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Workshop på hydroakustiske undersøkelser i Norskehavet

Workshop on hydro-acoustics scrutinizing in the Norwegian Sea

By Benjamin Planque, Eckhard Bethke, Konstantin Drevetnyak, Alf Harbitz, Kjell Nedreaas, Andrey Pedchenko, Ronald Pedersen, Fróði Skúvadal and Valery Zubov

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PROSJEKTRAPPORT

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Sammendrag (norsk):

Denne rapporten beskriver det internasjonale uer-toktet som ble gjennomført i Norskehavet i august 2008, samt metodikken som ble brukt for å gjennomgå og sammenligne de ulike akustiske tolkeprosedyrene. Resultatene av analysene viser klart at forskjellen i tolkemetodikk har en svært stor innflytelse på estimatet av uer-bestanden. Trolig utgjør dette den største usikkerhetskilden til ethvert kvantitativt estimat. Innsatsen i retning standardisering av tolkeprosdyrer bør derfor forsterkes eller i det minste opprettholdes.

Summary (English):

This report presents the international redfish survey carried out in the Norwegian Sea in August 2008 and the methodology used to review and compare the different hydroacoustic scrutinizing procedures. The results of the comparative analysis clearly show that differences in scrutinizing methods have a very large impact on the abundance estimate of redfish. They probably constitute the major source of uncertainty for any quantitative estimate. Efforts towards standardisation of scrutinizing procedures should be amplified or at least maintained.

Emneord (norsk):	**Subject heading (English):**
1. Snabeluer	**1.** Redfish
2. Hydroakoustikk	**2.** Hydro acoustics
3. Norskehavet	**3.** Norwegian Sea

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Faggruppeleder

Executive summary

During August 2008, Norway, Russia and the Faroes conducted a joint survey of redfish (*Sebastes mentella*) in the Norwegian Sea. Abundance estimates based combined trawling and hydroacoustics revealed important discrepancies and it was envisaged that these resulted from differences in the methodologies used for scrutinizing the hydroacoustic data. To resolve this issue, the present workshop was organised with the following objectives: (1) to review the scrutinizing procedures used by each participants, (2) to run parallel analysis of the hydroacoustic data on selected registrations, and (3) to advise on "good practice" for scrutinizing hydroacoustic data collected in the Norwegian Sea. The workshop was held in Tromsø (Norway) on the 25-27 November 2008 and attended by 9 participants from Norway, Russia, Germany and the Faroes.

The present report briefly presents the survey carried out in August 2008 and the methodology used to review and compare the different hydroacoustic scrutinizing methodologies. The results of the comparative analysis clearly show that **differences in scrutinizing methods have a very large impact on the abundance estimate of redfish. They probably constitute the major source of uncertainty for any quantitative estimate**. Efforts towards standardisation of scrutinizing procedures should be amplified or at least maintained.

The report provides a series of recommendation for the conduction of future international redfish surveys. These include standardisation of equipment and methodologies, increase in biological sampling, cross-comparison of data and results.

Contents

1 Opening of the meeting

The meeting opened on Tuesday 25 November 2008 at 9:00. However, at the time not all participants were present, due to delays in plane schedules. Benjamin Planque introduced the background to the meeting and its objectives. The rest of the morning was devoted to open discussions and a presentation by Kjell Nedreaas on the report of the Institute of Marine Research to the last coastal states consultancy meeting hosted by the North East Atlantic Fisheries Commission (NEAFC) in mid-October 2008. The list of participants is provided in Annex 1.

2 Adoption of the agenda

The agenda was adopted after modification to account for the late arrival of two participants. The agenda is given in Annex 2.

3 Objective of the meeting

The workshop follows the recommendation from AGRED (Ad Hoc Working Group on the international Redfish Survey in the Norwegian Sea, ICES 2008). The AGRED meeting was conducted to report on the international Redfish Survey conducted in the Norwegian in August 2008. At the time of the meeting it had not been possible to produce reliable abundance estimates based on hydroacoustic data due to differences and uncertainties in the hydroacoustic data scrutinizing protocols. The aim of the workshop was to resolve this issue by:

1. reviewing the scrutinizing procedures used by each participants of the redfish survey in the Norwegian Sea in August 2008,
2. running parallel analysis of the hydroacoustic data on selected registrations, and
3. advising on "good practice" for scrutinizing hydroacoustic data collected in the Norwegian Sea.

4 International redfish survey in the Norwegian Sea in August 2008

In August 2008, Norway, the Russian Federation and the Faroe Islands conducted a joint survey on beaked redfish (*Sebastes mentella*) in the Norwegian Sea. The objectives of the survey, as set by NEAFC AM 2007/58 were to measure the horizontal and vertical stock distribution and provide an abundance estimate. During the two weeks of investigation, the distribution, abundance and biology of *S. mentella* in the Norwegian Sea were studied by means of hydroacoustics and pelagic trawling on-board three commercial vessels: Atlantic Star (Norway), Osveyskoe (Russia) and Skálaberg (Faroes).

S. mentella was observed between 100 and 800 m, with maximum concentrations in the 350–550 m depth layer. This depth corresponds to the Deep Scattering Layer (DSL), were high concentration of small preys occur (myctophids, shrimps, cephalopods,…). *S. mentella* was observed in more than 90% of the trawls, over most of the area covered by the survey. The geographical distribution of the stock extended beyond the survey coverage, so only a fraction of the population could be studied by the survey.

At the time of the post-survey meeting (ICES, 2008), not all hydroacoustic data were made available to the group. In addition there were important methodological difficulties and discrepancies which required additional work to be resolved. For these reasons, a joint robust estimate of distribution and abundance of *S. mentella* in the Norwegian Sea could not be produced at the time of the meeting.

A series of recommendations were proposed to further analyse the data collected during the survey and converge toward common methodologies in future surveys. This included the recommendation to conduct an international workshop on the scrutinizing of hydroacoustics data (AGRED recommendation 7). The present workshop is the response to this recommendation.

5 Individual scrutinizing protocols

5.1 Norway

Data collection

During the August survey, Norway conducted sampling and hydroacoustics measurments onboard the F/T Atlantic Star. Acoustics was performed at 38kHz frequency using Simrad ek60 GPT / ER60 with a split beam transducer ES 38-B and pulse length of 1.024ms. Hydroacoustics registrations were recorded down to 1000m. The equipment was calibrated at the beginning of the survey according to the protocol of Foote et al. (1987). Interpretation of hydroacoustics registration were made using the species composition obtained from trawl hauls using a Hampidjan Gloria trawl 2048 HO. A multisampler was attached to the trawl, which allowed for the collection of three samples (i.e. in three cod-ends) for each haul. In total, 72 samples, each refereeing to a specific depth, were used. The registration were made along 9 parallel transects separated by 40 nautical miles (NM). Inter-transect registrations were not analysed. Trawling was performed in the direction of hydroacoustic registration (or as close as possible to it) and registrations perfomed during trawling were analysed. Due to generally calm weather conditions and good acoustic performances of F/T Atlantic Star, the data collected showed little noise and could be analysed completely.

Scrutinizing

The scrutinizing was performed onboard F/T Atlantic Star at the time of the survey using the LSSS software (Large Scale Survey System, Korneliussen et al. 2006). The registrations were divided into blocks of 5 NM length, and the signal analysed down to 800m at a s_V threshold level of -82dB. Species allocation was derived from the nearest trawl hauls on the basis of s_A proportions in the catch. The s_A proportions can be calculated directly using the ‘trawl module’ in LSSS. The calculations are based on length-dependent *TS* equations and the length distribution in the catch. Equations for the 3 most common species captured during the Norwegian part of the survey are:

S. mentella: $TS_L = 20 \times \log(L) - 68.0$
Blue whiting: $TS_L = 21.8 \times \log(L) - 72.8$
Herring: $TS_L = 20 \times \log(L) - 67.3$

The acoustic categories used were: redfish (*S. mentella*), blue whiting, herring, plankton, other, cod, greater argentine, and saithe. The 'plankton' category comprised all small targets (e.g. myctophids, shrimps), including ribbon barracudina (*Arctozenus risso*). The 'other' category' comprised all large targets which were not identified (i.e. other fish species).

Each 5 NM section was divided into horizontal layers which positions depended on visible layers in the registrations (in particular the Deep Scattering Layer, DSL) and the availability of neighbouring trawl data at specific depths. Each layer was scrutinized separately.

Possible sources of error such as ghost bottom echoes or 'noisy pings' were removed from the layers, either by 'schooling them out' (i.e. by drawing a school object which is removed from the layer analysis) or by adapting the layer contour. The fraction of the layer removed from the analysis was allocated the mean s_A of the analysed fraction.

When layer of small targets were visible, the s_V threshold was raised until these targets were no longer visible (often s_V threshold was raised to values around -72dB). In deep layers (>400m) strong thresholding can result in the loss of true fish targets, so the thresholding level was decided as a compromise between maximising the removal of small targets and minimizing the loss of larger (fish) ones. The total s_A in the layer after threshold was allocated to fish and partitioned according to the species s_A proportions from the sample collected in the nearest trawl haul and depth. The difference between total s_A at -82dB and total s_A at thresholding was allocated to small targets (termed 'plankton'). When no catch data was available, all fish s_A was assigned to the category 'other'.

When each horizontal layer had been analysed, the 5 NM block was stored to the LSSS database with a resolution of 10m vertical and 0.1 NM horizontal.

5.2 Russia

Data collection

The International trawl-acoustic survey on pelagic redfish in Norwegian Sea has been carried out from 13 to 29 August. The area covered by F/T Osveyskoe extended from 67 N up to 70 N and from 8 W to 14 E. Acoustic survey was carried out using echosounder Simrad EK60, connected to split beam transduser ES38-B and pulse length of 1.024 ms. Hydroacoustics registrations were recorded down to 750 m. Calibration of the acoustic equipment using a reference sphere was performed at the beginning of the survey, in the vicinity of the island of Vannyoja (Troms) on depth of 25 m.

The fishing gear used was a pelagic trawl Gloria 2048 HO, in accordance with survey planning recommendations (ICES, 2008). The trawl had a vertical opening of 100 m, and a horizontal opening of 110 m. Geometry of the trawl was monitored using indications of gauges and trawling sonar Simrad FS70, on a trawl there were gauges of filling FA-701. The area boards - 14 m^2, length of a bag - 30 m. The cod end was fitted with a 12 m long inner net with mesh size of 40 mm. During trawling the vessel speed was set to 3.0 – 3.2 knots. Trawling duration was usually around 2 hours.

Two types of trawls were carried out. Type 1: above the DSL; Type 2: within and below the DSL. Acoustics was registered over a total distance of 2200 NM over an area of 95403 NM^2, and 28 trawl hauls were carried out (ICES, 2008).

Scrutinizing

Data processing was carried out using the post-processing systems FAMAS and Simrad BI60. The technique of processing echogram in Norwegian Sea was similar to the method used in the Irminger Sea. The interval of integration was equal 5 NM, using a s_V threshold level of -80 dB.

During scrutinizing, particular attention was given to redfish (*S. mentella*) and blue whiting (*Micromesistius poutassou*). Other targets have been allocated into the acoutic categorie 'DSL' or 'other'. Areal backscattering coefficients (s_A) for redfish on each 5-mile interval were estimated separately for the layer above the DSL (as a rule, is higher 200-350 m), and for the layer within and below the DSL. In the first layer (200-350 m) allocation s_A to redfish was carried out by changing the s_V threshold to levels up to -72 dB. Within and below the DSL it was considered impossible to allocate acoustic energy to redfish. Instead, s_A allocation was based on estimated s_A from reference trawl(s), using the trawl method. The method is based on the recalculation of individual species catch in the reference trawl into equivalent acoustic units $s_{A(tr)}$ (m^2/nm^2). The calculation is based on the equations by Mamylov (1999) presented in section 8.2 of this report. As the trawl catchability is not known, the method can only provide relative number of $s_{A(tr)}$. Calculation of $s_{A(tr)}$ from trawl catches was made following the method used in the Irminger Sea. Trawl data was calibrated by measuring the density of fish above the DSL with both, hydro acoustic and trawling. The regression between the two estimates was used as a relative measure of catchability. With this information trawl results can be transformed into s_A-values and vice versa. Due to bad weather conditions, the acoustic registrations between log1300 - log1400 and between log 1625 – log 2035 were excluded from the analysis.

5.3 Faroes

Data collection

The Faroe Islands are in shortage of acoustic personnel and have very limited experience in redfish acoustics. Therefore it was requested that other parties could provide this expertise. Iceland agreed to provide hydroacoustic expertise.

The Faroese part of the survey was conducted onboard the factory trawler M/Tr Skálaberg. Hydroacoustic measurements were performed at 38kHz using a Simrad EK 60 and a split beam transducer ES 38-B and pulse length of 1.024ms. The hydroacoustic registrations were recorded down to 750 m. The acoustic equipment was calibrated at the beginning of the survey using the same procedure as Norway. A total estimate of the hydroacoustic data obtained from the survey has not been done yet. The basis for the interpretations of the hydroacoustic data are the species compositions derived from two trawls, a Vónin Red Lion 3072 and a Hampidjan Gloria Helix 4096. The codend was lined with a 40 mm mesh 12 m long netting at the end. In total 23 hauls were obtained; 18 with the 3072 and 5 with the 4096 trawl. The registrations were made along 5 parallel transects starting with 63º North with one degree of latitude between transects. Inter transect registrations will not be analysed. Trawling was generally performed in the direction of hydroacoustic registrations. The data collected was quite noisy and it did not seem to be possible to reduce the noise by regulating the speed or pitch of the propeller. At the end of the survey there was bad weather, so data from this part of the survey is even noisier.

Scrutinizing

The final scrutinizing has not been completed yet, but some was performed onboard as the cruise progressed. The processing software used is Echoview. From the trawl hauls and the experience of the skipper it was possible to distinguish marks on the echogram that could be allocated to redfish. Originally the threshold was set to -70 dB, but the final value has not been finally set. As the data was quite noisy it was determined to scrutinize data from 10 m below the surface down to 500 m. Below 500 m the data will not be used. When trawling has been done, the s_A proportions calculated from the trawl will be used on the adjacent registrations. This will also be the case if trawling has been conducted within the DSL. The TS equations mentioned above and recommended in the planning document for the survey are used. The acoustic categories used are: redfish (*S.mentella*), blue whiting, herring, cornish blackfish, plankton and other. The category 'other' comprises large targets that could not be identified while the category 'plankton' refers to small targets.

6 Comparative analysis of reference registrations

6.1 Scrutinizing using LSSS (Norway)

The text below provides the detailed scrutinizing method employed for the three reference registrations provided by the participants. Note that the depth limits of the layers are provided as indicative limits. The true contours of the layer may have more complex forms as they can follow the shapes of fish aggregations, schools or the DSL. The surface is taken at 15 m depth. Information on trawl composition is given in ANNEX 3. Ribbon barracudina (*Arctozenus risso*) has always been assigned to the 'plankton' category. In Russian data on trawl composition, the s_A allocation specific to ribbon barracudina has been set to zero and s_A proportions for other species re-adjusted accordingly. The analysis of Russian and Faroese registration is subjected to a large uncertainty since little biological information was available for the interpretation of the echograms (few trawl hauls often at one single depth and several hours and nautical miles away from the registration).

Norwegian registration 1. 13.08.08 02:54 (log 6405) to 13.08.08 03:26 (log 6410)

Layer 1, surface – 200 m: no trawl information available. All s_A (19.3 m^2/NM^2) allocated to 'other'.

Layer 2, 200 m – 300 m: No thresholding. All s_A (8.0 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80307.

Layer 3, 300 m – 400 m: Thresholding up to -74dB. The remaining s_A (18.0 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80308.

Layer 4, 400 m – 500 m: Thresholding up to -72dB. The remaining s_A (16.8 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80309.

Layer 5, 500 m – 600 m: Thresholding is not possible because the density of the DSL is to high (low thresholding would leave too much plankton and high thresholding would remove too many fish targets). The mean s_A for fish is estimated using a school box in the lower part of the layer, where DSL is absent. Estimated s_A from the box (2 m^2/NM^2) is allocated to *S. mentella* (based on species composition in sample 80303). Remaining s_A (43.1 m^2/NM^2) is allocated to plankton.

Layer 6. 600 m – 800 m: No thresholding. All s_A (1.3 m^2/NM^2) is allocated to redfish (based on species composition in samples 80304/80305).

The total s_A allocated to *S. mentella* in this 5 NM block is 25 m^2/NM^2.

Norwegian registration 2. 17.08.08 17:35 (log 7150) to 17.08.08 18:09 (log 7155)

Layer 1, surface – 100 m: no trawl information available. All s_A (160 m^2/NM^2) allocated to 'other'.

Layer 2, 100 m – 350 m: Thresholding up to -75 dB. The remaining s_A (62.6 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80331.

Layer 3, 350 m – 560 m: Thresholding up to -70 dB. The remaining s_A (21.3 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80332.

Layer 4, 560 m – 800 m. No thresholding. Elimination of one 'noisy ping'. All s_A (1.7 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80333.

The total s_A allocated to *S. mentella* in this 5 NM block is 19 m^2/NM^2.

Norwegian registration 3. 20.08.08 09:27 (log 7560) to 20.08.08 10:53 (log 7565)

Layer 1, surface – 300 m: no trawl information available. All s_A (231 m^2/NM^2) allocated to 'other'.

Layer 2, 300 m – 350 m: Thresholding up to -71dB. The remaining s_A (406 m^2/NM^2) is allocated herring on the basis of 1) information collected at the time of the survey that fishing vessels were catching herring as the main species in the area at the time of registration and 2) the dense schools visible on the echogram.

Layer 3, 350 m – 500 m: Thresholding up to -71dB. The remaining s_A (41.3 m^2/NM^2) is allocated to fish species using s_A proportions from sample 80352.

Layer 4, 500 m – 800 m: There are many 'noisy pings' in this layer and it was not possible to easily exclude them from the layer. Instead, the mean s_A allowable to fish has been estimated using s_A measured in 'school boxes' placed in portions of the layer where noise was absent. The resulting sA (7.0 m^2/NM^2) was allocated to *S. mentella*.

The total s_A allocated to *S. mentella* in this 5 NM block is 46 m^2/NM^2.

Russian registration 1. 17.08.2008 09:16 (log 565) – 17.08.2008 11:00 (log 570).

Layer 1, surface – 380 m: no trawl information available. All s_A (231 m^2/NM^2) allocated to 'other'.

Layer 2, 380 m – 480 m: Thresholding up to -70dB. The remaining s_A (23.5 m^2/NM^2) is allocated to fish species using s_A proportions from station 1.

Layer 3, 480 m – 650 m: Thresholding up to -68dB. The remaining s_A (10.1 m^2/NM^2) is allocated to fish species using s_A proportions from station 2.

Layer 4, 650m – 750m: Thresholding up to -73dB. The remaining s_A (1.1 m^2/NM^2) is allocated to fish species using s_A proportions from station 3.

The total s_A allocated to *S. mentella* in this 5 NM block is 12 m^2/NM^2.

Russian registration 2. 17.08.2008 22:12 (log 625) – 17.08.2008 23:20 (log 630).

Layer 1, surface – 100 m: no trawl information available. All s_A allocated to 'other'.

Layer 2, 100 m – 400 m: thresholding for plankton up to -75dB. The remaining s_A (20.5 m^2/NM^2) is allocated to *S. mentella* (33%) and blue whiting (67%) according to s_A proportions in trawl haul 4.

Layer 3, 400 m – 750 m: thresholding for plankton up to -75dB. The remaining s_A (20.5 m^2/NM^2) is allocated to *S. mentella* and blue whiting with a lower proportion of blue whiting (25%) as in the above layer.

The total s_A allocated to *S. mentella* in this 5 NM block is 44.4 m^2/NM^2.

Russian registration 3. 19.08.2008 10:34 (log 1000) – 19.08.2008 12:06 (log 1005).

Layer 1, surface – 170 m: no trawl information available. All s_A allocated to 'other'.

Layer 2, 170 m – 400 m: Thresholding up to -78dB. The remaining s_A (40.3 m^2/NM^2) is allocated to fish species using s_A proportions from station 5.

Layer 3, 400 m – 440 m: This layer is difficult to scrutinize and the values from the above layer between 360 and 400m are used as reference. s_A allocated to *S. mentella* is 4.1 and to blue whiting is 4.8 m^2/NM^2.

Layer 4, 440 m – 680 m: Thresholding up to -68dB. The remaining s_A (10 m^2/NM^2) is allocated 2/3rd *S. mentella*, 1/3rd blue whiting.

Layer 5, 580 m – 750 m: The mean s_A allocated to *S. mentella* is determined using a school box placed in area with low noise and reverberation. The estimated s_A is 2 m^2/NM^2

The total s_A allocated to *S. mentella* in this 5 NM block is 31.2 m^2/NM^2.

Faroese registration 1. 15.08.2008 17:31 (log 182) – 15.08.2008 18:01 (log 187)

Layer 1, surface to ~280 m: no trawl information. All s_A is allocated to other.

Layer 2, ~280 m to 500 m: Thresholding up to -65dB. The remaining s_A (84 m^2/NM^2) is partitioned between blackfish (25%), saithe (7%) and blue whiting (68%) according to trawl haul 8090005.

The total s_A allocated to *S. mentella* in this 5 NM block is 0 m^2/NM^2.

Faroese registration 2. 17.08.2008 17:14 (log 334) – 17.08.2008 17:42 (log 339)

Layer 1, surface to ~340 m: no trawl information. Removal of false bottom echo. Thresholding up to -70dB. The remaining s_A(122 m^2/NM^2) is allocated to other.

Layer 2, ~340 m to 420 m: no trawl information. However, information from trawl 8090005 indicates large proportion (71%) of *S. mentella* and smaller proportions of saithe and blue whiting (20%) below 450m. Thresholding up to -67dB and isolation of a school box which contains mostly individual targets. The s_A in the school (12 m^2/NM^2 over 40m depth) is allocated for the whole layer (90m) and partitioned to 50% *S. mentella* and 50% to blue whiting and saithe. s_A allocated to *S. mentella* is 13.5 m^2/NM^2.

Layer 3, 420 m to 700 m: information from trawl 8090005. However, the data is too noisy to be analysed. s_A allocated to redfish with arbitrary ½ value of the above layer ($7m^2/NM^2$)

The total s_A allocated to *S. mentella* in this 5 NM block is 20.5 m^2/NM^2.

Faroese registration 3. 21.08.2008 12:32 (log 917) – 21.08.2008 13:01 (log 922)

Layer 1, surface to ~210m: no trawl information. Presence of large schools, probably herring. No thresholding. All s_A(186 m^2/NM^2) is allocated to other.

Layer 2, 210m to ~350m: The trawl information provided is in very different time and conditions and can not be used directly (hauls 8090015 and 8090020). Thresholding up to -75dB reveals many individual or small groups of targets. Remaining s_A in the layer (35.6 m^2/NM^2 over 40m depth) is partitioned to 50% *S. mentella* and 50% to blue whiting. s_A allocated to *S. mentella* is 18 m^2/NM^2.

Layer 3, ~350 m to 700 m: very dense DSL and very noisy signal. No interpretation possible.

The total s_A allocated to *S. mentella* in this 5 NM block is 18 m^2/NM^2.

6.2 Scrutinizing using FAMAS (Russia)

All scrutinizing with FAMAS have been performed with a s_V threshold of -80 dB.

Russian registration 1. 17.08.2008 09:16 log 565 – 17.08.2008 11:00 log 570.

Layer 1, 15-200 m: no trawl information available. All s_A 31.2 m^2/NM^2 allocated to 'other'.

Layer 2, 200-400 m: Trawl haul on depth 380 m. Total s_A is 20.8 m^2/NM^2. Thresholding up to -74 dB. s_A allocated to *S. mentella*: 4.2 m^2/NM^2, DSL and other s_A: 6.3 m^2/NM^2, blue whiting: 10.3 m^2/NM^2.

Layer 3, 400-600 m: Thresholding is not possible because the density of the DSL is to high. Trawl haul on depth 470 m. Total s_A: 173.2 m^2/NM^2. *S. mentella* s_A(from direct traul estimate): 9.2 m^2/NM^2.

Layer 4, 600-750 m: No thresholding. All s_A (17.5 m^2/NM^2) is allocated to plankton.

The total s_A allocated to *S. mentella* in this 5 NM block is 13.4 m^2/NM^2.

Russian registration 2. 17.08.2008 22:12 log 625 – 17.08.2008 23:20 log 630.

Layer 1, 15-200 m: no trawl information available. All s_A 36.4 m^2/NM^2 allocated to 'other'.

Layer 2, 200-400 m: Trawl haul on depth 300 m. Total s_A is 36.0 m^2/NM^2. Thresholding up to -74 dB. . s_A allocated to *S. mentella*: 7.2 m^2/NM^2, DSL and other s_A: 11.5 m^2/NM^2, blue whiting: 17.3 m^2/NM^2.

Layer 3, 400-600 m: Total s_A is 72.9 m^2/NM^2. Thresholding up to -73 dB. sA allocated to *S. mentella*: 8.7 m^2/NM^2. s_A allocated to DSL and other: 64.2 m^2/NM^2.

The total s_A allocated to *S. mentella* in this 5NM block is 15.9 m^2/NM^2.

Russian registration 3. 19.08.2008 10:34 log 1000 – 19.08.2008 12:06 log 1005.

Layer 1, 15-200 m: no trawl information available. All s_A (71.1 m^2/NM^2) allocated to 'other'.

Layer 2, 200-400 m: Trawl haul on depth 335 m. Total s_A is 32.1 m^2/NM^2. Thresholding up to -74 dB. s_A allocated to *S. mentella*: 12.9 m^2/NM^2. s_A allocated to DSL and other: 6.1 m^2/NM^2, blue whiting: 13.1 m^2/NM^2.

Layer 3, 400-500 m: Total s_A is 84.5 m^2/NM^2. Thresholding to -71 dB. s_A allocated to *S. mentella*: 9.3 m^2/NM^2. s_A allocated to DSL and other: 65.1 m^2/NM^2, blue whiting: 10.1 m^2/NM^2.

Layer 4, 500-600 m: No thresholding. All s_A (21.5 m^2/NM^2) is allocated to plankton.

The total s_A allocated to *S. mentella* in this 5NM block is 22.2 m^2/NM^2.

Norwegian registration 1. 13.08.08 02:54 (log 6405) to 13.08.08 03:26 (log 6410)

Layer 1, surface 15-200 m: no trawl information available. All s_A 24.5 m^2/NM^2 allocated to 'other'.

Layer 2, 200-300 m: No thresholding. Total sA: 8.0 m^2/NM^2 is allocated to fish species using s_A proportions from sample 80307. s_A allocated to *S. mentella* 0.5 m^2/NM^2.

Layer 3, 300-400 m: Thresholding to -74 dB. Total s_A: 28.3 m^2/NM^2 is allocated to fish species using s_A proportions from sample 80308. s_A allocated to *S. mentella*: 4 m^2/NM^2. s_A allocated to DSL and other: 16.7 m^2/NM^2. s_A allocated to *blue whiting*: 7.6 m^2/NM^2.

Layer 4, 400-500 m: Thresholding to -73 dB. Total remaining s_A: 77.2 m^2/NM^2 is allocated to fish species using s_A proportions from sample 80309. s_A allocated to *S. mentella*: 14 m^2/NM^2. s_A allocated to DSL and other: 62.5 m^2/NM^2.

Layer 5, 500-600 m: Thresholding is not possible because the density of the DSL is too high. Catch on depths 400 and 500 m are practically identical, therefore s_A are approximately identical. s_A allocated to *S. mentella:* 10 m^2/NM^2). s_A allocated to DSL and other: 74.5 m^2/NM^2.

Layer 6, 600-750 m: No thresholding. All s_A (0.3 m^2/NM^2) is allocated to *S. mentella*.

The total s_A allocated to *S. mentella* in this 5NM block is 28.8 m^2/NM^2.

Norwegian registration 2. 17.08.08 17:35 (log 7150) to 17.08.08 18:09 (log 7155)

Layer 1, 15-100 m: no trawl information available. All s_A (144.5 m^2/NM^2) allocated to "other".

Layer 2, 100-200 m: No thresholding. Total s_A is 35.8 m^2/NM^2., s_A allocated to blue whiting and herring.

Layer 3, 200-350 m: Thresholding to -75 dB. Total s_A is 17.5 m^2/NM^2 is allocated to fish species using s_A proportions from sample 80331. s_A allocated to *S. mentella*: 1.0 m^2/NM^2.

Layer 4, 350-560 m: Thresholding To -70 dB. Total s_A is 52.5 m^2/NM^2. is allocated to fish species using s_A proportions from sample 80332. s_A allocated to *S. mentella*: 12.1 m^2/NM^2. s_A allocated to DSL and other: 40.4 m^2/NM^2.

Layer 5, 560-750 m: No thresholding. Total s_A (0.5 m^2/NM^2) allocated to *S. mentella*.
The total s_A allocated to *S. mentella* in this 5NM block is 13.6 m^2/NM^2.
Norwegian registration 3. 20.08.08 09:27 (log 7560) to 20.08.08 10:53 (log 7565)

Layer 1, 15-300 m: no trawl information available. All s_A (562 m^2/NM^2) is allocated to "other".

Layer 2, 300-350 m: Thresholding to -71 dB. Total s_A is: 157.6 m^2/NM^2). s_A allocated to herring: 144 m^2/NM^2. s_A allocated to DSL and other: 13 m^2/NM^2.

Layer 3, 350-500 m: Thresholding to -71 dB. Total s_A is 82.4 m^2/NM^2. s_A allocated to DSL and other: 47.8 m^2/NM^2. s_A allocated to *S. mentella*: 34 m^2/NM^2.

Layer 4, 500-750 m: S.mentella sA (7 m^2/NM^2).

The total s_A allocated to *S. mentella* in this 5NM block is 41 m^2/NM^2.

Faroes Registration 1. 15.08.08 17:23 (log 180) to 15.08.08 17:52 (log 185)

Layer 1, surface 15m – 200m: no trawl information available. All s_A (70.7 m^2/NM^2) allocated to 'other'.

Layer 2, 200m – 250m: no trawl information available. All s_A (161.1 m^2/NM^2) allocated to 'other'.

Layer 3, 250m – 450m: no trawl information available. Thresholding up to -71dB. All s_A (380.6 m^2/NM^2). Very dense SSL. At change of a threshold up to-71 dB are observed separate red fish on depth 350-400m, thus we are much more whole than fishes have removed. Estimated s_A from the box (3 m^2/NM^2) is allocated to *S. mentella.* Remaining s_A (377.6 m^2/NM^2) is allocated to plankton.

Layer 4, 400m – 600m: It is very difficult to allocate red fish in this range since there is a plenty of acoustic noise. In this case it is necessary to reduce speed of a vessel to reduce acoustic noise. To allocate with a threshold red fish practically it is not possible. Therefore here we take only the trawling data. All s_A (212.9 m^2/NM^2). Estimated s_A from the box (7 m^2/NM^2) is allocated to *S. mentella.* (based on species composition in samples 8090005).

Layer 5, 600m – 750m: no trawl information available. Continuous acoustic noise. Allocation of a useful signal is impossible.

The total s_A allocated to *S. mentella* in this 5 NM block is 10 m^2/NM^2.

Faroes Registration 2. 17.08.08 17:25 (log 335) to 17.08.08 17:52 (log 340)

Layer 1, surface 15m – 200m: no trawl information available. All s_A (163.4 m^2/NM^2) allocated to 'other'.

Layer 2, 200m – 300m: no trawl information available. All s_A (101.5 m^2/NM^2). Thresholding up -71dB. In a layer of 270-300 m are observed jambs blue whiting. The remaining s_A (76.1 m^2/NM^2) allocated to blue whiting. Remaining s_A (25.4 m^2/NM^2) is allocated to plankton.

Layer 3, 300m – 450m: no trawl information available. Thresholding up to -71dB. All s_A (263.3 m^2/NM^2). Estimated s_A from the box (5 m^2/NM^2) is allocated to *S. mentella.* *(*The layer of 310-350 m where it is possible to allocate S. mentella was considered). Remaining s_A (258.5 m^2/NM^2) is allocated to 'other'.

Layer 4, 450m – 750m: In this range basically acoustic noise. To allocate S. mentella practically it is not possible. Therefore we take the trawling data. All s_A (509.9 m^2/NM^2). Estimated s_A from the box (7 m^2/NM^2) is allocated to *S. mentella.* (based on species composition in samples 8090005).

The total s_A allocated to *S. mentella* in this 5 NM block is 12 m^2/NM^2.

Faroes Registration 3. 21.08.08 11:35 (log 915) to 21.08.08 12:49 (log 920)

Layer 1, surface 15m – 200m: no trawl information available. All s_A (171.0 m^2/NM^2) allocated to 'other'.

Layer 2, 200m – 300m: Thresholding up -71dB. All s_A (24.2 m^2/NM^2). The remaining s_A (6 m^2/NM^2) allocated to *S. mentella*. Remaining s_A (25.4 m^2/NM^2) is allocated to 'other'.

Layer 3, 300m – 400m: Thresholding up to -74dB. All s_A (137.3 m^2/NM^2). The remaining s_A (5 m^2/NM^2) allocated to *S. mentella*. Remaining s_A (122.3 m^2/NM^2) is allocated to 'other' (based on species composition in samples 8090015).

Layer 4, 400m – 500m: Thresholding up to -71dB. All s_A (200.9 m^2/NM^2). The density of the SSL is to high. In this layer change of a threshold does not give positive results. The remaining s_A (7 m^2/NM^2) allocated to *S. mentella*. Remaining s_A (193.9 m^2/NM^2) is allocated to 'other' (based on species composition in samples 8090005).

Layer 5, 500m – 750m: no trawl information available. Continuous noise. All s_A (826.6 m^2/NM^2) allocated to 'other'.

The total s_A allocated to *S. mentella* in this 5 NM block is 18 m^2/NM^2.

6.3 Scrutinizing using EchoView (Faroes)

Faroese registration 1, 15.08.08 kl. 17:31 (log 182) to 15.08.08 kl. 18:01 (log 187)

Layer 1, surface to DSL (15-250 m), no trawl information available, all s_A allocated to other. Total s_A 370

Layer 2, Threshold up to – 66 dB, the remaining s_A (84) is allocated to fish proportions according to trawl station 08090001, blue whiting, saithe and cornish blackfish.

Total s_A allocated to redfish is this 5 nm block is 0 m^2/nm^2.

Faroese registration 2, 17.08.08 kl. 17:14 (log 334) to 17.08.08 kl. 17:42 (log 339)

Layer 1, surface – 250 m: No trawl information available. All s_A allocated to other, total s_A at threshold level – 82 dB is 250.43 m^2/nm^2.

Layer 2, 250-400 m: Raise threshold to – 65 dB, remaining s_A (40.74) is allocated to fish and split into species proportions by using trawl station 08090005 at 450 m depth.

Layer 3, 400-500 m: Threshold to – 65 dB s_A (13.24)is allocated to fish according and split into species proportions according to station 08090005, redfish, Saithe and blue whiting. Threshold down to -82 dB, total s_A (54.27 m^2/nm^2). Fish s_A subtracted from total s_A gives plankton or other.

Total s_A allocated to redfish in this 5 nm block is 37.76 m^2/nm^2

Faroese registration 3, 21.08.08 kl. 12:32 (log 917) to 21.08.08 kl. 13:01 (log 922).

Layer 1, surface -220 m: No trawl information available, so all s_A assigned to other species and plankton, threshold -82 dB, total s_A 177.23 m^2/nm^2.

Layer 2, 220-400 m: Threshold to – 65 dB, s_A 28.6 m^2/nm^2 assigned to fish, then lower threshold to -82 dB total s_A 116.22 m^2/nm^2. Use trawl station 080900015 s_A proportions to split in species.

Layer 3, 400-500m: Mixed layer. Threshold to -65 dB, s_A 28.6 m^2, lower threshold to -82 dB, s_A 62.7 allocated to smaller targets. Use trawl station 080900015 s_A proportions to split in species.

Total s_A allocated to redfish in this 5 nm block is 35.7 m^2/nm^2.

Norwegian registration 1, 13.08.08 kl. 2:54 (log 6405) to 13.08.08 kl. 3:26 (log 6410).

Layer 1, surface -200 m: All s_A is allocated to other.

Layer 2, 200 -300 m: Threshold -65 dB, s_A is allocated to fish. Then use the proportions according to trawlstation 80307. S_A allocated to redfish in this layer is 7.43 m^2/nm^2.

Layer 3, 300-500 m: Threshold -70 dB, total fish s_A is 27.95 m^2/nm^2, s_A allocated to redfish is 18.09 m^2/nm^2 according to proportions in trawlstations 80308, 80,309 and 80304.

Layer 4, 500-600 m: use school box, in a clean area, threshold -72 dB. S_A allocated to redfish is 0.95 m^2/nm^2

Layer 5, 600-bottom: All s_A is assigned to redfish. 2.74 m^2/nm^2.

Total s_A assigned to redfish in this 5 nm block is 29.21 m^2/nm^2.

Norwegian registration 2, 17.08.08 kl. 17:35 (log 7150) to 17.08.08 kl: 18:09 (log 7155).

Layer 1, surface-200 m: All s_A is allocated to other.

Layer 2, 200 -350 m: Threshold -72 dB, total fish s_A is 28.91 m^2/nm^2. Redfish s_A in this layer is according to trawlstation 80331 is 2.6 $m^2/nm^{2.}$

Layer 3, 350-500 m: Threshold is -72 dB, total fish s_A is 20.38 m^2/nm^2. From trawlstation 08332 the proportions are used, redfish s_A is 16.4 m^2/nm^2.

Layer 4, 500-600m: Threshold -72 dB, use trawlproportions from station 80333. S_A allocated to redfish is 1.54 m^2/nm^2.

Layer 5, 600-900 m: Threshold -82 dB, noise removed. Remaining s_A allocated to species according to trawlstation 80333. S_A allocated to redfish in this layer is 0.89 m^2/nm^2.

Total s_A allocated to redfish in this 5 nm block is 21.43 m^2/nm^2.

Norwegian registration 3, 20.08.08 kl.09:27 (log 7560) to 20.08.08 kl. 10:53 (log 7565).

Layer 1, surface -150 m: All s_A is allocated to other.

Layer 2, 150 -300 m: threshold -66 dB. Total fish s_A is 282.21 m^2/nm^2. Redfish s_A in this layer is 13.89 m^2/nm^2. Proportions derived from station 80349.

Layer 3, 300 -400 m: 148.42 m^2/nm^2. Threshold -66 dB. In this layer there is apparently a great deal of herring. All s_A allocated to herring.

Layer 4, 400-500 m: Threshold – 66 dB. Total fish s_A is 14.68 m^2/nm^2. Redfish s_A is 10.15 m^2/nm^2.

Layer 4, 500-600 m: Some noise, use school box in area with little noise. Threshold-77 dB, total s_A 0.93 m^2/nm^2. S_A for redfish is 0.89 m^2/nm^2.

Layer 5, 600- 700 m: Same procedure as the layer above. Redfish s_A is 0.22 m^2/nm^2.

Total s_A allocated to redfish in this 5 nm block is 25.15 m^2/nm^2.

Russian Registration 1, 17.08.08 kl. 09:19 (log 565) to 17.08.08 kl. 11:03 (log 570).

Layer 1, surface -380 m: No trawl information available so all s_A assigned to other species and plankton, threshold -82 dB, total s_A 51.85 m^2/nm^2.

Layer 2, 380- 470 m: Threshold -68 dB. S_A allocated to redfish 1.16 m^2/nm^2. Proportions according to trawlstation 1.

Layer 3, 470-650 m: Threshold -68 dB. S_A allocated to redfish 6.84. m^2/nm^2. Proportions according to trawlstation 2.

Layer 4, 650-750 m: Threshold set to -68 dB. S_A allocated to redfish 0.15 m^2/nm^2. Proportions according to trawlstation 3.

Total s_A allocated to redfish in this 5 nm block is 8.15 m^2/nm^2.

Russian registration 2, 17.08.08 kl. 22:12 (log 625) to 17.08.08 kl. 23:19 (log 630).

Layer 1, surface-300 m: No trawl information available therefore all s_A is allocated to other.

Layer 2, 300-400 m: Threshold -70 dB. Total s_A 14.20 m^2/nm^2. S_A allocated to redfish according to the proportions in trawlstation 4 is 4.74 m^2/nm^2.

Layer 3, 400-650 m: Threshold -65 dB. Total s_A 3.09 m^2/nm^2, all is allocated to redfish.

Layer 4, 650-750, all s_A is allocated to redfish, 0.55 m^2/nm^2.

Total s_A m^2/nm^2 in this 5 nm is 8.38 m^2/nm^2.

Russian registration 3, 19.08.08 kl. 10:37 (log 1000) to 19.08.08 kl. 11:07 (log 1005).

Layer 1, surface-335 m: No trawl information available, all s_A is allocated to other.

Layer 2, 335-435: Threshold – 72 dB. S_A allocated to redfish in this layer is 6.30 m^2/nm^2according to proportions in trawlstation 5.
Layer 3, 435-550: All s_A is allocated to other.

Layer 4, 550-750: All s_A 2.24 m^2/nm^2 is allocated to redfish, threshold -72 dB.

Total s_A allocated to redfish in this 5 nm block is 8.54 m^2/nm^2.

6.4 Summary of comparative scrutinizing

The results of comparative scrutinizing of the selected registrations are summarised in Table 1. Difference between maximum and minimum s_A allocated to redfish vary between 16% and 450%! This clearly shows that **differences in scrutinizing methods have a very large impact on the abundance estimate of redfish. They probably constitute the major source of uncertainty for any quantitative estimate**. There does not seem to be a constant bias towards low or high values in any of the methods employed. The availability of biological information from trawl catches seem to reduce the differences between abundance estimates, through better allocation of acoustic energy. However, even in conditions where highly resolved sampling data is available (e.g. Norwegian registration 1) the difference between low and high catches reaches 16%. In more difficult situations such as in the Russian registration 2 with little biological data and strong DSL, individual choices of depth layers and thresholding levels can vary greatly, leading to radically different abundance estimates.

Table 1. s_A allocated to redfish for the nine selected registrations, using the three different scrutinizing procedures. The max difference is calculated as the difference between min and max s_A, divided by the min s_A.

		s_A ALLOCATED TO REDFISH			
REGISTRATION	LOG: START/STOP	NORWAY	RUSSIA	FAROES	MAX DIFFERENCE (%)
NO-1	6405/6410	25	29	29	16%
NO-2	7150/7155	19	14	21	50%
NO-3	7560/7565	46	41	25	84%
RU-1	565/570	12	13	8	62%
RU-2	625/630	44	16	8	450%
RU-3	1000/1005	31	22	8	290%
FO-1	182/187	0	10	0	NA
FO-2	334/339	20	12	38	217%
FO-3	917/922	18	18	36	200%

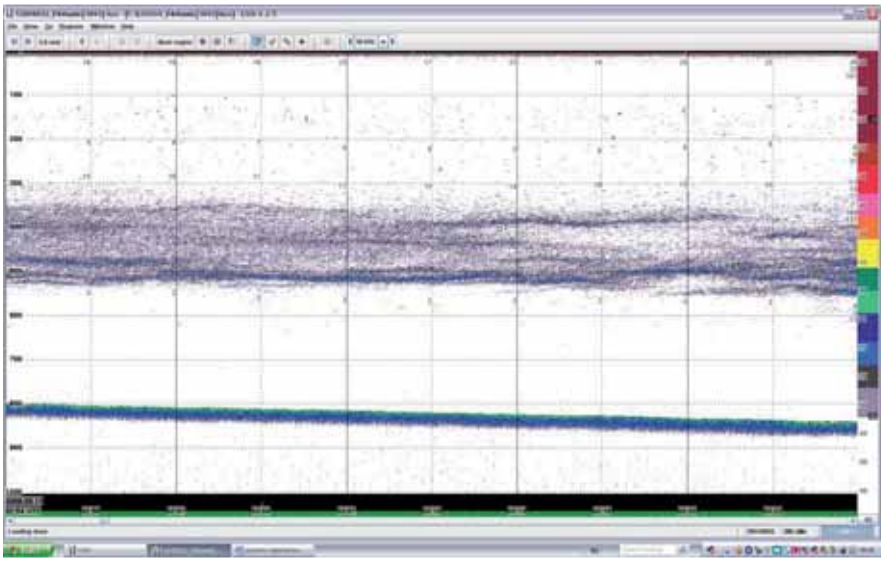

Figure 1. Norwegian acoustic registration 1.

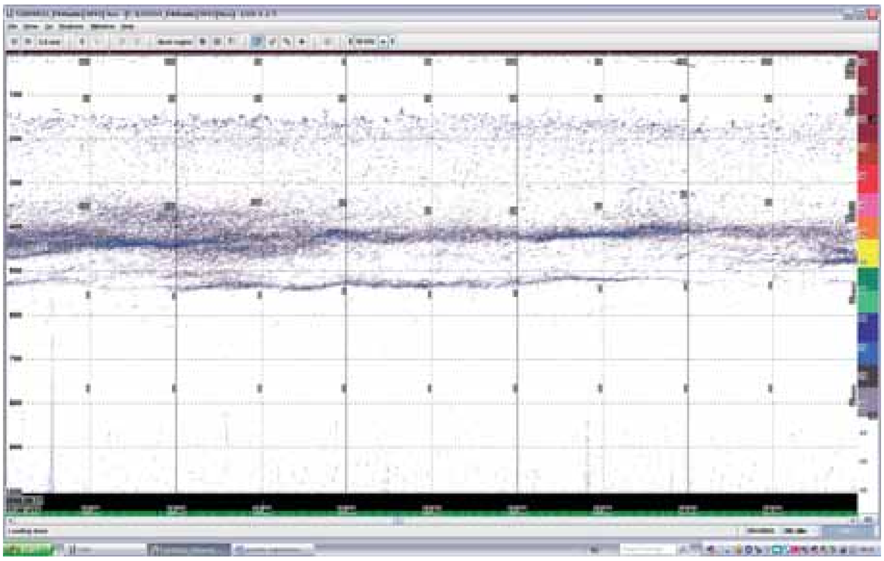

Figure 2. Norwegian acoustic registration 2.

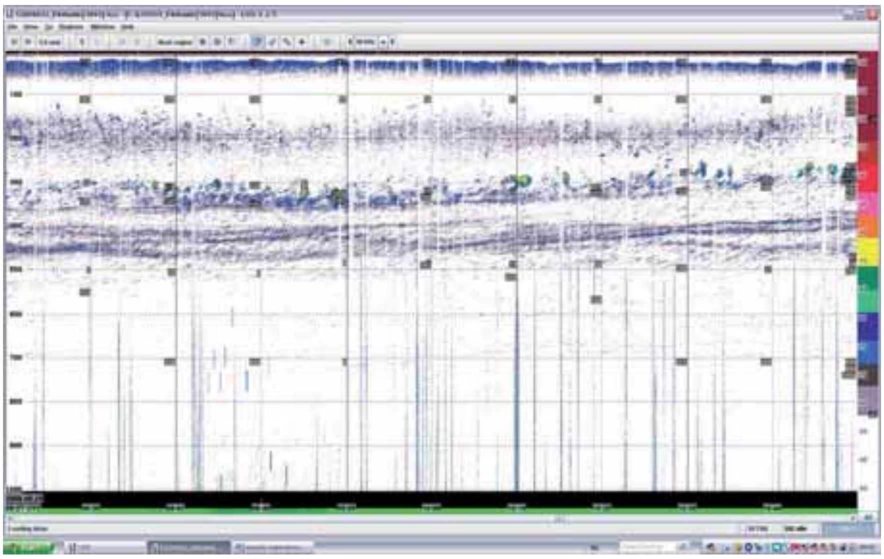

Figure 3. Norwegian acoustic registation 3.

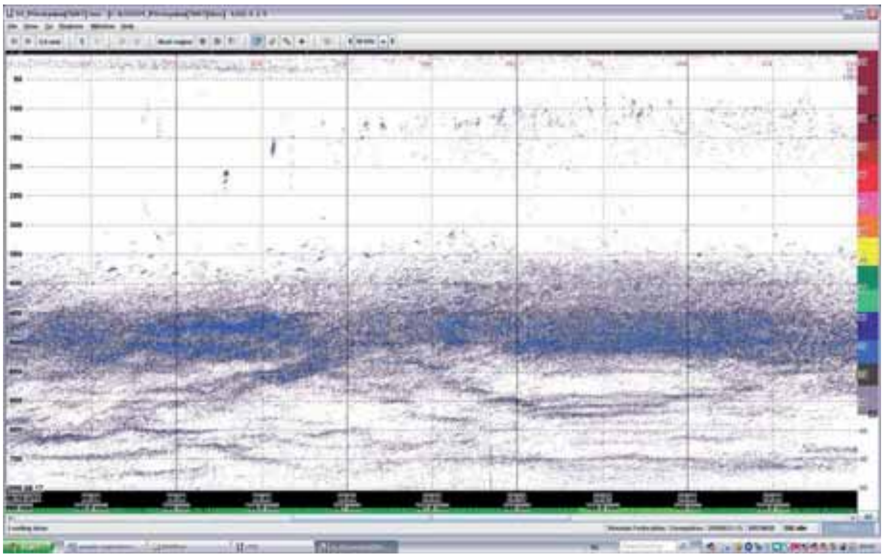

Figure 4. Russian acoustic registration 1.

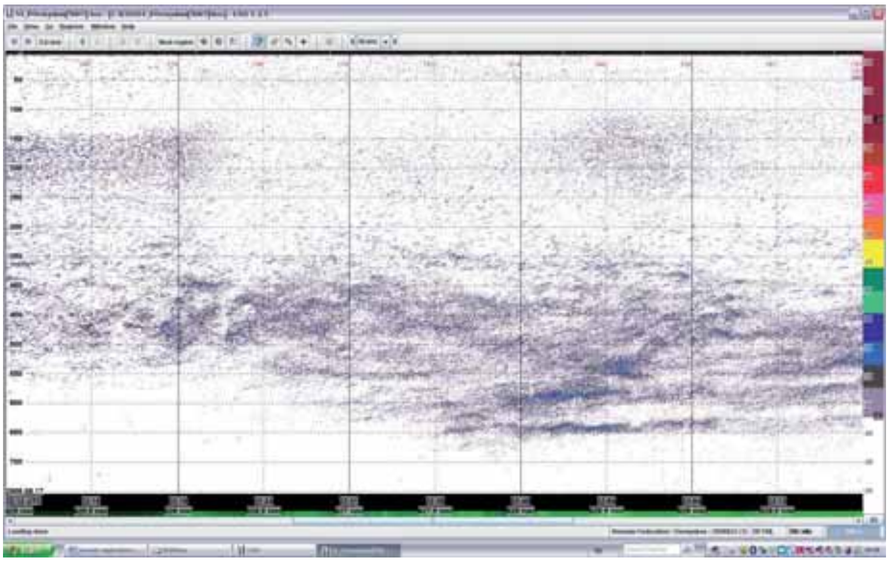

Figure 5. Russian acoustic registration 2.

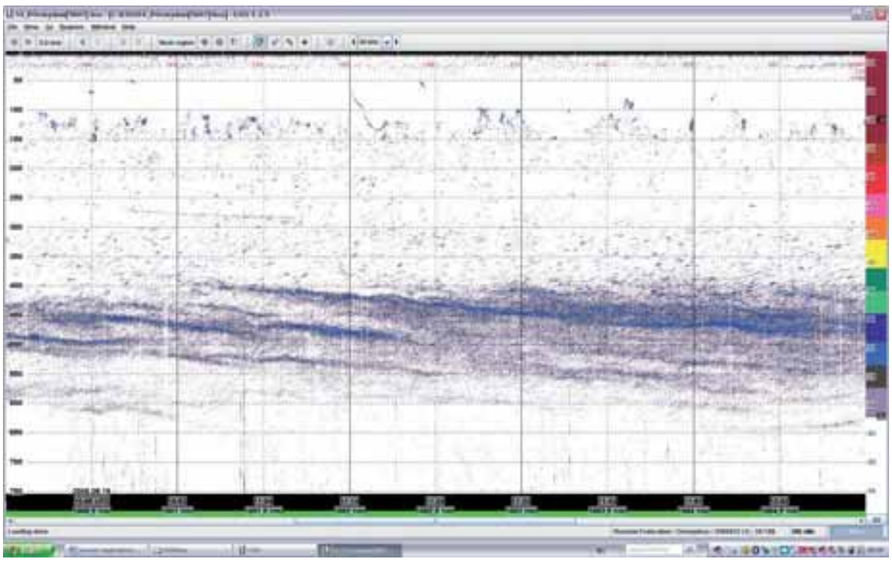

Figure 6. Russian acoustic registration 3.

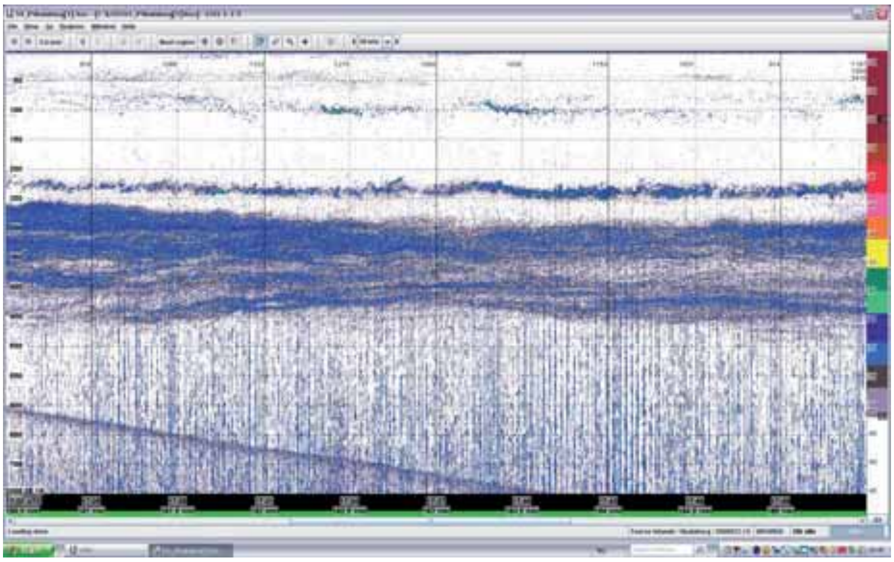

Figure 7. Faroese acoustic registration 1.

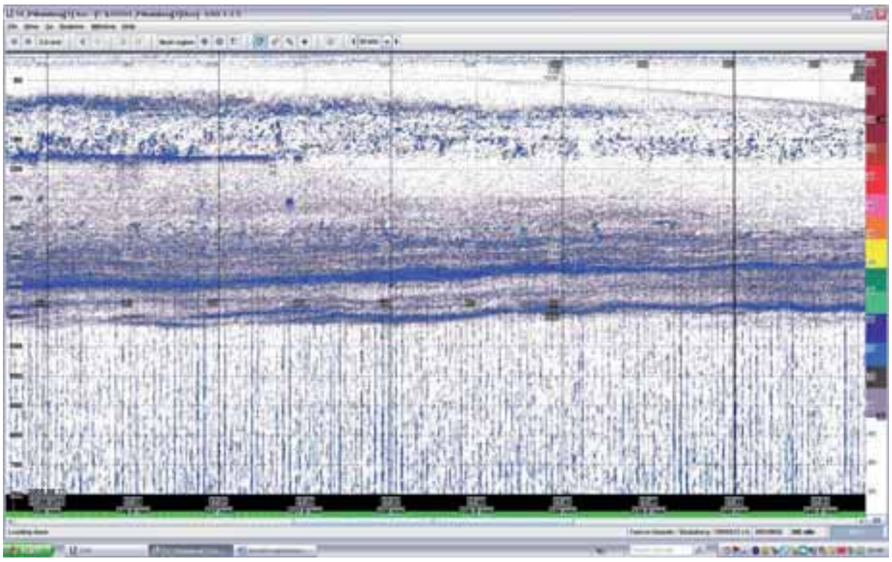

Figure 8. Faroese acoustic registration 2.

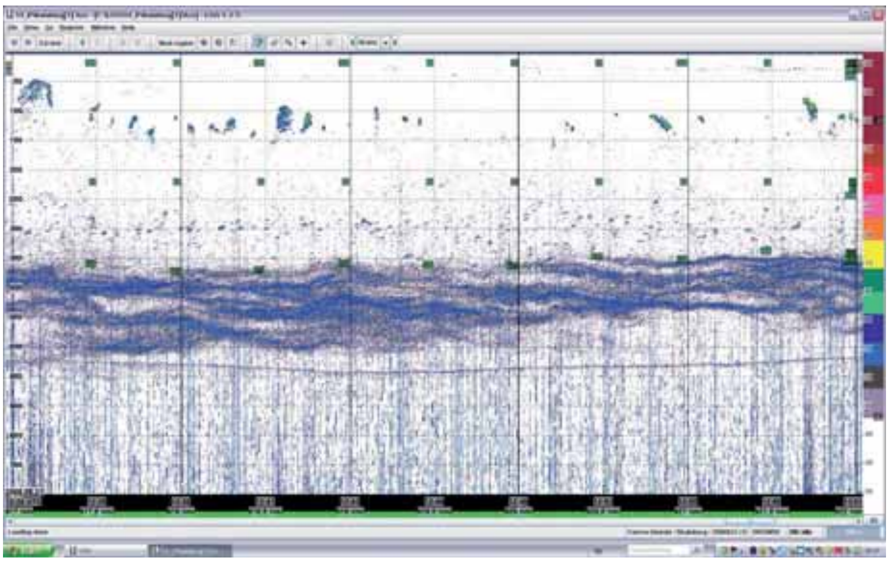

Figure 9. Faroese acoustic registration 3.

7. Commonalities, difficulties and discrepancies in the scrutinizing methods currently used

7.1 Scrutinizing softwares

The scrutinizing was performed using three different softwares: LSSS (Norway), FAMAS (Russia) and EchoView (Faroes). Each software was thought to offer sufficient capabilities for the scrutinizing of the hydroacoustic data collected in the Norwegian Sea. However, the use of different tools by different parties does not help when comparing or standardising the scrutinizing procedures. It was therefore though that it would be beneficial if all parties would use the same scrutinizing software.

7.2 Target Strengths

The value of Target Strength (TS) to be used for *S. mentella* in the Norwegian Sea is still an unresolved issue. Currently, three equations for the length-dependent TS are used:

Eq. 1: $TS_L = 30.9 \times \log(L) - 88.9$ used by Russia for Barents Sea redfish

Eq. 2: $TS_L = 20 \times \log(L) - 71.3$ used for the Irminger Sea redfish and by Russia for Norwegian Sea redfish

Eq. 3: $TS_L = 20 \times \log(L) - 68.0$ used by Norway for the Norwegian Sea redfish, on the basis of recently published material (Gauthier and Rose, 2001, 2002, Kang and Hwang, 2003)

The choice of the TS equation has implication for the final abundance estimate (here, the choice of eq. 2 or 3 would lead to abundance varying by a factor of 2). It is also affecting the calculation of individual catch composition with regards to s_A proportions. Final abundance estimates can be recalculated *a posteriori* with 'new' or 'agreed' TS equations. However, the effect of TS choice on individual catch composition estimates is more complicated to be corrected for. The whole scrutinizing needs to be redone in order to account for changes in the TS equation.

It was agreed that a final decision about which common TS to use for *S. mentella* in joint surveys should be further discussed in another workshop. Recent publications on the issue as well as new data collected and analysed should be presented at such a workshop as a basis for final decision. Paper copies of the most recent publications of target strength measurements of redfish, i.e., Gauthier and Rose (2001, 2002); Kang and Hwang (2003), was distributed among the participants. New TS measurements derived from existing data, or acquired with the TS-probe, Target-tracker or other device should assembled for such workshop.

Ribbon barracudina (*Notolepis* or *Arctozenus Risso*) is a small deep pelagic fish that was commonly caught during the survey, with presence recorded in 74% of the catches. Currently, this species is included in the acoustic category 'plankton' by Norway, but it is considered as an independent acoustic entity by Russia. According to Mamylov (1988), the TS_{kg} of ribbon barracudina at 38 kHz is around -34 dB/kg (σ_{kg}=50 cm^2/kg).

The TS values for all other fish species caught during the survey seem to be similar for all countries (although there was no systematic exploration of the formulas used).

7.3 Thresholding

The thresholding procedure used during scrutinizing consists of raising the minimum s_V in order to remove background noise and small targets from the s_A estimate. What is assumed is that only large (fish) targets are preserved. One disadvantage of using such method (in particular at great depth) is that thresholding will also 'remove' large targets, when these are present in low concentrations and at the edge of the acoustic beam. This results in a reduction of the effective beam angle, which leads to underestimation of fish biomass if not properly accounted for. Procedures to correct for the reduction of the effective beam angle were discussed during the workshop but it appeared that no adequate solution can be applied within the DSL. This is mostly due to the 'pumping' effect of dense plankton patches. The problem of separating between fish targets and smaller targets is not solved.

The choice of thresholding level is done on an ad hoc basis with often little theoretical justification or clearly stated methodology. Some of the scrutinizing was done with a threshold of -68 dB. That threshold corresponds to a TS threshold of -34.4 dB for a depth layer of 400 – 500 m. The application of this threshold would exclude all individual redfish in a clean situation. With this level of thresholding in this depth layer, redfish can only be detected if noise or other fish to bring the redfish above the threshold (pumping effect). The measured s_A-value would thus depend on the strengths of NOT-redfish echoes, but it is not possible to determine to which extent (mostly because many of the small targets present in the DSL are not adequately sampled by the trawl). Therefore, scrutinizing within the DSL remains difficult and the effect of thresholding in this layer is uncertain. Alternative approaches with multiple-frequency may be developed in the future.

7.4 Separation of species based on TS distribution

A possible way of partitioning s_A between species is to use the TS distribution provided in the scrutinizing software (LSSS, FAMAS or EchoView). The Russian procedure used this partitioning method and allocated , -35 to -29 dB to blue whiting and -41 to -35 dB to redfish. This procedure was discussed by the group and it was concluded not to be suitable. Indeed, during the survey, the average length of blue whiting was around 27cm and that of redfish around 37cm. This results in TS values of -41.6 dB for blue whiting and -39.9 / -36.7 dB for redfish (using equation 2 or 3 respectively). Blue whiting and redfish are the two most common species and since they have very close TS so it was recommended that this technique should not be used in the Norwegian Sea.

However, when in doubt on which trawl haul information to use, it may be of help to look at the shape of the TS-distribution rather than the exact values and consider to use an earlier trawl haul that were conducted on registrations that gave a similar TS pattern.

7.5 Trawl based s_A estimates

Norway and Faroes used a 'pure' hydroacoustics methodology, in which all registrations/ layers are scrutinized directly. For each individual registration/layer, the sA allocated to fish is partitioned between the different species found in the nearby trawl hauls with sA proportions dependent on species proportion in the catch and length composition (on the basis of length-based TS equations). The method employed by Russia differs from this. It is a combined trawl-hydroacoustic method which is currently employed in the Irminger Sea surveys (see section 2.4 in ICES 2007b). The differences resulting from the use of one or the other method were not investigated during the workshop. The combined method may be a good alternative to direct acoustic estimates in the DSL in the Irminger Sea. However, it was felt that it could not be transferred easily in the Norwegian Sea where most fish are located within the DSL (rather than above) and where abundance of *S. mentella* in shallow and deeper components are not expected to be strongly linked.

7.6 Noise

Because redfish is distributed down to 800m depth (ICES, 2008) noise levels should be minimised as much as possible. Vessel noise measurements can be made following the standard procedure recommended by SIMRAD (2008). Information on vessel noise should be collected during the survey and vessel selection should take such information into account, in addition to the set of recommendations listed in ICES (2007a). During the August survey vessel noise was recorded for the Atlantic Star.

Noise resulting from poor weather conditions is also problematic and it was observed that the acoustic signal highly deteriorated when sea state was higher than 8 (approx. 3m wave height). Noise resulting from cavitation is manifested by vertical stripes, i.e. single pings with very high backscattering through most of the water column. The group believed that it should be possible to use a method to automatically remove these 'noisy pings' prior to echointegration. The KORONA module of LSSS scrutinizing software includes a specific procedure (the 'SPIKE' module) to perform such operation. However, the group did not have sufficient knowledge to test this module. This will be considered in the future.

Other types of noise (white noise?) maybe automatically removed prior to echo integration, as in Korneliussen (2000). Some procedures for noise removal are implemented in LSSS but have not been applied to the data analysed in this workshop.

7.7 Trawl sampling strategy

Due to the current difficulty of performing acoustic estimates, the group recognised that standardisation of trawl methodology should be maximised so that estimates that are independent from the hydro-acoustics can be achieved, compared and combined. It was recommended that all parties involved should use the Gloria 2048 trawl.

It was also recognised that without many trawl hauls the hydro-acoustic method would be very uncertain. It was concluded that more trawl hauls are needed during the acoustic surveys. This should be done preferably with a multisampler cod-end which increases the precision (accurate depth and duration of sampling) and the sampling intensity (3 samples at different depths per haul).

Observations from the August 2008 survey showed that the redfish population within, above and below the DSL has different biological characteristics, i.e. size and age distribution, sex ratio,… For this reason, trawl hauls should not be carried in more than one layer at a time. Individual haul (or individual sample in the case of use of the mutlisampler) should be carried either above or within or below the DSL.

For the purpose of hydro-acoustics scrutinizing and direct abundance estimates from trawls, the trawl sampling should be stratified by geographical areas and vertical layers. Although exact trawl location and depths need to be determined on the basis of hydro-acoustics registrations observed during the survey.

8 Alternative methods, good practices and way forward

8.1 Echo counting

During the survey often strong disturbances arose on the echograms recorded when the vessel is measuring in bad weather. The exact causes could not be determined but are probably caused by cavitation. For this reason, the echo integration can not be applied, unless the registrations are filtered-out of those disturbances. For the evaluation of the echograms, the echo counting method can be used instead of echo-integration. This is facilitated by the fact that redfish appeared in this time in this area within very thin concentrations and form no shoals. The procedure is described in Bethke (2004) and the equation used resembles the frequently used calibration equation:

$$s_A = \frac{4\pi}{p_{Mean}\psi_{eff}} Mean\left[\sum_{Ping}\sigma_{bs}\frac{r_0^2}{r_\sigma^2}1852^2\right]$$

with: $$\psi_{eff} = \int_0^{2\pi}\int_0^{\theta_{comp}} \frac{\rho\ \theta}{\rho_0}\sin\ \theta\ d\theta d\phi$$

The parameter p_{Mean} is the mean probability that a single target will be detected ($p_{Mean} = 0.85$ for EK500) in the centre of the beam. Outside the centre the detection probability decreases with the angle θ (Figure 10). This is taken into account by the parameter ψ_{eff}, the effective solid two-way beam angle, depending upon the maximum compensation angle controlled by the echo-sounder settings (ψ_{eff} = 0.0083918).

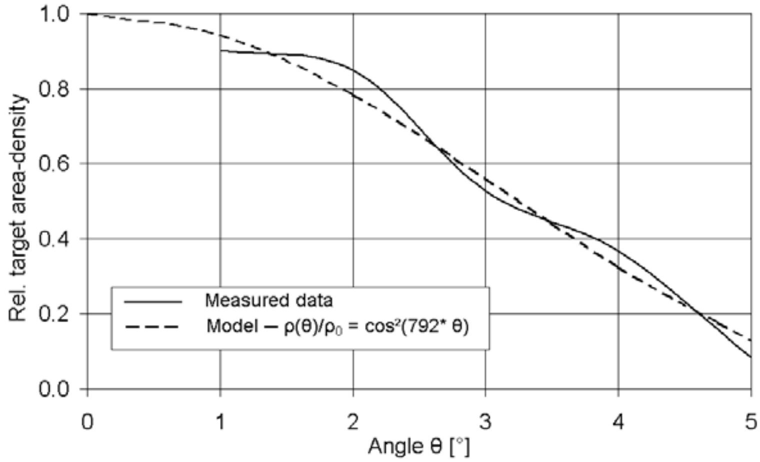

Figure 10. Relative area based target density within the beam of the transducer as a function of the angle θ.

The s_A -values computed by these equations can be used exactly in the same way as the traditional output values of the echo integration method. The procedure was tested with the undisturbed Icelandic data from measurements in the Irminger Sea in 2005. A comparison for echo integration and echo counting for these data is presented in Figure 11.

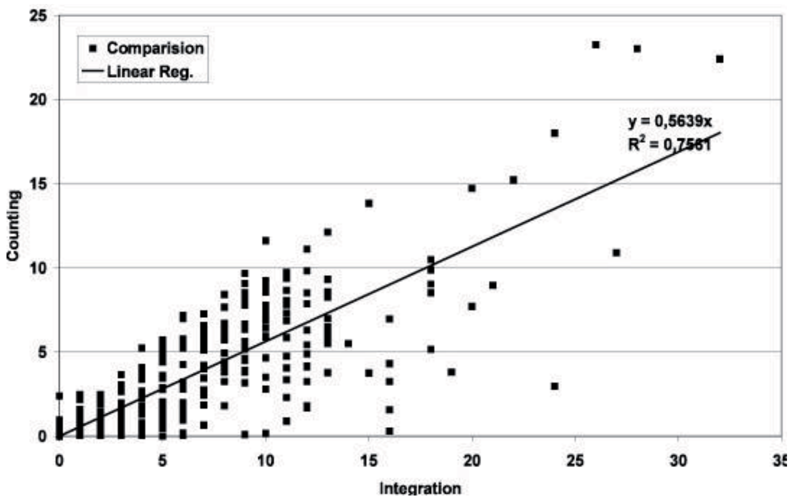

Figure 11. Comparison of Icelandic acoustic data: Echo Integration against Echo Counting (ICES 2005).

Since echo counting is a different measuring procedure in principle, no identical results can be expected compared to echo integration. The advantages of echo counting are in situations in which the redfish appears slightly mixed with other deep-sea species (myctophids etc. but not within the DSL!). In those situations, echo counting is clearly the more exact measuring procedure, however, tending towards underestimations of stock size. Almost identical values are measured if redfish appears in an undisturbed environment as a single fish. In situatons in which the redfish have to be measured in denser concentrations, the echo integration has to be preferred. The counting procedure is based on the fact that fish are recognized as single targets according to the parameter settings of the echo sounder. If this, as within redfish shoals, is not the case, these data are rejected from counting and this leads to an underestimation of the stock.

When measurements were done with the SIMRAD echosounder EK500, the probability that a single target was detected was relative high. The SIMRAD EK60 used in the Norwegian Sea surveys has a much lower detection probability (about 30 %) than for the older EK500. Until now it is not clear if the EK60 sounder can be used for echo counting and further work has to be done to validate this. During the survey, one should ensure that in addition to the raw–data, data in the EK500 format are recorded in a similar format as the BI500 data.

8.2 Estimation of specific catchability coefficients

Species allocation during scrutinizing was derived from the nearest trawl hauls on the basis of s_A proportions in the catch. This procedure is based on the assumption of equal catchability of the species caught. However this may not necessarily be the case. Specific differences in catchability between redfish and blue whiting could change the survey results to a large extent. A procedure for the measurement of catchability was proposed to resolve this issue. The procedure is based on the comparison of fish density measurements from hydro-acoustics and trawl samples. A comparison of both measurements can be done by using the following equation (Mamylov 1999):

$$s_{ATR} = \frac{1852\, C\, \sigma_{kg}\, H}{k\, D_{TR}\, L_{TR}\, H_{TR}}$$

Where s_{ATR} is the expected area backscattering coefficient (s_A), C is the catch [kg], σ_{kg} is the acoustic scattering cross section [m²/kg], H is the depth layer [m] for which the s_{ATR} are extrapolated, k is the catchability [%], D_{TR} is the trawled distance [NM], L_{TR} and H_{TR} are the horizontal (distance between trawl wings) and vertical opening of trawl [m]. Using the equations:

$$\sigma_{kg} = \frac{\sigma}{m},$$

$$\sigma = 4\,\pi\,10^{\frac{TS}{10}},$$

$$TS = B\,\lg(L) - A \quad and$$

$$\sigma = 4\,\pi\,10^{-\frac{A}{10}}\,L^{\frac{B}{10}}$$

the s_{ATR} equation can be re-written as follows:

$$s_{ATR} = \frac{1852\, H}{k\, D_{TR}\, L_{TR}\, H_{TR}}\, 4\,\pi\,10^{-\frac{A}{10}} \sum_L F_L\, L^{\frac{B}{10}}$$

assuming that the catch C is the sum of single target (and representing those targets, however, multiplied by an unknown catchability k which could be different for each species but constant for each length group of a species) with individual masses m in the swapped volume. F_L is the frequency that a fish with length L occurs in the catch. A and B are parameters of the TS-Equation. The total s_A-value of a trawl haul can be calculated by summing the portions for each species in the catch:

$$s_{ATotal} = s_{AR} + s_{ABW} + \ldots$$

The calculated total s_A-value can be compared with the measured value originating from echo–sounder measurements for each haul. Doing this for several trawl hauls obtained in 'clean' situations, i.e. where only redfish and blue whiting were caught, the catchability can be calculated by least square estimation. An Excel-spreadsheet was prepared to estimate the catchability for redfish and blue whiting (results are not available yet) comparing hydro-acoustic and trawl data.

8.3 Acoustic categories

It was decided to use the following acoustic categories: beaked redfish, blue whiting, herring and saithe. These should be the compulsory categories. Other fish categories are optional. Fish species which are not registered into a specific category should be listed as 'Others'. PINRO will check if TS for Ribbon barracudina exists, and if it is necessary to establish as a separate category for this species. The category 'Plankton' includes small targets, e.g. plankton and myctophids.

8.4 Multiple frequency

None of the commercial trawler used for the August 2008 survey were equipped with multiple frequency hydro-acoustics, and it is likely that surveys in the near future will have the same restrictions. However, it was felt that current developments in multi frequency acoustics could provide useful tools for the processing of hydroacoustics data within the DSL.

8.5 Recommendations for future surveys

The current hydroacoustic estimates suffer from a number of theoretical and practical limitations (section 7). The major one being the uncertainty in hydroacoustic estimates in the DSL, where the concentration of redfish is higher.

Considering the results obtained at the workshop and the points discussed in section 7 and 8 of this report, we suggest the following recommendations for the conduct and interpretation of future hydroacoustic surveys on redfish in the Norwegian Sea:

1. Hydroacoustics should be used as a complement to trawl based estimates. For that purpose, the number of trawl hauls should be maximized. The use of the multisampler by all participants is recommended (section 7.7).
2. All vessels/nation should use the same equipment for trawling (Gloria 2048), hydroacoustic registrering (EK60) and scrutinizing.
3. Individual trawl hauls should be conducted in single vertical layers (e.g. above, within or below DSL, section 7.7)
4. Additional hydroacoustic observation methods should be considered (e.g. deep towed transducer, multiple frequencies)
5. All vessels/nations should use a common set of acoustics categories (see section 8.3)
6. Species partition based on TS distribution should be avoided (section 7.4)

7. The distance between acoustic tracks should be reduced as much as possible without compromising the survey extent. A distance of no more than 45 miles is recommended. This could be reduced in areas of high redfish densities.
8. 1-2 days should be allocated to inter-vessel comparison of acoustic systems and joint parallel trawls.
9. The scrutinizing cross-comparison (as conducted during the workshop, section 6) should be conducted systematically, as a measure of data qualification
10. Methods for automatic removal of noise should be implemented in the scrutinizing process (section 7.6)
11. All vessels should start and end the survey simultaneously.
12. Data collected during the international redfish survey should be stored and made available through an international database

9 Acknowledgements

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Annex 2: Agenda

Tuesday 25 November 2008

9:00–9:30	Welcome / Coffee – Adoption of the agenda
9:30–10:30	Presentation of the hydroacoustics data and scrutinizing procedure used by Norway (Benjamin Planque, Ronald Pedersen) + discussion
10:30 – 11:30	Presentation of the hydroacoustics data and scrutinizing procedure used by Russia (Valery Zubov) + discussion
11:30 – 12:30	Lunch break
12:30 – 13:30	Presentation of the hydroacoustics data and scrutinizing procedure used by the Faroes/Iceland (Fróòi Skúvadal) + discussion
13:30 – 15:00	Presentation of the selected registrations from each vessel (Planque, Zubov, Skúvadal) and the scrutinizing results + discussion
15:00 – 15:30	Coffee break
15:30 – 17:00	Writing of report sections on current individual scrutinizing practices.

Wednesday 26 November 2008

9:00 – 11:30	Comparative scrutinizing of selected registrations from the three vessels (in 3 groups)
11:30 – 12:30	Lunch break
12:30 – 13:00	Plenary, report on scrutinizing status
13:00 – 15:00	Comparative scrutinizing continues (in 3 groups)
15:00 – 15:30	Coffee break
15:30 – 16:00	Plenary: report on scrutinizing status
16:00 – 17:00	Writing of report sections on comparative scrutinizing

Thursday 27 November 2008

9:00 – 11:30	Plenary: commonalities, difficulties and discrepancies in the scrutinizing methods currently used.
11:30-12:30	Lunch Break
12:30 – 13:30	Plenary: good practice and way forward for redfish (and other species) hydroacoustics assessment in the Norwegian Sea.
13:30 – 17:00	Writing of report sections on good practices and way forward.

Annex 3: Selected hydroacoustics registrations

Reference hydroacoustic registrations from Norway, Russia and the Faroes. For each 5NM reference block, the reference trawl(s) is (are) indicated together with the species composition in number, biomass proportion and s_A proportion.

	hydroacoustic registration	start	stop	station	start	depth	species	number	biomass (%)	sA (%)
NORWAY (Atlantic Star)	1	8/13/08 2:54	8/13/08 3:26	80304	8/12/08 21:51	500	*S. mentella*	155	95.3	97.5
		log: 6405	log: 6410				ribon barracudina	52	1.5	0
							blue whiting	5	0.9	2.5
				80305	8/12/08 22:51	600	*S. mentella*	17	87.9	92.7
							ribon barracudina	24	6.7	0
							blue whiting	2	1.8	7.3
				80306	8/12/08 23:51	700	*S. mentella*	2	82.3	100
							ribon barracudina	3	7	0
				80307	8/13/08 7:53	200	blue whiting	441	84.4	83.5
							herring	30	11.7	15.2
							S. mentella	5	9.9	1.3
				80308	8/13/08 8:53	300	*S. mentella*	56	55.6	31.2
							blue whiting	151	44.4	68.8
				80309	8/13/08 9:53	400	*S. mentella*	122	98.3	98.4
							ribon barracudina	21	0.6	0
							blue whiting	2	0.5	1.5
	2	8/17/08 17:35	8/17/08 18:09	80331	8/17/08 14:37	200	blue whiting	419	60	57.9
		log: 7150	log: 7155				herring	129	34.8	41.2
							S. mentella	5	3.6	0.9
				80332	8/17/08 15:27	350	*S. mentella*	155	92.3	80.9
							blue whiting	30	4.9	12.9
							greater argentine	4	1.8	5.3
							herring	1	0.2	0.8
				80333	8/17/08 16:17	500	*S. mentella*	167	97	98.1
							greater argentine	1	0.8	1.9
	3	8/20/08 9:27	8/20/08 10:53	80352	8/20/08 10:21	400	*S. mentella*	557	98.7	96.7
		log: 7560	log: 7565				blue whiting	21	1.2	3.3
				80353	8/20/08 11:11	500	*S. mentella*	450	98.7	99
							blue whiting	4	0.4	1
				80354	8/20/08 12:01	600	*S. mentella*	179	91.9	99.5
							Greenland halibut (male)	6	3.2	0.5
							ribbon barracudina	87	1.7	0

RUSSIA (Osveyskoe)	1	8/17/08 9:16 log: 565.0	8/17/08 11:00 log: 570.0	1	8/17/08 8:00	380	*S. mentella*	284	36.0	14.43
							ribon barracudina	270	1.5	1.64
							blue whiting	1935	61.5	83.55
							Herring	3	0.2	0.11
							Schedophilus medusophagu	2	0.2	0
							Pollachius virens	1	0.6	0.06
				2	8/17/08 12:30	470	*S. mentella*	420	82.1	56.25
							ribon barracudina	1526	11.6	28.32
							blue whiting	130	6.4	15.42
				3	8/17/08 16:20	650	*S. mentella*	241	53.7	28.45
							blue whiting	93	4.3	9.08
							ribon barracudina	4902	41.7	62.3
							Lampanictes spec.2	26	0.2	0
							Myctophum	4	0.0	0.17
	2	8/17/08 22:12 log: 625	8/17/08 23:19 log: 630	4	8/17/08 23:00	300	*S. mentella*	122	64.8	33.43
							blue whiting	278	35.2	66.57
	3	8/19/08 10:34 log: 1000	8/19/08 12:05 log: 1005	5	8/19/08 11:07	335	herring	7	0.2	0.15
							S. mentella	1793	75.8	46.39
							sygnathus acus	1	0.0	0
							Schedophilus medusophagu	1	0.0	0
							blue whiting	2296	23.9	53.25
							ribon barracudina	65	0.1	0.21
FAROES (Skálaberg)	1	15/08/08 kl.17:31 log:182	15/08/08 kl.18:01 log:187	8090001	8/15/08 15:06	300	Black fish	21	29	25.26
							Saithe	2	17.5	6.76
							blue whiting	100	41.2	67.69
	2	17/08/08 kl.17:14 log:334	17/08/2008 kl:17:42 log:339	8090005	8/17/08 14:25	450	*S. mentella*	241	72.1	71.31
							Saithe	1	4	27.8
							blue whiting	277	15.7	0.89
				8090014	8/20/08 16:25	380	S.Mentella	42	1.15	0
							Herring	7300	98.6	0
							Cod	1	0.01	0
	3	21/08/08 kl.12:32 log:917	21/08/08 kl:13:01 log:922	8090015	8/21/08 0:45	300	*S. mentella*	358	94	96.21
							Blue whiting	35	6	3.79
				8090020	8/23/08 23:30	350	*S. mentella*	2899	100	100

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