 were measured for length.

Hydrographic data were obtained using expendable bathythermographs (XBTs).

Considerable numbers of large mackerel schools were detected. The mackerel were contained within the survey area and there was no evidence of significant numbers of mixed schools (herring and mackerel). The interlaced survey and intercalibration with the G.O.Sars was carried out successfully. Provisional biomass estimates for the combined survey are presented in section 6.1.2

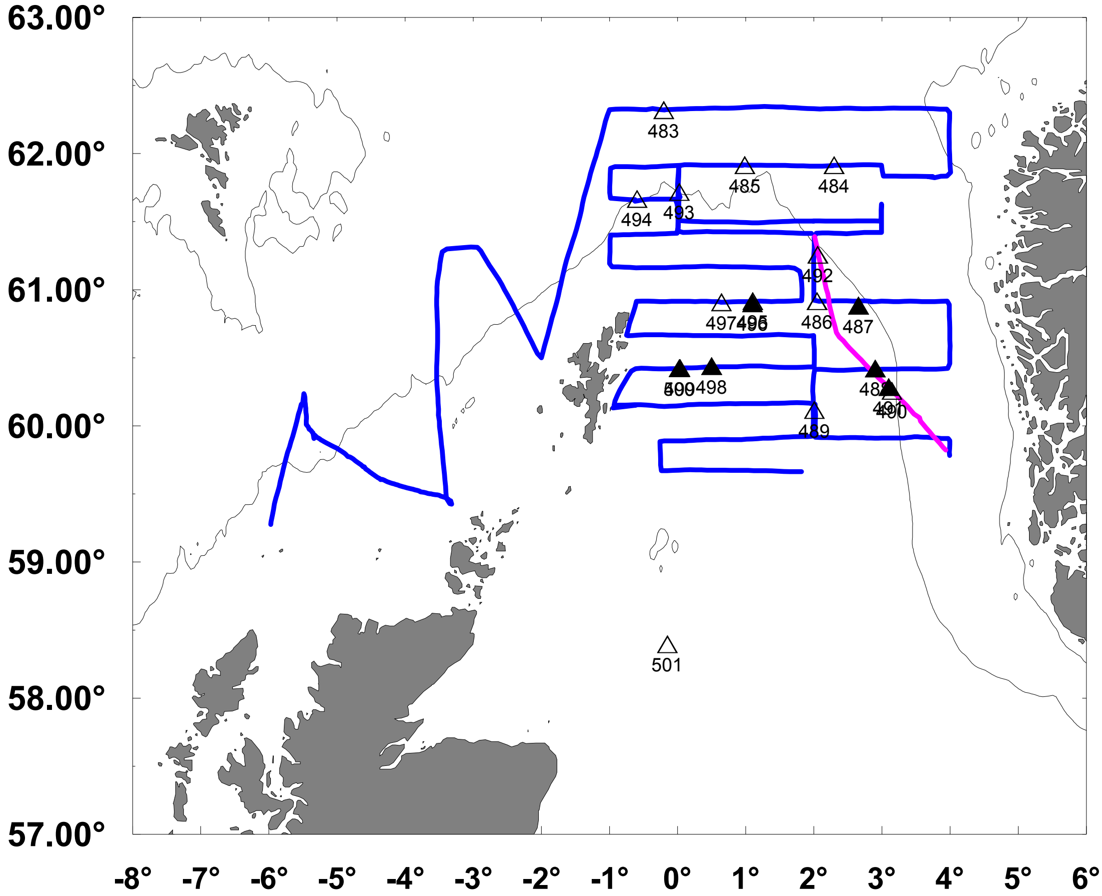

Figure 6.1.2.1. Cruise track of FRV Scotia's October 2002 mackerel acoustic survey (blue). Inercalibration with G.O. Sars in purple. Triangles indicate positions of trawls (catches of mackerel are filled triangles; catches with no mackerel are open triangles).

Table 6.1.2.1. Simrad EK500 and analysis settings used on the Scotia mackerel acoustic survey October 2002. Calibration carried out at Fetla, Shetland Isles on 21 October 2002.

Transceiver Menu	
Frequency	38, 120 & 200 kHz
Sound speed	1492 m.s^{-1}
Max. Power	2000 W
Equivalent two-way beam angle	$-20.6_{38\ kHz}$ $-20.8_{120\ kHz}$ $-20.8_{200\ kHz}$
Default Transducer Sv gain	26.5 dB
3 dB Beamwidth	7.1°
Calibration details	
TS of sphere	-42.38 dB
Range to sphere in calibration	$14.11_{38\ kHz}$ $10.48_{120\ kHz}$ $10.27_{200\ kHz}$
Measured NASC value for calibration	$1732_{38\ kHz}$ $2249_{120\ kHz}$ $2168_{200\ kHz}$
Calibrated Transducer Sv gain	$26.91_{38\ kHz}$ $24.70_{120\ kHz}$ $24.15_{200\ kHz}$
Calibration factor for NASCs	$0.83_{38\ kHz}$ $2.32_{120\ kHz}$ $2.87_{200\ kHz}$
Calibration constant for MILAP (optional)	?? at -35 dB
Log Menu	
Simulated	2.5 n.mi. at 10 knots
Operation Menu	
Ping interval	1.6 s at 250 m range 2.5 at 500 m range
Analysis settings	
Bottom margin (backstep)	0.5 m
Integration start (absolute) depth	11 m
Range of thresholds used	-70 dB on 38 -170 on combined blurred 38,120,200

6.1.3 Combined estimate

The surveys in the northern North Sea, carried out by Norway and Scotland, were co-ordinated to allow for a combined estimate of mackerel abundance. The area with the expected high densities of mackerel was surveyed by both vessels using an interlaced parallel transect design (Fig. 6.1.3.1). After this, an intercalibration was carried out to assess the performance of each vessels acoustic system and to evaluate any differences in scrutinising. After the intercalibration the Scottish vessel continued with the combined survey, to cover the remaining un-surveyed area east of the Shetland Islands, whilst the Norwegians carried out a second survey of the eastern part of the overall area (Fig. 6.1.3.2). Analysis of the data would, therefore, provide two abundance estimates: one complete area coverage including an interlaced section (Fig. 6.1.3.1); and one more restricted survey covering the area occupied by the higher densities and the area north west of Shetland (Fig. 6.1.3.2). The latter consists of all Norwegian data after the intercalibration exercise. Two estimates were provided by Skagen (WD 2003): the first was based on all data from the first Norwegian coverage, including the interlace and the Norwegian part of the intercalibration; the second was based on all data from the second Norwegian coverage.

It was not possible to provide a comprehensive combined estimate at the meeting. Prior to the meeting data submission protocols had not been agreed and the large volumes of data required do not allow for processing to be carried out beyond the host institute, for example the Scottish survey alone collected over 40Gb of data. Integration thresholds, for example, were not established prior to the meeting, such that some of the data will need to be reprocessed at the agreed threshold (see Section 3). In addition, significant difficulties in sampling mackerel in the surveys created two problems associated with the estimation of biomass: determination of valid mean lengths for calculating target strength and also a valid mean weight. The calculations in Skagen (WD 2003) were based on a mean length of 33 cm and a mean weight of 295 g; these were derived from 13 samples with a total of 585 fish. The Scottish survey provided 202 fish from 6 samples: the mean length from these was also 33 cm, but this equates to a weight of 331 g using the length-weight relationship derived from the data.

Provisional estimates were, nonetheless, prepared. Two estimates were provided in Skagen (WD 2003): 493,000 t from the first coverage and 488,000 t from the second. This was based on a rectangular grid-averaging method (10 minutes of latitude by 20 minutes of longitude). The combined estimate calculated at the meeting was a simple approach which defined a large area (25,000 square nautical miles) and used the average NASC in that area and the mean length and weight from the Scottish survey. This gave a result of 675,000 t. This value was greater than those provided by Skagen (WD 2003) due to: (1) the higher mean weight applied (see above); and (2) the larger, more complete coverage of the combined survey. The Scottish survey data will be re-analysed at the same threshold as that of the Norwegian data (-82 dB) and a more comprehensive estimate will be prepared for WGMHSA. The estimate will be increased with the incorporation of a higher threshold, by the order of 5-10%.

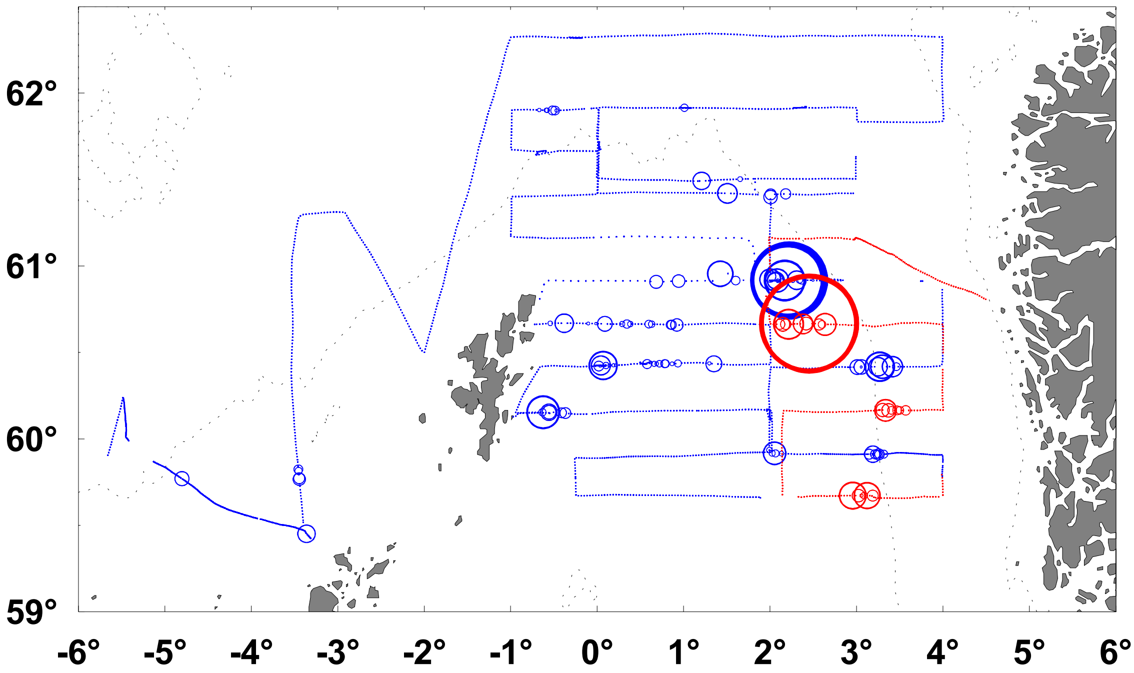

Figure 6.1.3.1. Map of the northern North Sea and a post plot of the distribution of mackerel. Circle size proportional to NASC attributed to mackerel, from the combined acoustic survey in October 2002: red circles = G.O. Sars; blue circles = Scotia; on a square root scale relative to a maximum value of 971 $m^2.nmi.^{-2}$.

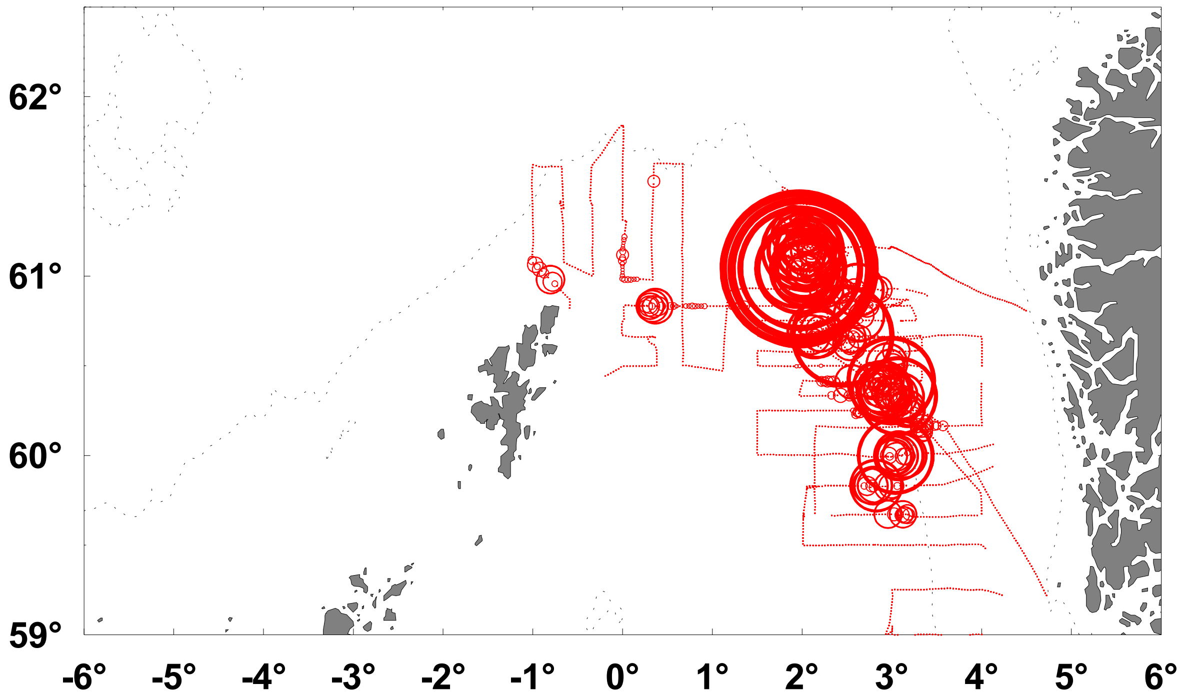

Figure 6.1.3.2. Map of the northern North Sea and a post plot of the distribution of mackerel. Circle size proportional to NASC attributed to mackerel, from the second coverage of the Norwegian acoustic survey in October 2002: red circles = G.O. Sars; on a square root scale relative to a maximum value of 3802 $m^2.nmi.^{-2}$.

6.1.4 Intercalibration

An intercalibration between FRV Scotia and RV GO Sars was carried out on 18 October 2002. The results of this exercise are still to be analysed for similar reasons to those given above for the combined estimate. Provisional analyses suggest, however, that the systems are working comparatively well (Fig. 6.1.4.1). Examination of the data revealed that the major difference between the two data sets was in the scrutiny decisions for a few echotraces which were difficult to assess. Overall, however, the mean NASC values from both ships were similar: 7.8 $m^2.nmi.^{-2}$ for the Scotia and 7.05 $m^2.nmi.^{-2}$ for the G.O. Sars. A more comprehensive analysis of the data will be prepared ahead of WGMHSA. This will be separated into an analysis of (1) system performance, which requires integrals of the whole water column (i.e. without any scrutiny); and (2), of the scrutiny process, which requires integrals attributed to mackerel using the same threshold.

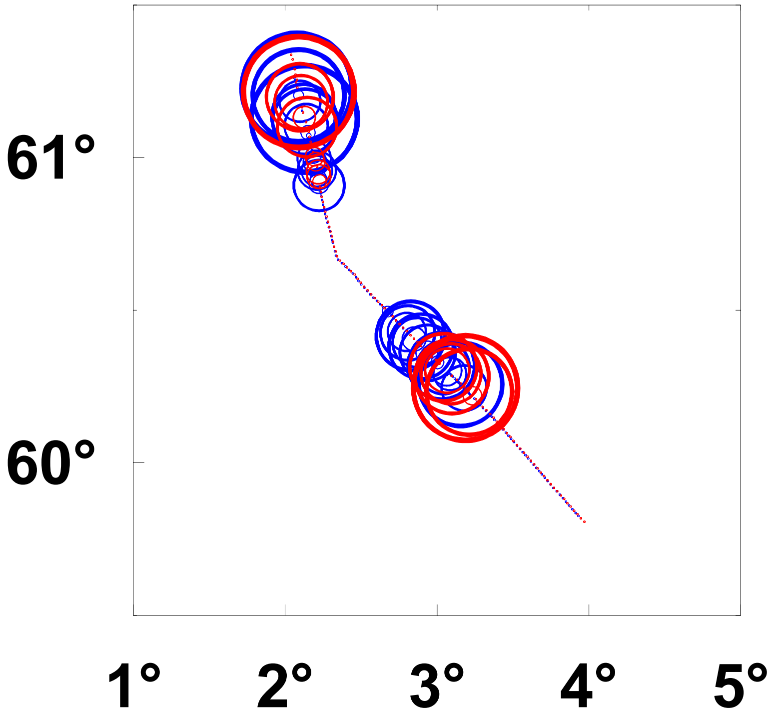

Figure 6.1.3.2. Post plot of the distribution of mackerel during the intercalibration between RV G.O. Sars and FRV Scotia. Circle size proportional to NASC attributed to mackerel: red circles = G.O. Sars; blue = Scotia. Scaled on a square root scale relative to a maximum value of 216 m^2.$nmi.^{-2}$.

6.2 Acoustic surveys for mackerel in autumn 2003

In 2003, Norway (RV "G. O. Sars" (3)) and Scotland (RV "Scotia") will conduct a co-ordinated survey for mackerel in the North Sea and its western approaches (Table 6.2.1). The new Norwegian research vessel RV "G.O. Sars" (3) will be used[1]. Three independent replicate surveys will be carried out. From 4-17 October, FRV Scotia will carry out a stratified survey containing the whole of the northern North Sea (Figure 6.1); from 17-21 October Scotia and G.O. Sars will carry out an interlaced stratified survey containing the whole area; finally, from 22 October – 3 November G.O. Sars will carry out a final stratified survey containing the whole area. The intertransect distance, specific stratification and rendezvous location will be planned in the interim period and agreed by correspondence prior to September 30 2003. The area of stratification will be decided once local knowledge of the location of the main concentrations of mackerel has been obtained from the fishery. The two vessels will inter-calibrate at an appropriate time.

Table 6.2.1

Country (Vessel)	Dates	Area	Cruise leader contact
Scotland (RV "Scotia")	4 October – 22 November	Northern North Sea (Viking Bank) and central North Sea	Paul Fernandes fernandespg@marlab.ac.uk
Norway (RV "G. O. Sars" (3))	16 October – 4 November		Rolf J Korneliussen rolf@imr.no

7 ACOUSTIC SURVEYS IN ICES DIVISIONS VIII AND IX

7.1 Spanish acoustic survey in 2002

In 2002, the Spanish acoustic survey took place in March in Sub-division IXa Central North, Sub-division IXa North and Division VIIIc. In the 2002 survey the target strength changed for mackerel as recommended by the Planning Group on Aerial and Acoustic Surveys for Mackerel: TS from –82 to –88 and to treat the gross data to a threshold of -60 dB (Anon. 2002). The total of mackerel biomass was estimated to be 1,382,995 t.

[1] The old RV "G. O. Sars" (2), used during the previous Norwegian surveys in 1999 – 2002, has now been renamed to RV "Sarsen".

The number of juvenile fish estimated in 2002 was higher than that observed in 2001. Fish measuring less than 25 cm accounted for more than 80% in Portuguese waters, 38% in the west and central of Cantabrian Sea and a negligible proportion in the east of Cantabrian Sea.

Due to the results of this survey it may be conclude as follow:

- the change in TS in multispecific areas led to a lower assignation with respect to other years;
- there are still problems of discrimination with the plankton;
- regarding previous years, mackerel was not so close to the bottom, with a greater horde behaviour (pulses, which followed the coast) and the consequence was less accessibility for the trawl fleet with a lot of mixing along the coast;
- a noteworthy increase in juveniles, very difficult to delimit the most suitable nursery areas;
- a noteworthy increase in Portugal with respect to previous years;
- in IXa-N and part of VIIIc-W observation was difficult due to the extremely adverse conditions, with a great deal of hydrodynamic noise. The fishing was practically negative in any area.

For details see WD B. Villamor and P. Carrera 2003.

7.2 Spanish acoustic survey in 2003

At the same time when the present PGAAM meeting held the Spanish acoustic surveys in southern area conducted by the IEO take place already. The survey followed the same strategy as previous and undertaken within the frame of the Minimum Data Collection Programme. The survey undertook on board R/V "Thalassa" using several acoustic frequencies (12, 38, 49, 120 and 200 kHz) aiming at providing data for the SIMFAMI project. Fig. 7.2. is show the area where Spanish survey 2003 is planed. For details see WD B. Villamor and P. Carrera 2003.

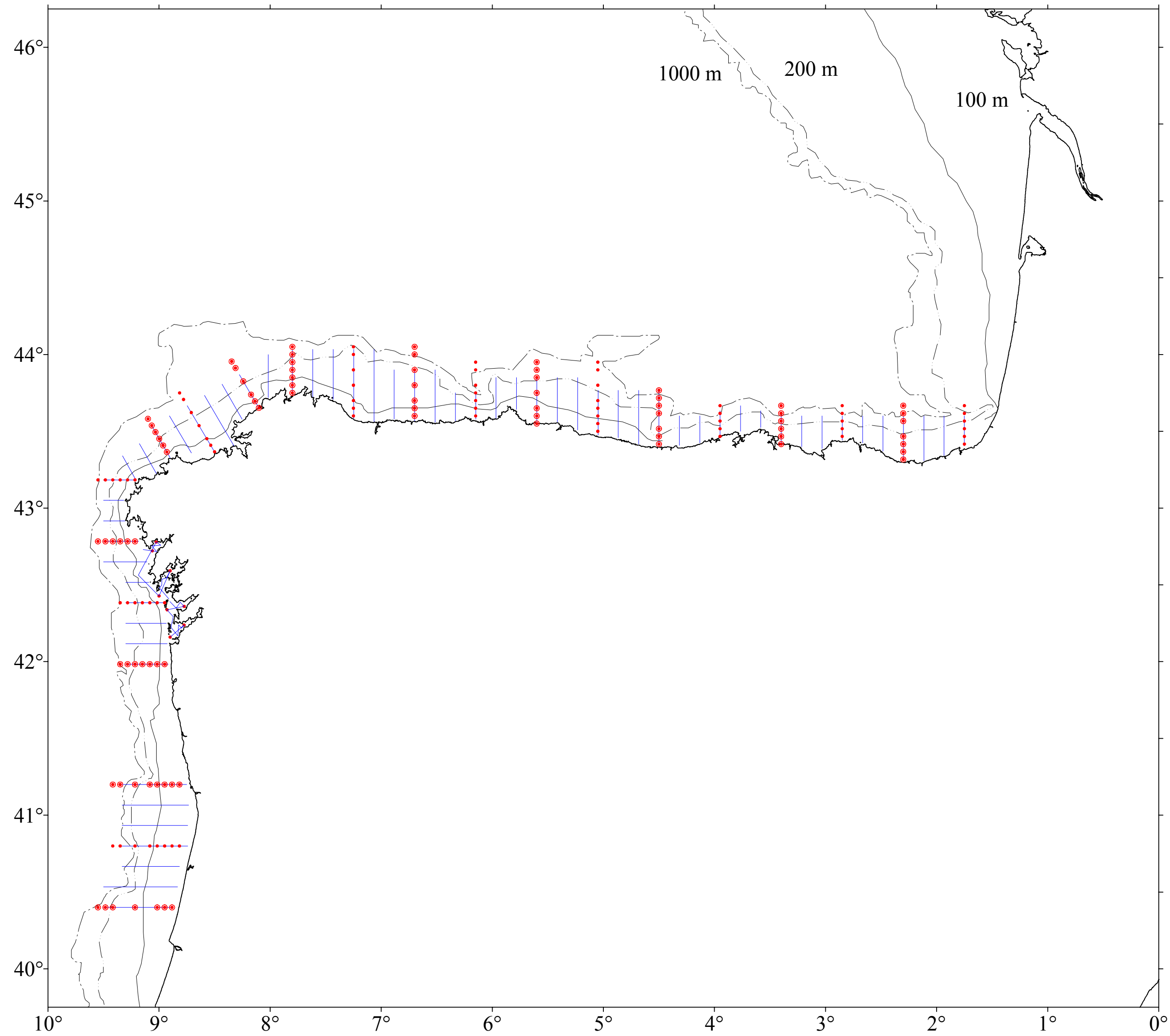

Figure 7.2. Planned Spanish survey for spring 2003.

7.3 Portuguese surveys

The Portuguese acoustic surveys usually take place in March and November and are mainly targeted to sardine and anchovy. The survey area is limited by the North Portuguese-Spanish border and Cape Trafalgar (Cadiz Bay).

Surveys execution and abundance estimation followed the methodologies adopted by the Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX (Anon. 1996, 1998). Echo integration is carried out using a Simrad EK500 scientific echo sounder with 38 KHz (split beam) and 120 KHz (single beam). The sounder echograms were registered for frequency 38 KHz in hardcopy.

The surveyed area, limited by 20 m and 200 m isobaths, was covered following a parallel grid with a mean distance between transects of 8 nautical miles. Survey speed was 10 knots and the acoustic signals were integrated over one nautical mile intervals.

In order to identify the species, collect the biological data, opportunistic pelagic and bottom trawls are performed according to the echogram information.

The mackerel abundance is relatively low near the Portuguese coast. In the trawl hauls performed during the surveys there is some occurrence of mackerel mainly in the North coast. However this species is usually mixed with other species (mainly horse-mackerel, sardine, snipe fish and blue whiting).

From the Portuguese bottom trawl surveys it is known that mackerel depth distribution extends up to 400 m depth. The mainly mackerel concentration detected in the surveys lays near the bottom, mostly over rocks, and can not be fished. With the current acoustic survey design it is not possible to cover all the mackerel distribution area being impossible to assess acoustically the mackerel.

In the future surveys we intend to acquire the acoustic data with a threshold of –70 dB to help in the visualisation of the mackerel schools and will also intend to fish some of those schools to step ahead in the identification of mackerel echotraces.

For details see WD V. Marques and A. Morais 2003.

7.4 Future of the investigations in the Southern area (Portuguese-Spanish–French survey)

The surveys, performed by Portugal and Spain in the Southern area routinely covered in spring. These surveys have been co-ordinated since 1997 (Anon 1997). France also undertook surveys in spring covering the French plateau from the Spanish/French border to the French Brittany. Much of the continental shelf in these waters is covered by these surveys, providing good coverage of acoustic data. Biological data's, however, specific to individual surveys because the Spanish/Portuguese target sardine whilst the French target anchovy.

Since 1998, survey design and survey strategies are the same for the whole area. Acoustic track is only surveyed during daytime while nighttime is used for oceanographic measurements. Besides, fishing station is performed during daytime (Anon. 1998).

From 2000 to 2001 a DG XIV Project called "Direct Abundance Estimation And Distribution Of Pelagic Fish Species In North East Atlantic Waters. Improving Acoustic And Daily Egg Production Methods For Sardine And Anchovy", *PELASSES*, coordinated the surveys in this area. The main objective of this project was concerned with the acoustic estimation of the sardine and anchovy populations and to map the distribution of the main pelagic fish species in southern NEA waters. Survey strategies were updated with the inclusion of new sample procedures. A Continuous Underwater Fish Egg Sampler (CUFES) was installed, providing relative egg abundance at 3-5 meter depth. In addition, together with the 38 kHz, data from the 120 kHz transducer was stored for post-processing.

The Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX was active until 1999. In 2000 and 2001 the acoustic surveys in this areas were coordinated under the PELASSES project. Now that this project has finished there is a need to activate again the older Planning Group, which involves people from France, Spain and Portugal, to proper coordinate the acoustic surveys in their areas.

8 INFORMATION FROM OTHERS SURVEYS

This chapter presented some results of the acoustic surveys which are not targeted at mackerel, but followed previous PGAAM recommendations.

8.1 Russian acoustic survey in the Norwegian Sea

Taking into account recommendations by PGAAM (Anon. 2002) Russian RV "Fridtjof Nansen" during the international survey for the Atlanto-Scandian herring in the Norwegian Sea in summer 2002 much attention was given to collection of any available information on mackerel, both biological and acoustic. The RV "Fridtjof Nansen" surveyed the southern and central Norwegian Sea from 8 June to 26 June 2002, as well as the northern sea from 03 July to 26 July 2002.

Check tows were done using a mid-water trawl with a 24-mm mesh size insertion. Data on all catches were converted into equivalent acoustic estimates for each species occurred.

When estimating abundance and biomass, power regression relationships between weight and length of mackerel body for different size groups were used. Operation modes of EK-500 echo-sounder (Version 5.30) was used during investigations.

When estimating mackerel abundance and biomass three relationships between reflectivity and length of an individual were used:

TS=20.0*Lg (L)-84.9 dB,
TS=20.0*Lg (L)-82.0 dB,
TS=28.9*Lg (L)-91.8 dB

Like in previous surveys, this year investigations covered only a part of the mackerel feeding area in the Norwegian Sea. Thus, areas to the south of 63°N in June and to the south of 66° N in July where mackerel are traditionally distributed in this season were not surveyed. However, the new data from all the vessels participated in the herring survey as well as from commercial vessels can provide the most complete estimation of distribution and biomass of the feeding mackerel.

Identification of mackerel in summer is much handicapped by the presence of larval and young herring distributed in the same depths. However, data collected within the frames of the SIMFAMI project as well as new data on the mackerel target strength will make it possible to elaborate an identification algorithm taking into account such the case.

Distribution of mackerel received during this survey are presented in Fig. 8.1.1. - 8.1.2.

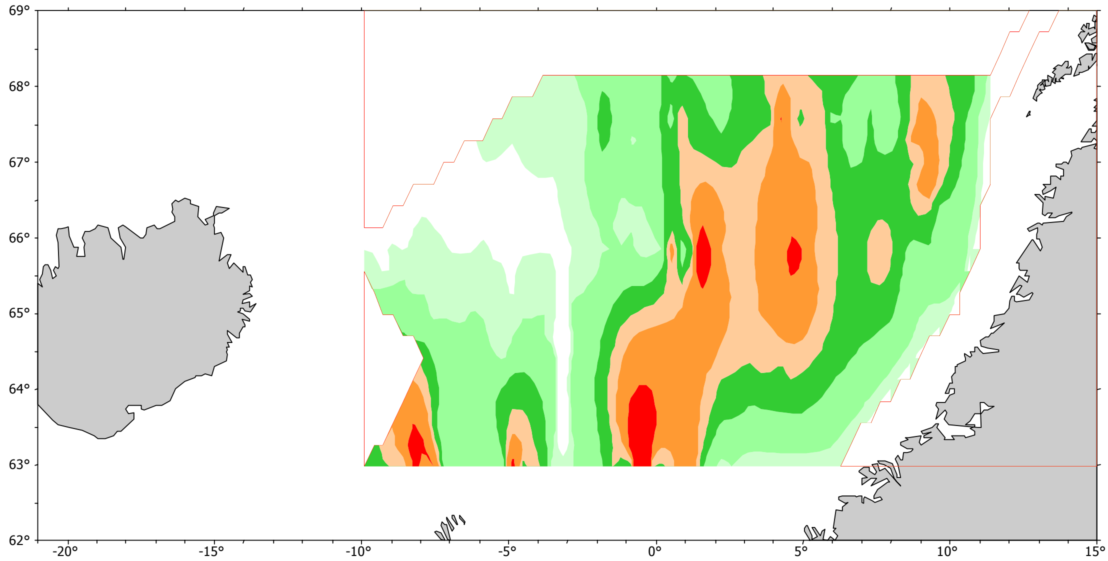

Figure 8.1.1. Distribution of mackerel in the Norwegian Sea in June 2002. (Kryssov A. et. al. 2003)

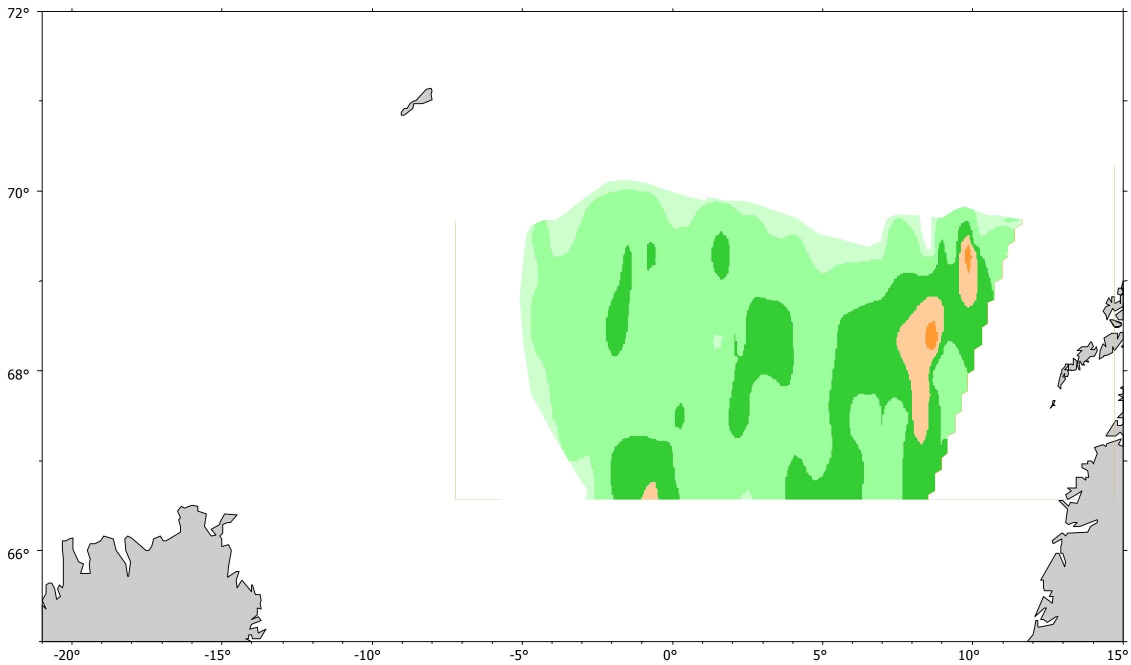

Figure 8.1.2. Distribution of mackerel in the Norwegian Sea in July 2002. (Kryssov A. et. al. 2003)

The details results were presented during WGMHSA meeting in September 2002 (Anon. 2003)

8.2 Norwegian acoustic survey in the Norwegian Sea

During the period 21 June-8 July a combined salmon–mackerel trawl survey was carried out with the R/V Johan Hjort in the Norwegian and international zone in the Norwegian Sea. This is the period when the mackerel protrudes into the Norwegian Sea and the period when the trawl fishery for mackerel starts in the international zone. The area covered was approximately 65ºN to 68º30’ N and 0º- 7ºE. The trawl gear was the “Salmon Trawl”, a trawl designed to target quick swimming pelagic species in from the surface and down to about 13-15 meters depth. Catches of mackerel were made throughout the area, with the main concentrations close to the 2000-meter depth contour on the western edge of the Vøring plateau. The catch rates were up to 2.2 tonnes mackerel per hour trawling at 5 knots. The mackerel appeared in a mix with salmon in the area, with catches of postsmolt salmon up to 132 per hour trawling.

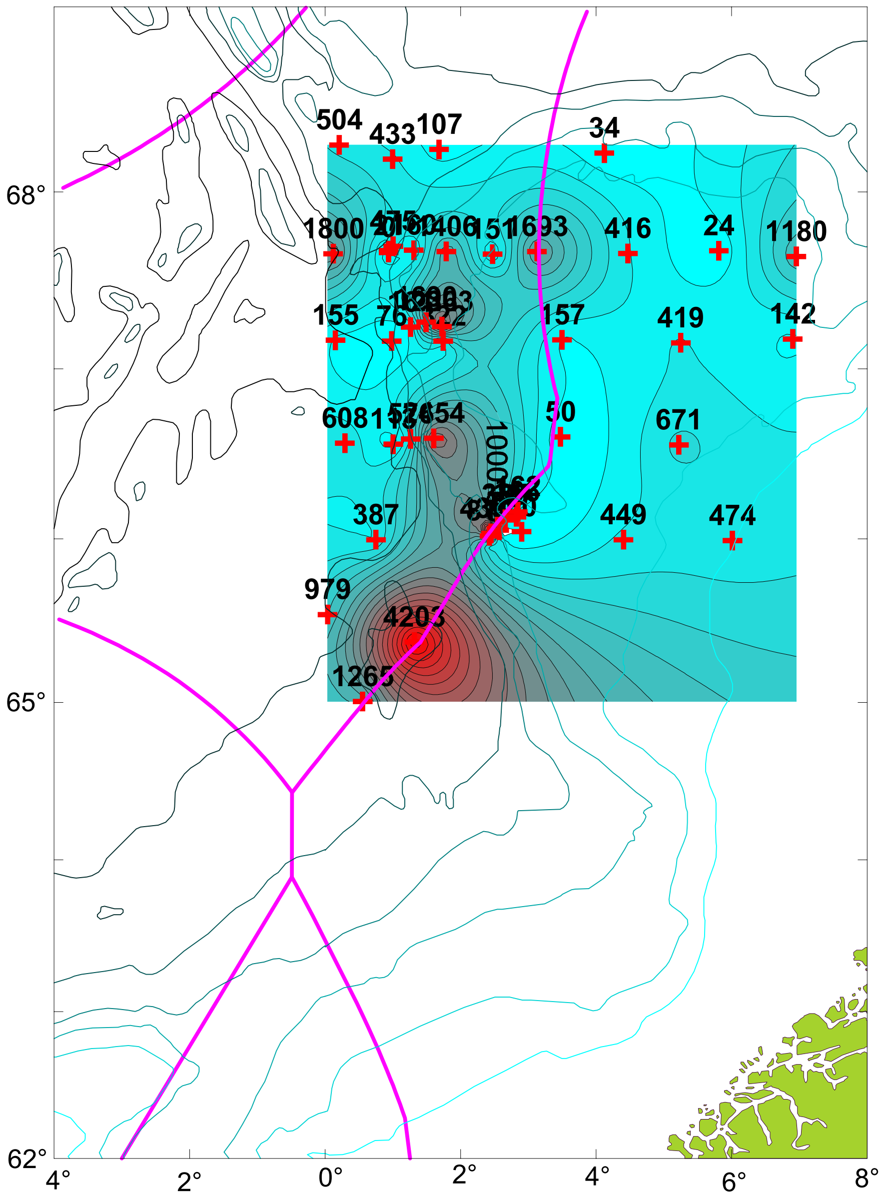

Figure 8.2.1. Catch rates of mackerel by trawling at the surface during a survey with R/V Johan Hjort in June-July 2002.

8.3 Irish acoustic surveys in the western area

Acoustic surveys for herring are carried out by Ireland in the Celtic sea in September and in ICES sub divisions VIaS and VIIb in November/December/January. The timing of surveys is designed to coincide with the occurrence of pre-spawning aggregations of herring in Irish coastal waters and may be subject to small interannual variation. To date only estimates of herring and sprat biomass have been calculated from these surveys, however the echograms have been partitioned for mackerel traces, and in most cases marks attributed to mackerel have been sampled by fishing. In general 20-75% of fishing operations on surveys yield mackerel, indicating that mackerel is frequently encountered. Herring acoustic surveys are carried out on chartered commercial vessels, using an EK60 and a Simrad ES-38B 38 Khz split beam transducer mounted in a towed body. Fishing is carried out for species identification (ground-truthing the data from the EK-60) and the decisions to fish on particular echo-traces are largely subjective. Attempts are made to obtain a sample from any large fish trace contributing to a reasonably large NASC[2] value together with smaller well-defined traces which required further identification. A single pelagic trawl of 25m x 16m with a mesh size of 160 cm in the wings, through to 1.8 cm in the cod-end is used for fishing. It is fished with a vertical mouth opening of approx. 15 m, which can be seen on the Furuno netsonde (50 kHz). Details of the acoustic survey procedures and area coverage of these surveys in given in the WD Kelly et al. 2003.

8.4 Joint Russian-Norwegian blue whiting surveys west of the British Isles.

Annual Russian-Norwegian surveys on the estimates of total and spawning biomass of blue whiting are made since 1983. The research vessels surveyed blue whiting stock in the shelf edge and bank areas west of The British Isles and in Faeroese waters, in March-April. They are surveyed deep water where blue whiting distribute. However, these surveys may have potential to use for the biological data collection as well as estimation of mackerel abundance. In case some extension to the shallow waters it, give possibilities to find mackerel registrations and collected biological data. In 2004 it may be connect with annual international egg surveys (see section 9.2).

9 INTEGRATED MACKEREL SURVEY IN 2004

2004 will be the year of the next ICES triennial mackerel egg survey. This will comprise an integrated and synoptic survey of the distribution of mackerel eggs from the Gulf of Cadiz to the Shetland Islands. In addition to this there are a large number of other surveys, which can provide data on the abundance distribution of this species. These include;

Acoustic surveys – both those included in the remit of the PG and others, which provide mackerel abundance as a secondary product.

The egg surveys themselves, which collect egg production data but may also be able to provide acoustic survey data.

Bottom trawl surveys, which provide juvenile mackerel CPUE, but could also provide this for adults, and could also collect acoustic data.

Aerial surveys, which provide distributions and potential abundance estimates. The vessel borne component can also provide biological data.

While not survey based, there are also substantial age disaggregated, commercial landing data available for this species.

In general these data are published in a variety of different Working Group reports, if at all. In the case of surveys targeted on other species, the mackerel data may simply be discarded. In any case, the data are never assembled into a single coherent document. This PG suggests that in 2004, this situation could and should be remedied. All data collected on mackerel could be collated by the WGMHSA and produced as a CRR or web publication. The proposal has been canvassed with the chairs of WGMHSA, WGMEGS, PGAAM, PGSPFN and PGHERS, who all broadly support the idea. The proposal will be raised at the next meeting of the Living Resources Committee, after which more detailed planning may be carried out subject to general agreement. The proposal represents a unique and valuable opportunity to gain added value from a wide range of surveys to produce the best picture possible of a key European commercial stock.

Surveys in 2004, which collect or can collect relevant mackerel data – including acoustic and aerial data are detailed below.

[2] Nautical Area Scattering Coefficient NASC is the term used in Echoview Version 2.20 to describe the Area Backscattering Coefficient – S_A which expresses the ratio between the targets area and the insonified area ($m^2.nm^2$). This is effectively a measure of fish density.

9.1 Acoustic Surveys

Table 9.1. Countries, vessels, purpose, areas of operation, and dates for acoustic surveys in the North East Atlantic (Gulf of Cadiz to Norwegian Sea) in 2004, which could provide mackerel acoustic data.

Country	Vessel	Purpose	Areas	Dates
Portugal	Capricorn?	Sardine and anchovy – could partition for mackerel	Portugal and Cadiz	March
Spain (IEO)	Thalassa	Sardine and anchovy – partitioned for mackerel	Galician waters and Cantabrian Sea	March-April
France	Thallasa	Sardine, anchovy, mackerel and horse mackerel	Biscay & S. Celtic Sea	May
Ireland	Celtic Explorer	Mackerel/Blue whiting	Shelf edge west of British Isles	Spring
	Charter	Herring – partitioned for mackerel	Celtic Sea	September/October
	Charter	Herring – partitioned for mackerel	VIa(S) & VIIb	Nov/Dec/Jan
Scotland	Charter	Herring - partitioned for mackerel	W of Scotland	July
Iceland	Bjarni Saemundson	Atlanto-Scandian Herring in the Norwegian Sea - partitioned for mackerel	63°30-68°N, 9°-15°W	May
			67°-71°N, 8°W-5°E	June/July
Faroe	Magnus Heinason	AS Herring – blue whiting	62°-73°N, 6°W-8°E	May
EU	WH III	AS Herring -	Norwegian Sea	April/May
Russia	Fridtjof Nansen	Blue Whiting -	West off the British Isles	March/April
		AS Herring - partitioned for mackerel	67°-72°N, 15°-38°E	May/June
			63°-68°N, 11°W-9°E	June
			66°-71°N, 5°W-10°E	July
Norway	GO Sars	AS Herring – blue whiting	62°-75°N, 8°W-20°E	May
			62°-77°N, 5°W-16°E	July/August

In general, few of these surveys are specifically targeted for mackerel; however, in many cases mackerel are routinely partitioned from the echo integrals. In some cases e.g. Portugal, the mackerel are in low densities, and fishing is targeted in different areas to those occupied by the mackerel. In these cases the mackerel densities are likely to be less reliable, however, the PG still feels that some useable data could be extracted – particularly as this is the southern limit of distribution.

There are further acoustic surveys in the North Sea by Scotland, Norway, Germany, Denmark and the Netherlands in July. These surveys can provide mackerel data, but at this time most of the western and southern spawning components are expected to be in the western area, so the mackerel biomass is likely to be the N. Sea component. These surveys are coordinated by PGHERS and the PG could be asked to provide combined mackerel biomass data.

9.2 Egg surveys

Table 9.2. Countries, vessels, areas assigned, dates for the 2004 mackerel egg survey.

Country	Vessel	Areas	Dates
Portugal	Capricorn	Cadiz, Portugal and Galicia	6-21 Jan
			3-18 Feb
			2-24 Mar
Spain (IEO)	Cornide de Saavedra	Cantabrian Sea	15 Mar - 5 Apr
			9-30 Apr
Germany	W. Herwig III*	Biscay (N), Celtic Sea & NW Ireland	16 Mar - 23 Apr
Netherlands	Tridens*	Biscay and Celtic Sea	10 – 27 May
			8 – 28 June
Spain (AZTI)	Investigador	Cantabrian Sea & Biscay	20 Mar - 10 Apr
			15-31 May
UK (CEFAS)	CEFAS Endeavour*	Biscay and Celtic Sea	22 Apr - 19 May
Norway	GO Sars*	North west Ireland & West of Scotland	23 May - 15 June
Ireland	Celtic Explorer*	Celtic Sea	13 Apr - 3 May
	Celtic Voyager	Biscay, Celtic Sea, North west Ireland & West of Scotland	6-20 July
Scotland	Scotia*	North west Ireland & West of Scotland	6 –26 Apr
		Celtic Sea, North west Ireland & West of Scotland	15 Jun - 5 July

All vessels will be carrying out egg surveys (GULF III or Bongo high speed samplers) as well as small scale trawling activities for adult fish for fecundity and condition factor analysis – also length, weight, age, maturity, sex. Vessels marked with a * are known to have state-of-the-art acoustic survey equipment and capabilities. Survey design is mostly based on parallel east/west transects.

These vessels could be asked to collect acoustic survey data during inter-station transit. Some biological data should be available from trawling operations, but this would not be expected to be at the same level as normal acoustic survey operations.

9.3 Bottom Trawl Surveys

Table 9.3. Countries, vessels, purpose, areas of operation, and dates for bottom trawl surveys in the western area (Gulf of Cadiz to Norwegian Sea) in 2004, which could provide mackerel CPUE, biological and possibly acoustic data.

Country	Vessel	Purpose	Areas	Dates
Portugal	Capricorn?	BT survey	Portugal	October
Spain (IEO)	Cornide de Saavedra-	BT survey	Cantabrian Sea	September-October
France	Thallasa	BT survey	Biscay & S. Celtic Sea	October
Ireland	Celtic Explorer	BT survey	Celtic Sea & W Ireland	October
Scotland	Scotia	BT Survey	W Scotland, NW Ireland	March
		BT Survey	W Scotland, NW Ireland	November
		BT Survey	Rockall	September (biennial)
England	CEFAS Endeavour	BT Survey	Celtic Sea	February
				October

The surveys are principally targeted on bottom fish assemblages, but are also used to provide a CPUE index for juvenile mackerel (first and second winter fish). The surveys also catch older, adult mackerel, although these are not currently collated. Overall the surveys in the fourth quarter cover the entire western shelf from Cadiz to the Shetland Islands. In the first quarter, coverage is only from the Celtic Sea to the Shetlands. Some of these survey vessels have acoustic survey capability, and on some e.g. Scotia, acoustic survey data are routinely collected.

There are further bottom trawl surveys in the North Sea (IBTS), but with the exception of those in the northern North Sea, these mostly sample mackerel from the North Sea spawning component. Catches from these surveys are archived in the ICES IBTS database, and data are readily available.

9.4 Aerial Surveys

The aerial surveys for 2003 are detailed in this report (section 5). It is anticipated that these will continue and possibly be extended in 2004, and will form an important component of the proposed integrated survey.

10 RECOMMENDATIONS

The PGAAM recommends that during acoustic survey mackerel TS –84.9 dB should be useful.

The PGAAM recommended that multi-frequency acoustic data for SIMFAMI project should be collected wherever possible using frequencies in the following priority: 38, 200, 120, 18 and 12 kHz.

The PGAAM recommends that during surveys which are not targeted at mackerel, but which may have potential use estimation of mackerel abundance or provide biological sampling should be collected data and enjoined their to mackerel surveys.

The PGAAM recommends that acoustic surveys for mackerel in the western approaches of the northeast Atlantic should be carried out in 2004.

The PGAAM recommends to activate again surveys coordination in the ICES Sub-Areas VIII and IX between Spain, Portugal and France. Spain, Portugal and France would be participate in next meeting to proper coordinate the acoustic surveys in their areas.

The PGAAM recommends to meet again in France or Aberdeen from 23 to 26 February 2004 to:

- Coordinate the timing and area allocation and methodologies for acoustic and aerial surveys for mackerel in the NEA;
- Collate and evaluate the data collected by the aerial surveys, fishing- and research vessels in the Norwegian Sea during the summer and autumn 2003;
- Coordinate acoustic surveys within the North Sea-Shetland area to ensure full coverage and appropriate areas and timings;
- Combine the October-November 2003 survey data of abundance and distribution of mackerel within the North Sea-Shetland area;
- Identify participants to contribute to the aerial surveys for mackerel in the Norwegian Sea and coordinate vessels collaboration;
- Combine the summer 2003 aerial surveys data with vessels data of distribution of mackerel in the Norwegian Sea;
- Seek survey time for northern extension of acoustic surveys in ICES Sub-Areas VIII and IX;
- Consider the latest findings from the SIMFAMI project;
- Identify surveys which are not targeted at mackerel, but which may have potential use for the estimation of mackerel distribution and abundance;
- Develop protocols and criteria to ensure standardization of all sampling tools and survey gears;
- Election of the new chair.

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ANNEX 1

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6-9 April 2003

Nacional Research Institute for Agriculture and Fisheries, Lisbon, Portugal

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ANNEX 2

CONTENTS

1. Transducer and calibration

The **ideal frequencies for the mackerel surveys are 18, 38, 120 & 200 kHz. The minimum would be for 38 and 200 kHz, however, the other frequencies are useful for discrimination of species other than mackerel.** In order of preference, it is advisable to mount the transducer in a dropped keel, a towed body or on the hull of the vessel. Steps should be taken to ensure that the flight of the towed body is stable and level, this should ideally be achieved with the aid of a motion sensor.

It is recommended that a transducer with the common 60% efficiency is not powered by more 25 kW/m^2 or less to avoid non-linear effects. See table 3.?? (Below)

Table 1. (from an attachment of the SIMFAMI annual report of 2002) give implications for common sizes of transducers.

Table 1. Implications for common sizes of transducers

Frequency [kHz]	18	38	70	70	120	200	400
Approx. transducer area [10^{-3} m^3]	200	100	30	12	10	4.4	1.1
Approximate 3 dB opening angle	11	7	7	11	7	7	7
Recommended input power for 60% electro-acoustic efficiency	5000	2500	750	300	250	110	28
Example EK500 [W]	2000	2000			1000 [1]	1000 [1]	-
Example EK60 [W]	2000	2000			500 [1,2]	100	

[1] Significant non-linear effects will be evident.

2 For calibration sphere 25 m below transducer the echo-integration over beam reduce the non-linear effects to less significant. (In the order of 5% non-linear loss from 25 to 400 m)

Calibration of the transducers should be conducted at least once during the survey. Calibration procedures are described in the Simrad EK500 **or EK60** manual and Foote *et al.* (1987). Ideally, the procedure as described in the Simrad manual should be followed with certain exceptions (see below). Minimum target range for the calibration of a split beam 38 kHz echosounder is 10 metres, although greater distances are recommended (about 20 m), particularly with hull mounted transducers, where centering of the target below the transducer is facilitated if the target is suspended at a greater depth. An average integrated value for the sphere, taken when it is centrally located, should be taken as the measured s_A. The calculations should be then performed a number of times (two or three) in an iterative procedure such that the values of measured NASC and theoretical NASC should converge, as described in the Simrad manual. A choice is then made as to whether the S_v Transducer gain should be changed, rendering absolute **NASC's**, or alternatively, the S_v Transducer gain can be unaltered and a correction factor applied to the **NASC's**. Only one strategy should be applied during a cruise, such that for example, the latter option is to be employed when calibration is only possible after the cruise has started. If possible, the transducer should be calibrated both at the beginning and the end of the survey; with a mean correction factor applied to the data. If a new calibration differs by more than 0.4 dB, the system should be thoroughly inspected.

There are a number of parameters which require knowledge of the speed of sound in water. It is therefore recommended that appropriate apparatus be used to determine the temperature and salinity of the water so that sound speed can be calculated (see MacLennan & Simmonds 1992 for equations) and entered into the EK500.

It is important that all frequencies used in the survey should be calibrated according to the set protocols. This is particularly important when multifrequency ID algorithms are being employed.

It is evident that all versions of the EK500 up to and including version 5.* do not take account of the receiver delay in the calculation of target range (see Fernandes & Simmonds 1996). This is particularly important when calibrating at short range (10 m) as it can lead to a systematic underestimate of biomass of 3%. The correct range to the target should therefore be applied in calibration (see below). The equivalent two way beam angle (ψ) should also be corrected for sound speed according to Bodholt (1999).

A number of calibration parameters and results should be included as a minimum in the survey report. These are tabulated in Table 1.2. Some of these parameters are not included in the Simrad operator manual and are defined as follows.

Table 2. Calibration report sheet

Calibration report	
Frequency (kHz)	
Transducer serial no.	
Vessel	
Date	
Place	
Latitude	
Longitude	
Bottom depth (m)	
Temperature (°C)	
Salinity (ppt)	
Speed of sound (m.s-1)	
TS of sphere (dB)	
Pulse duration (s)	
Equivalent 2-way beam angle (dB)	
Receiver delay (s)	
Default S_v transducer gain	

Iteration no.	1	2	3
Time			
Range to half peak amplitude (m)			
Range to sphere (m)			
Theoretical NASC (m2.nmile-2)			
Measured NASC (m2.nmile-2)			

Calibated S_v transducer gain			
DeltaG = New gain - Old gain			
Correction factor for pre-calibration NASC's on EK			
Correction factor for pre-calibration S_v's			

Default TS transducer gain			
Iteration no.	1	2	3
Time			
Measured TS			
Calibrated TS gain			

Receiver delay = $\mathbf{t_{del}}$ This is very specific to the echosounder bandwidth (due to the band pass filters), to the transducer bandwidth, and to a lesser extent to the standard target and the pulse duration which may affect the peak value. Target, bandwidth and pulse duration specific values for the Simrad EK400 are given in Foote *et al.* (1987, their Table 1.). Values for the EK500 are not available, but Simrad recommend using 3 sample distances (10 cm) in wide bandwidth (3 kHz). This equates to a value of $\mathbf{t_{del}}$ of 0.00039 s at 38 kHz.

Range to half peak amplitude = $\mathbf{r_m}$ This is the measured range between the start of the transmit pulse and the point on the leading edge of the echo at which the amplitude has risen to half the peak value (m). This is usually determined from experience with the readings from an oscilloscope display. For example, for a 38.1 mm tungsten carbide standard target insonified at 38 kHz at a colour threshold setting of -70 dB (S_v colour min.), it is measured as from the top of the transmit pulse to the leading edge of the pink colour on the target sphere echo.

Range to sphere = $\mathbf{r_{sph}}$ may then be calculated from:

$$\mathbf{r_{sph} = r_m\text{-}((c \times t_{del})/2)}$$

Correction factor for pre-calibration NASC's on EK500 = K = 1/(10^(DeltaG/5))

Where:

DeltaG = Calibrated S_v Transducer Gain – Default S_v Transducer gain

Correction factor for pre-calibration S_v's on EK = 10($\log_{10}$(s_A correction factor))

2. Instrument settings during the survey (for the Simrad EK500)

For most settings the default values from the manufacturer may be used, or alternatively the operator can choose his own settings depending on the circumstances. It is recommended that each year the same settings be used for the printer in order to facilitate comparison of echograms.

There are a number of settings that are set during calibration that have a direct influence on the fundamental operation for echo-integration and target strength measurement and therefore affect logged data. Once set according to the particular transducer, these should **NOT** be changed during the survey. These important settings are listed in Table 2.

The minimum detection level on the bottom detection menu depends on the water depth and bottom type. At depths less than 100 m and hard bottoms, the threshold level may be set at –30 dB: this will enable the instrument to detect dense schools close to the bottom. At depths greater than 100 m or soft bottoms, the threshold has to be lowered (-60 dB), otherwise the upper layer of the bottom will be counted as fish as well.

In the operation menu it is recommended to use as short a regular ping interval as possible. It is not advisable to use a ping rate of 0.0 seconds (variable interval according to depth) as this brings about irregular sample (ping) numbers per equivalent distance sampling unit which may bias the analysis.

A bottom margin of the order of 0.5 m is recommended for the layer menus. In shallow areas (<100 m) this can be somewhat reduced.

Although not yet finalised the S_V minimum for mackerel surveys should be set at –82dB in recognition of the lower acoustic cross section of mackerel. Increasing the S_v minimum will reduce the integration values if the fish occur in scattering layers or in loose aggregations. This setting is less important when the data is collected by a post processing package such as Simrad's BI500 or Sonardata's echoview software as the threshold can be determined in post processing.

Table 3 lists those settings which are important for target strength measurements. It should be noted however, that the transducer depth setting may affect the calibration if the range to target is read form the echo sounder.

3. Survey design

Transects should be spaced at a maximum distance of 15 nautical miles. Two aspects should be considered in choosing the direction of the transects. Transects should preferably run perpendicular to the greatest gradients in fish density, which are often related to gradients in bottom topography and hydrography. This means that transects will normally run perpendicular to the coast. The second aspect considers the direction in which the fish are migrating. If there is evidence of rapid displacement of the fish throughout the area, it is advisable to run the transects parallel to the direction of the migration. This survey design will minimise the bias caused by migration. A detailed simulation study of the effects of motion on the survey design of North Sea herring is available in Rivoirard *et al*. (in press).

Ship's speed during the survey is typically 10-12 knots. At higher speeds, problems are encountered with engine noise or propellor cavitation. These problems, however, depend on the vessel. In rough weather, the ship's speed may be reduced in order to avoid problems with air bubbles under the ship, although this problem is alleviated by the use of a dropped keel.

Current practice is to carry out the mackerel surveys over the full 24 hours, as these surveys are carried out in periods when day length is short. Examination of the implications of this, particularly in relation to mixing with other species at night, should be a subject of early research attention.

Table 2. Important calibration and survey settings, which should not be changed during the survey. Those marked * indicate settings that are specific to the transducer / transceiver.

/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/BANDWIDTH
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/PULSE LENGTH
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/MAX. POWER*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/2-WAY BEAM ANGLE*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/SV TRANSD. GAIN*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/TS TRANSD. GAIN*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/ABSORPTION COEF.*
/OPERATION MENU/TRANSMIT POWER
/BOTTOM DETECTION MENU/BOTTOM DETECTION-1 MENU/MINIMUM DEPTH
/BOTTOM DETECTION MENU/BOTTOM DETECTION-1 MENU/MAXIMUM DEPTH
/BOTTOM DETECTION MENU/BOTTOM DETECTION-1 MENU/MINIMUM LEVEL
/SOUND-VELOCITY MENU/PROFILE TYPE
/SOUND-VELOCITY MENU/VELOCITY MIN
/SOUND-VELOCITY MENU/ VELOCITY MAX

Table 3. Settings affecting tracking or locating objects within the beam. Those marked * indicate settings that are specific to the transducer / transceiver.

/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/TRANSDUCER DEPTH
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/ANGLE SENS.ALONG*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/ANGLE SENS.ATHW.*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/ALONGSHIP OFFSET*
/TRANSCEIVER MENU/TRANSCEIVER-1 MENU/ATHW.SHIP OFFSET*
/TS DETECTION MENU/TS DETECTION-1 MENU/MIN. VALUE
/TS DETECTION MENU/TS DETECTION-1 MENU/MIN. ECHO LENGTH
/TS DETECTION MENU/TS DETECTION-1 MENU/MAX. ECHO LENGTH
/TS DETECTION MENU/TS DETECTION-1 MENU/MAX. GAIN COMP.
/TS DETECTION MENU/TS DETECTION-1 MENU/MAX. PHASE DEV.
/MOTION SENSOR MENU/HEAVE
/MOTION SENSOR MENU/ROLL
/MOTION SENSOR MENU/PITCH
/MOTION SENSOR MENU/TD-1 ATH. OFFSET
/MOTION SENSOR MENU/TD-1 ALO. OFFSET
/MOTION SENSOR MENU/TD-2 ATH. OFFSET
/MOTION SENSOR MENU/TD-2 ALO. OFFSET
/MOTION SENSOR MENU/TD-3 ATH. OFFSET
/MOTION SENSOR MENU/TD-3 ALO. OFFSET

4. Species allocation of acoustic records

Different methods of species allocation are being used in the various areas. The method used depends largely upon the schooling behaviour of the **mackerel**, and the mixing with other species. **Species allocation can be based on the identification of individual schools on the echogram or for looser aggregations can be based on composition of trawl catches. Multifrequency ID methods should also be used when calibrated data are available (see below).** All three methods are described in more detail below.

Only persons who are familiar with the area and the way fish aggregations of different species occur in the area should scrutinise the echo records. The way species aggregate either in schools or in layers, mixed or not mixed with other species is very different in **different areas and seasons**. Allocation of **NASC's** to species always needs support of trawl-information. However, one has to be aware that the catch composition is influenced by the fish behaviour in response to the net. It is therefore necessary to judge whether the catch-composition is a reflection of the real species composition and whether the allocated percentage of sprat/herring needs correction.

Both groups involved in the North Sea mackerel surveys have deployed different methods for using multi-frequency data for allocating schools to species. Particularly for separating herring and mackerel. One of these methods is implimented in SonarData EchoView, the other in the SIMRAD BI500. Particularly for separating herring and mackerel. One key area for concern is the degree of smoothing used between adjacent samples. This can vary between simple neighbourhood averaging algorithms up to using an overall average dB difference value for each identifies school. The degree of smoothing is seen as a critical choice, although exact guidelines are not yet formulated. In th short term, participants should document the scale of smoothing and be alert to the potential for a "school" to be made up joined aggregations of two species. This area should be the subject of ongoing research. Multi-frequency metods of species ID have not been deployed by other groups, but their use is encouraged. Such data can be collected in suitable format using Echoview, BI500 or Movies+. Logging programmes should collect both echogram and power telegrams (Q and W). Standard protocols will be defined for this procedure when research is complete.

4.1 Using the EK500 printer output and/or post processing systems

Scrutiny of the echo recordings may be done by measuring the increment of the integrator line on the printed paper output of the echogram. **It should be noted that the low target strength and generally dispersed school structures of mackerel make this a more difficult and problematic procedure than for species like herring.** This is a simple and efficient way of scrutinising if one deals with single species schools and if there are no problems with bottom integration. Post processing systems may then be used as backup. More generally, computer based post-processing systems such as the Simrad BI500, Sonardata Echoview or Movies+ systems are currently being used for scrutinising. The printer output is mostly used as a visual backup.

It is recommended that one depth-range is used for the whole area in the printer output and on post-processing systems. This will ensure that similar echo traces from all parts of the survey area will have the same appearance and hence are visually more comparable.

Mackerel echotraces appear to be highly variable according to location, local hydrography, time of year and possibly the presence of other species. Scrutiny should, wherever possible, be solidly backed by extensive ground truth trawl data.

Use of trawl Information

The allocation of echo-traces to species is guided by the results of the trawl hauls. In many cases these should be considered together with observations from the netsonde and the echogram during the haul, **as well as multi-frequency data. In all cases an experienced operator should be involved these decisions.** In some cases it is not possible to assign schools (echo traces) to species directly e.g. where the haul contains a mixture of species and no clear differentiation can be made between the observed schools. In such situations the integral is assigned to a species mixture category according to the trawl results. This is defined as percentage by number or weight taking into account the correct conversion to scattering length (see section 6.2); post processing software is then used to apply weights and lengths. There are two main problems with using trawl data to define "acoustic" mixtures:

- **Different species are known to have different catchabilities, so the exact proportions in the trawl are unlikely to be an exact sample of the true mixture. For instance mackerel are likely to be faster swimmers than herring.**

- **Mackerel can be found mixed with herring, sprat, sardine, anchovy and many other, often small, species, some of these may be lost through the meshes. Plankton is a particular problem in this context. In this case the exact proportions will unavailable and the operator must make an informed guess.**

Splitting by trawl proportions is a highly vulnerable process for mackerel, as the target strength is very much lower than almost all other species present, which generally have a swim bladder. Ideally, this should be avoided

wherever possible, and alloocation to schools be used. If this is not possible, the partitioning should be highly conservative with regards to mackerel proportions.

Thresholding to filter out plankton

An advantage of using a post-processing systems like the BI500, EchoView, and Mvies+ is the ability to change the threshold-value of the received echos. By changing the threshold the non-target-species (plankton in particular) can be filtered out. The threshold used may differ, depending on a variety of conditions, including the water depth (more care should be taken at greater depth) and the particular size of fish. Examples of conditions where certain thresholds have been applied are described below; they should not be used without verification. At the beginning of the survey it is advisable to find the right thresholds by isolating schools and changing the threshold.

This approach can work well for swim bladder fish such as herring. For mackerel, the use of threshold to eliminate plankton should be applied with caution due to the low target strength of this species. The threshold can be raised to –70dB where the mackerel are in discrete schools. Where the mackerel are more generally scattered in dense plankton it is unlikely that any thresholding wiil be successful.

Use of single target TS distribution data

The SIMRAD EK500 used with a split-beam transducer allows the collection of TS values for all single targets detected in the beam. A TS distribution can then be produced for each EDSU. In some situations there may be two species present in an area with substantially different TS values, and this could be used to determine the species allocation. Again, this data must be used with caution. There are doubts about the precision of the TS detection algorithm, particularly in older firmware releases. By definition, single targets are unlikely to be detected from fish in schools. As schools are often the main subject for mackerel acoustic surveys, such data may be unrepresentative. However, where the survey encounters diffuse mixtures, there may be value in such data.

Use of image analysis techniques

The Marine Laboratory Aberdeen has developed an image processing system for post processing of echograms. This can extract a range school descriptors; energetic, morphometric and positional, which can be used to define the characteristics of schools of a particular species. Such systems have also been applied elsewhere e.g. Echoview and Movies+ post processing software. In general, such systems can help differentiate most observed schools to species, however, these are usually the schools which an experienced survey operator can also discriminate by more traditional methods. A combination of the IA approach with a multi-frequency data analysis approach is recommended.

5. Biological sampling

5.1 Trawling

Species allocation of the acoustic records is impossible if no trawl information is available. The general rule is to make as many trawl hauls as possible, especially if echo traces are visible on the echosounder after a blank period. If surface schools are known to occur in the area it is often advisable to take occasional surface trawls even in the absence of any significant marks.

The principal objective is to obtain a sample from the school or the layer that appears as an echo trace on the sounder. The trawling gear used is of no importance as long as it is suitable to catch a sample of the target-school or layer**. In general, it is recommended that high headline pelagic trawls (e.g. >30m) towed at a minimum of 4 knots, faster speeds e.g. >5 knots are highly recommended as mackerel is a fast swimming fish.** (Some dimensions of the trawls used in some acoustic surveys are given in Table 4.

During trawling it is important to take note of the traces on the echosounder and the netsonde in order to judge if the target-school entered the net or if some other traces "spoil" the sample. It is recommended that notes be made on the appearance and behaviour of fish in the net during every haul. If a target is missed during a haul, the catch composition should not be used for species allocation.

Table 4. Characteristics of trawl gear used in the North Sea herring survey. "Mesh sizes in all panels" are listed for panels from the mouth of the net to the cod end; the number of entries is not an indication of the number of panels as adjacent panels may have the same mesh size.

Country	Vessel	Power	Code	Name	Type	Panels	Headl	Groundr	Sweeps	Length	Circum	Mesh sizes in all panels						Codend	Height	Spread
		kW			B/P	2/4	M	m	m	m	m	mm	mm	mm	mm	mm	mm	**mm**	m	m
DEN	DAN2																	**16**		
GFR	WAH3	2900	GOV	GOV	B	2	36.0	52.8	110.0	51.7	76.0	200	160	120	80	50			4	23
GFR	WAH3	2900	PS205	PSN205	P	4	50.4	55.4	99.5	84.3	205.0	400	200	160	80	50		**10**	15	28
GFR	SOL	588	AAL	Aalhopser	B	2	31.0	29.7	63.5	57.5	119.0	160	120	80	40				6	19
GFR	SOL	588	PS388	Krake	P	4	42.0	42.0	63.5	59.8	142.4	400	200	80				**10**	10	21
NED	TRI2	2940		2000 M Pel. Trawl	P	4	64.0	72.0	100.0	140.0	400	800	400	200	120	80		**20**	16	45
NOR	GOS	1700	3532	Akratral	P	4	72.0	72.0	160.0	130.0	486.4	3200	1620	400	200	100	38	**10**	33	
NOR	**GOS**	**1700**		**[bottom trawl]**	**B**															
SCO	SCO2	3000	PT160	Pel. Sampl. Trawl	P	4	36.0	36.0	70.0	87.0	256.0	800	600	400	200	100	38	**20**	14	20

5.2 Biological sampling procedure

The fish sample obtained from the trawl catch are to be divided into species by weight and by number. Length measurements are taken to the 0.5 cm below for sprat and herring (and to the whole cm below for mackerel and other species). For mackerel, representative or length stratified samples should be taken for maturity, age (otolith extraction) and weight.

6. Data analysis

This section describes the calculation of numbers and biomass by species from the echo-integrator data and trawl data. Most of this section is taken from Simmonds *et al.* 1992. **The approach remains valid for acoustic surveys aimed at mackerel.**

The symbols used in this section are defined in the text but for completeness they have been collated and are given below:

F_i	estimated area density of species i
K	equipment physical calibration factor
$<\sigma_i>$	mean acoustic cross-section of species i
E_i	partitioned echo-integral for species i
E_m	echo-integral of a species mixture
c_i	echo-integrator conversion factor for species i
TS	target strength
TS_n	target strength of one fish
TS_w	target strength of unit weight of fish
a_i, b_i	constants in the target strength to fish length formula
a_n, b_n	constants in formula relating TS_n to fish length
a_w, b_w	constants in formula relating TS_w to fish length
a_f, b_f	constants in the fish weight-length formula
L	fish length
W	weight
L_j	fish length at midpoint of size class j
f_{ij}	relative length frequency for size class j of species i
w_i	proportion of species i in trawl catches
A_k	area of the elementary statistical sampling rectangle k
Q	total biomass
Q_i	total biomass for species i

The objective is to estimate the density of targets from the observed echo-integrals. This may be done using the following equation from Foote *et al.* (1987):

$$F_i = \left(\frac{K}{<\sigma_i>}\right)E_i \qquad \textbf{(1)}$$

The subscript i refers to one species or category or target. K is a calibration factor, $<\sigma_i>$ is the mean acoustic cross-section of species i, E_i is the mean echo-integral after partitioning and F_i is the estimated area density of species i. The quantity is the number or weight of species i, depending on whether σ_i is the mean cross-section per fish or unit weight. $c_i= (K/<\sigma_i>)$ is the integrator conversion factor, which may be different for each species. Furthermore, c_i depends upon the size-distribution of the insonified target, and if this differs over the whole surveyed area, the calculated conversion factors must take the regional variation into account.

K is determined from the physical calibration of the equipment, which is described in section 1 above. K does not depend upon the species or biological parameters. Several calibrations may be performed during a survey. The measured values of K or the settings of the EK500 may be different but they should be within 10% of one another. If two successive measurements are very different the cause should be investigated since the equipment may be malfunctioning. Otherwise, K should be taken as the average of two measurements before and after the relevant part of the survey.

6.1 Conversion factors for a single species

The mean cross-section $<\sigma_i>$ should be derived from a function which describes the length-dependence of the target-strength, normally expressed in the form:

$$TS = a_i + b_i Log_{10}(L) \qquad \textbf{(2)}$$

Where a_i and b_i are constants for the i'th species, which by agreement with the other participants in the survey are given in Table 5.

Table 5. The recommended target strength relationships for herring surveys in the North Sea and adjacent waters.

	Target Strength Equation Coefficients	
Species	$\mathbf{b_I}$	$\mathbf{a_i}$
Herring	20	-71.2
Sprat	20	-71.2
Gadoids	20	-67.5
Mackerel	20	-84.9
horse mackerel	20	-71.2

The equivalent formula for the cross-section is:

$$\sigma_i = 4\pi 10^{\left(\left(a_i + b_i Log(L)\right)/10\right)} \qquad \textbf{(3)}$$

The mean cross-section is calculated as the σ average over the size distribution of the insonified fish. Thus L_j is the mid-point of the j'th size class and f_{ij} is the corresponding frequency as deduced from the fishing samples by the method described earlier. The echo-integrator conversion factor is $c_i= K/<\sigma_i>$. The calculation may be repeated for any species with a target strength function.

$$< \sigma_i >= 4\pi \sum_j f_{ij} 10^{\left(\left(a_i + b_i Log(L_j)\right)/10\right)} \quad \textbf{(4)}$$

Note that it is the cross-section that is averaged, not the target-strength. The arithmetic average of the target-strengths gives a geometric mean, which is incorrect. The term "mean target-strength" may be encountered in the literature, but this is normally the target-strength equivalent to $<\sigma_i>$, calculated as $10\log_{10}(<\sigma_i>/4\pi)$. Some authors refer to TS as 10 $\log(\sigma_{bs})$ the definition of σ is different from σ_{bs} and should not be confused.

6.2 Conversion factors for mixed species layers or categories

Sometimes several species are found in mixed concentrations such that the marks on the echogram due to each species cannot be distinguished. From inspection of the echogram, the echo-integrals can be partitioned to provide data for the mixture as one category, but not for the individual species. However, further partitioning to species level is possible by reference to the composition of the trawl catches (Nakken and Dommasnes, 1975).

Suppose E_m is the echo-integral of the mixture, and w_i is the proportion of the i'th species, calculated from fishing data. It is necessary to know the target-strength or the acoustic cross-section, which may be determined in the same manner as for single species above. The fish density contributed by each species is proportional to w_i. Thus the partitioned fish densities are:

$$F_i = \frac{w_i K}{(\sum_i w_i < \sigma_i >)} E_m \quad \textbf{(5)}$$

The w_i may be expressed as the proportional number or weight of each species, according to the units used for $<\sigma_i>$ and c_i. Consistent units must be used throughout the analysis, but the principles are the same whether it is the number of individuals or the total weight that is to be estimated.

6.3 Using weight-length relationships

The abundance is expressed either as the total weight or the number of fish in the stock. When considering the structure of the stock, it is convenient to work with the numbers at each age. However, an assessment of the commercial fishing opportunities would normally be expressed as the weight of stock yield. Consistent units must be used throughout the analysis. Thus if the abundance is required as a weight while the target-strength function is given for individual fish, the latter must be converted to compatible units. This may be done by reference to the weight-length relationship for the species in question.

For a fish of length L, the weight W is variable but the mean relationship is given by an equation of the form:

$$W = a_f L^{b_f} \quad \textbf{(6)}$$

Where a_f and b_f are taken as constants for one species. However, a_f and b_f could be considered as variables varying differently with stock and time of year as well as species. Suppose the target-strength of one fish is given as:

$$TS_n = a_n + b_n \log_{10}(L) \quad \textbf{(7)}$$

The corresponding function TS_w, the target-strength of unit weight of fish has the same form with different constants:

$$TS_w = a_w + b_w \log_{10}(L) \quad \textbf{(8)}$$

The number of individuals in a unit weight of fish is (1/W), so the constant coefficients are related to the formulae:

$$b_w = b_n - 10b_f \quad \textbf{(9)}$$

$$a_w = a_n - 10\log_{10}(a_f) \quad \textbf{(10)}$$

6.4 Abundance estimation

So far the analysis has produced an estimate of the mean density of the insonified fish, for each part of the area surveyed, and for each species considered. The next step is to determine the total abundance in the surveyed area. The abundance is calculated independently for each species or category of target for which data have been obtained by partitioning the echo-integrals. The calculations are the same for each category:

$$Q_i = \sum_{k=1}^{n} A_k F_i \qquad \textbf{(11)}$$

The total biomass for all species is:

$$Q = \sum_{i} Q_i \qquad \textbf{(12)}$$

The F_i are the mean densities and A_k are the elements of the area that have been selected for spatial averaging. The may be calculated from the shape of an area or measured, depending upon the complexity of the area. The presence of land should be taken into account, possibly by measuring the proportions of land and sea.

7. Data exchange

7.1 Exchange of data for the combined survey results

Where the intention is to combine data for overall abundance estimates, the following data shoulkd be provided:

Acoustic Data.

<u>Summarised data in spreadsheet (Excell) format for each EDSU including;</u>

- <u>Time and date</u>
- <u>Longitude and latitude</u>
- <u>Calibrated scrutinised mackerel NASC</u>

Biological data

<u>By trawl haul;</u>

- <u>Time and date</u>
- <u>Longitude and latitude</u>
- <u>Root mean square length of mackerel</u>
- <u>Weight length relationship parameters</u>

More detailed exchange formats will be developed when the precise methodology and data requirements are finalised.

8. References

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Table 6. An example of the excel worksheet used to submit survey data by ICES statistical rectangle - the 'cruise sheet' with data from four ICES statistical rectangles.

1999 Cruise sheet on ICES stat square scale.							
Ship name and country (in here):			Scotia				
					Stat	**Abundance**	**Survey**
		Latitude	**Longitude**	**Sub-area**	**Rect**	**(millions)**	**weight (n.mi.)**
		59.75	2.5	**A**	**48F2**	15.00	40
		59.75	3.5	**A**	**48F3**	9.35	45
		59.25	2.5	**B**	**47F2**	2.65	27
		59.25	3.5	**B**	**47F3**	12.33	60
					-71F0		
					-71F0		
Origin:	**00A0**				**-71F0**		
lat	**35.5**				**-71F0**		
long	**-50**				**-71F0**		
					-71F0		
					-71F0		
					-71F0		
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					-71F0		

Table 7. An example of the excel worksheet used to submit survey data broken down by age/sub area - the 'proportions sheet'

	North Sea Autumn spawners.									Mean weights and lengths in over here >>>>>>				
		Abundance (Millions)......								Weights - column AC, lengths in column BC				
Sum	**Stratum**	**0**	**1i**	**1m**	**2i**	**2m**	**3i**	**3m**	**4**	**5**	**6**	**7**	**8**	**9+**
77.000	**A**	0.000	0.000	24.987	0.555	51.281	0.000	0.177	0.000	0.000	0.000	0.000	0.000	0.000
48.300	**B**	0.000	0.000	0.000	0.000	47.620	0.000	0.680	0.000	0.000	0.000	0.000	0.000	0.000
109.600	**C**	0.000	0.000	8.921	0.000	100.679	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
217.500	**D**	0.000	0.000	0.000	0.000	214.048	0.000	3.452	0.000	0.000	0.000	0.000	0.000	0.000
0.801	**E**	0.000	0.000	0.303	0.004	0.490	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
494.200	**F**	0.000	0.000	191.716	4.260	298.224	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

North Sea Autumn spawners.... Mean weight (grams).....												
0	**1i**	**1m**	**2i**	**2m**	**3i**	**3m**	**4**	**5**	**6**	**7**	**8**	**9+**
0.000	6.375	6.375	27.750	35.826		70.429	120.667	181.000	0.000	0.000	0.000	0.000
0.000	6.375	6.375	27.750	35.826		70.429	120.667	181.000	0.000	0.000	0.000	0.000
0.000	6.375	6.375	27.750	35.826		70.429	120.667	181.000	0.000	0.000	0.000	0.000
0.000	6.375	6.375	27.750	35.826		70.429	120.667	181.000	0.000	0.000	0.000	0.000
0.000	6.375	6.375	27.750	35.826		70.429	120.667	181.000	0.000	0.000	0.000	0.000
0.000	6.375	6.375	27.750	35.826		70.429	120.667	181.000	0.000	0.000	0.000	0.000

North Sea Autumn spawners.... Mean length (cm).....												
0	**1i**	**1m**	**2i**	**2m**	**3i**	**3m**	**4**	**5**		**7**	**8**	**9+**

Table 8. Maturity scales currently used by the participants in ICES coordinated acoustic surveys in ICES divisions III, IV and Va.

Reporting state	**8 point scale (Scotland, Norway, Denmark)**	**5 point scale (HERSUR)**	**4 point scale Netherlands**	**4 point scale (Germany)**
Immature	1. Virgin	1. Virgin	I. Virgin	1. Virgin
	2. Small gonads			
Mature	3. Gonads half cavity	2. Maturing	M. Maturing	2. Maturing
	4. Gonads long cavity			
	5. Gonads fill cavity			
	6. Ripe & running	3. Spawning	R. Spawning	3. Spawning
	7. Spent	4. Spent	S. Spent & recovering	4. Spent
	8. Recovering spents	5. Resting		