ICES PGAAM Report 2005

ICES Living Resources Committee
ICES CM 2005/G:13
REF. ACFM, B

Report of the Planning Group on Aerial and Acoustic Surveys for Mackerel (PGAAM)

5–7 April 2005

Bergen, Norway

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

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer
H.C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:
ICES. 2005. Report of the Planning Group on Aerial and Acoustic Surveys for Mackerel (PGAAM), 5–7 April 2005, Bergen, Norway. ICES CM 2005/G:13. 56 pp.

Contents

Executive summary

Mackerel are widely distributed in the North-East Atlantic. Many countries fish for mackerel and the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA) assembled the distribution of commercial catches. However the distribution of commercial catches should be interpreted with caution due to environmental factors, stock size, and quota/area limitations for the participating nations (some countries cannot fish in the different national EEZs).

The WGMHSA assessment of the North-East Atlantic mackerel 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. However, the various annual research surveys by different countries have verified that there is an even wider distribution of mackerel than that indicated by the commercial fisheries. All surveys have the potential to deliver information on the distribution and abundance of mackerel. However, the surveys cover only part of the known distribution area and consequently have not been able to deliver a valid stock estimate or complete distribution map.

The Planning Group on Aerial and Acoustic Surveys for Mackerel (PGAAM) was established during the WGMHSA meeting in September 2001 with the main purpose of coordinating a number of surveys on pelagic species that can provide the information on the distribution and abundance of mackerel (Section 1, 5, 6, 7, 8).

The main objectives of PGAAM are to provide the distribution of mackerel and biomass/number indices that may be used by WGMHSA in future assessments. Furthermore, it aims to collate information on the hydrographic and plankton conditions of the Norwegian Sea and adjacent waters to describe how feeding and migration of mackerel are influenced by this.

The PGAAM met to coordinate vessels from appropriate countries which can collaborate with the Russian aerial surveys in the Norwegian Sea (Section 5), to coordinate Scottish and Norwegian acoustic surveys in the Viking Bank area (Section 6), to coordinate Spanish, Portuguese and French acoustic surveys (Section 7). Mackerel do not possess a swim bladder. As a result, they are poor reflectors of sound and have a low target strength (TS), so it's very difficult to use the acoustic assessment. The PGAAM has tried to utilize the findings of the EU SIMFAMI project to provide tools to identify mackerel echo-traces (Section 2, 3) as well as to develop protocols and criteria to ensure standardisation of all sampling tools and survey gears (Section 4).

The PGAAM made a list of the surveys in the North-East Atlantic not targeted at mackerel, but with the potential of collecting mackerel data to provide indices of mackerel abundance. Some surveys followed the PGAAM recommendations and collected data, and passed them to PGAAM (Section 8).

Norway has surveyed the mackerel acoustically during the autumn for the last six years and PGAAM recommends that WGHMSA consider the use of these data as a relative index in the assessment as well the joint Scottish and Norwegian autumn surveys on mackerel. The Russian and Norwegian summer surveys should also be considered as tuning indices for the assessment of the mackerel stock (Section 5, 6, 10).

Commencing from 2004, the ICES advice has changed in several aspects as well as the approach to the investigations. A new Ecosystem-based approach to the fishery advice/management has begun. Near collaboration between the various surveys and descriptions of the ecosystem as a whole (including most of the marine exploration aspects) are requested today. Many of the issues carried out by PGAAM, PGNAPES and PGHERS overlap today,

and therefore it is felt that the PGAAM duties are now finalized for the present time and the relevant references be passed onto the PGNAPES and PGHERS starting from 2006 (Section 9).

1 Introduction

1.1 Terms of Reference

The Planning Group on Aerial and Acoustic Surveys for Mackerel [PGAAM] (Chair E. Shamray, Russia) met in Bergen, Norway from 5–7 April 2005. The terms of reference and sections of the report in which the answers are provided, follow:

ITEM	TOR 2005	SECTION
a)	coordinate the timing and area allocation and methodologies for acoustic and aerial surveys for mackerel in the NEA;	4, 5, 6 and 7
b)	collate and evaluate the data collected by the aerial surveys, fishing- and research vessels in the Norwegian Sea during the summer and autumn of 2003;	5
c)	coordinate acoustic surveys within the North Sea-Shetland area to ensure full coverage and appropriate areas and timing;	6
d)	combine the October-November 2003 survey data of abundance and distribution of mackerel within the North Sea-Shetland area;	6
e)	identify participants to contribute to the aerial surveys for mackerel in the Norwegian Sea and coordinate collaboration between vessels;	5
f)	combine the summer 2003 aerial survey data with vessels data of distribution of mackerel in the Norwegian Sea;	5
g)	seek survey time for northward extension of acoustic surveys in ICES Subareas VIII and IX;	7
h)	consider the latest findings from the SIMFAMI project;	2, 3
i)	identify surveys which are not targeted at mackerel, but which may have potential use for the estimation of mackerel distribution and abundance;	8
j)	develop protocols and criteria to ensure standardisation of all sampling tools and survey gears.	4

PGAAM made its report available to the WGMHSA, Living Resources Committees, Fisheries Technology and for the attention of ACFM.

1.2 Participants (see Annex I)

Doug Beare (part time)	U. K. (Scotland)
Paul Fernandes (by letter)	U. K. (Scotland)
Svein Iversen	Norway
Rolf Korneliussen	Norway
Aril Slotte	Norway
Evgeny Shamray (Chair)	Russia
Eirik Tenningen	Norway
Vladimir Zabavnikov	Russia

1.3 Background information

Mackerel are widely distributed in the North-East Atlantic. Examination of the time series of commercial mackerel catches taken from 1977–2004 reveals that 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 is described in detail annually in the WGMHSA report should therefore be interpreted with caution: for example, some countries cannot fish in the different national EEZs or they have quota limitations. The commercial data are, therefore, indicative only of the wide area where mackerel are caught in the Northeast Atlantic, and the quarterly changes in the distribution of the fishery.

Various research surveys by different countries have verified that there is an even wider distribution of mackerel than that indicated 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 cover 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.

The PGAAM met 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, and to utilize the findings of the EU SIMFAMI project to provide tools to identify mackerel echo-traces.

The main objectives of PGAAM are to provide distributions of mackerel and biomass/number indices that may be used by WGMHSA in future assessments. Furthermore, it aims collate information on the hydrographic and plankton conditions of the Norwegian Sea and adjacent waters to describe how feeding and migration of mackerel are influenced by this.

During the PGAAM meetings it was possible to group surveys (excluding triennial egg survey) as follows:

GEOGRAPHICAL AREA	TIME	ICES AREA	EEZ	PRESENT STATUS
Norwegian Sea	June-August	IIa, IIb, Vb, Va	Norwegian, Jan-Mayen, Faroese, Icelandic, International water	Coordinated
North Sea-Shetland area	October-November	IVa,	Norwegian, Great Britain,	Coordinated 2000–2004 but not available for 2005
Western area	March-May	VIIj, VIIb, VIIc, VIa	Irish, Great Britain	Non-targeting on mackerel but provide all kind of samples
SOUTHERN AREA	FEBRUARY-APRIL	VIII, IXA	PORTUGUESE, SPANISH, FRENCH	UNKNOWN FROM 2004
NORTH SEA		IVB, IVC	EU	EXPECT IN FUTURE
Irish and Celtic Seas		VIIa,d,e,f,g,h	EU	Expect in future

It will be noted that surveys on atlanto-scandian herring in the Norwegian Sea and on blue whiting west off the British Isles coordinated by the PGNAPES (Anon. 2004) also provide mackerel distributions and biological samples.

Detailed results of the coordinated surveys in 2004 were evaluated at the 2005 PGAAM meeting and are presented in this report. The purpose of the report is to provide a short summary of the surveys and their findings: some results of PGAAM work are subject to further analyses and will be reported to the WGMHSA in September 2005.

2 Mackerel target strength (ToR h)

Target strength of mackerel has been measured in a national Norwegian project, but is included here for completeness of this report. The measurements of target strength were done with a Simrad split-beam echo sounder EK500 at 38 kHz. The measurements were made after a proper calibration of the equipment. Detection of single-fish was in practice only possible in complete darkness. The approximately 5000 single-fish detections per channel were scrutinized, and processed by target tracking were used to keep good data for further processing. There were 3068 accepted measurements on 38 kHz, and 1305 on 120 kHz. The measurements at 38 kHz gave the TS-relation:

$$TS[38kHz]=20\log_{10}(L)-86.0 \text{ dB} \quad (2.1)$$

The target strength of a mackerel of total length of 34 cm and weight of 555 g, was measured to be: TS=-55.4±0.2 within 95% confidence interval. The condition factor of the fish was 1.5, which is larger than the 0.95 found during, e.g., the 1999 IMR survey. Note that the relation above assumes that $TS=20\log_{10}(L) + b$, i.e., that the square of the length of the scattering object(s) is proportional to the length of the fish. This assumption is acceptable if the back-bone, head-bone and fish-body are all assumed to have approximately the same length-width relation independently of the size of the fish, at least for sizes of mackerel not too far from the ones used to estimate the TS.

TS were also simultaneously measured at 120 kHz with a split-beam EK500. Note that some time after the measurements were done, non-linear acoustic effects due to too high input power, 1000W, at the EK500/120-kHz system were discovered. It is still unclear how much these non-linear effects affect the TS-measurements at 120 kHz. Note also that modeling work done after these measurements indicate that a “step-frequency” may exist somewhere between 100 and 200 kHz, where the backscatter from the backbone increase from being insignificant as compared to the fish-body to be of equal importance or even dominate the backscatter. The “step-frequency” should in theory depend on the size of the fish. The measurements of TS at 120 kHz gave the following TS-relation:

$$TS[120kHz]=20\log10(L)-79.4 \text{ dB} \quad (2.2)$$

The target strength of a mackerel of total length of 34 cm and weight of 555 g, was measured to be: TS=-48.8±0.2 within 95% confidence interval. It has not been found anything close to 6 dB differences between measurements 38 and 120 kHz at any later occasion, neither during measurements in pen, nor during measurements at sea. The later measurements gave 0 – 3 dB difference. Due to the large variations of measurements at 120 kHz relative to 38 kHz, 120 kHz recommended not to be used in calculation of mackerel stock abundance.

It was not possible to measure TS at 200 kHz since a split-beam EK500/200-kHz system nor a EK60/200-kHz system was available.

3 The SIMFAMI project (ToR h)

3.1 The SIMFAMI project progress

The SIMFAMI project ended in February 2005, the content of the final report has been written, and the final report are now being edited before it is being delivered. The content of Chapter 2 and 3 in this report are mainly taken from the SIMFAMI final report.

Institute of Marine Research, IMR, Norway, was leading the mackerel activities of the SIMFAMI project. The findings of IMR have been incorporated into an algorithm for the identification of mackerel, and the algorithm has been implemented into an operational system, namely the post-processing system Bergen Echo Integrator, BEI. The mackerel identification algorithm has also been simplified somewhat by Fisheries Research Services, FRS, Scotland, and has been implemented into the post-processing system EchoView. The two implementations of the mackerel identification algorithm are referred to as “The IMR implementation of the mackerel identification algorithm” and “The FRS implementation of the mackerel identification algorithm”.

3.2 The IMR implementation of the mackerel identification algorithm

Preparing data for combination

The acoustic data is expected to be collected according to the recommendations in Korneliussen *et al*., 2004a. Further, the data are smoothed with weights that are shifted horizontally and vertically to compensate for transducer placement and pulse transmission delay described illustrated in Figure 3.2.1 and described by Korneliussen *et al*., (2004a), Korneliussen and Ona (2003). Noise is removed according to Korneliussen (2000).

The weights have Gaussian shape both horizontally and vertically, which means that the centre element is weighted more than the surrounding elements. The weights are normalised, i.e., the sum of the weights are unity as illustrated below (ping-rate: 1.4 pin per second, vertical resolution 0.3 m, smoothing diameter 7.5 m horizontally, 0.75m vertically). The four elements closest to the centre of the matrix are marked

EK500/200kHz (LONG/NARROW) Transducer 23 cm behind 38kHz

0.00477898	0.01223264	0.02769307	0.01382470	0.00525152
0.00964781	0.02469524	0.05590676	0.02790929	0.01060176
0.02068821	0.05295507	***0.11988329***	***0.05984710***	0.02273381
0.02309033	0.05910371	***0.13380298***	***0.06679596***	0.02537345
0.01129115	0.02890167	0.06542956	0.03266318	0.01240760
0.00543163	0.01390319	0.03147499	0.01571267	0.00596869
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

Algorithm overview

The mackerel categorisation algorithm is implemented in a function that runs in parallel with several other similar categorisation functions. The inputs to the each of the categorization functions are firstly pre-processed acoustic multi-frequency data, but also spatial information such as bottom depth, depth below surface are used to some extent. Note that the spatial information longitude, latitude, time of year and time of day are only used if the acoustic category tested is equivalent to a single species, i.e., mackerel or capelin. All smoothing, noise-removal and scrutinizing tools are included in the Bergen Echo Integrator post-processing system (Korneliussen, 2004).

Figure 3.2.1 gives an overview over how the categorisation system of the Bergen Echo Integrator, BEI, works, step by step. First, the volume-segments (pixels) accepted by the models behind the categories "BOTTOM", "NO_TARGET" and "NOISE_18" are identified. The acoustic data are not tested against these categories later, and if any of these categories is allocated to a volume-segment, the category of that volume-segment cannot be changed later.

The Stage-1, Stage-2, and Stage-3 categorisation-functions that take the final decision of which category should be allocated to the tested volume segment. In the final stage, some categories are split. Currently, the acoustic category "FISH" (fish with swim bladder) is split into capelin and other fish with swim bladder.

In each of Stages 1–3, the acoustic, and sometimes also spatial, input-data are tested against a number of feature-based models implemented in functions (=sub-routines). Each of the functions returns three flags of how likely it is that the measured acoustic data is due to backscatter from the tested category. For mackerel, the function is called "Mackerel()", and the flags the function returns are called mackerel_1, mackerel_2, mackerel_3, where "mackerel_1=TRUE" means that the backscatter is accepted by the strongest acoustic criteria. In Stage-1, the acoustic measurements of a volume-segment (pixel) have to fit strict acoustic requirements for acoustic category to be assigned to that volume-segment. For mackerel, this means that "mackerel_1=TRUE", or that "mackerel_2=TRUE" when all other categories give "nnnnn_3=FALSE".

Further, the results of the Stage-1 categorisation are used as input to the Stage-2 categorisation. In the Stage-2 categorisation, the same functions as in Stage-1 are used, e.g., the same function "Mackerel()" as in Stage-1. In "Stage-2", a volume-segment (pixel) is accepted to be due to backscatter from mackerel in "Mackerel()" returns the flag "mackerel_2=TRUE" at the same time as the acoustic category "MACKEREL" is the most common of the surrounding volume-segments.

The Stage-3 categorisation function proceeds the same way, but with even stronger requirements to belong to the same acoustic category as the surrounding volume-segments.

In total, the three stages of categorisation, running all categorization functions that each returns three similar flags compare these flags as follows:

- If only one function return a flag like *"pixel-almost-certainly-category_X",* the pixel is marked as Category_X. If there is only one function return a flag like *"pixel-possibly-category_X",* the pixel is also marked as Category_X.
- If there are more than one category accepted at the same level, i.e., more than one *"pixel-almost-certainly-category_X"*, or if none accepted at the highest level, more than one *"pixel-possibly-category_X"*, the categories of the nearest neighbours in space is examined. If no other of the neighbouring pixels are categorised as "mackerel", the category of that pixel is considered doubtful, and is changed to "uncertain". If the most common category in the 5x5 surrounding pixels is "mackerel", and at least 15% of the pixels are categorised as "mackerel", the examined pixel is set to "mackerel". If the examined pixel is categorised as "strong-target" (i.e., mackerel or swim bladdered fish), the pixel category is changed to "mackerel" if at least 15% of the surrounding pixels and at least 25% of the surrounding categorised pixels are categorised as "mackerel".
- If the acoustic category of the pixel is still uncertain, it is tested at the lowest level for some categories, but not for mackerel.

Mathematics of the IMR implementation of the mackerel identification function

Each of the algorithms of the categorization system works the in a similar manner as illustrated by the algorithm implemented in the function "Mackerel()".The Similarity number, S, is composed by the relative frequency response similarity, $S_{r(f)}$, the behaviour similarity, $S_{behavior}$, and the backscattering strength similarity, S_{sv}. S for mackerel is currently defined as:

$$S \equiv Sr(f) * Sbehavior * SsV \quad (3.2.1)$$

where
$0 < Sr(f) < 1$
$0 < Sbehavior < 1$
$0 < SsV < 1$

Pre-categorisation

The mackerel-categorization starts with the pre-categorization to speed up the total categorisation process. This is a set of simple tests that is considered the minimum requirements for a multi-frequency data-point to be considered as mackerel (i.e., the acoustic category "mackerel"). This is intended to reject 95% of the data that is not mackerel. Some volume-segments marked as "BOTTOM", and "NO_TARGET" as described above and illustrated in Figure 3.2.1, are inherently already marked as "not mackerel" and are not tested again. For the acoustic category "mackerel", the calculation of S proceeds as follows:

S = 0, i.e., volume-segment or "pixel" cannot be mackerel if:

- Not data at both 38 kHz and 200 kHz (since "pixel" cannot be tested to be mackerel or not)
- s_v(38kHz) = $s_v(38) > 1.3 * s_v(200)$
- If 18kHz data exist: $s_v(18) > 4.0 * s_v(200)$
- If 120kHz data exist: $s_v(120) > 2.0 * s_v(200)$
- $4\pi 1852^2 s_v(38) < 0.1$
- $4\pi 1852^2 s_v(38) > 50000$
- $4\pi 1852^2 s_v(200) < 0.33$
- $4\pi 1852^2 s_v(200) > 165000$

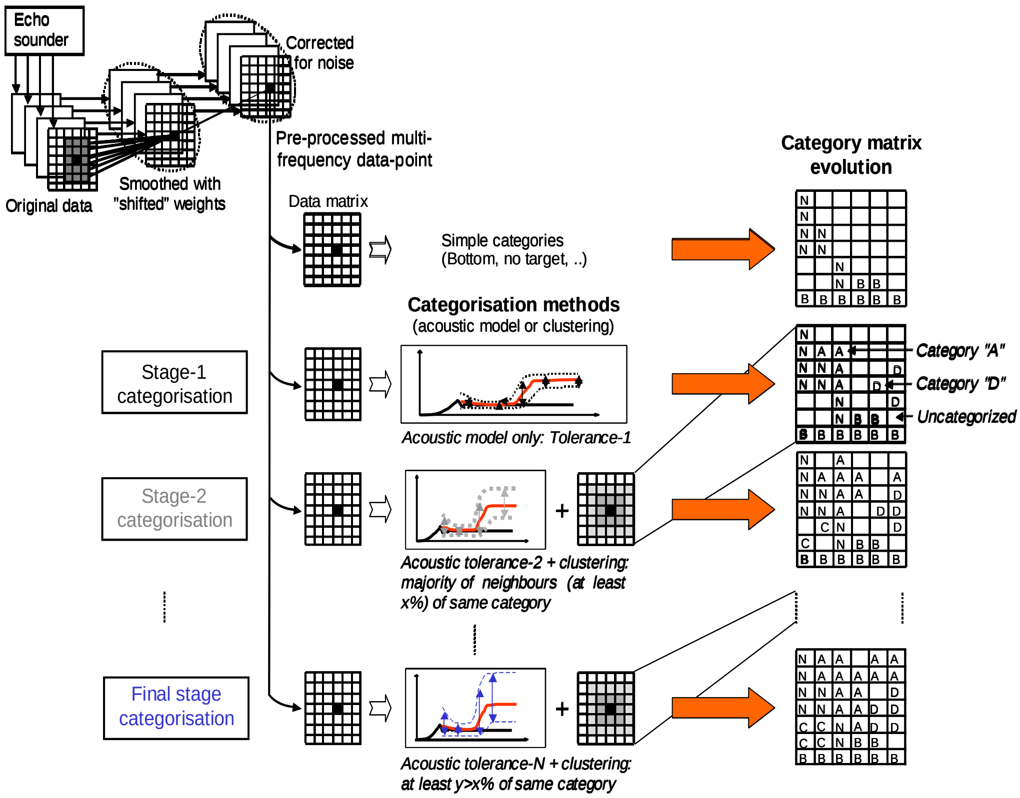

Figure 3.2.1: Overview of the categorization system of the Bergen Echo Integrator. The data are first smoothed and corrected for noise. Then the acoustic data from the volume-segment, i.e., the multi-frequency data-points, are tested against simple categories. Further, the acoustic data are tested against acoustic models with an error band. The acoustic model of the category "mackerel" is used as example. In each stage of the categorization step the error-band increase, and so does the requirement to belong to the same acoustic category as the neighbour volume-segment.

Behavior, position and date similarity, $S_{behavior}$

This similarity can only be connected to acoustic categories that can be connected to a quantifiable behavior of some kind. $S_{behavior}$ can be set only if the acoustic category is identical to a known set of species as is the case for mackerel. The default value of $S_{behavior}$ is unity, 1, if there is no known information. Figure 3.2.2 illustrates how $S_{behavior}$ is currently set by the categorization system. Figure 3.2.2 shows that $S_{behavior}$ for mackerel is:

- $S_{behavior} = 1$ — default
- $S_{behavior} = 1$ — if position and time of year is where mackerel is very likely to be, e.g., the North Sea and Norwegian Sea in September, October or November.
- $S_{behavior} = 0.9$ — for close positions and time, where mackerel is very likely to be found.
- $S_{behavior} = 0.8 - 0.6$ — where mackerel is decreasingly likely to be found
- $S_{behavior} = 0$ — if the position of the data is far outside waters where mackerel has never been observed.

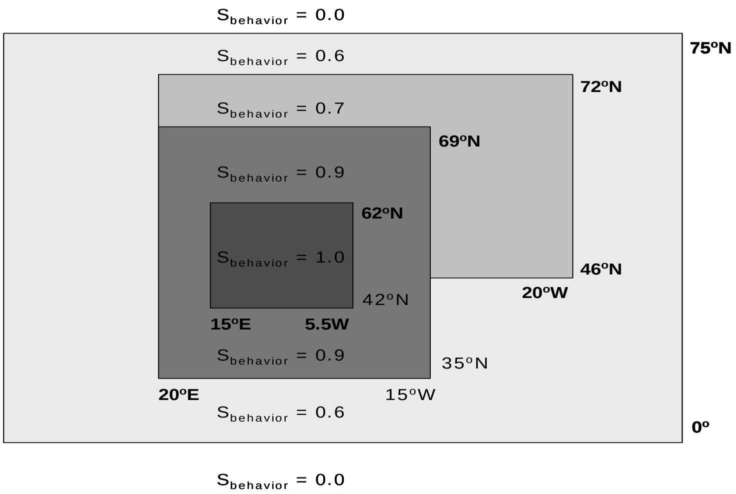

Figure 3.2.2: Illustration of setting the position, time of year and time of day similarity, $S_{behaviour}$.

Backscatter strength similarity, S_{sv}

S_{sv} is used to avoid multi-frequency measurements to be associated with an unlikely acoustic category. Very weak s_v at all frequencies should, as an example, not be associated with mackerel or fish with swim bladder. Since the mean volume backscatter depends on which acoustic frequencies are available, the backscatter at the low frequencies (38 and 70 kHz) are given the same weight as the high frequencies (200 kHz), and 18 and 364 kHz are avoided. The 200 kHz data will always exist due to previous test. The max range of 200 kHz data is set to 300 m for mackerel (although this is probably too long range for 200 kHz, there is really no choice if mackerel is to be recognised). The average value is calculated according to equation (3.2.2). The value of S_{sv} currently implemented is shown in Figure 3.2.3.

$$s_{v,avg} = \frac{s_{v,38}W_{38} + s_{v,70}W_{70} + s_{v,120}W_{120} + s_{v,200}W_{200}}{W_{38} + W_{70} + W_{120} + W_{200}} \qquad (3.2.2)$$

where $W_{38} = 1$

$W_{70} = 1$ if data exist at 70 kHz, $W_{70} = 0$ if data do not exist

$W_{70} = 1$ if data exist at 120 kHz, $W_{120} = 0$ if data do not exist

$W_{200} = W_{38} + W_{70}$

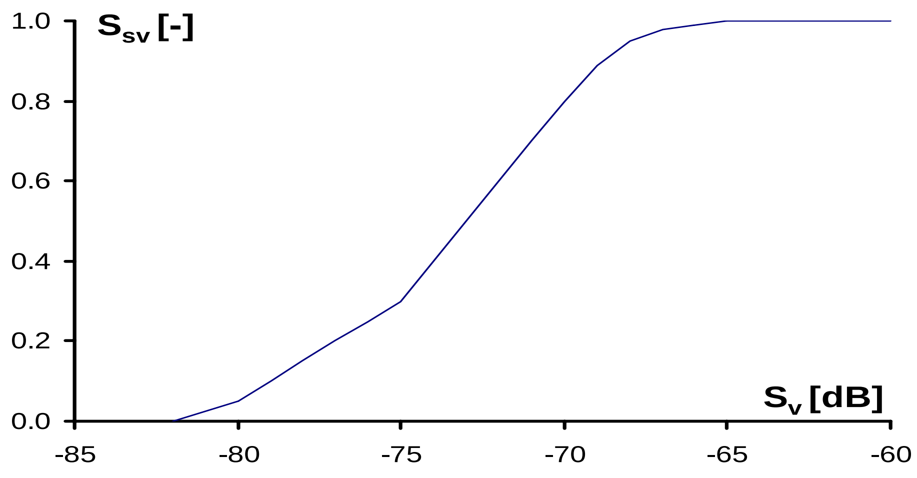

Figure 3.2.3: Volume backscatter similarity, S_{sv}, plotted as function of average volume backscatter strength, $S_v=10\log_{10}(s_{v,38}+s_{v,70}+s_{v,120}+2s_{v,200})/5$.

Relative frequency response similarity, $S_{r(f)}$

Figure 3.2.4 illustrates the frequency dependency of the backscatter of mackerel, and how the error-band evolves through different stages of the categorization process. r(f)±Δr(f) is essential for the identification of mackerel.

The idealized relative frequency response, r(f), of mackerel is based on measurements at sea and in pen as described below. The r(f) currently used by the categorisation system is given by equation 3.2.3. Note that the available 18kHz systems generate wider beams than at the other frequencies, and that the EK60/364-kHz system showed some irregularities (described in more detail below).

$r_i(18) : r_i(70) : r_i(120) : r_i(200) : r_i(364) = 1.2 : 1.0 : 1.5 : 4.0 : 3.8$ (3.2.3)

The general trend in of r(f) are verified by models (Gorska *et al.*, 2004a,b, 2005). Note the following main features of Figure 3.2.4, and how those are explained by the theory:

- Below approximately 100 kHz, r(f) is relatively frequency independent. Backscatter from flesh dominates. At the lowest frequencies, the interference of the backscatter between the top and bottom of the flesh gives fluctuations in backscatter, which may give either larger or lower values than the stable level (especially for small schools).
- From approximately 100 kHz, the bone starts to contribute, and r(f) increase rapidly until it reaches a stable level at, hopefully at some frequency below 200 kHz. For large mackerel, the increase in r(f) should start at lower frequencies than for small mackerel due to the width of the bones.
- At 200 kHz and above, the backscatter is relatively frequency independent. In this region, backscatter from bone dominates.

The uncertainties, Δr(f), are also based on measurements, but in a more broad sense than r(f) itself. The minimum value accepted for r(f) in first pass is $r_{ideal}(f)/e(f)$, and the maximum is $r_{ideal}(f)e(f)$. If

$r_{ideal}(f)/e(f) < r(f) < r_{ideal}(f)e(f)$, $S_{r(f)=}1.0$. (3.2.4)

The values if e(f) currently used by the categorization system are:

e(18) : e(70) : e(120) : e(200) : e(364) = 1.7 : 1.6 : 1.8 : 1.6 : 2.0 (3.2.5)

For each pass of maximum 3, e(f) is increased by a factor 1.5. If accepted in second pass, $S_{r(f)=}$1.0*0.7, and in third $S_{r(f)=}$1.0*0.7*0.7=0.49. The total S_{rf} is a weighted sum of the individual $S_{r(f)}$ at the frequencies f where data exist, and is measured within the maximum range of the frequency. The weights are:

w(18) : w(70) : w(120) : w(200) : w(364) = 1.0 : 2.0 : 1.0 : 4.0 : 1.0 (3.2.6)

which mean that the combination of 200 and 38 kHz data, r(200kHz) counts 4 times the combination of 364 and 38 kHz data, r(364kHz). For data not used, either because data does not exist at that frequency, or because the range from transducer to measured volume-segment is too large, the weight w=0. The result is then:

$$S_{rf} = \frac{S_{r(18)}w(18) + S_{r(70)}w(70) + S_{r(120)}w(120) + S_{r(200)}w(200) + S_{r(364)}w(364)}{w(18) + w(70) + w(120) + w200 + w(364)} \quad (3.2.7)$$

The resulting total similarity, S, for mackerel

The total similarity is: S = $S_{mackerel}$ = S_{rf} * $S_{behavior}$ * S_{sV}. Depending on the value of S, the following flags are set to TRUE:

- If S > 0.8: *"pixel-almost-certainly-mackerel"*
- If 0.5 < S < 0.8: *"pixel-possibly-mackerel"*
- If 0.2 < S: *"cannot-exclude-pixel-to-be-mackerel"*

All categorization functions returns three similar flags. The results of all categorization functions are compared as follows:

- If only one function return a flag like *"pixel-almost-certainly-category_X",* the pixel is marked as Category_X. If there is only one function return a flag like *"pixel-possibly-category_X",* the pixel is also marked as Category_X.
- If there are more than one category accepted at the same level, i.e., more than one *"pixel-almost-certainly-category_X"*, or if none accepted at the highest level, more than one *"pixel-possibly-category_X"* , the categories of the nearest neighbours in space is examined. If no other of the neighbouring pixels are categorised as "mackerel", the category of that pixel is considered doubtful, and is changed to "uncertain". If the most common category in the 5x5 surrounding pixels is "mackerel", and at least 15% of the pixels are categorised as "mackerel", the examined pixel is set to "mackerel". If the examined pixel is categorised as "strong-target" (i.e., mackerel or swim bladdered fish), the pixel category is changed to "mackerel" if at least 15% of the surrounding pixels and at least 25% of the surrounding categorised pixels are categorised as "mackerel".
- If the acoustic category of the pixel is still uncertain, it is tested at the lowest level for some categories, but not for mackerel.

The result of the categorization process can be visualised as identified categories in a generated synthetic echogram, or it can be used to mask selected categories at a single frequency, i.e., keep some categories and remove others at that frequency.

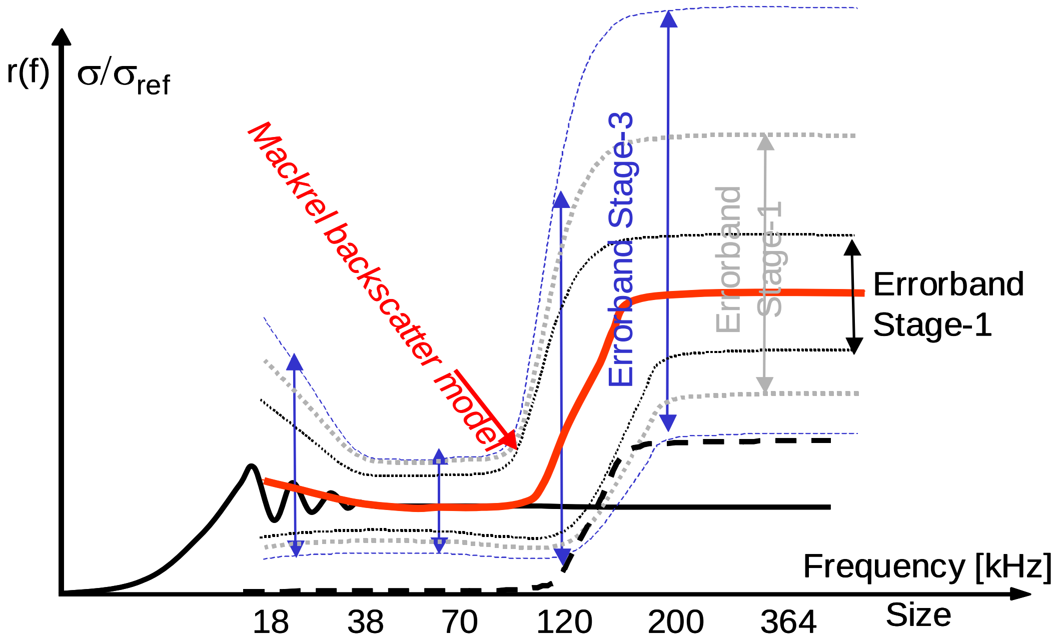

Figure 3.2.4: Illustration of mackerel backscattering model, with increase of error bands in each categorization stage shown.

Methods of verification

There are different ways to verify the multi-frequency mackerel identification algorithm described above. All methods require use of biological sampling, e.g., trawl catches or purse-seining. Each method of verification depends on to which extent the biological sampling can be relied upon. The methods evaluated below are listed in increasing requirement of reliability:

1) The results of biological sampling are used only as an indicator of a species being in the sampled volume. The biomass-composition of the catch is not relied upon.

2) Interpretation of acoustic data is aided by the results of biological sampling. Each result of the biological catches is evaluated individually when used in the interpretation process. The result of the catch is relied upon, but not blindly.

3) The results of biological sampling used as an independent and equally reliable source of abundance estimation of mackerel as acoustics. The result of the catch is relied upon. This is called the "Similarity of Identification", SID (Fernandes and Stewart, 2004).

Results

Estimated r(f) for mackerel

The relative frequency response, r(f), measured during surveys and during measurements of caged mackerel, partly financed trough SIMFAMI, and partly trough national founded projects. Table 3.2.1 and Figure 3.2.5 summarize the measurements. During analysis, it turned out that there was no significant difference in the sub-groups (large and small) of the manual split feeding groups in the pen experiment, and it is therefore only three measurement groups in the pen experiment.

For the data from the 2003 and 2004 surveys, r(f) was measured in two depth intervals, 30–90 m and 30–300 m. This was done to have all measurements in the valid depth range of 364 kHz, at the same time as all values at larger depths was used for the other frequencies as well. In 2003 and 2004, r(200kHz) was lower at large depth than in small depth. Measurements of depth dependencies of r(f) are so far still inconclusive since there are not many mackerel schools found at large depths during since 1999. In 2004, some schools were found in the Norwegian trench at 300 m depth, and although r(200kHz) show a trend to decrease at such large depths, it is also quite possible that 300 m is beyond the usable range of 200 kHz. It is therefore too early to jump to a conclusion when it comes to depth dependency of r(200kHz).

Table 3.2.1. Measured relative frequency response, r(f)=sA(f) / sA(38kHz), for mackerel.

SURVEY	EK60/ EK500	MEAN WEIGHT [G]	MEAN LENGTH [CM]	DEPTH-RANGE[M] OF R(F)	R(18)	R(38)	R(70)	R(120)	R(200)	R(364)	S_A(38) KHZ
1999012_GS2	EK500	360	34.9	30–300	1.1	1.0	-	1.1	4.2	-	340
2000012_GS2	EK500	285	32.8	30–300	1.3	1.0	-	1.1	3.8	-	230
2001013_GS2	EK500	420	36.3	30–300	1.8	1.0	-	-	5.4	-	260
2002015_GS2	EK500	295	33.3	30–300	1.4	1.0	-	1.2	3.0	-	240
2003112_GS3	EK60	295	33.0	*30–90*	*1.3*	*1.0*	*1.1*	*2.0*	*4.2*	*3.6*	
				30–300	1.2	1.0	1.0	1.6	3.3		
2004113_GS3	EK60	322	34.1	*30–90*	*1.6*	*1.0*	*1.0*	*2.0*	*3.7*	*4.0*	
				30–300	1.5	1.0	0.9	1.7	2.9	-	
2001_Cage_N	EK500	253	31.8	10–15	1.5	1.0	0.8	1.3	4.1		
2001_Cage_F	EK500	383	32.8	10–15	1.5	1.0	0.8	1.6	4.3		
2002_Cage_FF	EK500	665	38.2	10–15	1.3	1.0	1.0	2.0	4.0		
Average r(f) ± Δr(f)					**1.3 ±0.2**	**1.0**	**1.0 ±0.1**	**1.5 ±0.5**	**4.0 ±0.8**	**3.8 ±1.4**	

For diurnal variation of r(f) show a clearer trend. Figure 3.2.6 shows the diurnal variation of r(f) for the frequencies 18, 70 120 and 200 kHz (compared to 38 kHz) during the October survey for mackerel in the North Sea in 2004. Note that the beams at 70, 120 and 200 kHz are all 7°, the same as the 38 kHz beam. The 18 kHz beam are 11°, and r(18) does not show significant diurnal variation.

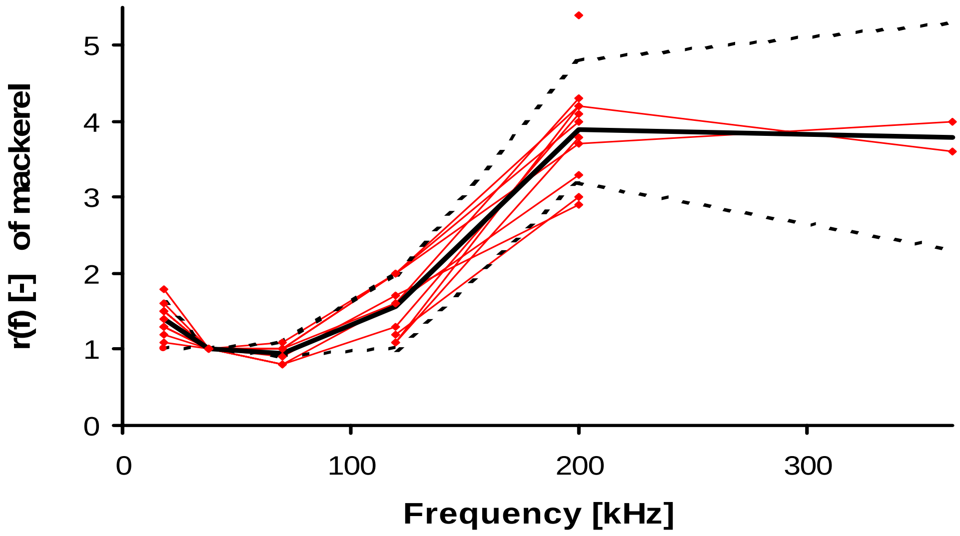

Figure 3.2.5: Measured relative frequency response, r(f) for mackerel. Red curves are average either per cruise or per cage measurement series.

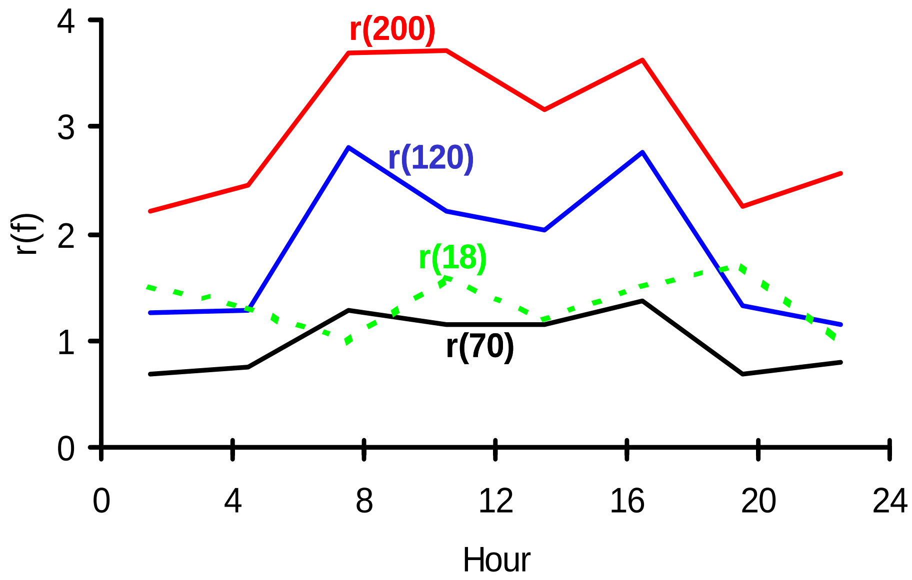

Figure 3.2.6: Diurnal variation of r(f) in October 2004. The 18 kHz beam are 11° unlike the other beams of 7°.

Test of algorithm implemented by IMR

Unless stated explicit otherwise, the acoustic data were interpreted using the Bergen Echo Integrator system, BEI, for post-processing acoustic data (Korneliussen, 2004). Unless stated explicit otherwise, the term "algorithm" means an algorithm developed at the Institute of Marine Research, IMR IMR is continuously improving the algorithms and updating the implementation of the algorithms in the operational system BEI (Korneliussen and Ona, 2002, 2003).

The examples below are selected to illustrate different situations of mackerel registrations.

Example: A fairly complex situation

Some example datasets are selected to illustrate strengths, weaknesses, and possible future improvements of the mackerel identification algorithm. The multi-frequency data visualised as echograms in Figure 3.2.7 are reasonably complex, since mackerel, swimbladdered fish and zooplankton are identified. The biological samples are also reasonably good since a 3-bag multi-sampler trawl (Engås, 1997) was used. Figure 3.2.7 a-d, f-g show the pre-processed echograms at their original frequencies. Figures 3.2.7 e and h show the relative frequency response, r(f), of the encircled region, of which all but the first in Figure 3.2.7. e is believed to be due to backscatter from mackerel. Note that most schools are at a too long range for the 364 kHz data to be used by the identification algorithm, which makes the low value of r(364) of no importance for identification of mackerel at these depths. The 364 kHz data are not used by the categorization system at depths below 90 m when drop-keel-mounted transducers are used (Ona and Traynor, 1990).

The three polygons marked in Figure 3.2.7f shows what the trawl was believed to catch in each of the three bags. Note that the acoustic registrations was first passed, then the ship turned, and finally the trawl was set out to catch, i.e., at the third time the registrations was passed. In the catches, there are three acoustic categories of importance: fish with no swimbladder (mackerel), fish with swimbladder (herring, saithe, horse mackerel), and a target resonant at 18 kHz (pearlside).

The catch-ability of mackerel is thought to be low compared to herring with the trawl and trawl-speed used by RV "G.O. Sars" (2) and (3). For 35 cm fish, 1 kg herring give the same backscatter as approximately 4 kg mackerel. If the catch-ability of mackerel is 25% of herring (which is not unreasonable), and mackerel only give 25% of the backscatter at 200 kHz compared to herring, the fraction mackerel of the biomass in catch would be comparable the fraction backscatter of mackerel at 200 kHz. Based on this argumentation, and the catches in the three bags, the following acoustic abundance is expected in the regions marked by the polygons:

- Left polygon: Mackerel biomass: 10% Expected acoustic abundance at 200 kHz: 10%
- Middle polygon: Mackerel biomass: 25% Expected acoustic abundance at 200 kHz: 25%
- Right polygon: Mackerel biomass: 10% Expected acoustic abundance at 200 kHz: 90%

What was found in the catches were 60% of the fish-weight was mackerel in Bag 1, and 100% in Bag 2 and Bag 3. Although this is not a perfect match, it is still reasonable.

Figure 3.2.8 show the 200-kHs echogram masked with different combinations of categories. Figure Figure 3.2.8.a shows some "peak" categories, Figure 3.2.8.b fluid-like zooplankton, Figure c swimbladdered fish, Figure 3.2.8.d mackerel, and Figure 3.2.8.e mackerel and the pixels that are still of unknown category.

Algorithm applied on a subset of available frequencies

Figure 3.2.9a-e shows the implemented algorithm applied on a subset of the available acoustic data. In Figure a, only 38 kHz and 200 kHz data are used, in Figure b 38, 120 and 200 kHz, in Figure c 38, 70 and 200, and in Figure d 38, 70, 120 and 200 kHz as compared to Figure 3.2.9c and 3.2.9d where all frequencies, 18, 38, 70, 120, 200 and 364 kHz were used to identify mackerel. There is surprisingly little difference between the result using only the two most important frequencies 38 and 200 kHz as compared to the one using all frequencies.

The rightmost school is used as reference, by noting that the best estimate of the correct acoustic abundance of the school at 200 kHz is “1076”. This is not much more than “1052” (98%) found by using two frequencies at 200 kHz and data at all frequencies give “1064” (99%) when all frequencies are used. It is, however, not possible to recognise equally many acoustic categories when only two frequencies are used as compared to using six.

Verification of mackerel identification algorithm implemented by IMR

The algorithm was developed using data collected until 2003, but is verified on data collected in 2004. The relative frequency response is the most important acoustic feature of the mackerel identification algorithm. The method was verified by Korneliussen and Ona, 2004b.

Figure 3.2.10 shows comparison of the manual scrutiny and the result of applying the implemented algorithm on the 2004 data. The blue diamonds show the result of scrutinizing the acoustic data in a 0.1 nautical mile resolution aided by trawl samples. The square root of the acoustic abundance at 200 kHz, $\sqrt{s_{A,200kHz}}$, is plotted as a function of distance. The use of square-root scale vertically shows small values better than linear, but does not exaggerate the small values as the use of logarithmic scales does. The automatic categorisation, showed as orange diamonds in the same figure, gave a total acoustic mackerel abundance of 95% of the abundance found through manual scrutiny.

The result of the manual scrutiny give exactly the same acoustic abundance for the manual scrutiny as for the automatic categorisation that clearly demonstrate the validity of the algorithm. Note that the relative frequency response, r(f), calculated from prior to 2004 was used in the algorithm. The r(200kHz) have been slightly lower for EK60 than for EK500, but in the data used to calculate r(f), most data (except 2003 and some test data in 2002) is collected using EK500. Preliminary tests have shown that the precision of the algorithm applied on 2004 data improves when r(200kHz) used in the implemented program is reduced slightly. Note that in 2004, there were unusually many schools at large depths in the Norwegian Trench compared to the previous years (1999–2003). At large depths, there is a tendency that r(200kHz) is reduced, although that may be due to limitation in useful range in the 200 kHz data.

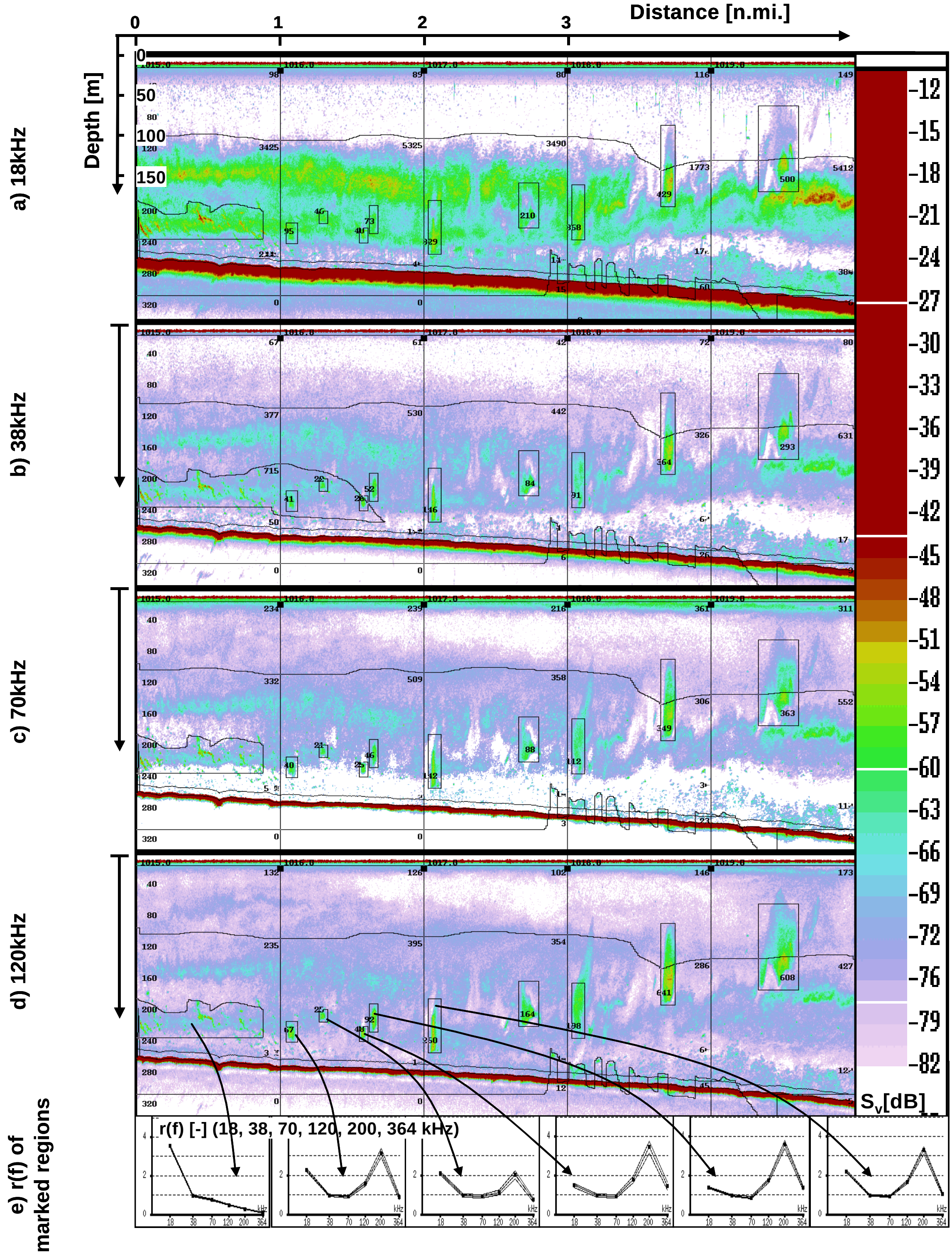

Figure 3.2.7 (a-e). Fairly complex registrations. Acoustic multi-frequency 5 nautical mile echograms collected in the North Sea 2003.10.26 7:36-8:50 (UTC). The data are first smoothed with Gaussian averaging diameters 7.5 m horizontally and 0.75 m vertically, and then corrected for noise. The colour scale is shown in the right part of the figure. The depth scal is shown in the upper left part of the figure. The six curved in Figure e are the backscatter relative to backscatter at 38 kHz for the encircled regions.

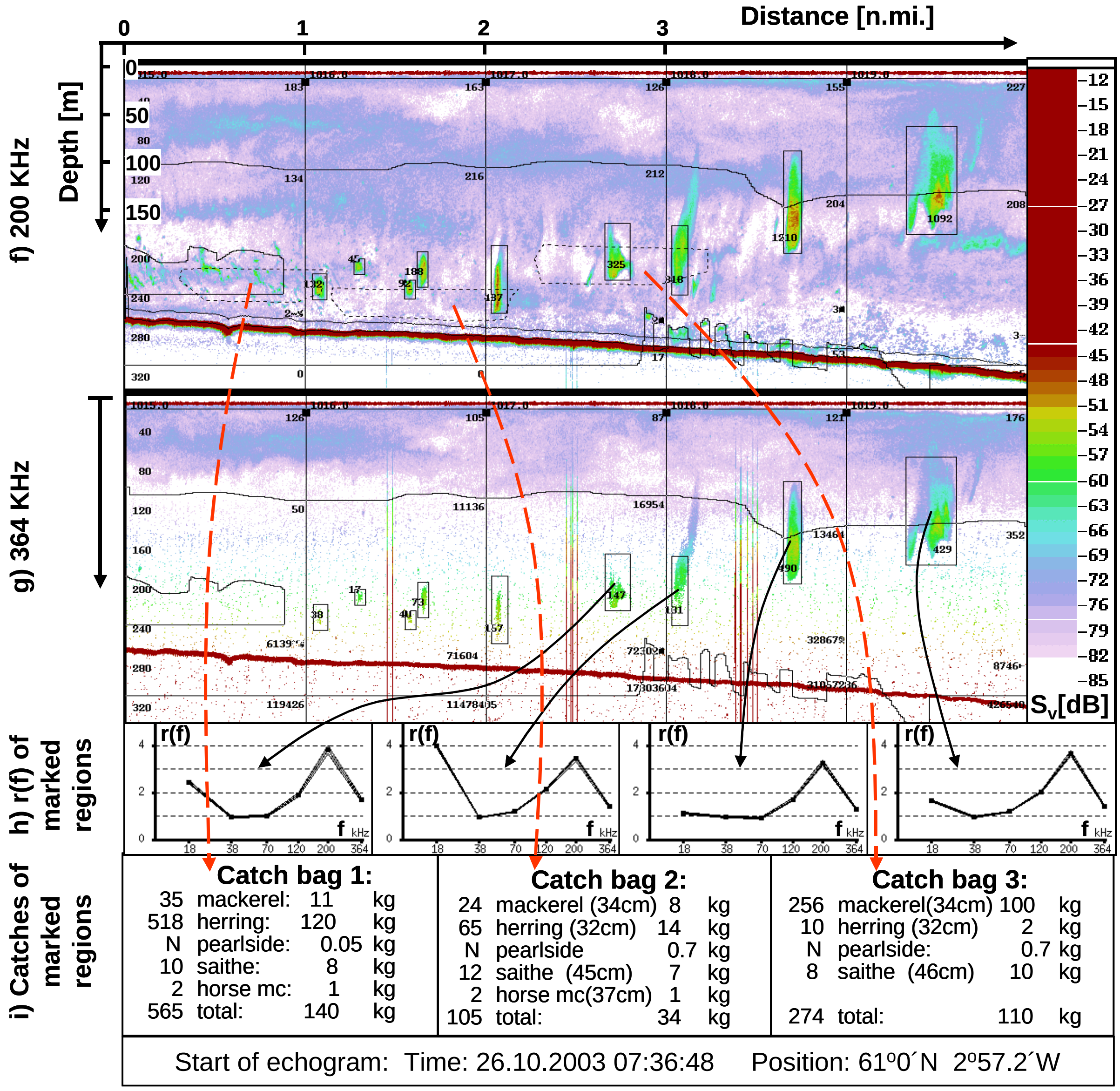

Figure 3.2.7 (f-i). The 200 kHz and 364 kHz data are shown at the top. In the 200 kHz echogram, the three polygons mark each of the three bags of the opening-close trawl system. The catches are shown in Figure i. The vertical dark-red lines in the middle of Figure g is due to noise.

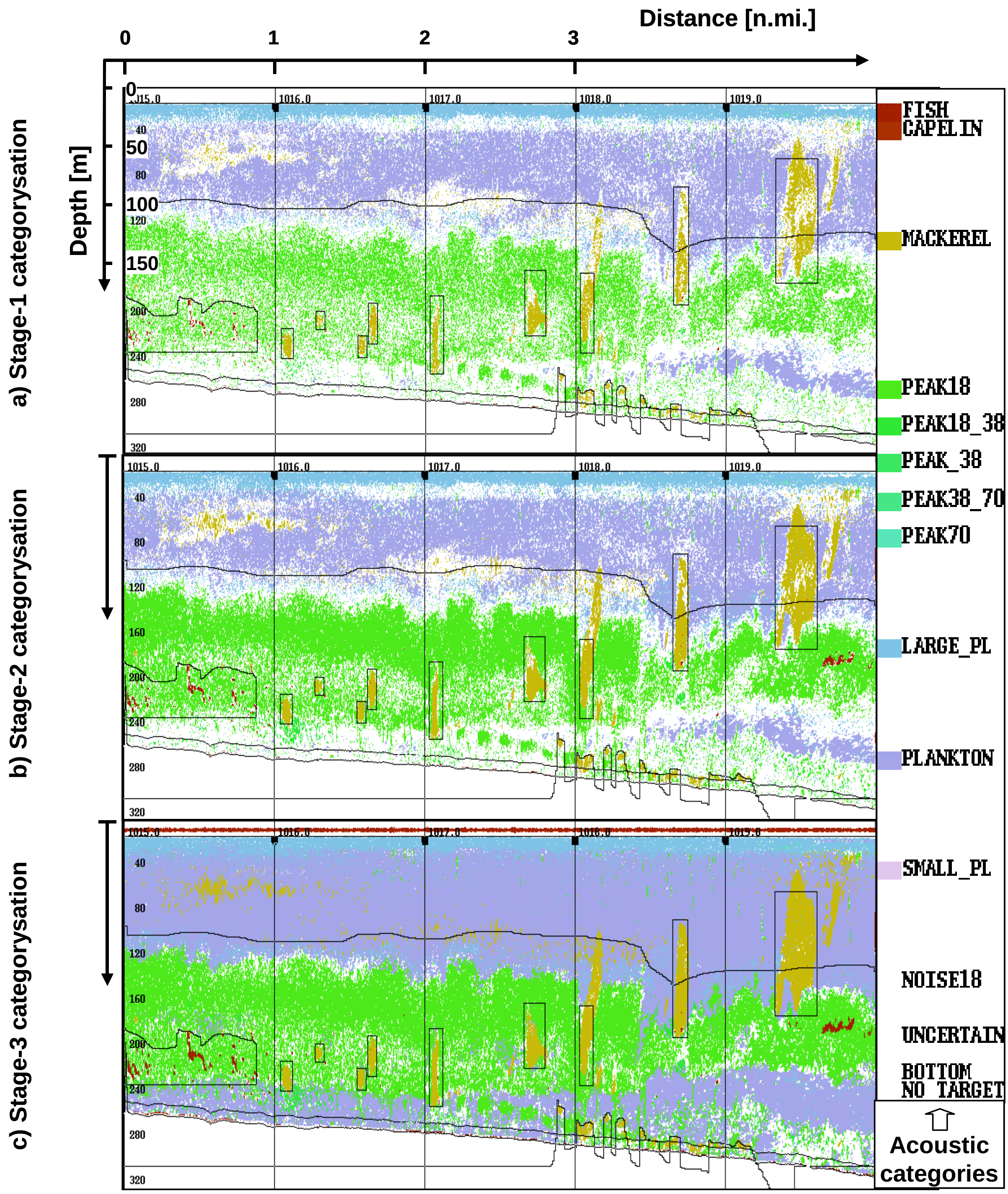

Figure 3.2.8. Output from each of the three categorisation stages when all algorithms are applied. Figure c show the final outcome of the last stage. The colour-scale (right) shows which categories were found.

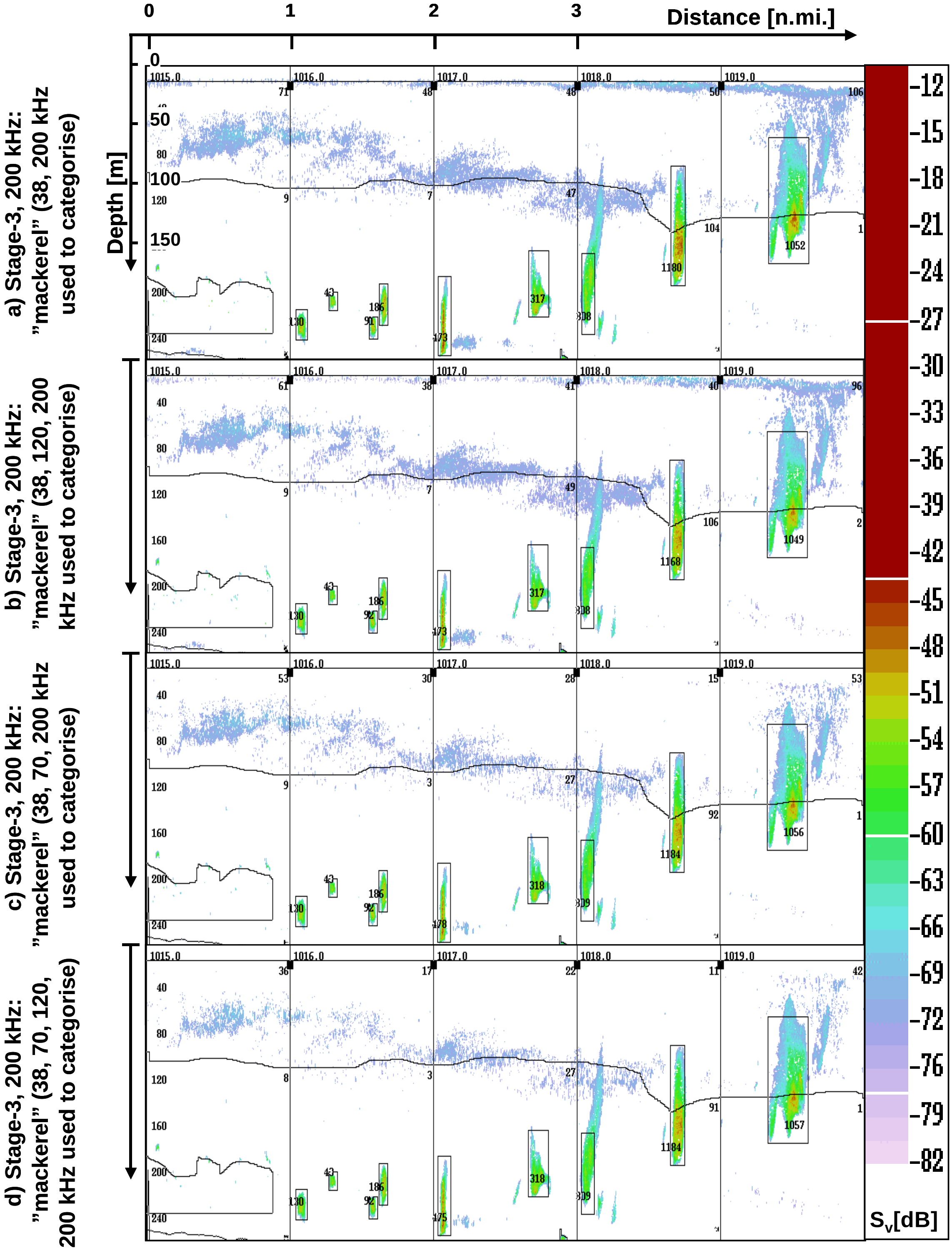

Figure 3.2.9. The 200 kHz data as in Figure 3.2.8f, masked with the pixels identified as mackerel.

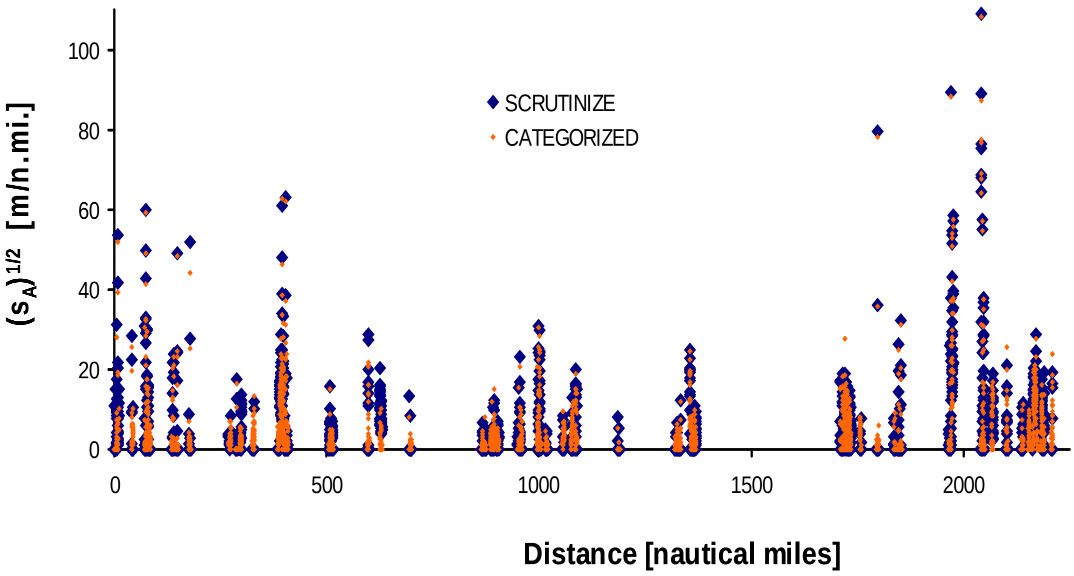

Figure 3.2.10: Validation of algorithm precision by comparing acoustic data from the 2004 North Sea survey at a resolution on 0.1 nautical miles. The blue diamonds are the acoustic mackerel abundance due to traditional scrutinizing aided by the trawl samples. The orange diamonds are the similar results of the automatic categorization. In total, 95% of the original acoustic abundance at 200 kHz was found by the categorization. In addition a part of the category "uncertain" was thought to be mackerel.

Discussion of the mackerel identification algorithm

The relative frequency response, r(f), has been used by IMR to identify mackerel during many years, and the result of the identification seems to be reliable. The r(f) has been investigated through many years, and it seems to be most stable at 38, 70 and 200 kHz. This is also confirmed by modelling (Gorska *et al*., 2004a, b, 2005). The use of the additional frequencies 18 and 120 kHz is also valuable for the identification of mackerel, but may be even more valuable to identify what is definitely not mackerel.

To stabilise the inherent stochastic nature of the acoustic backscatter and make them more comparable between the frequencies, the measurements are slightly smoothed. The measurements are also shifted vertically and horizontally to account for the total echo-sounder system delay and the transducer positioning by using non-symmetric weights in the smoothing-matrix. The use of smoothed data only has simplified the process of identifying mackerel (Korneliussen and Ona, 2003 as compared to Korneliussen and Ona, 2002).

There may be several species in a volume segment, but the categorization system will assign a maximum of one acoustic category to a single volume segment or to a pixel as it appears on the screen. Some acoustic categories are defined to allow for several species, i.e., "fluid-like-plankton" that may or may not be split into "small"- and "large-fluid-like-plankton". It is obvious that pixels that contain several species may be wrongly categorized. Korneliussen and Ona (2002; 2003) conclude that the categorization system works best for aggregations of the same species. This is confirmed here.

The Figures 3.2.7–3.2.9, and numerous examples not shown here, seem to confirm that the mackerel identification algorithm is really able to identify mackerel, at least in a broad sense. The trawl samples confirm largely the acoustic data, but due to the slow trawling speed of RV

“G.O. Sars” (2) and (3), the fast swimming mackerel has a greater ability to avoid the trawl than most other fish. The common strategy of trawling is first to pass the acoustic registrations to assure that the collected acoustic data are largely undisturbed from avoidance reactions, and then to turn the ship for trawling. Mackerel, as other fish, may then be at another location than originally, so that the trawls hit different schools than expected. Even if the trawl hits the mackerel school as desired, mackerel is found from video-recordings to sometimes swim faster than the trawl, and may therefore also avoid it easily. The trawl speed of 4 knots is known to be too slow for efficient trawling of mackerel.

The verification of the mackerel identification algorithm can be done by using biological samples in at least three different ways. The simplest way is to use trawl samples as an indicator of species only. This method is considered too subjective to verify the acoustic data. Another way is to consider the result of trawl sampling as an equally good estimator of abundance as acoustic measures. The second method is not considered to be very good either, due to the way the trawling is done (pass registration – turn, and pass again – turn and trawl while passing third time) that disturbs the fish, and due to the low trawling speed at RV “G.O. Sars” (2) and (3) of 2.5 and 4 knots which mackerel can outswim. IMR will surely get new survey-trawls in the future able to be towed at higher speed. The trawling speed of RV “Scotia” used to verify the S_{id} algorithm was somewhat higher than for RV “G.O. Sars” (2) and (3).

The third method of verification is the one used: the automatic algorithm is compared to the manual scrutiny. The acoustic abundance of the manual scrutiny is after all used to calculate the biological abundance. A team of three has scrutinized the acoustic data of the IMR mackerel surveys to have an objective result of the interpretation process. The team consists of the chief scientist, a scientist, and the chief instrument acoustician, and represents high expertise in the biology of mackerel, the scattering characteristics of fish, and performance of instruments and trawls. The interpretation process is slightly described in Korneliussen, 2004.

Figure 3.10 shows that there are not many differences in the manual and automatic identification of mackerel even at the high resolution of 0.1 nautical miles. This means that there is neither large over-estimates nor under-estimates at any single 0.1 nautical mile distance-segment. This is considered to be good. The automatic identification of mackerel gives 95% of the acoustic abundance of the manual scrutiny, which is considered to be acceptable. Note however that the r(200kHz) used in the algorithm is mainly based on measurements done with EK500, and that the latest survey in 2004 has not got any weight. An updated r(f) gave a slightly better result.

The main reason for using an acoustic frequency above 200 kHz was to verify that 200 kHz is on the stable, flat region illustrated in Figure 3.4. If the 200 kHz data are in this flat region, it is expected to follow a similar TS-size relationship as at 38 kHz, i.e., something close to 20log10L-B. Since the backscatter of mackerel at 200 kHz is verified to be 4 times stronger than at 38 kHz, and since also many swim bladder fish has weaker average backscatter at 200 kHz than at 38 kHz (Foote *et al.*, 1993, Pedersen *et al.*, 2004), the TS of mackerel could increase as much as 8 dB compared to swim bladder fish. The consequence of wrongly identifying e.g., herring as mackerel will then be reduced in an acoustic abundance estimate.

Due to the problems of the 364-kHz data, the stable region is still not satisfactory verified. The original frequency of 400 kHz could not be used to verify the stable region since the strength non-linearly generated 400-kHz second-harmonic of 200 kHz was large enough to make the linear 400 kHz data unusable. The frequency of the of the electronic part of the echo sounder was therefore reduced to 363.6 kHz, but it turned out that the 400-kHz transducer was not operating optimally at that frequency, partly due to a deformed beam-shape, partly due to the short range, and partly due to the third-harmonic generated sound from the 120 kHz echo sounder (really 121.2 kHz). The solution seem to be to reduce the frequency further, e.g., to 333 kHz, and to make a new acoustic transducer resonant at 333 kHz. However, even if the value of r(364kHz) cannot be trusted, the measurements in both 2003 and 2004 indicate that r(364kHz) has a value comparable to r(200kHz), so that intuitive shape of r(f) in Figure 3.4 is supported, but still not fully proved. The full modelling of mackerel backscatter (Gorska *et al*., 2005) supports this conclusion.

Automatic identification of any acoustic registration should never be trusted blindly. Therefore, the categorization system is implemented in at least one acoustic post-processing system (Korneliussen, 2004) where the identified acoustic categories of each pixel (volume segment) may be turned on or off at will at the acoustic frequencies. However, the backscatter is sometimes so complex that such automatic categorization systems will be a good help.

Conclusions

The algorithm for identification of Atlantic mackerel (*Scomber scombrus*) from multi-frequency acoustic information has been developed on acoustic data collected in the North Sea during 1999–2003, and acoustic data in measured in pen in 2002 and 2003. The main features used by the identification algorithm is the relative frequency response, r(f), and clustering. The main acoustic feature, r(f), has been verified through many years. The relation between 200 and 30 kHz, r(200kHz), has been reasonably stable through all years, and can therefore be trusted as the main component of the identification algorithm. The modelling work supports the original suggestion that backscatter at high frequencies (120 and 200 kHz) is stronger than t the low frequencies (18 and 38kHz), and have given a better understanding of the scattering mechanisms of fish in general, and mackerel especially.

Measurements r(200kHz) show diurnal variations, and that average r(f) may be depth-dependent. By weighting the measurements of r(f) from 2003 and 2004 higher than for the previous years, the implemented mackerel identification algorithm performs somewhat better.

The algorithm and has been verified on a new dataset collected in the North Sea in 2004. There is no single 0.1-nautical-mile segment of any of the verified echograms in 2004 where the mackerel identification obviously fails by either identifying much to large acoustic or much to small abundance of mackerel. The identification algorithm identifies 95% of the total acoustic abundance of mackerel.

The algorithm has been tested on different frequency combinations. The frequency combination 38 and 200 kHz works almost as well for the identification of mackerel as when all the frequencies 18, 38, 70, 120, 200 and 364 kHz was used on some selected sample datasets. When only two frequencies are used, however, the identification of many of the other acoustic categories than Atlantic mackerel fails.

The algorithm performs best on clusters of acoustic registrations, but is also capable of identifying schools that are contaminated by swimbladdered fish.

The use of synthetic echograms containing acoustic categories instead of acoustic frequencies, will give a fast overview of the species composition, and therefore also improve the quality of the interpretation process. The time needed to achieve a higher quality of the scrutinized data has been reduced compared to before at the same time as the resulting quality has been improved.

The mackerel identification algorithm is incorporated as a standard part of the BEI post-processing system, and is being integrated as a part of the routine tools to be used at IMR surveys. Each category identified can be “turned on” of “turned off” during routine operations.

3.3 The FRS mackerel identification algorithm

An alternative algorithm for the identification of mackerel was produced in a format that could be implemented in EchoView. The algorithm is known as the FRS mackerel algorithm (FRS is Fisheries Research Services). It is based on three frequencies, 38, 120 and 200 kHz, but the component which identifies mackerel concentrates on the difference between scattering at 38 and 200 kHz.

The algorithm primary requirements are the raw data, consisting of mean volume backscattering strengths (MVBS) at 38, 120 and 200 kHz. These are threshold at -100 dB to ensure that all operations are carried out on all data (copies are made of processed data and displayed at a more appropriate threshold e.g., -82 dB). Noise reduction parameters (Sv at 1 meter and absorption coefficient) were obtained from the FRS noise reduction algorithm. Finally, a specific dB-difference colour scheme (dB diff 40.evc) helps to display some of the interim processes.

The algorithm involves 31 steps and is implemented in Sonardata's EchoView software. Each step represents an operation which modifies a variable (the operand) to produce a new virtual variable (synthetic or virtual echogram). The full list of the steps are illustrated in the Figure 3.3.1. These can be broken down into 3 main processing sections. The first is preparation of the raw data (Figure 3.3.2a), removing noise at high frequencies (200 kHz) and removing echoes from the transmit pulse and seabed. These filtered data can then be displayed at a desired threshold (e.g., -82 dB Figure 3.3.2b). The next set of processes aim to identify echoes from potential fish schools using the simple three frequency filter to remove non-fish schooling targets such as plankton and small-bubbles. This results in a fish school echogram (Figure 3.3.2c). Mackerel targets are identified on the basis of the difference in Mean Volume Backscattering Strength (the decibel difference or ΔdB). These processes involve some image analyses to smooth the data, subtraction of the MVBS at 200 kHz from those at 38 (Figure3.3.2d), and selection of values for mackerel where ΔdB_{38-200}<-6 dB followed by further image analyses (Figure 3.3.2e). This value was determined from the analysis using the similarity of identification parameter. The final mackerel echogram (Figure 3.3.2f) is a combination of both the potential fish school candidates (Figure 3.3.2c) and potential mackerel (Figure 3.3.2e).

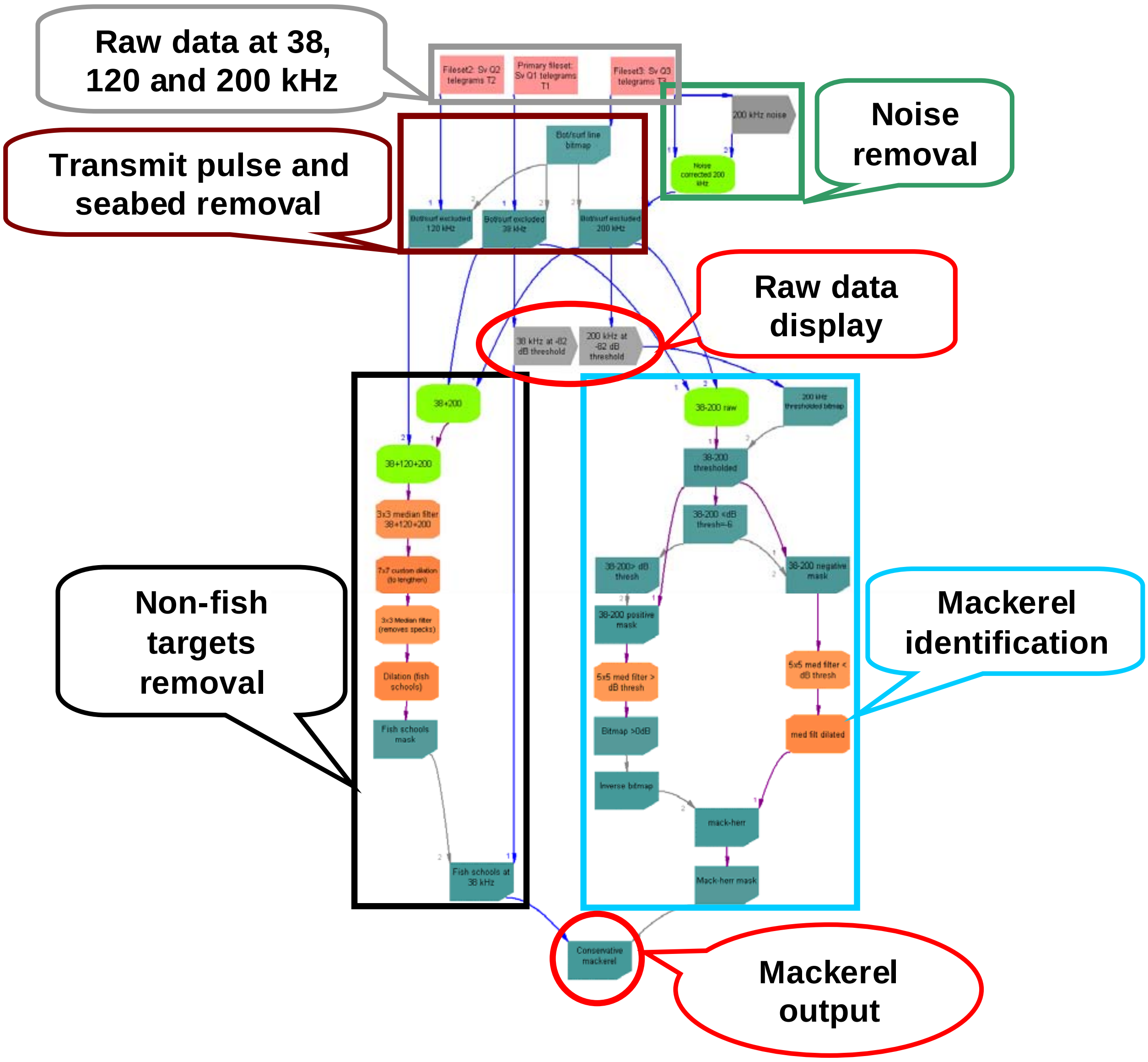

Figure 3.3.1. The FRS mackerel algorithm. Each of the small coloured boxes represents a processing step resulting in a virtual or synthetic echogram. The larger boxes represent sets of processing. Some of the more pertinent virtual echograms are illustrated in Figure 3.3.2.

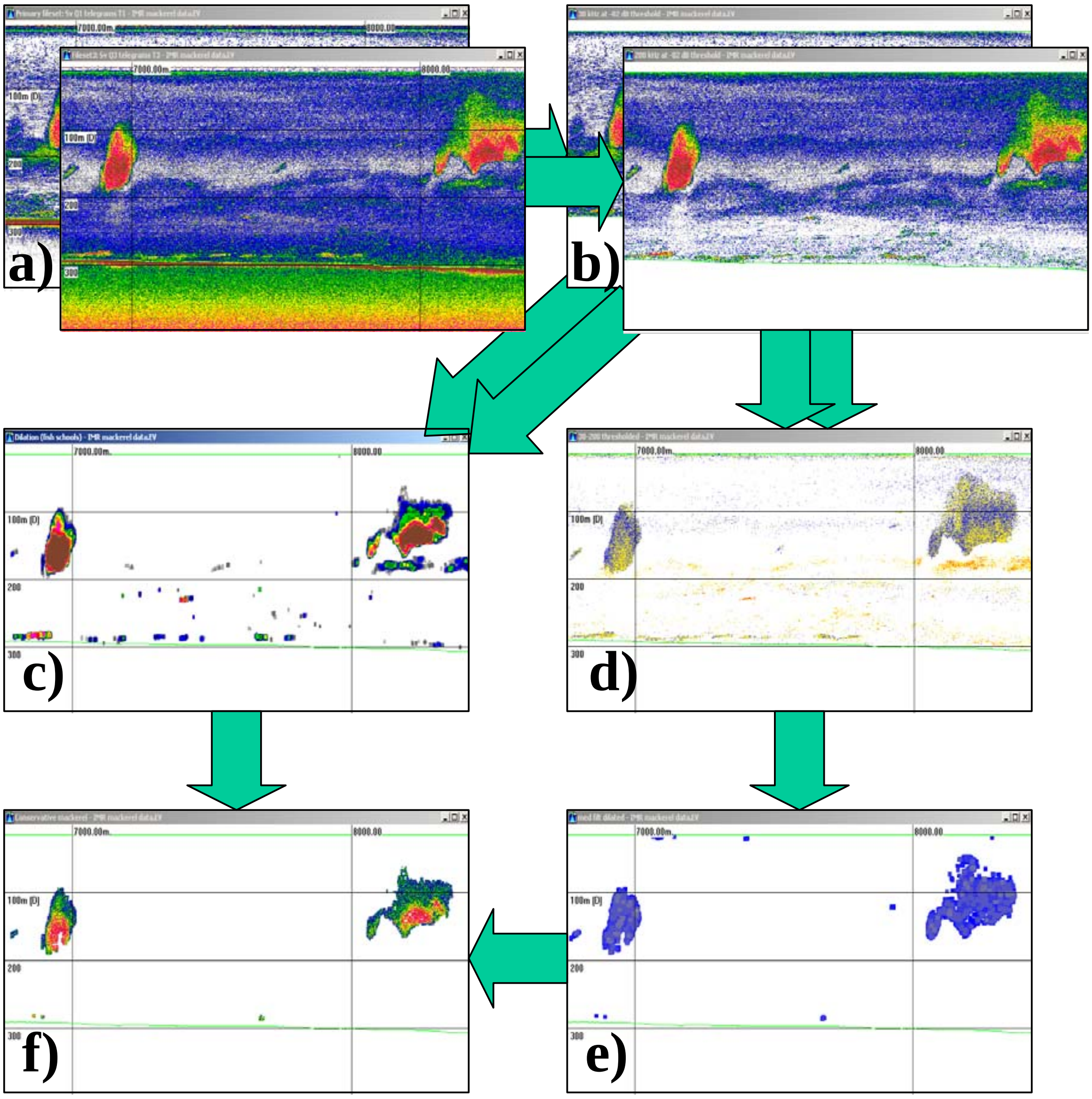

Figure 3.3.2. Six major processing steps in the FRS mackerel algorithm; the virtual echogram names are given in italics. a) Raw data (MVBS) at 38, 120 (not shown) and 200 kHz. b) 38 and 200 kHz MVBS filtered for noise, seabed and transmit pulse, 38 kHz at –82 dB threshold & 200 kHz at –82 dB threshold; the processed data are input to both of the following processes. c) potential fish school after non-fish filtration, Dilation (fish schools); d) 38-200 dB difference echogram, 38-200 thresholded; e) potential mackerel schools echogram, med filt dilated; f) final output, conservative mackerel echogram.

4 Acoustic survey procedures (ToR a, j)

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 still under development and many of the tools and protocols are subject to improvements. 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 herring acoustic 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 of the 2003 PGAAM report (Anon. 2003)). Where the procedures for mackerel surveys deviate significantly the text includes areas in **bold and underline** giving advice in these cases.

No suggestions or recommendations on its issue are available for the PGAAM as well as the situation with adaptation unknown at present time.

The PGAAM again advised all participants on mackerel investigations to examine this document with a view to updating its contents. 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. The manual is attached as Annex I in the 2003 PGAAM report.

5 Surveys in the Norwegian Sea (ToR a, b, e, f)

5.1 Surveys in 2004

5.1.1 Aerial surveys

Russian aerial surveys (airborne research) as an element of the mackerel annual investigations in the Norwegian Sea were carried out in the summer 2004. They were a joint Russian-Norwegian (PINRO-IMR) survey carried out under following:

- PGAAM recommendations,
- Protocol of the 32nd Joint Russian Fisheries Commission,
- By-literal agreement between Russia and Norway as well as between PINRO and IMR,
- Russian-Norwegian Programme for the investigations in the Norwegian Sea.

The principal purpose this research was carrying out of the airborne surveys (including joint researches with vessels) on study of feeding mackerel including receipt data about marine current conditions and also distribution and numbers of marine mammals and sea birds to receive information about their influence as predators on feeding mackerel stock. Thus, these researches were complex and had some ecosystem approach.

As in previous 8 years aerial surveys carried out onboard Russian research two-engine aircraft Antonov-26 (An-26) "Arktika" with using remote sensing equipment, main principles, and methods, which were presented in detail many times earlier (Anon. 2002, 2003, Zabavnikov *et al*., 1997). In 2004 airborne research was carried out during 11 July - 1 August in the area presented on Figure 5.1.1.1 During this time were made research flights with total duration about 90 hours. All the main flight tracks were oriented along latitudes with distance between it's no more than 45 n. miles. The total space of all flights track was about 13,500 n. miles.

As in previous two years during preparing of airborne research in 2004 were continued and made special works for modernization, development and improvement of Russian polarization aviation LIDAR (PAL-1), including hardware and software. These works and researches allowed expanding technical and researching PAL-1 possibilities for using of LIDAR methods in study of feeding mackerel. For example, in 2004 work was continued for more efficiency, reliably and quality mackerel schools identification and interpretation with using, so named "lidarogrammes". Example of it with using developed software for mackerel identification, including determination of geometric parameters is presented on Figure 5.1.1.2. In the future these researches and work will continue.

The main difference this airborne research in comparing previous years was using Norwegian LIDAR system (NLS) on board "Arktika". Three research flights were carried out with NLS in the end of July. The main difference from previous years was the use of the new Norwegian LIDAR System (NLS) on board "Arktika". Three research flights were carried out with NLS in the end of July as a part of the total lidar survey and also to test the new system. The system is very similar to the Russian PAL-1 and it was further tested onboard RV "G.O. Sars" during autumn (see Section 5.3).

During aerial surveys were registered 225 pelagic fish schools in total (by LIDAR, synthetic aperture radar – SAR and visual observations), who were interpreted as mackerel, among them 60% by LIDAR. The most part of mackerel schools was registered by two or three systems simultaneously and confirmed by vessels trawling if it's do it no later than 6 hours after mackerel schools recognizing from aircraft.

As showed results of airborne research the most meeting of feeding mackerel schools were registered in the Northern-West part of Faroese Fisheries Zone (FFZ), central and Southern-West part of International Water (IW), and the Northern border of the most density mackerel aggregation was located in 68°N. Also the local density mackerel aggregation was registered in the Norwegian Economical Zone (NEZ) with position of center 68°N/06°E.

Besides, under preliminary understandings and PGAAM-2004 recommendations were carried out joint research between "Arktika", from one side, Russian M/S "Persey-4" and Norwegian M/S "Libas" and M/S "Endre Doroy", from other side. This joint research included as surveys along the same tracks or part of its as 3 or more aircraft flights over vessels. This research was carried out on 18, 22, and 25 July. Here were got a good correlation between aircraft remote sensing data and vessels (in situ) data as in comparing of oceanographic data (SST, depth of picnocline bedding, transparency and under surface plankton concentration) as mackerel schools discovering and other results of acoustic surveys and LIDAR measuring.

The map of the mackerel distribution during July 2004 designed according to airborne and vessels investigations, is presented in Figure 5.1.1.3.

Under above carried out research were defined more precisely some aspects of feeding mackerel distribution and migration, got and accumulated new data, including LIDAR data, that can extend knowledge about feeding mackerel behaviour. The same information can be used in preparing of the main principles for feeding mackerel biomass calculation.

5.1.2 Norwegian trawl survey

Between 15 July – 1 August two Norwegian commercial purse seiners, "Endre Dyroy" and "Libas" carried out a trawl survey at prefixed stations. M/S "Endre Dyroy" started in the south and worked northwards while M/S "Libas" started in the north and worked southwards. Both vessels trawled the surface layer (the upper 40 m) at each station for 30 minutes. The largest catches were taken in the southern area, while the catch rates in the international zone were relatively low. The largest mackerel were caught in the Jan Mayen area. For details see Section 8.3.

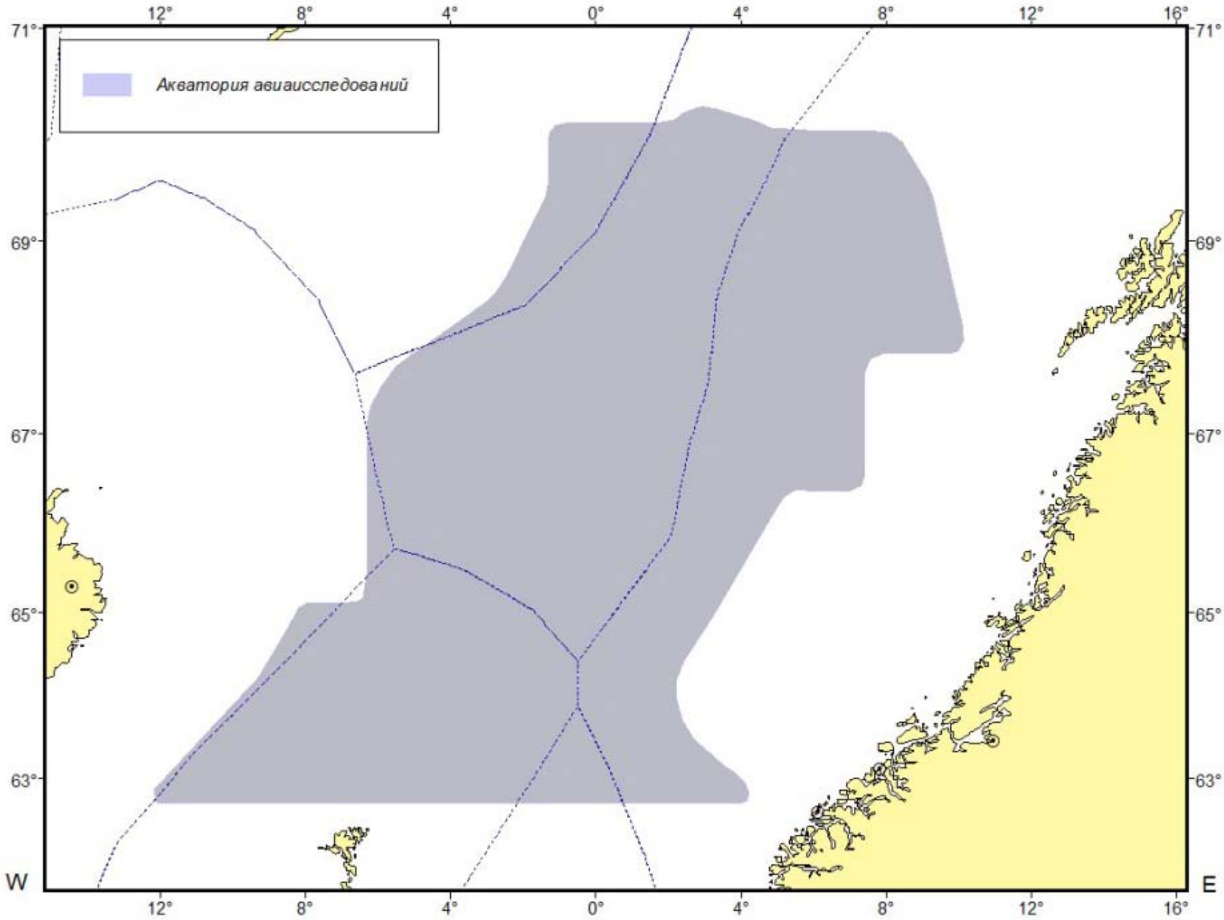

Figure 5.1.1.1 The area of the Russian airborne mackerel investigations in summer 2004.

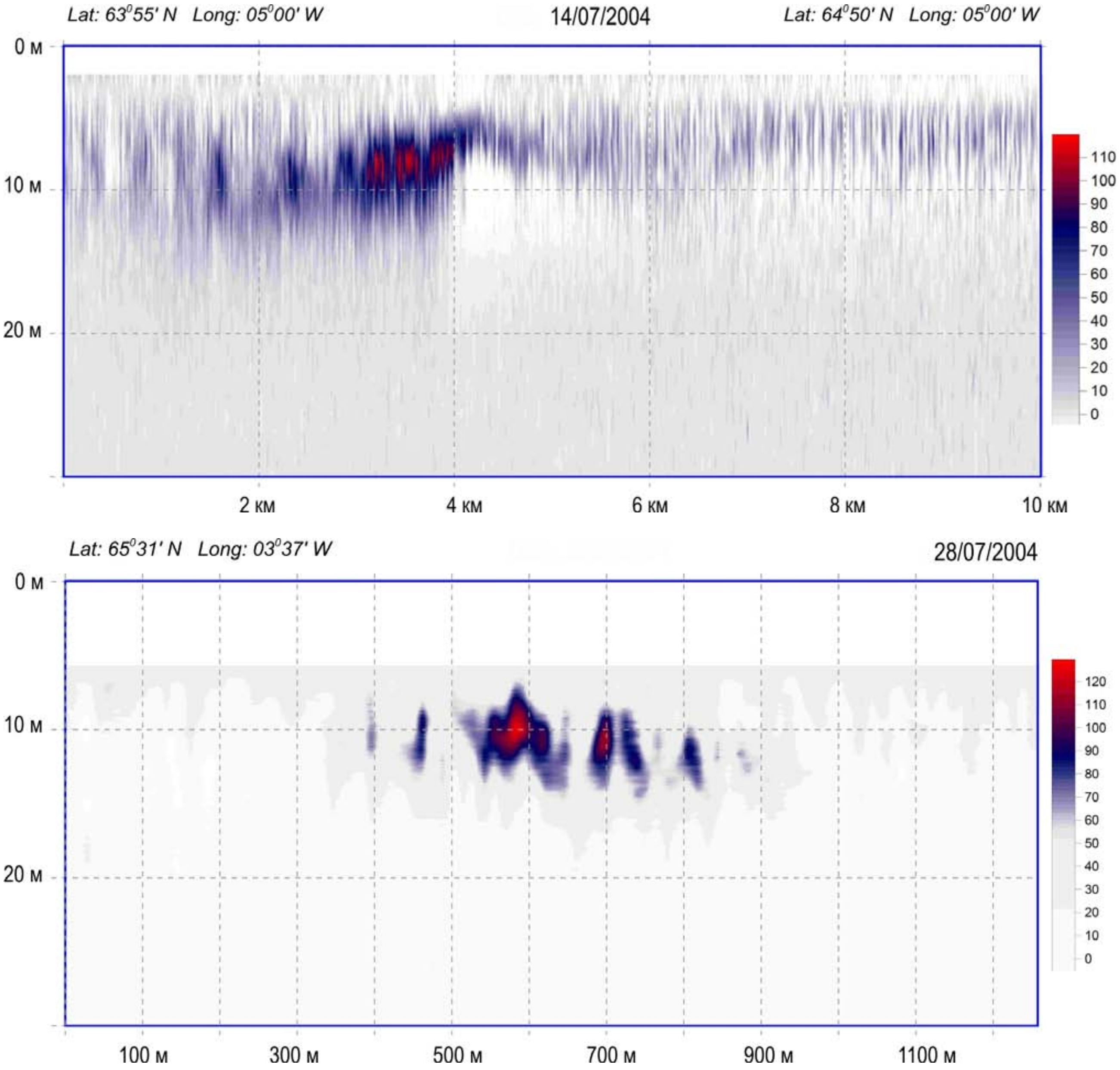

Figure 5.1.1.2. Example of the "lidarogramme" with the plankton concentration and mackerel (above) and mackerel schools aggregation cleared from plankton and noises (below).

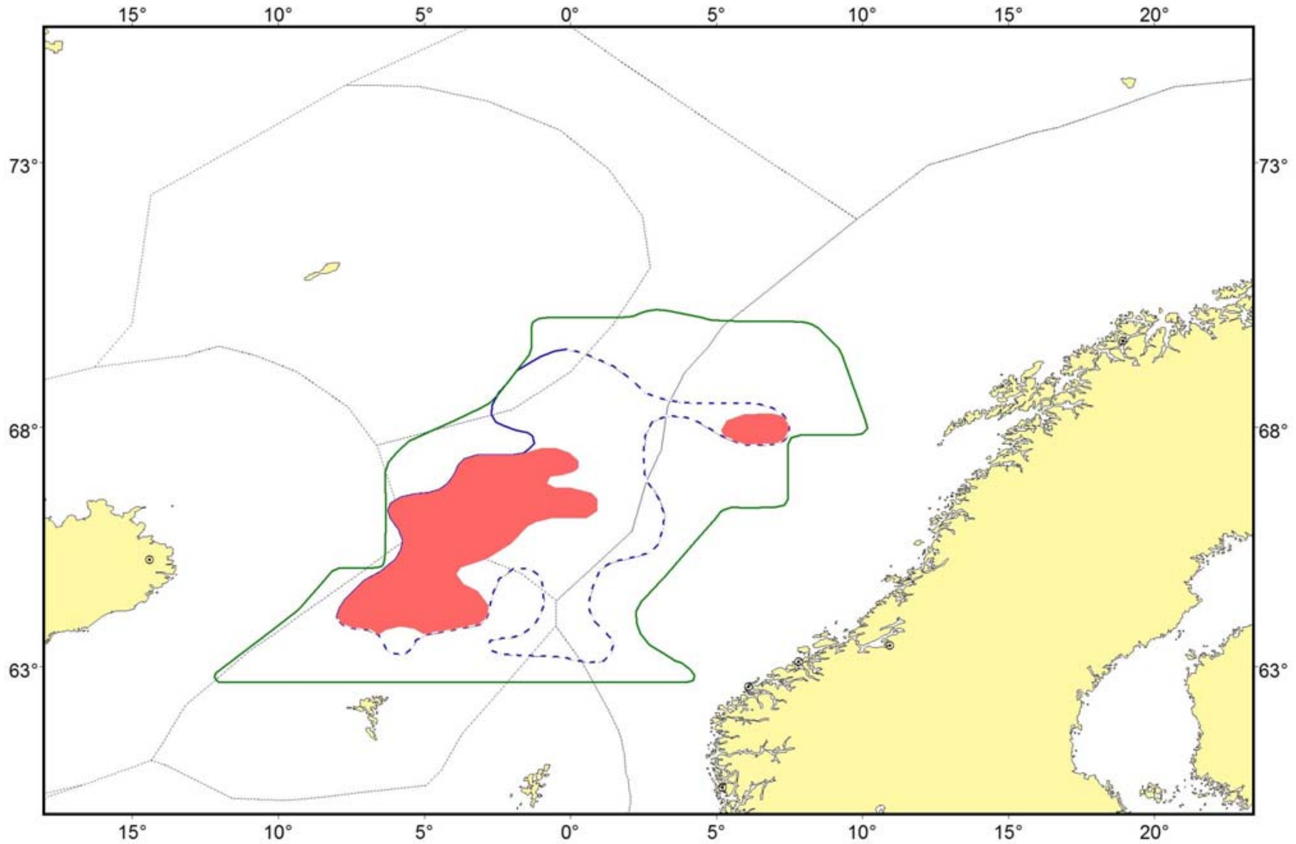

Figure 5.1.1.3. Mackerel spatial distribution in the Norwegian sea, July 2004

5.2 Aerial survey in the Norwegian Sea in 2005

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). Russia plans to cover the same area as in 2003–2004 with about 80 flight hours during the period late June – end July. The main part of research flights will be carried out in the International waters and nearby areas 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.

During aerial surveys plan to continue joint aircraft-vessels experiments and research with using of Russian and Norwegian vessels. For that purpose prepare proposals for Program of joint research, which will be considered in detail and agreed during the closest time and then signed (no later than begging of June).

Detailed plans for the joint airborne remote sensing and vessels surveys between Russia and Norway will be corrected once more before surveys. The Russian and Norwegian contact persons for the joint research will be Vladimir Zabavnikov (ltei@pinro.ru copy inter@pinro.ru) and Eirik Tenningen (eirik.tenningen@iMrno) respectively

The Russian aerial surveys will, if possible, be assisted by a Faroese commercial vessel working in the FFZ during second part of July. Aspects and possibilities of this cooperation will be agreed by correspondence in May-June 2005. The Faroese contact person is Jan Arge Jacobsen (janarge@frs.fo).

The Russian aerial surveys will probably also co-operate with Icelandic Marine Research Institute on pelagic fish stock distribution and abundance in the western area.

5.3 LIDAR onboard RV “G.O. Sars”

To compare LIDAR data to acoustic measurements the Norwegian LIDAR was mounted on RV “G.O. Sars” during the annual autumn mackerel survey. The LIDAR collected data from the surface down to about 30 m and these data were compared to the echosounder data from the EK60. During the first part of the cruise the schools were too deep to be observed by LIDAR and during the whole cruise vessel avoidance was a problem. A few small schools were observed and an example is presented in Figure 5.3.1. The lidargram shows a small school close to the surface and in the blind zone of the echosounder.

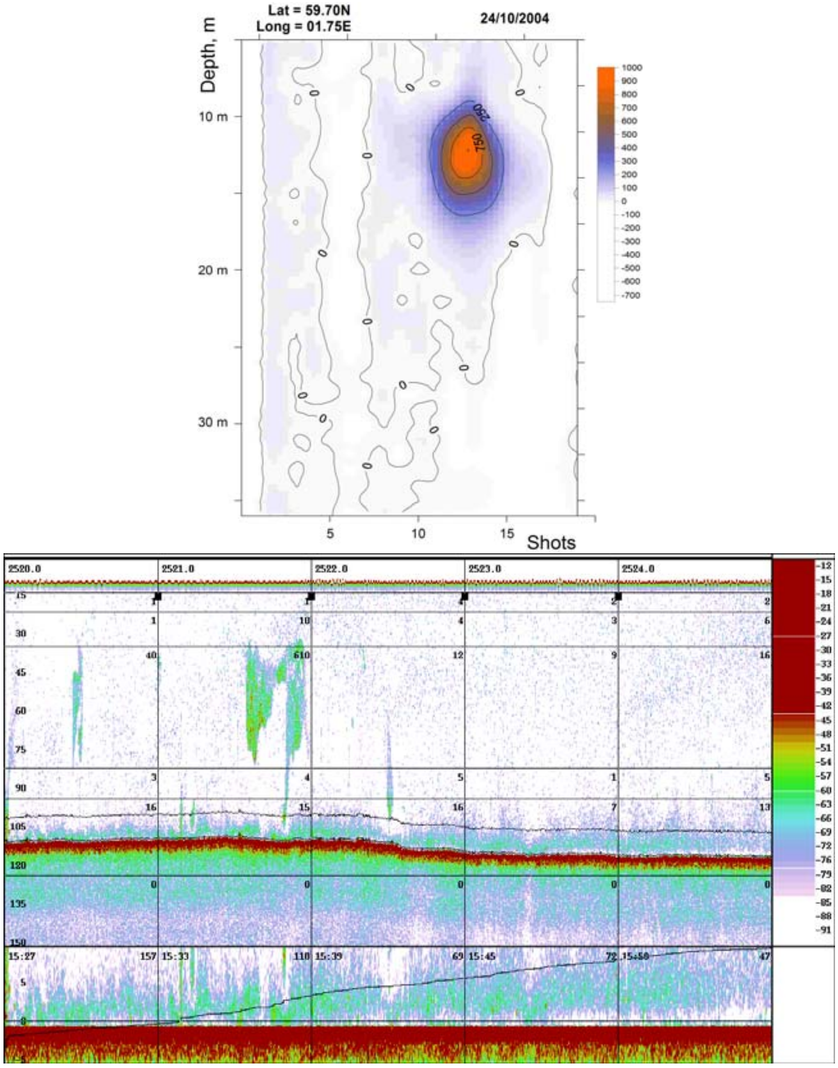

Figure 5.3.1: Lidargram (left) showing small school close to the surface. This is in the blind zone of the echosounder, whereas the schools in the echogram are too deep to be observed by LIDAR.

6 Acoustic surveys in the North Sea – Shetland Area (ToR a, c, d, e)

6.1 Acoustic surveys for mackerel in autumn 2003

6.1.1 Norwegian survey

The 2004 survey from 18 October to 8 November (Korneliussen *et al*. 2004), was a continuation of surveys from 1996, 1997, 1999, 2000, 2002, and 2003, with the main purpose of finding distribution of Atlantic mackerel during fall annually, and to estimate abundance through acoustic methods. In 1996 and 1997, a standard version of the scientific echo sounder EK500 was used. From 1999, techniques for multi-frequency data-collection and post-processing were developed systematically. RV "G.O. Sars" (2) was used until 2002, as that was the best available vessel for multi-frequency data-collection. During the years 1999 – 2002, a special version of EK500 was used to improve multi-frequency analysis of the acoustic data, with the same pulse-duration 0.6 ms on all available acoustic frequencies, 18, 38, 120 and 200 kHz. Experience gained through the early years of this period was used as input to Simrad AS when the new scientific echo sounder EK60 was developed and modified, and when the new research vessel RV "G.O. Sars" (3) was designed. EK60 was tested during the survey in 2002, and was used through the whole survey when RV "G.O. Sars" (3) entered service in 2003.

The mackerel distribution in 2004 was similar as in 1999 – 2003 (Figure 6.1.1.1), most of the schools were observed in Norwegian waters along the western side of the Norwegian trench. The acoustic biomass estimate of 375 thousand tonnes in 2004 was the lower than in previous years (Table 6.1.1.1). Note that the ship did not have permission to enter British waters in 1999, and did not have permission to trawl in British waters in 2002.

There may be a potential problem of gear selectivity affecting the acoustic estimates. During these surveys the mackerel has been sampled with a small pelagic trawl (20 m opening) at a speed of 3–3.5 knots, and the age, length and weight has been measured for use in the biomass estimation. Slotte *et al*. (WD this working group) has demonstrated that the size, both in terms length (mean length and length at age) and condition (weight at length), of mackerel caught in the research vessel trawl hauls is significantly lower than that observed in the purse seine catches from nearby commercial vessels (Figure 6.1.1.2). By using data from purse seine caught mackerel instead of the trawl caught ones, the biomass during 1999–2003 increased with 30% on average. These results also signify the importance of being careful with using research vessel trawl haul samples in any biological study concerning variations in growth and condition of high speed swimming species like mackerel.

1 n.mi. bottom depths recorded acoustically during all surveys 1999–2004 was used to make a 3D map of the bottom topography in the surveyed area, and the average depth of mackerel based on 1 n.mi. data from the same period was marked in the same map (Figure 6.1.1.3). This 3D perspective demonstrated that mackerel schools followed the bottom depth, and in fact they were found down to depths of 300 m and even deeper. The reason for this behaviour became more apparent when the horizontal and vertical distribution of schools was related to temperature (Figures 6.1.1.4–5). In 2003 and 2004 CTD stations were taken both inside and outside the mackerel distribution area, to study potential relations between environmental conditions and mackerel migration behavior. From a 2D perspective it seemed like the mackerel these years avoided water colder than 9°C (Figure 6.1.1.4). When the depth of 9–10 °C isoclines in 2003 and 2004 were and the related to the average depth of mackerel in a 3D perspective (Figure 6.1.1.4), the reason for the very deep mackerel school observations also became clearer. It seems like the mackerel follows this isocline. Due to the tongue of warm At-

lantic water entering from the north along the western side of the Norwegian trench, this isocline is very deep.

Table 6.1.1.1: Area, time, length, weight and total biomass based on acoustic registrations 1999 – 2004.

YEAR	DATES	AREA	AVERAGE LENGTH [CM]	AVERAGE WEIGHT [GR.]	BIOMASS [X10^3 TONN]
1999	12. Oct. – 22. Oct	Norwegian waters north of 59°N	34.9	358	828
2000	15. Oct – 5. Nov	North of 57°30' N	32.8	286	541
2001	8. Oct. – 25. Oct.	North of 57°30' N	36.3	418	409
2002	15. Oct – 3. Nov	North of 59°N partly with RV "Scotia"	33.3	295	535
2003	16. Oct – 6. Nov	59–62°N; 1°W – 4°E partly with "Scotia"	33.0	296	581
2004	18. Oct – 8. Nov	59–62°N; 1^0 W – 4°E with RV "Scotia"	34.1	322	375

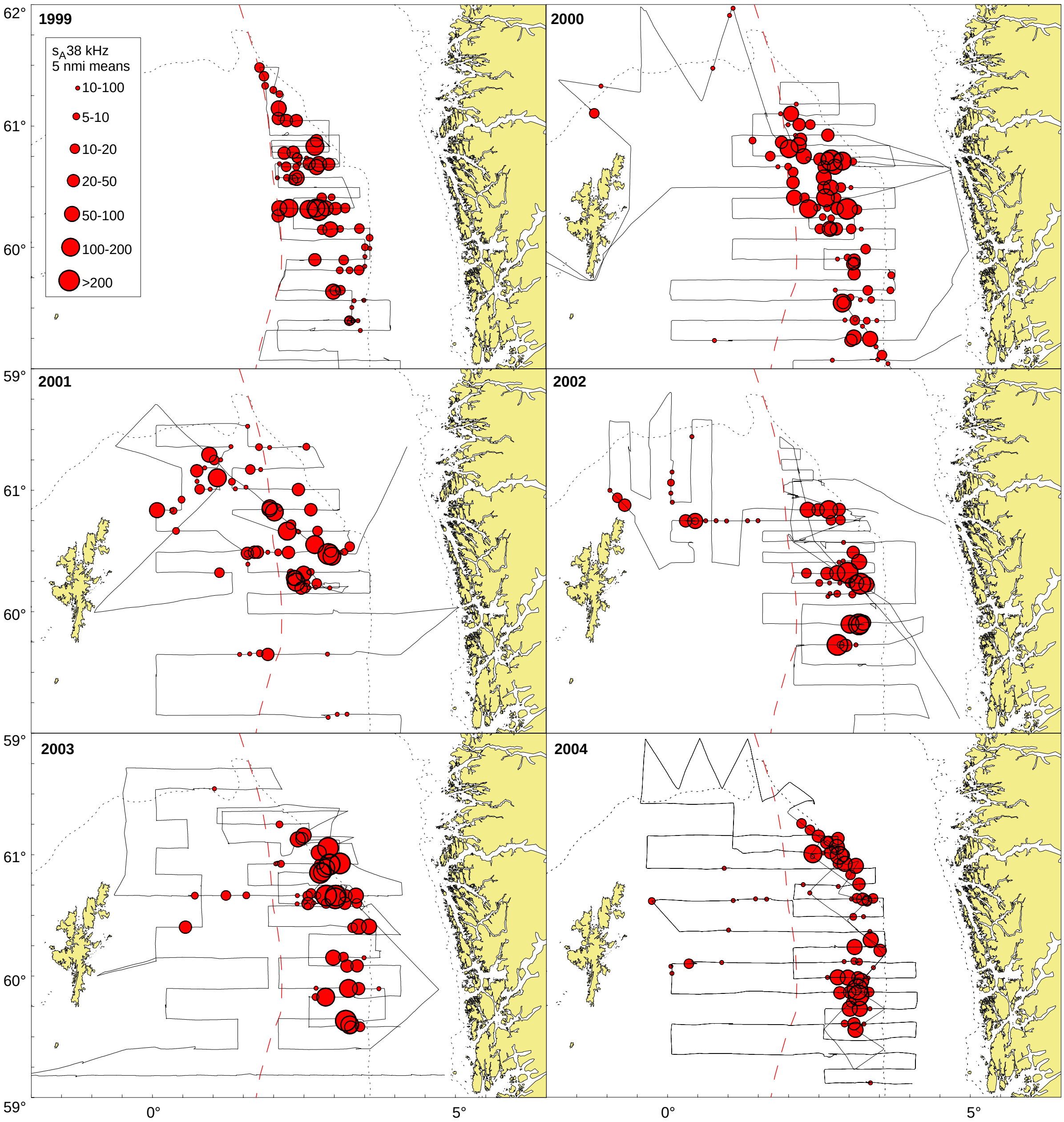

Figure 6.1.1.1. Distribution and density (in terms of s_A) of mackerel during October-November in the years 1999-2004. The size of the discs show the area density averaged over 5 n.mi. sailed distance.

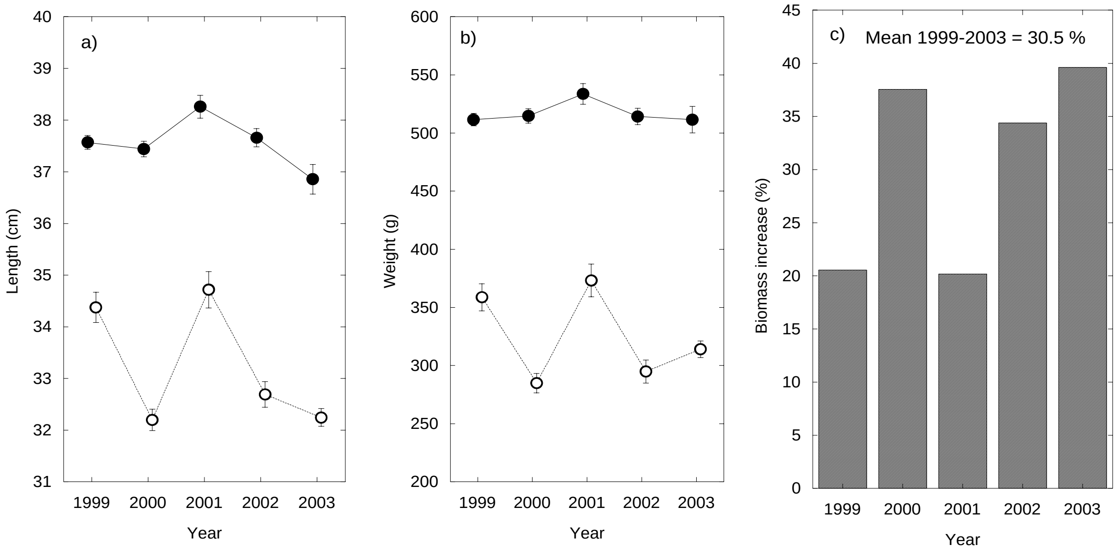

Figure 6.1.1.2. Total length (a) and weight (b) of mackerel in ICES Area IVa during autumn related to year and catch gear; commercial purse seine catches (filled symbols) and pelagic trawl catches (open symbols) from the Norwegian RV "G.O. Sars". Mean values ± 95% confidence intervals are given. The increase (%) in the acoustic the coherent biomass estimates with use of purse seine samples instead of trawl samples from the research vessel.

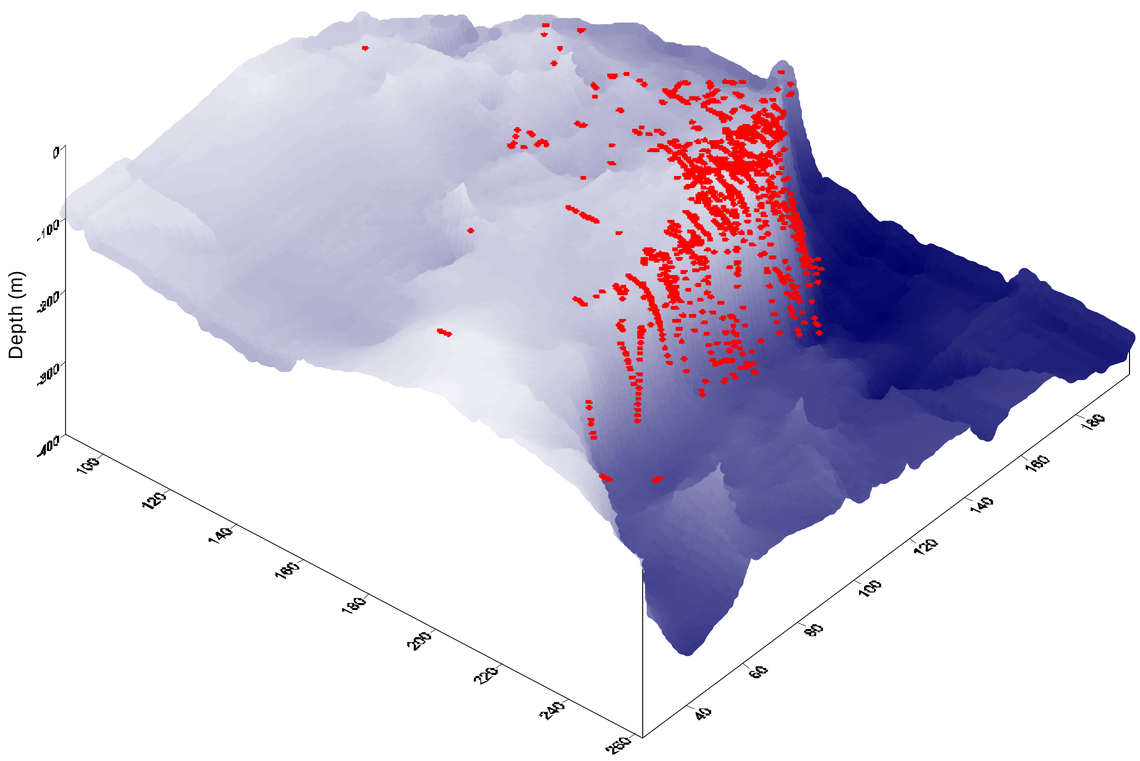

Figure 6.1.1.3. Bottom topography of the surveyed area based on 1 n.mi. bottom depths recorded acoustically during all surveys 1999-2004. The average depth of mackerel based on 1 n.mi. data from the same period is marked with red spots.

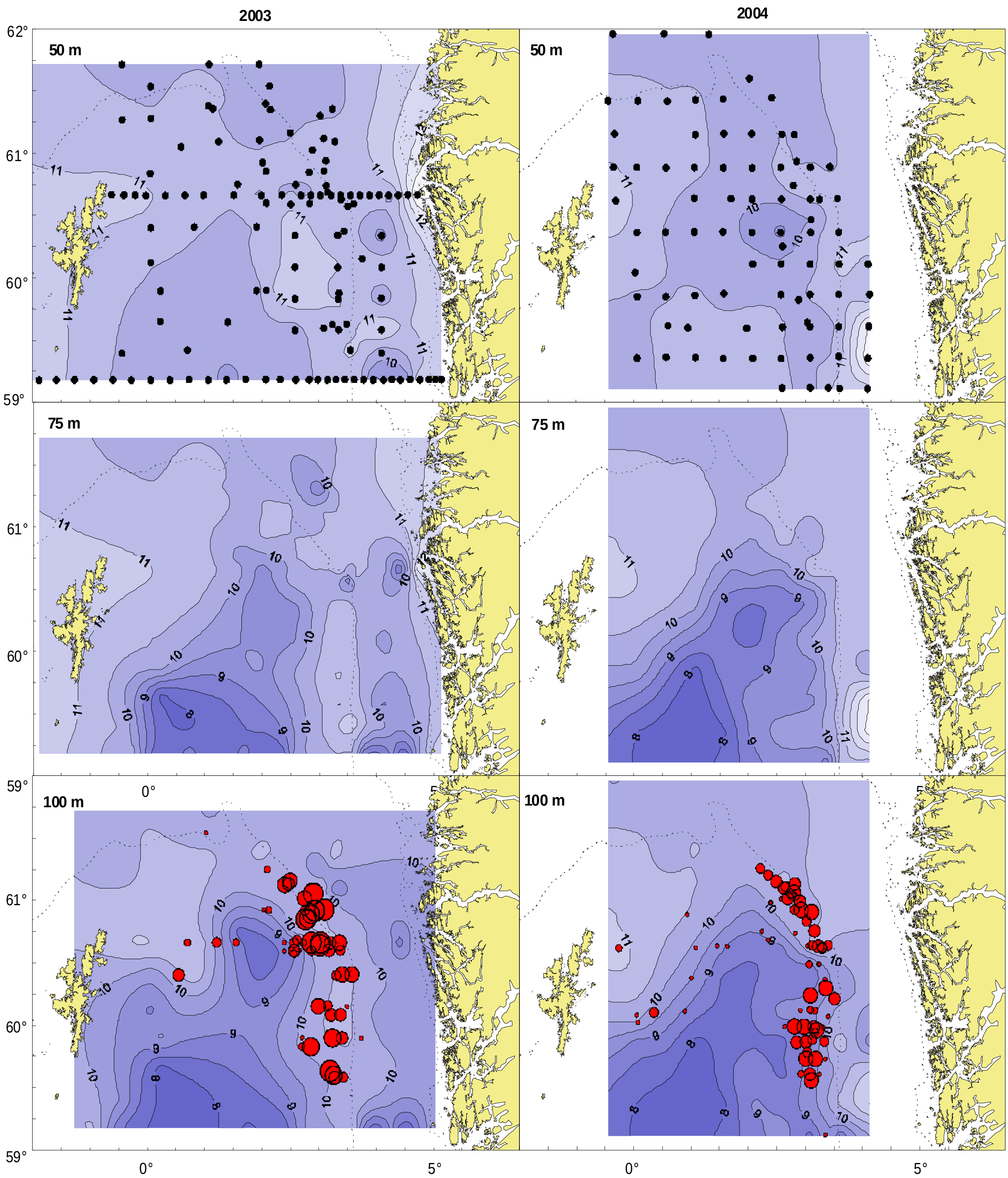

Figure 6.1.1.4. Temperature contour plots at various depths (50, 75 and 100 m) in the surveyed areas in 2003 and 2004. The belonging CTD-positions are given in the upper panel. The related mackerel distribution, as from Figure 6.1.1.1, is given in the bottom panel.

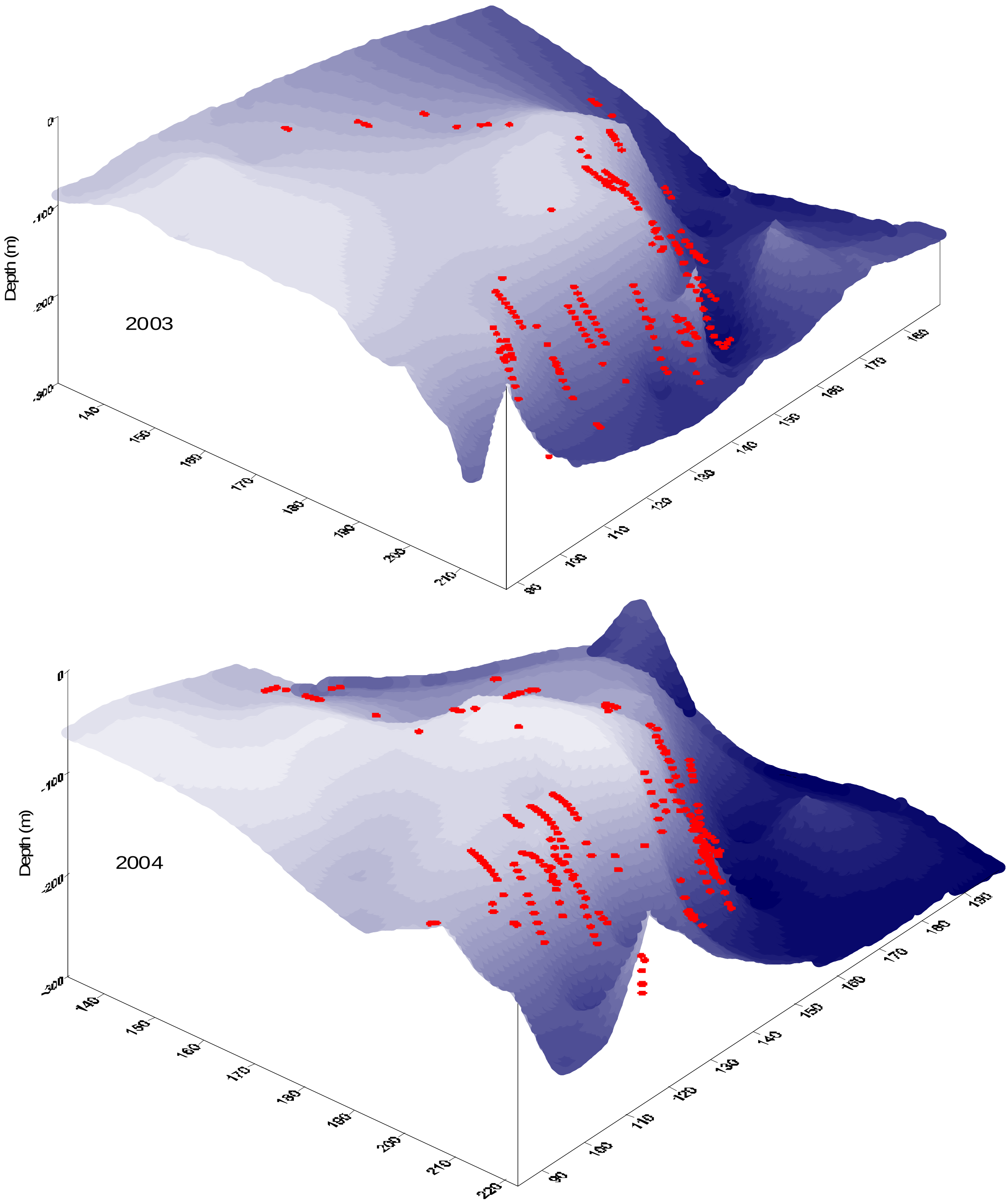

Figure 6.1.1.5. The depth of 9-10°C isoclines in 2003 and 2004, and the related the average depth of mackerel (red spots) based on 1 n.mi. acoustic data.

6.1.2 Scottish survey

The 2004 North Sea mackerel acoustic survey by Fisheries Research Services (Aberdeen, Scotland) was carried out by Scotland in October and November 2004. This survey is the third carried out by the Marine Laboratory in the current series. (Note: The survey was done in the same place and time as a similar one done by IMR in Norway). The survey covered the main area of mackerel concentration along the 200 m contour in the north-eastern North Sea.

The survey design (Figure 6.1.2.1) was selected to cover the area in two levels of sampling intensity based on fish densities found in 2002 and 2003. Areas with highest intensity sampling had a transect spacing of 15 nautical miles and lower intensity areas a transect spacing of 30 nautical miles. The track layout was systematic with a random start point. Between track data were discarded at the end of all transects. The survey area was limited to the nearest whole ICES rectangle beyond the 200 m contour to the north and east; to the Scottish coast or the 0° line to the west; and to 59°N to the south.

Two surveys were carried out using the same rational behind the design as described above. The first encompassed the entire area and was carried out by RV “Scotia”. The second was an interlaced design with RV “G.O. Sars” and was restricted to the area close to the 200 m contour.

Acoustic data were collected with a Simrad EK500 scientific multifrequency echosounder (38, 120 and 200 kHz) and an 18 kHz Simrad EA500 echosounder adapted for scientific research. Echo integrator data was collected from 13 metres below the surface (transducer at 8 m depth) to 0.5 m above the seabed.

Acoustic data were averaged in 15 minute equivalent distance sampling units (EDSUs) which, at a survey speed of 10 knots, represented 2.5 n.mi. per EDSU. Echo traces from mackerel were distinguished on the basis of the difference in acoustic return between the 38 and 200 kHz frequencies, using the latest version of the FRS mackerel identification algorithm, which was displayed in real time (assisting the direction of ground truth trawl hauls).

The data were then analysed using a refined version of the FRS mackerel identification algorithm. This algorithm provided NASC values for mackerel which were processed using Marine Laboratory Echo Integrator Survey Logging and Analysis Program (MILAP).

Target strength to length relationships used, were those recommended by the Planning Group for Herring Surveys (Anon., 1994):

Mackerel: $TS = 20\log_{10}L - 84.9$ dB per individual

As expected, most of the mackerel were detected close to the border between EU and Norwegian waters, towards the east of the survey area around Viking Bank (Figure 6.1.2.2). Overall, the survey proved very satisfactory. Considerable numbers of large mackerel schools were detected, and most of these were successfully ground truthed with pelagic trawls. The mackerel were contained within the survey area.

The survey estimates for the first survey carried out solely by RV “Scotia” were as follows:

Total mackerel weight:	433,479 tonnes
Total mackerel no’s:	1,169.51 million

A breakdown of the estimates by age class is given in Table 6.1.2.1.

Table 6.1.2.1: Results of the Scottish mackerel acoustic survey 22 October – 5 November 2004. Numbers are in millions of fish, length in cm, weight in grammes and biomass in thousands of tonnes.

Age	Number	Mean Length	Mean Weight	Biomass
0	34,39	22,71	118,66	4,08
1	29,85	29,62	278,08	8,30
2	778,13	32,26	359,47	279,71
3	205,73	33,35	400,92	82,48
4	66,04	34,98	465,41	30,73
5	29,66	35,08	472,12	14,00
6	14,66	36,04	510,31	7,48
7	6,53	37,53	583,82	3,81
8	2,09	39,65	690,29	1,44
9+	2,43	37,53	587,89	1,43
Total	**1 169,51**	**32,43**	**370,65**	**433,48**

The estimate of biomass based on the Scottish survey is likely to be an underestimate and possible reasons are either:

1) that the target strength function used is to low or;

2) the mackerel identification algorithms used are far too conservative or;

3) not all the mackerel stock are present within the surveyed area.

Successful fishing enabled a breakdown by age to be given: the year class strengths in the survey are similar to those observed in the fishery.

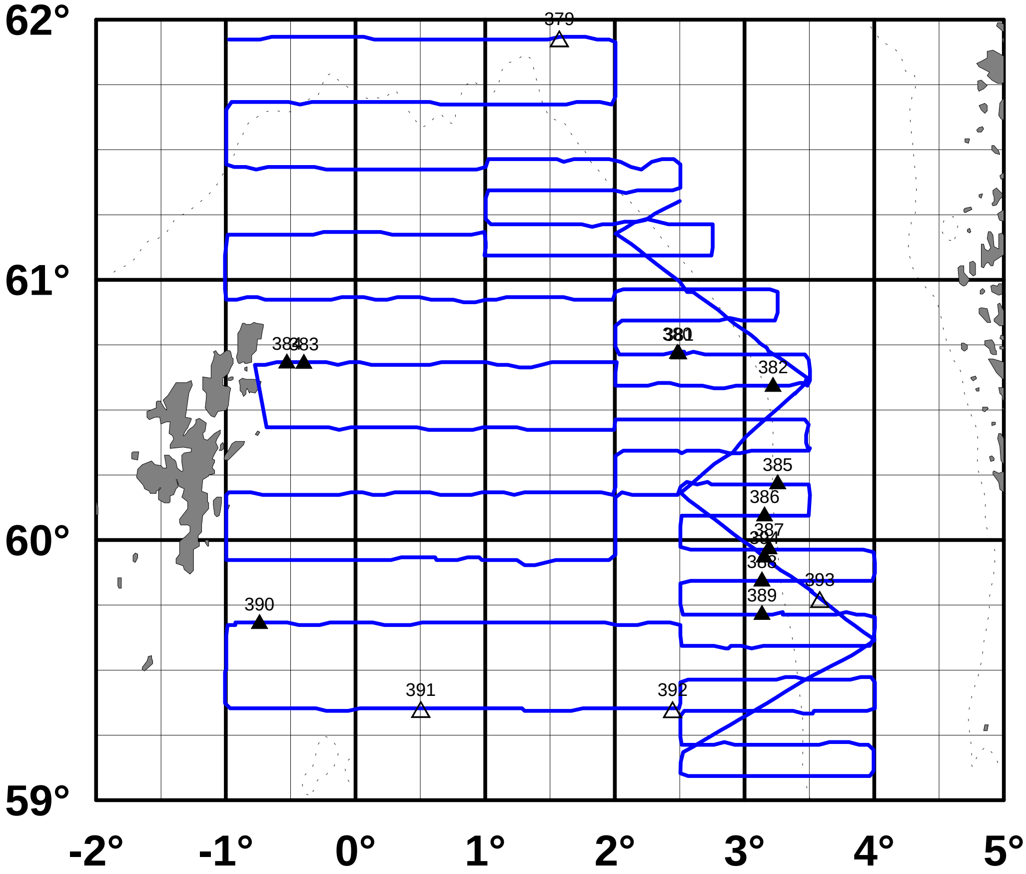

Figure 6.1.2.1: Cruise track of RV "Scotia" October 2004 mackerel acoustic survey (blue line). Triangles indicate positions of trawls (catches of mackerel are filled triangles; catches with no mackerel are open triangles; labels are trawl number). Zig-zag transects indicates the area surveyed by both RV "Scotia" and RV "G.O. Sars" to produce a combined estimate.

6.1.3 Combined estimate

During the 2004 acosutic surveys in autumn, there was a successful intercalibration between the Norwegian and Scottish vessels. The analysis of the intercalibration is not finished.

6.1.4 Intercalibration

The Norwegian and Scottish acoustic estimates of mackerel in the North Sea during autumn 2004 have not been combined yet.

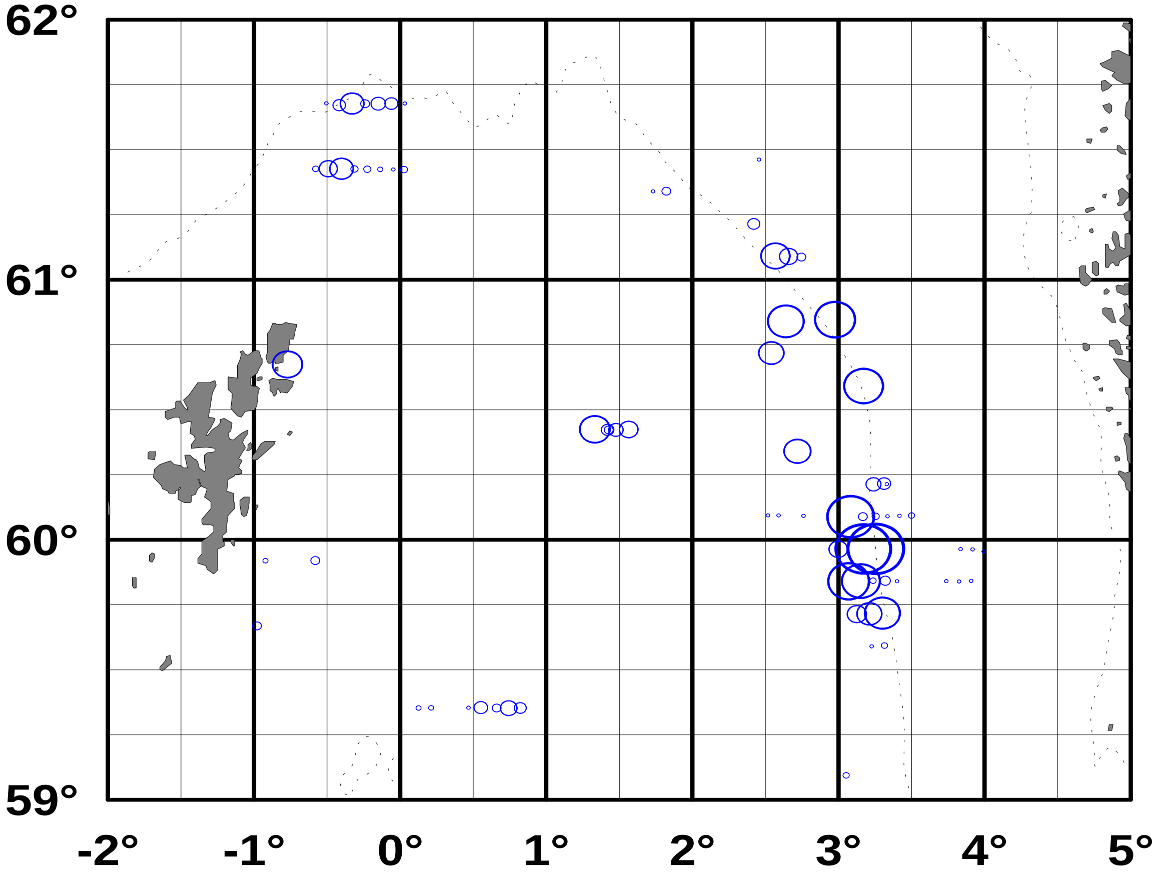

Figure 6.1.2.2: Map of the northern North Sea and a post plot of the distribution of mackerel. Circle size proportional to NASC attributed to mackerel in a 2.5 n.mi. EDSU, from the Scottish acoustic survey in October 2004; on a square root scale relative to a maximum value of 237 m^2.$nmi^{-2.}$

6.2 Acoustic surveys for mackerel in autumn 2004

Norway will continue to survey the mackerel acoustically i the autumn of 2005. The research vessel "G.O. Sars" will be used in the period 26 October to 19 November for this purpose.

There will be no Scottish acoustic survey for mackerel either in 2005 or in the foreseeable future. Priorities have changed and RV "Scotia" will now be conducting a monkfish trawl survey every autumn until 2008. There is no possibility that acoustic data for mackerel could be sensibly collected during this trawl survey. A three year review of the surveys will be presented to WGMHSA and they will be asked to evaluate the results and decide whether the surveys are suitable for assessment purposes.

7 Surveys in the southern area (ToR a, g)

Southern area (ICES Divisions VIII and IX) is routinely covered in spring by Portugal and Spain and surveys have been coordinated since 1997 (Anon 1997). France also undertook surveys in spring covering the French plateau. Since 1998, survey design and strategies are the same for the whole area (Anon. 1998).

The Planning Group for Acoustic Surveys in ICES Subareas VIII and IX was active until 1999. In 2000 and 2001 the acoustic surveys in these areas were coordinated under the DG XIV Project PELASSES. 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. The surveys cover large parts of the continental shelf in these waters. Even if the surveys are targeted at sardine and anchovy, they can also provide information and data on mackerel. This project finished in 2002 and the surveys in the Southern areas have not been coordinated since 2003.

Nobody from France, Portugal or Spain attended this meeting as well as no any information was available to the PGAAM 2005.

The PGAAM recommends to lift this issue on the national level in France, Portugal or Spain and to discuss on the WGMHSA meeting 2005.

8 Information from others surveys (ToR i)

The first PGAAM meeting presented a list of surveys in the North-East Atlantic not targeted at mackerel, but with potential to collect mackerel data to provide indices of mackerel abundance (Anon. 2003). Some surveys followed these recommendations and collected data and passed them to this planning group. Some of these results are presented below.

8.1 International ecosystem herring survey in the Norwegian Sea

Since 1995, the Faroes, Iceland, Norway, Russia, and the EU, have coordinated their survey effort on spring-spawning herring in the Norwegian Sea. The coordination of the surveys has enhanced the possibilities to assess abundances and distributions of the other pelagic fish species than herring. From 2004 this surveys included blue whiting as second main target species. The surveys have also provided information about general biology and fish behaviour in relation to the physical and biological environment.

These international surveys are coordinated by PGNAPES (Anon., 2004) and have provided oceanographic data as well as information about the distribution and abundance of pelagic fish species in late winter, spring and summer. The biological data on mackerel from these surveys are available for the PGAAM.

8.2 International blue whiting surveys west of the British Isles

Annual Russian-Norwegian surveys to estimate total and spawning biomasses of blue whiting have been carried out since 1983. The surveys are carried out during March-April in the deeper waters of the Faroese zone and in the shelf edge and bank areas west of The British Isles. These surveys might also be used for collecting biological data and provide estimates of mackerel abundance. To do this the present survey area has to be extended into shallower waters. In addition to Russia, Norway and EU to joined the survey in 2004. With this increased in effort some additional mackerel biological data are taken and given to the PGAAM. Therefore the PGAAM recommends that these investigations should also be targeting mackerel.

8.3 The Norwegian acoustic and trawl survey in the Norwegian Sea

In 2004, as in 2003, Norway carried out mackerel investigations during summer in the Norwegian Sea using two commercial vessels. During the period 17–30 July the vessels M/S “Endre Dyrøy” and M/S “Libas” surveyed the area, trawling at fixed positions (Figure 8.3.1) and logging data with sonars and echosounders. The acoustic data has not been analyzed yet. The largest catches (per nautical mile) were found in the south-western part of the investigated area, inside Faeroese waters and in international waters (Figure 8.3.2.). The size of the mackerel increased significantly with latitude, the biggest ones migrating farthest to the north (Figure 8.2.3). CTDs were also taken at each of the trawl stations, and Figure 8.2.4 shows the temperature distribution at 4 m depth.

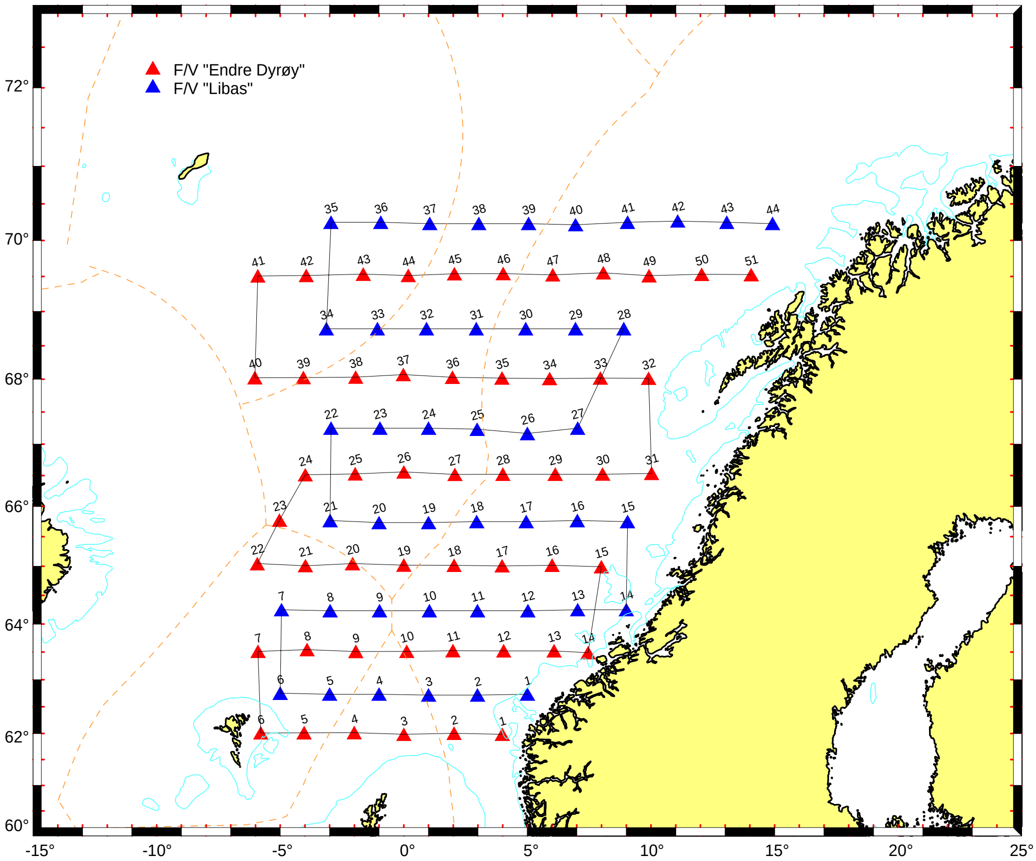

Figure 8.3.1: Norwegian M/S “Endre Dyrøy” and M/S “Libas” surveyed area during the period 17–30 July 2004.

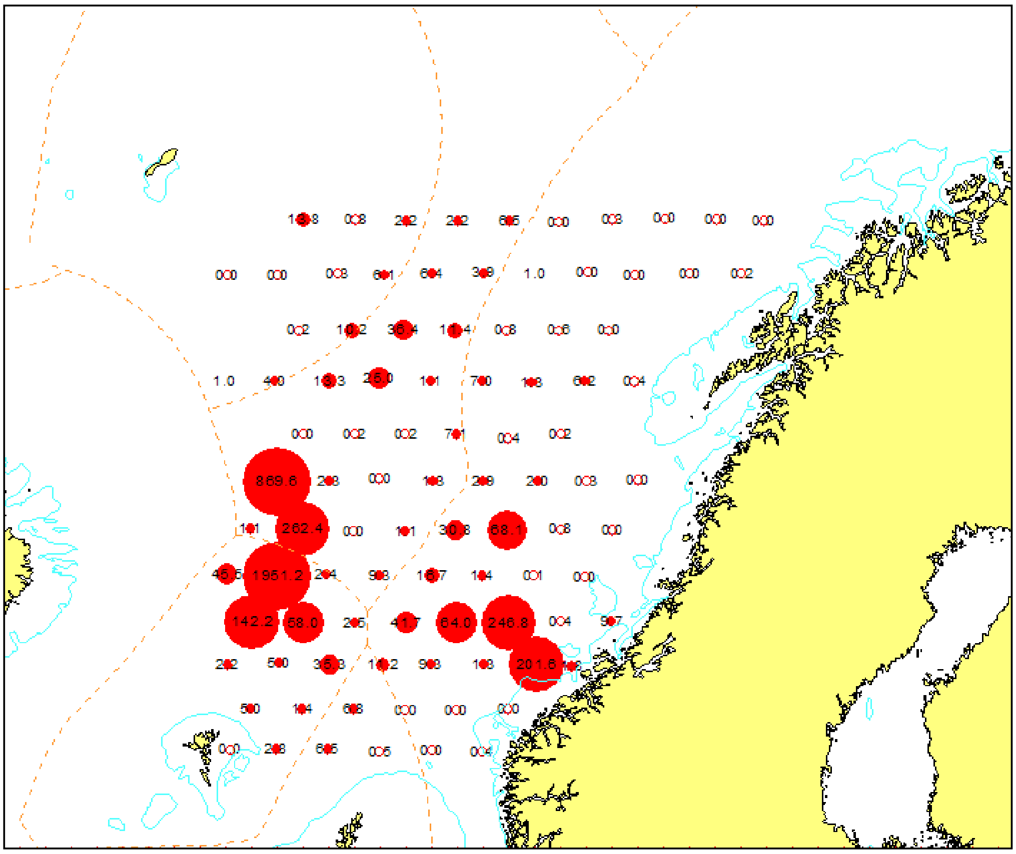

Figure 8.3.2: Distribution of mackerel catches given as kg/nautical mile, obtained by M/S "Endre Dyrøy" and M/S "Libas" during 15–31 July 2004.

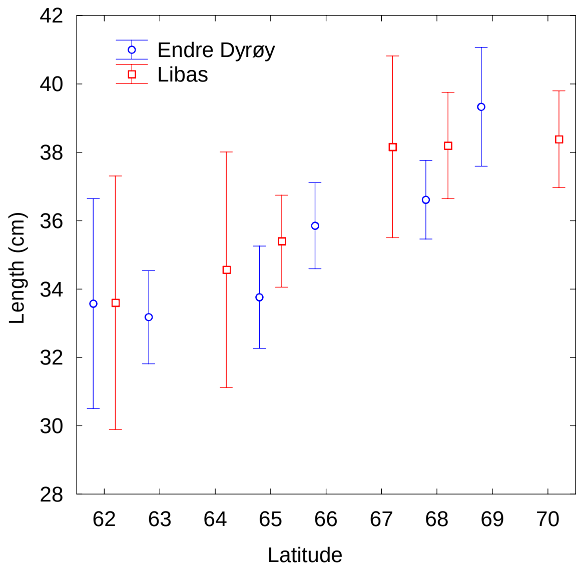

Figure 8.2.3: The size of the mackerel by latitude observed by M/S "Endre Dyrøy" and M/S "Libas" during 15–31 July 2004.

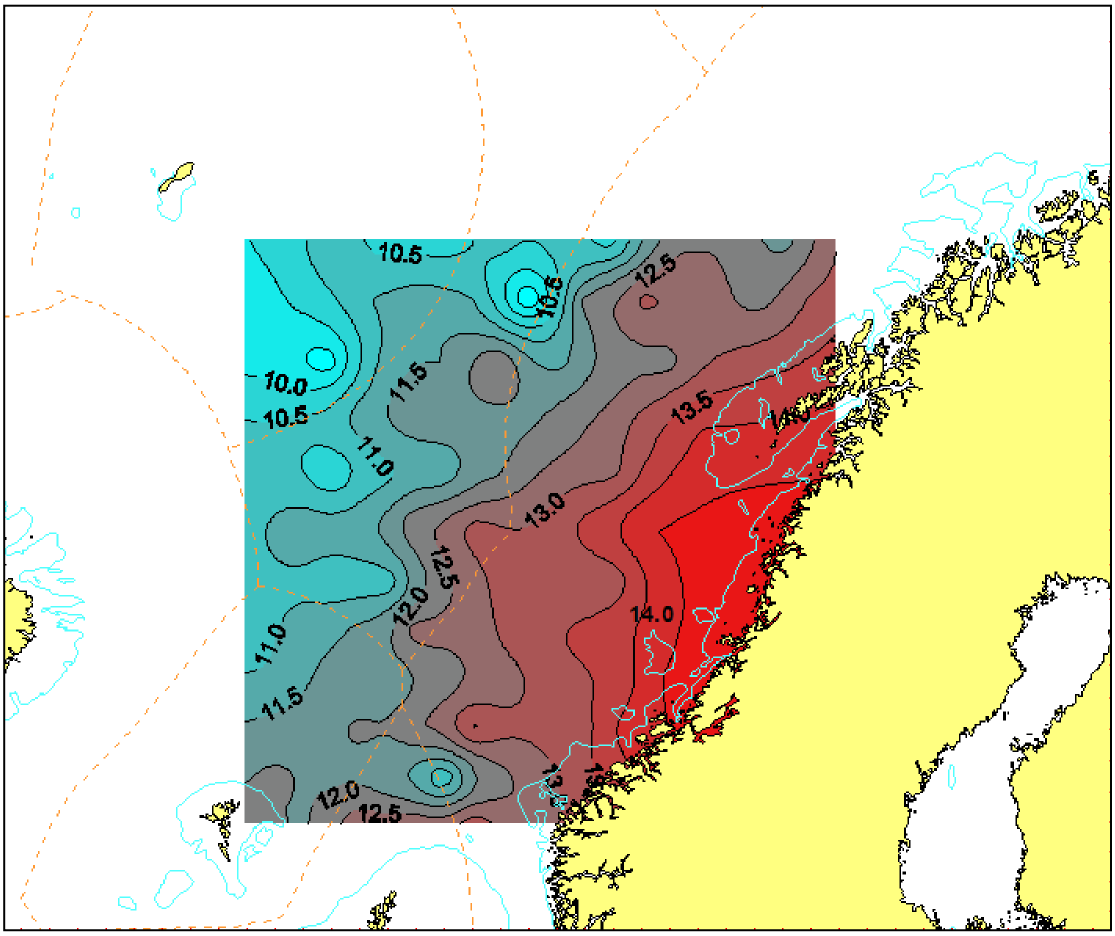

Figure 8.2.4: Temperature distribution at 4 m depth observed by M/S "Endre Dyrøy" and M/S "Libas" during 15–31 July 2004.

9 The future

The Planning Group on Aerial and Acoustic Surveys for Mackerel (PGAAM) was established after discussion during Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA) meeting in September 2001 with main purposes to coordinate a number of surveys on pelagic species that can provide the information on the distribution and abundance of mackerel (see Section 1). The PGAAM met for four times and made their work as much as possible. Detailed results of the PGAAM are presented in the reports for the years 2002–2005; however there is still a lot of work to do in future.

Commencing in 2004, the ICES advice has changed in several aspects as well as the approaches to the investigations. The new Ecosystem-based approaches to the fishery advice/management are started and it is assumed that there will be changes for the ICES Working and Planning Groups too. For example, the PGNAPES has grown out of PGSPFN, i.e., from planning of single species survey into planning and describing of the ecosystem survey that includes most of marine explorations aspects in the Norwegian Sea and adjacent waters during summer. Many points of the PGNAPES and PGAAM work are overlapping today that assume more near collaboration.

From the other hands last two years only three nations took part in the PGAAM meetings and may assume that for the year 2005 and 2006 only two will continue.

Therefore, the questions about future the PGAAM have to be left.

Due to this the participants of the present PGAAM meeting and the Chair of the ICES Living Resource Committee (Dave Reid) and the Chair of the ICES Resource Management Committee (Dankert Skagen) has discussed this issues during the meeting. All of participants had agreed that the PGAAM duty have to be finalizing for the present time and the relevant references have to be pass to the PGNAPES and PGHERS as well for others from year 2006.

10 Recommendations

The PGAAM recommends that during acoustic surveys for mackerel the Target Strength to length relationship TS=20 log L-84.9 dB should be used, integrating at an acoustic frequency of 38 kHz with a -82 dB threshold. Multi-frequency acoustic data should be collected wherever possible and should include at least 38 and 200 kHz.

The PGAAM advises all participants on mackerel investigations to examine “Manual for herring acoustic surveys in ICES Divisions III, IV and VIa” (PGAAM report 2003, Annex I) with a view to updating this for use in new or existing acoustic surveys specifically targeted on mackerel.

The PGAAM recommends that wherever possible, data should be collected from surveys not targeted on mackerel, to assess their potential for the estimation of mackerel abundance, distribution and to provide biological samples of mackerel.

The PGAAM recommends to France, Spain and Portugal to discuss the issue on the surveys for the pelagic species (mackerel included) in the Southern area (ICES Subareas VIII and IX) with the purposes of coordinating their efforts for the investigations.

Norway has surveyed the mackerel acoustically during the autumn for the last six years. The PGAAM recommends that WGHMSA consider the use of these data as a relative index in the assessment.

The PGAAM recommends that the results from the joint Scottish and Norway autumn surveys on mackerel as well as Russian and Norwegian summer surveys should be considered as tuning indices for the assessment of the mackerel stock.

Due to the new approaches in ICES system the PGAAM recommends to finalize the duty of this group and to pass the relevant references to the PGNAPES and PGHERS from year 2006.

11 Working Documents

Armstrong, F., Fernandes, P.G. and Stewart, M. 2005. The 2004 North Sea Mackerel Acoustic Survey. Working Document to ICES PGAAM 2005. Document available from: Armstrong, F., Fernandes P.G, and Stewart, M. FRS Marine Laboratory, PO Box 101, 375 Victoria Road, Aberdeen, Scotland AB11 9DB. E-mail: fernandespg@marlab.ac.uk

Slotte, A., Iversen, S. A. and Skagen, D. 2005. Size and condition of mackerel in research vessel trawl hauls versus commercial purse seine catches: implications for acoustic biomass estimation. Working Document to ICES PGAAM 2005. Document available from: Aril Slotte, Institute of Marine Research (IMR), P.O.Box 1870 Nordnes, N-5817 Bergen, Norway. E-mail: **aril.slotte@iMrno**

Tenningen, E. 2005. Surface Monitoring of Marine Resources by Lidar-IMR - NTNU Project. Working Document to ICES PGAAM 2005. Document available from: Eirik Tenningen, Institute of Marine Research (IMR), P.O.Box 1870 Nordnes, N-5817 Bergen, Norway. E-mail: eirikt@iMrno

Zabavnikov, V., Shamray, E., Lisovsky, A. and Tenningen, E. 2005. Results From Joint Surveys For Mackerel In The Norwegian Sea With The Use Of Airborne Observation. Working Document to ICES PGAAM 2005 Document available from: Vladimir Zabavnikov, PINRO, 6, Knipovich Street, Murmansk, Russia. E-mail: ltei@pinro.ru

12 References

Anon. 1994. Report of the Planning Group for Herring Surveys. ICES CM 1994/H:3. 26 pp.

Anon. 1997. Report of the Planning Group for Sardine Acoustic surveys in ICES Sub-Areas VIII and IX. Lisbon, 27–28 January 1997. ICES CM 1997/H:1.

Anon, 1998. Report of the Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX. Coruna, 30–31 January 1998. ICES CM 1998/G:2.

Anon. 2002. Report of the Planning Group on Aerial and Acoustic Surveys for Mackerel. ICES CM 2003/ ICES CM 2002/G:03. Ref. ACFM, B.

Anon. 2003. Report of the Planning Group on Aerial and Acoustic Surveys for Mackerel. ICES CM 2003/G:06. Ref. ACFM.

Anon. 2004. The Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys. ICES CM 2004/2004/D:07, Ref. ACFM, ACE and G.

Edwards, J. I., F. Armstrong, *et al.* (1984). Herring, mackerel and sprat target strength experiments with behavioural observations. ICES CM 1984/B:34. 21 pp.

Engås, A., Skeide, R., and West, C.W, 1997. The “Multisampler”: a system for remotely opening and closing multiple cod ends on a sampling trawl. Fish. Res.., 29: 295–298.

Fernandes, P.G., and Stewart, M. 2004. Determining the quality of a multifrequency acoustic identification algorithm. ICES CM 2004/R:11. pp.

Foote, K G., Hansen, K. A., and Ona, E., 1993. More on the frequency dependence of target strength of mature herring. ICES, C.M. 1993/B:30, Fish Capture Committee, Ref. H – Pelagic Fish Committee. 8 pp.

Gorska, N., Ona, E., and Korneliussen, R. J. 2004a. On backscattering mechanism for fish without swimbladder. Proceedings of the Seventh European Conference on Underwater Acoustics. ECUA 2004, Delft, Netherlands, 2004. 367–372.

Gorska, N., Ona, E., and Korneliussen, R. J., 2004b. “On acoustic multi-frequency species identification and separation of Atlantic mackerel, Norwegian spring spawn herring and Norway pout”. ICES Annual Science Conference, Vigo, Spain, 22–23 September 2004, CM2004/R:18.

Gorska, N., Ona, E., and Korneliussen, R. J. 2005. Acoustic backscattering by Atlantic mackerel, a representative of fish that lack a swimbladder. Part 1. Backscattering by individual fish. ICES Journal of Marine Science (In Press).

Korneliussen, R. J., 2000. Measurement and Removal of Echo Integration Noise. ICES Journal of Marine Science, 57: 1204–1217.

Korneliussen, R. J., 2004. The Bergen Echo Integrator post-processing system, with focus on recent improvements. Fisheries Research 68 (2004) 159–169.

Korneliussen, R. J., Diner, N., Ona, E., and Fernandes, P., 2004a. Recommendations for collection of acoustic multi-frequency data to be used for generation of combined-frequency data. ICES Annual Science Conference, Vigo, Spain, 22–23 September 2004, CM2004/R:36.

Korneliussen, R. J., Skagen, D. W., Slotte, A. 2004. Cruise summary report/Institute of Marine Research/ISSN 1503–6294/Nr. 3 - 2005

Korneliussen, R. J., and Ona, E., 2002. An operational system for processing and visualising multi-frequency acoustic data. ICES Journal of Marine Science, 59: 293–313.

Korneliussen, R. J., and Ona, E., 2003. Synthetic echograms generated from the relative frequency response. ICES Journal of Marine Science, 60, 636–640.

Korneliussen, R. J., and Ona, E., 2004b. Verified acoustic identification of Atlantic mackerel. ICES CM2004/R:20 2004, 14pp.

Pedersen, G., Ona., E., and Korneliussen, R., 2004. The relative frequency response, as derived from individually targets of cod, saithe, and Norway pout. ICES Annual Science Conference, Vigo, Spain, 22 – 23 September 2004, CM2004/R:16.

Zabavnikov V.B, Chernook V.I., Rodin A.V. 1997. Marine flying laboratory An-26 “Arktika”. *In*: Proceedings of the 3d International Airborne Remote Sensing Conference and Exhibition. – Copenhagen, Denmark. 1997, 3: 415–418.

Annex 1: List of participants

NAME	ADDRESS	PHONE/FAX	EMAIL
Doug Beare (part time)	FRS Marine Laboratory P.O. Box 101, Victoria Road Aberdeen AB11 9DB, Scotland, U.K.	n/a +44 1224 295403	n/a
Paul Fernandes (by letter)	FRS Marine Laboratory P.O. Box 101, Victoria Road Aberdeen AB11 9DB, Scotland, U.K.	+44 1224 295 511 +44 1224 295 403	fernandespg@marlab.ac.uk
Svein A. Iversen	Institute of Marine Research P.O. Box 1870 Nordnes, 5817 Bergen, Norway	+47 55 23 84 07 +47 55 23 85 55	Svein.iversen@iMrno
Rolf Korneliussen	Institute of Marine Research P.O. Box 1870 Nordnes, 5817 Bergen, Norway	+47 55 23 84 19 +47 55 23 85 55	rolf.korneliussen@iMrno
Aril Slotte	Institute of Marine Research P.O. Box 1870 Nordnes, 5817 Bergen, Norway	n/a +47 55 23 85 55	aril.slotte@iMrno
Evgeny Shamray (Chair)	PINRO 6, Knipovich Street, Murmansk, 183763, Russia	+7 8152 47 49 63 +7 8152 47 33 31	shamray@pinro.ru inter@pinro.ru
Eirik Tenningen	Institute of Marine Research P.O. Box 1870 Nordnes, 5817 Bergen, Norway	+47 55 23 84 19 +47 55 23 85 55	eirikt@iMrno
Vladimir Zabavnikov	PINRO 6, Knipovich Street, Murmansk, 183763 Russia	+7 8152 47 25 72 +7 8152 47 33 31	ltei@pinro.ru