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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark
Telephone + 45 33 38 67 00 · Telefax +45 33 93 42 15
www.ices.dk · info@ices.dk

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1 Executive Summary

The Working Group on Fisheries Acoustics Science and Technology (WGFAST) met at the Sea Fisheries Institute in Gdynia, Poland, from 20–23 April 2004. David Demer, USA, was Chair, and Paul Fernandes, UK, was Rapporteur. There were seventy-one participants from nineteen countries.

a) The first topic was "the effectiveness of noise-reduced platforms." Since the 1960s, ICES has recognized that fish may avoid survey vessels due to their radiated underwater noise. In 1995, the Cooperative Research Report No. 209 summarized evidence for fish avoiding vessels and proposed a specification for radiated noise from research vessels. Several vessels have now been built in compliance. There is still need to: 1) characterize the effectiveness of noise-quieted vessels; 2) improve our understanding of how fish detect and respond to sound; 3) identify the root causes of avoidance reactions; and 4) improve the measurements of radiated vessel noise fields. Currently, there is insufficient new information to revise *ICES Cooperative Research Report* 209.

b) The second topic was "the use of acoustics for evaluating ecosystem structure, with emphasis on species identification." Significant advances in acoustical species identification have been made over the past decade. A variety of scattering models are being used to predict differences in scattering spectra, interpret the output of species identification software, and direct validation efforts. These methods are most effective in simple systems involving sound scattering from a few dominant species having aggregations that are unmixed and dispersed. The primary challenges for further progress are: to account for the stochastic and non-stationary nature of sound scatter; and to improve the validation methods.

c) The third topic was "statistical characterisation and utilisation of target strength (TS). Empirical observations and model simulations have progressively elucidated the variability of TS due to many non-stationary abiotic and biotic factors. These observations have led us to view TS as a multivariate parameter that is best described by a probability density function. The primary factors affecting the magnitude and variability of TS have recently been explored for a variety of species. In some cases, these studies have resulted in additional variables being added to traditional TS-to-length regression equations. In other cases, multi-variate non-linear physics-based models have been developed and employed. In all cases, recognition of TS as a stochastic and non-stationary variable will greatly influence how TSs are measured and used.

d) The fourth topic was "error assessment for acoustical biomass estimates." There have been numerous studies investigating individual sources of error in acoustical surveys. Discussed were errors due to bubbles, thresholds, processing algorithms, spatial sampling, and inversion methods. Fewer attempts have been made to examine the total survey error including random and systematic components of measurement and sampling error. To account for covariance of some error sources, multiple components of the total survey error have been estimated and their pdfs combined via Monte Carlo simulation analyses. Recently, a multiple-frequency analysis served to treat many of the random errors as covariant, and highlighted the major systematic errors. Especially in the context of ecosystem-based assessments, absolute abundance estimates should be pursued via error analyses. The extent to which uncertainty in surveys is investigated and reported remains an issue of debate.

e) WGFAST recommends ICES sponsorship of "The 2007 Symposium on Fisheries Acoustics, Science and Technology," to be hosted by the Institute of Marine Research in Bergen, Norway in June 2007, and co-convened by Egil Ona, Norway, Rudy Kloser, Australia, and David Demer, the United States of America.

f) WGFAST recommends that it next meets at FAO in Rome, Italy, on 19, 20, and 22 April 2005 to examine works in the following research areas:

   i) Measuring underwater acoustic energy and its effects on fish;
   ii) Technologies for remote species identification (low-frequency, Doppler, multi-frequency, broadband, data integration, optical sensors);
   iii) Alternative technologies (small-craft, buoys, ROV, AUV, gliders, fishing vessels, multi-beam sonar, acoustic cameras), with special attention to shallow water and near boundary assessments (coastal, riverine, demersal and epipelagic species, and bottom typing);
   iv) Target strength (modelling and measurements).

2 Terms of Reference

In response to the ICES Resolutions of the 90th Statutory Meeting, the Working Group on Fisheries Acoustics, Science and Technology (WGFAST) (Chair: David Demer, USA; and Rapporteur: Paul Fernandes, UK) met in Gdynia, Poland from 20–23 April 2004 to review:

a) examine work in the following research areas as proposed at the 2003 meeting:
   i) effectiveness of noise-reduced platforms,
   ii) using acoustics for evaluating ecosystem structure, with emphasis on species identification,
   iii) statistical characterisation and utilisation of target strength (TS),
   iv) error assessment for acoustic biomass estimates;
b) review the reports of the:
   i) Planning Group on the HAC Data Exchange Format;
   ii) Study Group on Target Strength Estimation in the Baltic Sea;
   iii) Study Group on Acoustic Seabed Classification;
   iv) Study Group on Collection of Acoustic Data from Fishing Vessels (SGAFV);
c) in a joint session with the Working Group on Fishing Technology and Fish Behaviour [WGFTFB] on the 22 April, review:
   i) the questions raised at the ICES Symposium on Fish Behaviour in Exploited Ecosystems, held in Bergen in June 2003;
   ii) methods for estimating abundance of semi-demersal species, including combining trawl and acoustic estimates;
   iii) methods to observe fish behaviour in relation to fishing gears.

WGFAST will report by 15 May 2004 for the attention of the Fisheries Technology Committee.

3 Meeting Agenda and appointment of a Rapporteur

The Chair opened the meeting and Paul Fernandes from the Fisheries Research Services Marine Laboratory, Aberdeen, Scotland, was appointed as Rapporteur. Jessica Lipsky, Southwest Fisheries Science Center, La Jolla, California, U.S.A. assisted as recorder.

The adopted agenda was:

Topic 1. The effectiveness of noise-reduced platforms. The discussion on this topic was Chaired by Alex De Robertis, USA, and Ian McQuinn, Canada.

Topic 2. The use of acoustics for evaluating ecosystem structure, with emphasis on species identification. The discussion on this topic was Chaired by Rudy Kloser, Australia and Rolf J. Korneliussen, Norway.

Topic 3. Statistical characterisation and utilisation of target strength. The discussion on this topic was co-Chaired by John Horne, USA, and Gavin Macaulay, New Zealand.

Topic 4. Error assessment for acoustical biomass estimates. The discussion on this topic was Chaired by John Simmonds, Scotland.

Review of the report of the Study Group on Acoustic Seabed Classification (SGASC), by John Anderson, Canada.

Review of the report of the Study Group on Acoustics from Fishing Vessels (SGAFV), by Bill Karp, USA.

Review of the report of the Study Group on Baltic Herring Target Strength (SGTSEB), by Bo Lundgren, Denmark.

Review of the report of the Planning Group on HAC common data exchange format (PGHAC), By Laurent Berger, France (for David Reid, UK).

Discussion and recommendations:

- terms of reference for next FAST meeting;
- terms of reference for next Joint Session;
- theme sessions for the 2006 Annual Science Conference; and
- title, topics, and venue for the 2007 ICES Acoustics Symposium.

Closure of the meeting.

A list of the 71 participants from 19 countries appear in Annex 1

4 Topic 1 "Effectiveness of noised-reduced platforms"

4.1 Ron Mitson[1] (presented by Paul G. Fernandes[2]). Underwater noise; a brief history of noise in fisheries

[1]Acoustec, 5 Gunton Avenue, Lowestoft, Suffolk NR32 5DA, UK acoustec@acoustec.co.uk. [2]Fisheries Research Services Marine Laboratory Aberdeen, PO Box 101, Victoria Road, Aberdeen, AB11 9DB, UK. fernandespg@marlab.ac.uk.

Complaints of vessel noise effecting fish catches have been made since sail gave way to steam, then diesel power. Governments were repeatedly pressed to arrange scientific investigations and a few working groups were convened in the 1960s and 1970s. Apart from the recognition that 'noise can scare fish' and expressions of 'concern about effects of vessel noise on fish catches' little was done. An exception was the measurement of hearing thresholds for several fish species, essential information in finding answers to the problem. Vessel noise reduction techniques and technology was improving and, around the mid 1980s, measures being applied could achieve good results. An ICES study group produced a recommendation (CRR 209) for maximum radiated noise levels, based on fish hearing and reaction levels, in relation to vessel noise signatures. This has been adopted for a number of recently built vessels.

4.2 John Hotaling. Quiet research vessels for fisheries scientists

NOAA/ST, NMFS, Suite 12506, 13–15 East-West Highway, Silver Spring, MD 20910, USA. John.Hotaling@noaa.gov.

This paper introduces the mission needs of NOAAs new Fisheries Research Vessel (FRV) and the various design considerations necessary to produce a research ship which will serve the multi-mission needs of the scientific community. The design considerations for meeting the radiated noise criteria of ICES Cooperative Research Report 209 are reviewed, including quiet hull form, propeller design, diesel electric drive, equipment mounting and acoustic sensor placement.

4.3 Grazyna Grelowska and Ignacy Gloza. The acoustic transmissions of a moving ship and a grey seal

Polish Navel Academy, ul. Smidowicza 69, PL-81-103, Gdynia, Poland. ggrel@wp.pl. Affiliation

Animals living in the sea produce a wide range of sounds that could propagate under water over great distances. Submerged technical objects are also sources of acoustical waves in the water environment. This process has a detrimental effect on the ecological balance of the environment. Special kind of a technical underwater source is the ship that produces noise while the engine works. The aim of this paper is to present the result of the experimental research associated with the transmission of acoustic energy generated by a moving ship as well as a grey seal into the water. In this work the methodology of evaluation of the transmission of vibration energy from the ship's mechanisms into the sea environment and results of the grey seals underwater vocalization are presented. The signatures of both varieties of the noise sources have been presented in a form of narrow-band power spectra. Signatures of sound emitted by grey seals differ for particular individuals, like the signatures of different ships. The results of the investigation allow to state that the frequency range of the sounds emitted by grey seals covered the frequency range of underwater disturbances produced by moving ships. Noise produced by ship changes acoustical conditions and increases

environmental noise level. The fact is very important for whole sea ecosystem. The high traffic of the moving ships and the increased level of underwater noise, especially in the frequency range used by seals, can cause the mammals (grey seals) migration from the southern coast of the Baltic Sea. Investigations were carried out by means of sound intensity measurements. Results shown that the method is useful, especially in pool and shallow water, for identifying and finding the direction of the sound source.

4.4 Pall Reynisson. Noise reduced vessels; the Icelandic experience

Marine Research Institute, P.O. Box 1390, Skúlagata 4, IS-121 Reykjavík, Iceland. pass@hafro.is.

A presentation of the results of measurements of the underwater radiated noise of two Icelandic research vessels will be given. Both vessels use diesel-electric propulsion with a fixed propeller. One vessel was delivered in 1970, the other in 2000. The older vessel was refitted last year and results from measurements before and after refitting will be presented. For comparison measurements on two commercial trawlers will be shown.

4.5 Janusz Burczynski. New deployment options for digital sonar

Biosonics Inc., 4027 Leary Way NW, Seattle, WA 98107, USA. janusz@biosonicsinc.com

Digital sonar technology provides opportunities for various modes of deployment on new platforms, which were not available with older analogue technology. Digital sonar can be deployed on classic platforms, such as ships, and on variety of new and emerging platforms, such as AUV, buoys, sub-surface moorings, fixed platforms, platforms of opportunity (e.g. icebergs). Platforms and modes of operation can be autonomous or semi-autonomous. Autonomous sonar systems can acquire data without user interaction. Operation can be programmable and can be designed to process data in real time. This allows the sonar system to operate in an adaptive mode, changing modes or parameters according to acoustic analysis or feedback received from other external sensors (e.g. increase sampling rate with increase number of detected targets in time or water temperature). Semi autonomous sonar can operate with limited interaction with the user. For both autonomous and semi autonomous deployment, data can be either stored onboard and downloaded after deployment or transmitted via cable, wireless, fiber optic or satellite links. Examples of deployment options for BioSonics digital sonar systems are presented: underwater moored observatory, buoy, AUV. Deployment interests may focus on fish behaviour, plankton assessment, ecosystem monitoring, and study of methane from sea vents.

4.6 Philip Stacey. TONES - an overview

Ultra Electronics, Sonar and Communication Systems, 417 Bridgeport Road, Greenford, Middlesex, UB6 8UA, United Kingdom

There is an increasing obligation on the operators of fishing and research vessels to take account of their vessels acoustic signatures on fish and marine mammal behaviour. The updated Ultra Electronics TONES System provides an economic method for noise ranging ships and submarines entering environmentally sensitive areas. The system was developed for defence applications and so has sophisticated signature analysis methods that can be used, if required, to identify sources of noise on a vessel. Using a PC based commercial off the shelf design, the TONES system offers high reliability and sophisticated processing and analysis functions. It provides high sensitivity, high accuracy signature measurement using either expendable or re-usable buoys and greatly aids the task of signature management for vessels of all types.

4.7 Ron Mitson[1] (presented by D. Van Holliday[2]). Does *ICES Cooperative Research Report* 209 need revision?

[1]Acoustec, 5 Gunton Avenue, Lowestoft, Suffolk NR32 5DA, UK acoustec@acoustec.co.uk. [2]BAE Systems Applied Technologies, 4669 Murphy Canyon Road, Suite 102, San Diego, CA 92123–4333, van.holliday@baesystems.com.

Because of the perennial problem of vessel noise, a FAST Study Group considered the factors that had a potential to cause vessel avoidance behaviour by fish and also to contaminate acoustic survey data. Various aspects were studied, including the literature on fish hearing and noise signatures of a number of vessels with the reaction distances of fish to these vessels in a few instances. Recommendations were drawn up and the report was published as CRR 209 in 1995 and its proposals for maximum allowable noise levels have been used in contracts for building new vessels. Several such research vessels are now in service but most have had insufficient operational time to assess the effectiveness of the measures taken to achieve the CRR 209 levels.

4.8 Discussion

Since the 1960s, there has been increasing recognition in the ICES community that fish may avoid survey vessels by responding to their radiated underwater noise. Concern about potential avoidance reactions of fish to vessels led to the

formulation of a study group on the subject of Research Vessel Noise by the ICES Fisheries Acoustics Science and Technology Working Group (WGFAST). The recommendations of this study group were published in Cooperative Research Report No. 209 (CRR 209) in 1995. In this report, the evidence for reactions of fish to vessels was reviewed, and a new standard was proposed for radiated noise from research vessels. This standard was designed to prevent fish reactions at distances of greater than 20 m from vessels. Recommendations for low frequency (less than 1 kHz) noise assumed that fish avoid vessels when the ambient noise exceeds their hearing threshold by 30 dB. At higher frequencies, the noise standards were designed to minimize interference with echosounders.

Following publication of CRR 209, several vessels have been successfully constructed to comply with its radiated noise level specification. Application of advanced vessel technologies, including diesel-electric propulsion and custom fixed pitch propellers, has resulted in substantial reductions in noise levels (over 20 dB, or 100 fold), over a wide frequency range, compared to previous research vessels. Measurements of these vessels in noise ranges have indicated general compliance with the CRR 209 specification. However, there is a tendency for these vessels to slightly exceed the specification at low frequencies (<~15–20 Hz). Quiet vessels have been produced at costs of 5 to 20 percent more than comparable non-noise quieted designs. To justify the increased costs, it is important to conduct more studies to quantify the effectiveness of these noise reduced vessels, and to disseminate the results of these studies.
ICES WGFAST discussed the subject of the effectiveness of this new generation of noise-reduced research vessels during its 2004 meeting. Four major themes were identified as priorities for future research.

1) Further exploration of the effectiveness of noise-quieted vessels: Although vessels have been constructed in compliance with the ICES CRR 209 specifications for radiated noise, there have been few reports on the effectiveness of these vessels to reduce fish reactions. Consequently, to date, no survey time series has been corrected for reduced fish reactions to a noise-quieted vessel. There was consensus that research on the effectiveness of noise-quieted vessels should be a priority, and the results must be disseminated. Members of the working group were encouraged to pursue intercomparisons of trawl and echo-integration data from noise-reduced and conventional vessels, and to present these results to the working group.
2) Improved understanding of how fish detect and respond to sound: More research is required to determine the stimuli that evoke avoidance reactions by fish. It is the consensus of the working group that fish responses to radiated underwater noise are not consistent and do not always occur at levels of 30 dB above the hearing threshold as assumed in CRR 209. More study is required to predict when an avoidance response will occur. The roles of intense narrow bandwidth tones and gradients in perceived noise should be investigated as stimuli for avoidance responses of fish. The role of the lateral line in the perception of vessel noise warrants pioneering investigations. Additionally, factors such as fish species, size, reproductive condition, and area density, and the time-of-day and season may affect the probability of fish reactions to a vessel. Hearing thresholds should be established for all important commercial species. Members of the working group suggested that substantial gains in this subject could be made via collaborations with non-WGFAST members including experimental biologists and physiologists.
3) Identification of specific causes of vessel avoidance: In the last decade, there have been significant improvements in the broad bandwidth noise radiated by many new and improved fisheries research vessels. In some cases, however, these quieted vessels continue to exceed CRR 209 at infrasonic frequencies. Because further gains may be increasingly difficult and costly to achieve, future research should be conducted to identify specific features of the radiated noise field that result in reactions of fish to vessels. The importance of intense narrow bandwidth tones at frequencies less than 15–20 Hz, caused by individual machinery components, should be investigated. Studies should also address non-acoustic triggers of fish reactions, such as light (e.g. shadows caused by a passing vessel).
4) Improved measurement of radiated vessel noise fields: The majority of measurements of vessel noise have been conducted at naval noise ranges. These types of measurements are of high quality, but they are expensive and constitute a far-field noise measurement at a single point in time. It is desirable to monitor noise directivity patterns and spectra of research vessels under changing conditions. Low-cost and portable noise ranging systems were discussed and one such system was presented. It was recommended that the potential of such portable noise ranging systems be investigated. If they are effective, they should be used to routinely monitor the noise spectra and radiation patterns of research vessels operated in survey and trawling conditions. It is important to consider the effects of noise during trawling, when there is potential for increased noise from propeller cavitations and the trawl warps and gear. The group also discussed the increased use of hull-mounted hydrophones to routinely monitor noise radiated from vessels. Although these convenient measurements are made in the acoustic near field, they are likely to be correlated with the far-field radiated noise.

The working group reviewed research pertaining to the effectiveness of noise-reduced platforms. It concluded that there is currently insufficient new information to revise the recommendations for vessel radiated noise detailed in CRR 209. Through focused research as detailed above, it is hoped that CRR 209 may be justifiably revisited in the near future.

Discussion Leaders: Alex De Robertis, USA. Alex.DeRobertis@noaa.gov and Ian McQuinn, Canada. McquinnI@dfo-mpo.gc.ca

5 Topic 2 "Using acoustics for evaluating ecosystem structure, with emphasis on species identification"

5.1 John Horne. Challenges and trends in acoustic species identification

University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195–5020, USA. jhorne@u.washington.edu.

Non-invasive species identification remains the grand challenge when using acoustic technologies to evaluate ecosystem structure. Measurements and associated analytic methods used to classify, discriminate, and identify targets can be grouped in four categories: passive sonar; pattern recognition and direct sampling; echo statistics from geometric backscatter; and matching model predictions to resonant scattering measures. Variability in all scattering measurements is influenced by physical factors associated with the transmission of sound in water and by biological factors associated with the location, reflective properties, and behaviour of insonfied targets. The diversity of acoustic technologies available to aquatic researchers continues to increase with advances in digital electronics and computational power. The resulting trend is to increase the number of data channels by increasing frequency bandwidth using multiple discrete or broadband transducers, or by increasing the number of beams and volume measured using multibeam sonars. If each data channel contains a unique perspective on a target, then increasing the number of channels potentially increases the information content of the data. Current efforts are integrating multiple channels in computer visualizations and exploiting additional information for metrics that identify species over a wide range of packing densities and environmental conditions.

5.2 Michael Jech and William Michaels. Multi-frequency analyses of acoustical survey data.

Northeast Fisheries Science Center, 116 Water Street, Woods Hole, MA 02543–1026, USA. Michael.Jech@noaa.gov. William.Michaels@noaa.gov.

Routine acoustical surveys for estimating Atlantic herring (*Clupea harengus*) population abundance have been conducted on Georges Bank during the autumn spawning season from 1998 to present. Acoustical data are collected with a Simrad EK500 scientific echo sounder operating at 12 or 18, 38, and 120 kHz, and split-beam transducers. Biological measurements and verification of acoustical scatterers are obtained with a pelagic trawl. Acoustical data are scrutinized to remove noise, faulty bottom detections, and to classify acoustical backscattering to species. Species classification is currently subjective, and is based on the experience of the scientists and trawl catches. Objective species classification and automated fish density and abundance estimates are an obvious goal for fisheries surveys using advanced technologies. Classification methods using relationships among frequency-dependent volume backscattering strengths, such as presence-absence and combination-permutation, are described and presented. Results indicate that while classification using these methods and acoustical information alone is not robust, these methods highlight backscattering patterns within aggregations and have the potential to characterize backscattering patterns observed in fisheries acoustics data.

5.3 Paul G. Fernandes and Michael Stewart. Determining the quality of a multifrequency identification algorithm

Fisheries Research Services Marine Laboratory Aberdeen, PO Box 101, Victoria Road, Aberdeen, AB11 9DB, UK. fernandespg@marlab.ac.uk

The identification of species using multifrequency acoustic data has recently become a popular method, which has the potential to enhance acoustic surveys and enable them to be used for wider ecosystem studies. Many techniques are still focused on the development of algorithms for any one single species. There is, however, no agreed method of determining just how good any one algorithm may be relative to another for identifying the same species. This study aims to assess how the quality of a species identification algorithm can be evaluated. Using a multifrequency algorithm developed to distinguish North Sea mackerel from herring, a method is proposed which renders the probability of identification (P_{id}) for the algorithm. The data are based on a set of ground-truthed echograms collected during a survey in the North Sea in 2002 and 2003. It is expected that improvements in the algorithm would enhance the P_{id} and that other algorithms could be evaluated in the same framework.

5.4 Angus Mair, and Paul G. Fernandes. Examination of plankton samples in relation to multifrequency echograms

Fisheries Research Services Marine Laboratory Aberdeen, PO Box 101, Victoria Road, Aberdeen, AB11 9DB, UK. fernandespg@marlab.ac.uk.

This study aims to identify the acoustic signatures of common North Sea zooplankton communities. Zooplankton samples were collected using a Longhurst-Hardy Plankton Sampler installed in a U-tow vehicle in the North Sea (ICES area IVa) in July 2003. Samples were collected at depths ranging from 20 m to 75 m using a mesh size of 200 μm. These were identified to dominant species and groups of scatterers, including *Calanus finmarchicus* (C6 adult, C5 and C4 stages), *Metridia spp*. copepods, small copepods (mostly *Acartia* and *Oithona spp*.), euphausiids, polychaetes, chaetognaths and juvenile decapods. Length measurements were made of up to twenty individuals from each group in each sample and biovolume (mm^3 m^{-3}) by group was calculated from average measurements in order to identify dominant sound-scatterers. 38, 120 and 200 kHz echograms were recorded during each tow, and these were examined to relate samples to their acoustic returns. Nautical Area Scattering Coefficients (NASC) for each frequency were compared to the NASC at 38 kHz for the tow in question according to the frequency response ($NASC_{38kHz}/NASC_{frequency}$). Plots of the frequency response show several distinctive shapes, which are related to species composition of samples according to the relative biovolume of scatterer types present.

5.5 Valerie Mazauric and Laurent Berger. The numerical tool OASIS for echograms simulation

IFREMER, BP 70, 29280 Plouzané, France. Valerie.Mazauric@ifremer.fr.

IFREMER is developing the numerical tool OASIS for simulation of echograms from vertical echosounders. Initially planned for echograms prediction of the Fishery Multibeam EchoSounder currently developed by Simrad, the model is generic for the calculation of echograms from any types of vertical echosounders. OASIS aims to help users to explain echograms, depending on echosounders performances and settings (beam patterns, operating frequency but also signal level, pulse shape and processing threshold), underwater scene (shoal depth and density, seafloor backscattering strength and possible false echoes through beam pattern sidelobes) and operational conditions (ping rate, vessel displacement and attitudes). In order to produce realistic data, environment parameters are included in the model (i.e. absorption losses, ambient noise and self noise), and the underwater scene is described as a set of independent aggregations (shoals or plankton layers) detected above a plane and sloping seafloor. Aggregations are presented as a density of unmoving fishes with omnidirectional target strength and no multiple effects. For seafloor backscattering, the model is based on the estimation of signals time envelopes, and a wide range of seafloor roughness can be modelised using a generic formula including contributions from interface and sedimentary volume. Simulated data are homogeneous to individual target strength (*TS*) or volume backscattering strength (*Sv*). The software OASIS is based on a friendly user interface running on Windows operating system. It has been designed to allow reasonable simulation time using multiprocessor technology and optimised mathematical libraries. The whole model is presented and illustrated with typical echograms.

5.6 Rolf J. Korneliussen[1], Egil Ona[1], and Natalia Gorska[2]. Verified acoustic identification of Atlantic mackerel

[1]Institute of Marine Research, P.O. Box 1870, Nordnes, N-5817 Bergen, Norway. rolf.korneliussen@imr.no. [2]Institute of Oceanology of Polish Academy of Sciences, ul. Powstancow, Warszawy 55, PL-81-712 Sopot, Poland. gorska@iopan.gda.pl.

Calibrated, digitised data from simultaneously working multi-frequency echo sounders with nearly identical and overlapping acoustic beams have been used to generate new, synthetic echograms where only targets identified as Atlantic mackerel are retained. Echo sounder raw data are processed stepwise in a modular sequence of analysis to improve the ability to categorise acoustic targets. The relative frequency response measured over up to six acoustic frequencies, 18, 38, 70, 120, 200 and 364 kHz, is the main acoustic feature used to characterise acoustic backscatter. Mackerel seems to have a frequency-independent backscatter below approximately 100 kHz, and above approximately 200 kHz, but at 4 times higher level of the backscatter. Results from numeric modelling explaining the measured relative frequency response of mackerel are shown. Synthetic echograms containing targets identified acoustically as mackerel are presented and evaluated against trawl catches. Even though catching of the fast-swimming mackerel is difficult, the trawl catches confirm that the targets identified acoustically as mackerel is really mackerel.

5.7 Rolf J. Korneliussen, Egil Ona, Hans P. Knudsen, K. Røang, I. K. Elliassen, Y. Heggelund and D. Patel. KORONA; a toolbox for acoustic categorisation and species identification

Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway. rolf.korneliussen@imr.no.

Multi-frequency split beam echo sounders with nearly identical and overlapping acoustic beams have been regularly used in acoustic surveys for fish stock abundance estimation at Institute of Marine Research. Calibrated raw data from up to six simultaneously working echo sounders at 18, 38, 70, 120, 200 and 364 kHz was applied for developing a new processing tool for real time acoustic target categorisation and acoustic species identification. The toolbox handles raw data from the Simrad EK500 and EK60 echo sounders, and performs a stepwise, modular sequence of analysis, like bottom detection, noise quantification and removal, target categorisation and school detection in near real-time. Direct

generation of new, synthetic echograms, based upon the measured relative frequency response of the targets are one of the most useful features of the toolbox. This information may significantly increase the accuracy of acoustic survey estimates of fish and to some extent also for zooplankton. Routines for noise-removal, target categorisation and school detection will be presented, as well as new methods for training and building the artificial experience of the analyser.

5.8 Rolf J. Korneliussen. Recommendations for collection of acoustic multi-frequency data to be used for generation of combined-frequency data

Institute of Marine Research, P.O. Box 1870, Nordnes, N-5817 Bergen, Norway. rolf.korneliussen@imr.no.

Traditionally, collection of acoustic data is optimised for a single frequency, while requirements to the acoustic data for optimal combination of these has been given less attention. Even though data processing improves the ability of the single-frequency data to be combined, optimal output data cannot be achieved from a system if the input data are of poor quality. Multiple single-frequency [*s(f)*] data may be collected in various ways onboard research and fishing vessels. For detailed analysis, the physical and spatial characteristics of acoustic data should be as similar as possible. While direct comparability is impossible in all aspects, ideal data is defined as a reference point for the collection and analysis of multiple *s(f)* data. Acoustic data from several single frequencies are defined as ideal in this context if they can be used to generate combined frequency [*c(f)*] data at the same resolution as the original. This requires comparable physical measurements, done simultaneously from identical volumes, limited only by the effective range of the higher frequencies. Requirements necessary for recording ideally multi-frequency acoustic data are presented.

5.9 Valerie Mazauric[1] and John Dalen[2]. A multibeam echosounder and multibeam sonar based on Simrad's new scientific multibeam systems

[1]IFREMER, BP 70, 29280 Plouzane, France. Valerie.Mazauric@ifremer.fr. [2]Institute of Marine Research, P.O. box 1870 Nordnes, N-5817 Bergen, Norway. John.Dalen@imr.no.

Following two complementary requests expressed by IMR and IFREMER during 2002, Simrad has recently launched the development of a new generation of multibeam systems dedicated to fishery research: a Multibeam Echosounder (MBES) for IFREMER and a Multibeam Sonar (MBS) for IMR. Though these instruments are different in applications and produced data, they are similar in terms of global system designing. Due to the high capability of the transceiver unit and the wide frequency bandwidth, both MBES and MBS are promising tools offering a new range of operating modes while maintaining high side lobe suppression for minimizing parasite echoes from bottom and sea surface. The MBES will be highly operator configurable, with three fishery operating modes (multi-beam, reference beam and multi-frequency), plus a fourth dedicated to imagery/bathymetry purposes. MBES aims to open up new prospects in terms of 3D shoal characterization, species behaviour and demersal fishes detection. Designing a flexible tool was then a priority during the specification time, what led to make variable number of beams (and split beams) in the fan, beam opening and beam steering. Moreover, simultaneously to any multibeam operation, the ability to produce reference splits beams in the frequency range 70–120 kHz will make easier any comparison with others vertical echosounders. As a fishery research sonar system the MBS will be rather outstanding as operating in a frequency band of 75 – 112 kHz, and it will cover a large sampling volume by sectors of 60° horizontally and 45° vertically. The total beam fan is made up of 500 beams having average beam widths of 3° and 4° in the horizontal and vertical beam fans respectively. The transmitted signal form may be one out of several FM and CW signal types. The processor unit contains a ruggedized computer with serial interface for the auxiliary equipment (log, gyro, GPS, etc.) and a LAN output for the Data Logger. The display monitor will be a 20" high resolution colour LCD one. In addition to echograms, the monitor can also display the user menu for the interactive operation. Both systems will be delivered in 2005 and respectively installed on the R/Vs *Thalassa* and *G.O. Sars*.

5.10 Kjell Kr. Olsen, Geir Antonsen and Are Edvardsen. Broadband echo signals used for species identification

Norwegian College of Fishery Science, University of Tromsø, Breivika, 9037 Tromsø, Norway. kjello@nfh.uit.no.

A SciFish 2000 broadband echo sounder has been applied in experimental work for species identification. Broadband echo recordings (110–190kHz) of saithe, cod, herring and capelin have been collected and later used for training of the neural network in the system. The network classifies spectral signatures in the echoes, which gives the basis for fish species identification. Both sea trials with the sonar hull mounted on a research vessel, trials with the sonar mounted in a towed body and measurements by use of a specially constructed rig with the fish in a net cage, have been carried out. Analyses of the obtained data seem so far to show that under favourable conditions identification of at least some species is possible with sufficient precision. However, a number of "obstacles" are present when using this system and have to be attempted better controlled before such a system is really functioning in practical work.

5.11 James H. Churnside[1], David A. Demer[2], John R. Hunter, Jr.[2], and David A. Griffith[2]. Improved efficiency in direct sampling and species identification by incorporating LIDAR into echo sounder and trawl surveys

[1]NOAA Environmental Technology Laboratory, R/E/ET2, 325 Broadway, Boulder, CO 80305, USA. James.H.Churnside@noaa.gov. [2]Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA. David.Demer@noaa.gov

In July 2003, the National Oceanic and Atmospheric Administration (NOAA) surveyed the distribution of sardines off the NW coast of the continental United States. The acoustic component was a 38-kHz split-beam echo sounder that was operated during the day. These data were complemented by trawl samples taken at night, and an aerial LIDAR survey that operated both day and night. During the daytime, the echo sounder observed individual and schooling fish near the continental shelf at depths between 25 and 50 m. Data from 46 surface tows revealed adult sardines within about 10–50 km of the coastline. LIDAR data collected at night showed a reasonable good correlation (R = 0.75) with the daytime echo-sounder data. LIDAR data collected during the day were not as well correlated. Large plankton layers were observed far offshore by both the echo sounder and the LIDAR. An attempt to identify species by school shape using an imaging LIDAR receiver was unsuccessful. The results suggest the possibility of a nested grid survey strategy, where a large-scale aerial survey is used to direct more intensive acoustic sampling, which, in turn, is used to direct sampling efforts.

5.12 Rudy Kloser, Nick Mortimer and Tim Ryan. Echo-system to ecosystem, progress and challenges

CSIRO Marine Research, P.O. Box 1538, Hobart, Tasmania 7001, Australia, rudy.kloser@csiro.au.

As part of a large multi-discipline research effort off the west Australian coast, an acoustic methodology is being developed to characterise the spatial and temporal variability of continental shelf/slope marine life. We hypothesise that the acoustic remote sensing will provide population numbers and the spatial and temporal interaction of marine life with seabed and oceanographic features. A key element in this hypothesis is the ability of the acoustics to provide species-specific information or appropriate surrogates of them at a variety of spatial and temporal scales. In this study 9 frequencies are being used, ranging from 3 MHz to 70 KHz using BAE and Simrad instruments. The low frequency acoustic data should enable biological and physical samples to be better targeted and provide the necessary spatial and temporal context. Likewise the physical and biological samples are critical for the interpretation of the acoustic signatures and evaluation of the multi-frequency species-specific algorithms. The challenge beyond the application of new technologies for acoustic sensing is our ability to optimise their usage in conjunction with numerical and empirical models for sustainable ecosystem objectives. This is work in progress and some of the recent methods and data will be presented.

5.13 Anne Lebourge-Dhassy. Zooplankton classification

Centre IRD Bretange, BP 70, F-29280 Plouzané, France. Anne.Lebourges.Dhassy@ird.fr.

The aim of this work is to propose a method allowing to extend the principles of the high-frequencies classification of the small zooplankton, designed by V. Holliday and C. Greenlaw, in order to apply it to the classical echosounders frequencies. That means that the method should be able to classify also larger organisms. The data used are the S_vs at each available frequency. The method is based on the NNLS inversion algorithm, applied to an equations' system of as many equations than there are measured frequencies. A set of models have been introduced in the algorithm in addition to the truncated fluid sphere (TFS) one, which describes the copepods: the high-pass Stanton 89's models (fluid sphere or prolate spheroid for copepods, bent cylinder for euphausiids, gaseous sphere for gas-filled organisms), the DWBAs from Stanton and Chu 2000 (fluid ellipsoid for the copepods, bent cylinder for the euphausiids, gas bubble), the high-pass elastic shelled from Stanton 94. The way the algorithm optimize the model recognition is based on a minimization of the residual error between the S_vs measured and the S_vs recalculated from the reconstituted population. The stability of the various models with regard to different settings of the algorithm's internal parameters has been studied by means of simulations on virtual multisized populations. With the concern of a rather easy applicability of this classification method, the idea is to keep for each type of organism only one representative model. This one is chosen as the model insuring the more stable answer whatever are the internal parameters settings. The results observed on the simulated populations has led to keep finally the TFS model, the high-pass bent cylinder and the high-pass gaseous sphere models. For the elastic shelled there is no model choice currently. These results has shown also that to get rid of a maximum of the ambiguities between various models, that can happen for some of the virtual populations, it was necessary to run the processing several times with various settings and to use the results all together through an empirical protocol which has been designed. It has been applied on simulated populations with 6 frequencies but also 4, 3 and 2 frequencies, with rather similar results in a large number of cases, except particularly for the frequency couple 38/120, which behaves differently. This empirical protocol has been applied finally to an example of 4 frequencies data from IMR and the results were in coherence with what is known about the organisms present. But this work needs now a large effort of validation on field data.

5.14 Discussion

Great advances have been made over the past decade in acoustic species identification using new multi-frequency/broadband instruments and post-processing software. Many practical methods combine information from multiple frequencies. These methods are most effective in simple systems involving sound scattering from a few dominant species having aggregations that are unmixed and dispersed. The primary challenges for further progress are to account for the stochastic and non-stationary nature of sound scatter, and to improve the validation methods.

A common theme of presentations was the use of quantitative theoretical and empirical models of acoustic backscatter from various species to assist in the classification processes. Scattering models are being used prior to surveys to predict differences in volume backscattering strengths at various frequencies and to direct biological sampling efforts. Software tools for such multi-frequency backscatter prediction, and quality assurance of the acoustic data prior to classification, are now readily available.

Simulations are increasingly used to interpret the multi-frequency echograms and help characterize the limits of the techniques when species are mixed or when spatial scales are small. These simulations incorporate numerous system parameters such as beam patterns and pulse lengths.

It was recognized that target strength variability should be studied for all targeted species. Coupling the stochastic and non-stationary TS data with simulations of instrument parameters will facilitate the further development of species identification techniques that incorporate synthetic multi-frequency echograms.

The largest challenge to further developments in this area is validation of the techniques. A common limiting factor in field validation of multi-frequency species identification techniques is the direct capture and optical characterization of fish and zooplankton at appropriate spatio-temporal scales.

Discussion Leaders: Rudy Kloser, Australia. Rudy.Kloser@csiro.au and Rolf Korneliussen, Norway. rolf.korneliussen@imr.no.

6 Topic 3 "Statistical characterisation and utilisation of target strength"

6.1 David A. Demer, and Stéphane Conti. Considering target strength as a stochastic variable

Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA. David.Demer@noaa.gov.

The statistical characterization and utilization of target strength is reviewed, and an example related to krill is detailed. Recently, the total abundance of krill in the Scotia Sea was estimated from an international echosounder and net survey (CCAMLR 2000) to be 44.3 million tons (CV 11.4%). The new biomass estimate prompted the Antarctic Treaty's Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) to revise the precautionary catch level for krill in the area from 1.5 to 4 million tons. These survey results are based on the total echo energy attributed to krill, scaled by the Greene *et al.* model of krill acoustical reflectivity or target strength (*TS*). Presented here is a re-analysis of the CCAMLR 2000 data incorporating recent improvements in the characterization of krill *TS*. Results indicate that the estimated krill biomass in the Scotia Sea may be as high as 192.4 Mt (CV=11.7%), or as low as 109.4 Mt (CV=10.4%), depending solely on the expected distribution of krill orientations. As the lower krill biomass estimate is nearly 2.5 times the previous estimate, the standard krill *TS* model should be updated and a revision of the precautionary catch level for krill in the Scotia Sea may be warranted. Other methods and examples of characterizing and accounting for *TS* distributions are discussed.

6.2 Joanna Szczucka. Diel vertical migration and target strength variability observed via multi-hour echosounding conducted at a fixed point

Polish Academy of Sciences, Institute of Oceanology, P.O. Box 68, 81–967 Sopot, Poland. oceasz@univ.gda.pl.

On the basis of 16 series of multi-hour echosounding conducted in a fixed point of the Baltic Sea in various seasons, some acoustic features of the diel vertical migration can be concluded. The most interesting and worth discussing are:

- There exists a double-cycle of diurnal migration. Apart from typical nocturnal increase in the column backscattering strength there also exists a 3–4 dB midday increase of this quantity.
- Diel dependence between mean gravity centre depth and backscattering strength has a loop shape with a characteristic hysteresis. Different intervals of the gravity centre depth and SV changeability are recorded in various seasons; however they do not seem to depend on the temperature difference between day and night depth levels. They rather seem to depend generally on the food availability.

- Diel diagrams of normalised moment of inertia versus backscattering strength can help to classify various forms of aggregative behaviour. The measurements were stationary, so, in all probability, the scatterers were the same at night and during the day. Diel changes in SV can reflect diel changes in TS.

6.3 Marek Moszyski, Krzysztof Bikonis, and Andrzej Stepnowski. Virtual reality 3D visualisation of fish movement from split-beam data

Gdansk Technical University, Dept. of Geoinformatics, Ul. Gabriela Narutowicza 11/12, PL-80–952 Gdansk, Poland. astep@pg.gda.pl.

Throughout the last thirty years of sonar applications in fishery research, the various forms of data visualization have been developed. The paper presents the concept of dynamic echograms creation from the data acquired in acoustical surveys. As the modern split-beam echosounders allow unambiguous localization of targets in the water column, it is possible to visualize them in 3D coordinates in the form of 3D georeferenced scenes. Virtual Reality Modelling Language VRML is one kind of the computer language, which is particularly suited for modelling of virtual reality in various fields. It was successfully used in computer graphics, chemistry, medicine, astronomy, geography, navigation and other fields. In the paper we proposed the application of VRML in one specific class of fishery research. The written software constitutes the next stage of real-time echo data processing and creates virtual animated scene of fish movement. In a current version it processes data sequentially, which will allow for on-line processing in future implementation. Additionally, as any VRML code can be embedded in WWW browser, 3D fish visualization can be disseminated in the Internet.

6.4 Geir Pedersen and Egil Ona. Calibration of split-beam echo sounders; models for beam pattern correction

Institute of Marine Research, P.O. Box 1870, Nordnes, N-5817 Bergen, Norway. egil.ona@imr.no.

For quantitative acoustic surveys of fish it is very important that the echo sounders are correctly calibrated. An important part of the calibration procedure is the removal of the transducers directivity. A standard target is guided through the acoustic beam; the calibration data are then fitted to a three-dimensional model by the use of non-linear regression. This gives an expression for the beam pattern and target strength of the calibration points. The accuracy of the standard models and alternative models for several common echo-sounder transducers are considered.

6.5 Xianyong Zhao[1] (presented by Rolf Korneliussen[2]). Depth dependence of the target strength of anchovy measured *in situ*

[1]Yellow Sea Fisheries Research Institute, 10 Nanjing Road, 266071 Qingdao, China, zhaoxy@ysfri.ac.cn. [2]Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway, rolf.korneliussen@imr.no.

Three sets of single-fish echo-trace data were collected at the southern part of Yellow Sea using a calibrated 38 kHz Simrad EK500 split-beam echosounder around midnight 31 March 2001. Mid-water trawl sample showed that over 97% of the catch in number was composed of anchovy (*Engraulis japonicus*) with total length ranged from 6 cm to 15 cm, its arithmetic mean length and RMS length were 10.6 cm and 10.8 cm, respectively. The overall mean target strength (TS) of anchovy in the layers from 10 m to 45 m was -50.9 dB. The TS data showed a clear depth-dependent tendency that was very close to and not significantly different from what is predicted from the Boyle's law. The TS model was estimated to be TS=20log20L-71.5 for the conventional TS-length equation and TS=20logL-(20/3)log(1+z/10)-67.6 when the depth (z, m) effect was included according to Boyle's law.

6.6 Egil Ona, I. Svellingen, J.E. Fosseidengen, and R. Pedersen. Seasonal variability in the acoustic target strength of cod

Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway. egil.ona@imr.no.

The acoustic target strength of adult cod (*Gadus morhua*) was measured *ex situ* in a large, 4500 m^3, experimental net pen at the IMR Austevoll aquaculture station in eight periods between November 1996 and May 1998. A calibrated Simrad EK500 split beam echo sounder was used to collect the acoustic data from a vertically observing transducer, positioned in the middle of the 21 m deep net pen. Groups of about 20 individual cod were transferred from the control storage population in each measurement series, but moved in every other aspect freely within the experimental net pen during the acoustic measurements. Natural variations in gonadosomatic index as well as changes in condition factor from an enforced starvation was monitored and correlated with changes in target strength. A General Linear Model (GLM) was used to estimate the functional relationship between the target strength at 38 kHz and important biological parameters. The significant ones were: Condition factor (CF), Liver index (LI), the spread of the tilt angle distribution (SDTILT), while the gonadosomatic index (GSI) mean swimming angle (MT) and the swimbladder index (SI) was not significant. For cod between 50 and 60 cm size, the target strength relationship is suggested to be:

$$<TS> = 20 \log L - 64.0 - 0.099(SDTILT) + 2.44(LI) - 1.86(CF) ,$$

where the effect of tilt angle may be converted to a day/night effect. Under normal liver index and condition factor, the new mean target strength is slightly higher than the one used in the surveys, but correspond well to the experimental night time observations.

6.7 Hector Peña A. Target strength investigations on Chilean Jack Mackerel (*Trachurus symmetricus murphyi*) from commercial vessels equipped with a scientific echosounder

Marine Research Institute, P.O. Box 1870 Nordnes, N-5817, Bergen, Norway. hector.pena@imr.no

Chilean Jack Mackerel fishery is the one of the most important single species fishery in the world, with yearly landings close to 1.5 million tons. In the purse seine fleet that operates on this resource are 3 vessels equipped with EK60 scientific echosounders. During August 2003, acoustical data was collected onboard the fishing vessel "Ligrunn", about 500 nm off central Chile. Due to the lack of detailed description on the swimbladder characteristics, traditional dissections and Magnetic Resonance were made on several samples. The results confirmed the physoclistuos status of the bladder, but also notice important features; a big torpedo shape swimbladder, with an orientation angle of +7º, which extends beyond the abdominal cavity inside the tail muscle, and massive gas and oval glands. In 3 fishing grounds the fish were observed in disperse layers of variable heights and single target data was collected for target strength estimates. A previous data filtering to ensure the best single targets data quality was made. Preliminary results showed high target strength values with an average of -34.4 dB and standard error 0.4 dB, for average fish of 28.6 cm fork length. No significant differences in depth, time of the day or length distribution of the samples could explain the high variability in target strength between the zones. Recent research is focus to determine the fish swimming angles between the different zones using ad hoc tracking software.

6.8 Pavel Gasyukov and Svetlana Kasatkina, "Sensitivity study of some methods of target strength equation parameters estimation"

AtlantNIRO, 5 Dmitry Donskogo Street, 236000 Kaliningrad, Russia. pg@atlant.baltnet.ru, ks@atlant.baltnet.ru.

The statistical characteristics of the method by MacLennon and Ments (1996) and the bootstrap-based method, applied to estimate parameters of target strength equation as function of fish length by comparing *in situ* measurements with the fish size distribution from trawl catches are presented. The observation data obtained in the trawling-acoustic survey of the Russian vessel *Atlantida* in the South Georgia area during 2002 were used in calculations. The study is based on multiple formations of repeated samples from the observation data with subsequent application of appropriate methods to estimate the target strength equation parameters. The robustness of the first method and high sensitivity of the second method were demonstrated. Not only statistical characteristics of parameter estimates but also statistical characteristics of its standard deviation and bias estimates were calculated.

6.9 Discussion

For pragmatic simplicity, target strengths of fish have been sometimes considered as constant values. Observations and recognition of TS variability, and its frequency dependence, have motivated improved characterizations of fish TS as expected values modulated by one or more factors (e.g. acoustic wavelength and animal length). Progressively, empirical observations and computer models are being used to quantify the primary biological and physical factors that control the magnitude and variability of TS for a variety of species. Reports were made on the development of hardware, measurement techniques, and analytic methods for characterizing TS and its forcing functions. A dominant theme was the demonstration of appreciable TS variability; and approaches to characterize, quantify, account for TS variability.

The approach to characterizing and accounting for TS variability continues to evolve. It is now thought that TS should be treated as a stochastic and non-stationary variable, and characterized by a probability density/distribution function (pdf). Multi-variate models of TS pdfs should account for the primary forcing functions and their pdfs. These TS models may be physics-based, or empirical. Empirical TS versus log (length) models may be expanded to include additional variables such as animal behaviour, depth, and morphology. The recognition and characterization of other important biological and physical parameters influencing TS will further influence how TS is modelled and measured. A cautionary note: Fisheries acoustics practitioners serve many masters. One primary function is to provide abundance or biomass estimates of specific populations. This advice is received and examined by fisheries managers and fishers seeking the best advice possible. The ongoing efforts to improve the accuracy and precision of TS are testimonials to the provisional nature of TS characterizations. Development and application of new instruments and techniques to improve TS characterizations will continue to be vetted within the scientific community before being adopted in routine assessment procedures. Accurate, yet positive, portrayal of current practices should accompany all reporting of acoustic-based abundance estimates to managers.

Chair: John Horne, USA. jhorne@u.washington.edu. and Gavin Macaulay, New Zealand. g.macaulay@niwa.co.nz.

7 FAST/FTFB Joint Session

7.1 Topic 1: The questions raised at the ICES symposium on Fish Behaviour in Exploited Ecosystems, held in Bergen in June 2003.

7.1.1 Steve Walsh. The questions raised at the ICES symposium on Fish Behaviour in Exploited Ecosystems, held in Bergen in June 2003

The 2nd ICES Symposium on Fish Behaviour in Exploited Ecosystems was held in Bergen 23–26 June, 2003. It attracted 180 participants from 31 countries who listened to 60 oral presentations and viewed 49 posters. Unlike the 1st symposium (1992) whose primary focus was on the role of fish behaviour in fish conservation and responsible fishing, the primary focus of the 2nd symposium was on the relationship between fish behaviour and resource surveys and the development of more selective fishing gears. It also recognized that studies of natural fish behaviour, such as movements, aggregations and migrations, and physiology of vision and sound had application to the primary focus. Some of the major conclusions are listed below.

Fish are multi-sensory and capable of learning, becoming stressed, communicating and feeling pain. In the past decade, the technology to observe and measure fish in 2D and 3D space allowing simultaneous measurements of behaviour and environmental data has progressed dramatically which has lead to improvement in both trawl and acoustic surveys and hence improved scientific advice for assessments. Because of the developments in technology fishing gear experts have also accelerated their development of more selective gears and environmentally friendly fishing gears. Nevertheless much of the research on behaviour relevant to catchability is being driven by requests from managers and this puts constraints on the type of experiments being carried out. As a result many studies under exploit the fish behaviour component, i.e. in most cases testable hypothesis are missing. It was widely accepted that developing a series of testable hypotheses within a defined behavioural ecology framework would greatly enhanced the results and interpretation of fish behaviour. This emphasizes the need for fishery scientists to look to other disciplines on animal behaviour for insights. It was also recognized that there is a need for greater integration of biology, behavioural, environmental and fishery data when modelling the influence of fish behaviour on catchability. It not simple anymore to say that fish react to sound of the vessel without bringing in the data on motivational and environmental effects which also could have contributed to the measured response. Since many studies are being carried out on stocks that have been heavily exploited or near collapse then a stronger emphasis should be placed on the role of 'stock behaviour' when interpreting results over a broader scale.

A selection of papers will appear in ICES Journal of Marine Science in 2004 and the abstracts and oral presentations can be found on the following website: www.imr.no/fishbehave. The third symposium is scheduled for 2013 in Bergen.

7.2 Topic 2: Methods for estimating abundance of semi-demersal species, including combining trawl and acoustic estimates

7.2.1 Andrzej Orlowski. Acoustic revision of fish distribution and its correlation to environmental factors in the demersal zone

Sea Fisheries Institute, Ul. Kollataja 1, PL-81–332 Gdynia, Poland. orlov@mir.gdynia.pl.

Systematic acoustic surveys (duration of 3 weeks) of fish resources in the Polish EEZ started in 1989 as the part if the ICES autumn international survey programme. The recording of samples 24 hours a day for each nautical mile distance unit, the elementary distance unit (ESDU), in a slice-structured database was carried out aboard R/V *Baltica* since 1994. The survey tracks of all cruises followed mostly the same grid to give high comparability of measurements. The paper describes results of studies based on four-dimensional measurements of the Sv distribution in 3m layer over the bottom in the southern Baltic area. These are correlated with values of coincident environmental factors: time, depth, water temperature, salinity and oxygen levels, bottom features, estimated on the basis of survey data and wide range of methods, elaborated by the author for fish behaviour studies. The purpose of the paper is to compare results collected during acoustic surveys in the Baltic to estimate irregularities in fish distribution potentially influencing the results of fish bottom trawling in a sense of its application for semi-demersal fish assessment.

7.2.2 Ian H. McQuinn and Pierre Nellis. A combined acoustic/trawl survey of lake (*Acipenser fulvescens*) and Atlantic (*A. oxyrhynchus*) sturgeon

Fisheries & Oceans Canada, Institut Maurice-Lamontagne, 850 route de la Mer, C.P. 1000, Mont-Joli, Québec G5H 3Z4, Canada. mcquinni@dfo-mpo.gc.ca.

A combined acoustic/trawl survey was conducted around the Montmagny Archipelago in the upper St. Lawrence River estuary to describe the distribution and relative abundance of demersal fish, and in particular lake (*Acipenser fulvescens*) and Atlantic (*A. oxyrhynchus*) sturgeon. The primary objective was to study the impact, if any, of the deposition of sediments near Isle Madame from dredging operations in the North Channel on the abundance, distribution and movements of the two sturgeon species. A two-phased sampling design was conducted using the methods of McQuinn *et al.* (1999) to produce independent acoustic and trawl abundance estimates. This series of surveys was the first known attempt to quantify sturgeon abundance and distribution through classic vertical hydroacoustic methods. Hydroacoustic techniques require knowledge of certain key parameters, several of which, such as the target strength (TS) versus weight relationship and the effect of vertical distribution on their detectability, are not known for these species. Therefore the acoustic estimates were compared to the trawl estimates on a relative scale. Lake and Atlantic sturgeon were presumed to dominate the acoustic echoes. They were the dominant demersal species group in the trawl catches with many very large individuals (>1 m), and the sturgeon TS can be assumed to be the strongest of the demersal fish in the area having both a multi-chambered swim bladder and bony dorsal plates. Using the high resolution sample data, echoes were often distinct from the bottom and with a little experience, echo classification as demersal fish and by inference as sturgeon, was straight forward. The combined acoustic/trawl survey produced independent estimates of demersal fish abundance and the two methods showed a good correspondence. Replicated sampling also showed a stability in distribution on both a scale of days and months. The study showed that under certain conditions, classic vertical hydroacoustics can be used reliably to assess these demersal fish species.

7.2.3 Noël Diner and Laurent Berger. Trawled layers echo-integration: a tool for improving fish identification by a trawl

IFREMER, Centre de Brest, BP 70, 29280 Plouzané, France. Noel.Diner@ifremer.fr.

MOVIES+ software has been fitted with a special function which operates echo-integration of vertical echo-sounder data in layers referenced to the trawl headrope depth.

Assuming that the displacement of fish between detection by vessel vertical sounder and catch is small, it is then possible to quantify the detection standing in water layers sampled by the trawl. The ratio of the catch to the acoustic detection gives a rough coefficient for the haul/trawl efficiency. Simultaneous acquisition of netsonde and storage in the same HAC data file as vertical echo-sounder enables to display on the same screen both detections. The obtained images are very useful to relate precisely catches to vertical echo-sounder detections. With this method, scientist can obtain precise information on the quality of echoes identification made during acoustic surveys.

7.2.4 Carla Scalabrin, Patrick Danel and Laurent Berger. Relationship between bottom trawl results and acoustic density estimates of trawled sample volume

IFREMER, BP 70, 29280 Plouzané, France. Carla.Scalabrin@ifremer.fr.

Every year a bottom trawl survey is carried out in the Bay of Biscay in order to provide abundance estimates of most important demersal fish resources over the continental shelf. Since 2002, 38 and 120 kHz acoustic data has been acquired simultaneously with fishing operations totalizing 300 samples. By combining information about geometry behaviour and position of the trawl with respect to hull mounted acoustics it is possible to automatically echo-integrate only fish echoes potentially located within the volume sampled by the trawl. Acoustic density estimates can then be related to trawl capture results.

7.3 Discussion

Examination of concurrently collected acoustical and trawl data can elucidate the performances of each measurement technique. Validation of acoustical data may be improved via more accurate determination of the trawl position relative to the insonified volumes. Conversely, the acoustical data may provide information about trawl gear selectivity and efficiency. There are three major obstacles to such advances: 1) the acoustical and trawl sampling volumes typically differ; 2) the fish may move between acoustical and trawl measurements; and 3) fish reside above and below the acoustical observation volumes.

Multibeam sonars provide observation volumes that match or exceed those of trawls. Consequently, these instruments can provide significant enhancements to our understanding of spatio-temporal sampling mismatches.

The quantity and species of fish in the near-surface and near-bottom areas may be estimated by extrapolation of measurements made immediately adjacent to these areas. The validity of these estimates depends on the spatial structure

of the fish. For patchily distributed fish schools, there is an increased probability that schools detected acoustically may be missed by the trawl, and vice-versa. Three-dimensional variograms of echosounder data may be used to enhance our understandings of demersal fish distributions and their relations to environmental factors. Such analyses may also be used to improve stratified sampling efforts.

7.4 Topic 3: Methods to observe fish behaviour in relation to fishing gears

7.4.1 Alex De Robertis and Christopher D. Wilson. Do walleye pollock react to trawling operations?

Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA. Alex.DeRobertis@noaa.gov.

Avoidance of survey vessels by fish has the potential to bias stock assessments. Although walleye pollock (*Theragra chalcogramma*) are the subject of a substantial commercial fishery in the North Pacific, their behavioural response to survey vessels remains poorly understood. For example, work with a free-floating acoustic buoy to identify an avoidance response by pollock to a free-running vessel during the day has produced inconsistent results, but recent work conducted at night did detect avoidance reactions for juveniles. As a first step in an effort to determine if walleye pollock avoid survey vessels engaged in trawling operations, we made pair-wise comparisons of acoustic backscatter recorded by survey vessels while free running, and while trawling. We present results from backscatter recorded from the research vessel Miller Freeman, which used a midwater trawl during 1996–2002 Eastern Bering Sea surveys, and a commercial vessel, which used a bottom trawl during a 2003 survey in the Gulf of Alaska. Preliminary results indicate that backscatter under the Miller Freeman was about 20% lower when trawling. The observed decrease in backscatter is consistent with increased fish avoidance while trawling. We are planning a series of more controlled field experiments using the acoustic-buoy in July 2004 to further evaluate whether pollock exhibit strong, consistent avoidance reactions to a commercial vessel engaged in trawling operations, and to document any changes in behaviour that may occur in the presence of a trawling vessel.

7.4.2 Yvan Simard and Nathalie Roy. Distant shipping noise: Should fish care?

Fisheries & Oceans Canada, Institut Maurice-Lamontagne, 850 route de la Mer, C.P. 1000, Mont-Joli, Québec G5H 3Z4, Canada. simrady@dfo-mpo.gc.ca.

During summer 2003, a passive acoustic network was installed in the path of a major continental seaway in eastern America, to record anthropogenic and natural noise sources for two months in continue. A coastal array of 6 hydrophones was deployed along a cape that merchant ship traffic regularly crosses at a few miles in the St. Lawrence seaway. AURAL M1 autonomous hydrophone recorders were moored along the shipping line, in the local sound channel. The ships were positioned in daytime from an observation belvedere at the Cape using laser rangefinder binoculars. Shipping noise over ranges of about 1 to 10+ km was recorded for a variety of ships transiting in the seaway. Preliminary results indicates that its intensity is generally high over a wide band of frequencies, which includes the fish hearing sensitivity band, and spikes at discrete frequencies are frequents. Shipping noise propagates over large ranges, its spectral characteristics shows typical Lloyds mirror interference patterns, and it can be distinctly detected in the background noise for the majority of the time. Such anthropogenic noise is likely common along major shipping lines on continental shelves. Does it affect the fish found along these paths? How does it compare with fishing and research vessel noises, notably for avoidance behaviours?

7.4.3 Discussion

Regarding 7.4.1: The question was raised whether the attitude of the ship has an effect, i.e. does the angle of the transducers differ between trawling and steaming? The author could not provide information on this issue but found it an interesting point of view and worth investigating. It was also asked whether there is an influence of bottom depth on the results. This is not the case but measurements were taken over a narrow depth range, and this study is not well suited to detect if fish responses to trawling vessels are depth-dependent. The author also noted that it was not possible to detect single fishes.

Regarding 7.4.2: The question was asked if the difference between the background noise and ship's noise was constant? The author replied that with high wind, the background noise is increasing due to the effect of the waves. The relative contribution of the ship was not constant, but the ship noise was always clearly discernible from the background. It was asked if reactions fish (pelagic) in that area were observed. The answer was that the project did not include this aspect. When a cargo ship passes, there is a temporary increase in noise. The question is whether fish react. We don't really know but if this is not the case, they may also not react to research vessels. A study was cited on the movement of herring in relation to a ferryboat passing. Apparently there was not much reaction of the fish, possibly explained by learning. Another comment was made that fish will surely react to noise. It is, however, well documented that fish will get adapted to high noise levels. If the source is approaching, there is a gradient that has an influence. However the 3D spatial structure of this gradient may be complex because of various propagation effects. In areas where high traffic occurs, fish will mainly react to a strange sound. It's also important to note the difference between

the detection threshold and the reaction threshold that can be very high (x30). Someone highlighted the observation that the noise level in reality does depend on the shape and type of the bottom – you can get concentrations in some places. He asked whether there were such critical places in the area of the study. The author had no information on that issue, though a 3D sound propagation model of the area was planed.

7.4.4 Norman Graham. Report from the SG on survey gears for use in southern and western areas

Marine Research Institute, P.O. Box 1870 Nordnes, N-5817, Bergen, Norway. norman.graham@imr.no

An overview of the Study Group report was given by Norman Graham. It was stated that this Study Group should report to the Joint Session.

7.4.5 Kevin Peach, Rob Kynoch and Dick Ferro. IBTS bottom trawl surveys – the geometry of GOV survey trawls

Fisheries Research Services Marine Laboratory Aberdeen, PO Box 101, Victoria Road, Aberdeen, AB11 9DB, UK.

Different versions of the GOV are used by France, Ireland, Netherlands, England and Scotland. The presentation discussed the variation in geometry of the Scottish version – 36/47 m GOV with 1 100 kg Morgere doors, 60 m sweeps giving a total wire length between doors and wing-ends and 305 mm diameter rubber wheel bobbins. ICES stipulates that in Quarter 1, the sweep length (including backstrops) should be 60 m in depths of less than 70 m but 110m for greater depths. Also a table of warp length against depth is given. The presentation asks the questions: Why change sweep length? What is the variation in geometry with sweep length and depth? Is there is a need to change the rule on sweep length? Variation in spread will affect the swept area which may become more important if absolute abundance estimates are required. Variation in bridle angle affects the herding efficiency of the sweeps and bridles.

Data were taken from random hauls during 1997–2002 when door and wing-end spreads, warp length and depth were recorded. FRS surveys do not appear to keep to the rules in the ICES Manual (ICES CM1999/D:2). Other measured data at the two different sweep lengths were also available. From this data set a regression equation was derived which could be used to predict horizontal bridle angle (ba) given water depth (d) and sweep length (s):

$$ba = 18.5 + 0.0552 * d – 0.0864 * s$$

This applies only to the Scottish trawl with the warp length rule as applied by FRS.
From this regression the variation in bridle angle during FRS surveys was shown to be about 14 to 22E while it would have been approximately 13 to 18E if the ICES Rules were obeyed. This may still be an unacceptable variation. There were options for limiting the range e.g. changing sweep length more frequently as warp length changed. A scenario where bridle angle varied only from 13.5 to 16.5E was illustrated.

The following questions were posed to the Working Group: Will the GOV continue to be used? Does bridle angle affect herding? If so, can we reduce variation in geometry? Less variation in spread could be achieved by restricting door spread using a restrictor rope. Less variation in bridle angle could be achieved by changing sweep length. Are these options practical? Should WGFTFB be considering a completely new gear and maintaining contact with e.g. the Norway initiative?

7.4.6 Kenneth L. Weinberg and David A. Somerton. Variations in trawl geometry due to unequal warp length

National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, WA 98115, USA

Survey standardization procedures can reduce the variability in trawl efficiency thus producing more precise estimates of biomass. One such procedure, towing with equal amounts of trawl warp when using locked winches, was experimentally investigated for its importance in determining optimal trawl geometry and for evaluating the effectiveness of the recent US national protocol on accurate measurement of trawl warps, which states that warp length differences between the port and starboard sides cannot exceed 4% of the distance between otter doors measured along the bridles and footrope. Trawl performance data from repetitive towing with warp differentials of 0, 3, 5, 7, 9, 11, and 20 m were analyzed for their effect on three determinants of flatfish catch efficiency: footrope distance off-bottom; bridle length in contact with the bottom; and area swept by the net. Our results showed towing with asymmetrical trawl warps can have a negative influence on CPUE. At 7 m difference in warp length, the NOAA threshold value for the survey net used in our study, we found that footrope distances off-bottom increased, particularly in the center region of the net, which can negatively impact capture efficiency for some species; the width of bridle path responsible for flatfish herding was reduced by 10.3%; and the effective net width or swept area between the wingtips was reduced by 0.5%.

7.4.7 Stan Kotwicki, Kenneth L. Weinberg, and David A. Somerton. The effect of autotrawl on the bottom – tending performance of a survey trawl.

National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, WA 98115, USA

Three aspect of the trawl performance (trawl geometry, footrope bottom-tending performance, and bridle bottom-tending performance) were compared between two autotrawl systems (tension and symmetry) and trawling with locked winches. The effects of heave, crabbing and bottom current on the trawl performance in different trawling modes were investigated. Means and standard deviation of trawl geometry measures were not significantly different between autotrawl and locked winches systems. The autotrawl systems were better than the locked winches system in improving the overall stability of the footrope bottom-tending performance. Tension mode was most effective in counteracting effects of environmental conditions on footrope stability. Footrope distance off bottom was most influenced by changing environmental conditions while towing with locked winches. The autotrawl systems also improved the overall stability of the bridal bottom-tending performance. Autotrawl systems proved to be effective in decreasing the effects of environmental factors on some aspects of the trawl performance and, as a result, have a potential to reduce variance in between hauls catchability of the survey trawl. Consequently incorporating autrotrawl into standard survey procedures may increase the precision of survey biomass estimates.

7.4.8 Discussion

Regarding 7.4.5: The author was asked if there is a need to maintain a constant geometry or is measuring it enough? The author replied that this is a question fish behaviour experts should answer. If it has an influence, then we probably should have a constant geometry. It was noted that bridle angle is extremely important for species selectivity. A different geometry gives a different species composition. Fishermen apparently continuously change depth and thus change gear geometry but aboard research vessels it seems to be difficult.

Regarding 7.4.7: The author was asked if there were plans to introduce the autotrawl on all RV's. He hoped this would be the case, so biomass surveys would be improved.

8 Topic 4 "Error assessment for acoustic biomass estimates"

8.1 David A. Demer. Estimating uncertainty in acoustical surveys (topic review).

Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA. David.Demer@noaa.gov.

Uncertainty in a generic acoustical survey is reviewed, and an example analysis of a krill survey is detailed. Combined sampling and measurement error is estimated for the CCAMLR 2000 acoustic estimate of krill abundance in the Scotia Sea. The error in system calibration is evaluated in relation to the effects of variations in water temperature and salinity on sound speed, sound absorption, and acoustic beam characteristics. Variation in krill target strength is estimated using a distorted-wave Born approximation model fitted with measured distributions of animal lengths and orientations. The variable effectiveness of two-frequency species classification methods is also investigated using the same scattering model. Most of these components of measurement uncertainty are frequency-dependent and covariant. Ultimately, the total random error in the CCAMLR 2000 acoustic estimate of krill abundance is estimated from a Monte Carlo simulation which assumes independent estimates of krill biomass are derived from acoustic backscatter measurements at three frequencies (38, 120, and 200 kHz). The overall coefficient of variation ($10.2 \le CV \le 11.6\%$; 95% CI) is not significantly different from the sampling variance alone ($CV = 11.4\%$). That is, the measurement variance is negligible relative to the sampling variance due to the large number of measurements averaged to derive the ultimate biomass estimate. Some potential sources of bias (e.g. stemming from uncertainties in the target strength model, the krill length-to-weight model, the species classification method, bubble attenuation, signal thresholding, and survey area definition) may be more appreciable components of measurement uncertainty. Other methods and examples of error analyses are discussed.

8.2 Cathy Goss. Sources of uncertainty in annual surveys for Antarctic krill

British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET.United Kingdom. cg@bas.ac.uk.

For the past nine years acoustic techniques have been used to carry out annual surveys of the distribution and abundance of Antarctic Krill at the same site, north–west of the Island of South Georgia. Since October 2000 the survey intensity has been increased to three per year. We have tried to maintain a constant set of methods throughout this period, but in 2002 the ship's Simrad EK500 echosounder was removed and replaced with an EK60. The change resulted in a dramatic reduction in noise on all three frequencies that we use. Data from surveys with the EK60 have been analysed in two ways, the first using noise thresholds that are as low as possible, and the second using the noise thresholds that had been necessary with the EK500. The additional krill uncovered by the new sounder poses some problems: how to verify that these deep, low density, targets really are krill and how to best compare surveys with the two sounders. The increased power of the EK60 to make deeper observations with reduced noise levels, has highlighted an interference problem that may have been present previously. A technique for removing this in post processing has been developed which uses Sonardata's Echoview software schools module. Echoview has also been used to develop a processing method to select out echoes that are lost or reduced owing to the obscuring effect of bubbles under the hull that is commonly encountered with hull-mounted transducers.

8.3 Dezhang Chu, Peter H. Wiebe, Gareth L. Lawson, Nancy J. Copley. Error assessment for acoustic biomass estimates

WHOI, Woods Hole, MA 02543, USA. dchu@whoi.edu.

Multi-frequency and/or broadband acoustic systems can be used to estimate the abundance and biomass distributions of marine organisms with inversion techniques. Despite many reported successful applications in abundance and/or biomass estimates acoustically, due to the diversity of the scattering targets and the complexity of the scattering process as well as the inherent non-uniqueness of the inversion techniques, the conventional linear inversion scheme widely used in fisheries and zooplankton acoustics will inevitably introduce errors or biases in biomass estimates. These errors or biases will be analyzed systematically in terms of the parameters used in the inversion, including the mean target strength of the involved fish stocks obtainable either form in situ measurements or from the scattering models, linearity assumption between the volume backscattering and the integrated echo intensity, data quality, and the frequencies of the sonar system. The characteristics of the data and model resolution matrices that are specific to the inversion problem are also investigated. An example of using a nonlinear inversion scheme on a multi-frequency acoustic data set collected with the Bio-Optical Multi-frequency Acoustical and Physical Environmental Recorder (BIOMAPER-II) during the austral fall Southern Ocean GLOBEC broad-scale cruise in 2002 was presented. Although, the scattering targets are the Antarctic krill (*Euphausia superba*), the principle and the physics used in the biomass and/or abundance estimates are the same as those used in the fisheries acoustics. Finally, guidance of reducing the estimate errors and improving the robustness of the inversion will be provided. [Work supported by the National Science Foundation].

8.4 Robert Kieser[1] and Lars Nonboe Andersen[2]. Signal processing at low sample rate and its possible effect on EK60 calibration, TS measurement and resampling of its sample data

[1]Department of Fisheries and Oceans, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6M7 Canada. kieser@pac.dfo-mpo.gc.ca; [2]Product Group Fishery Research / Fishery Horten, Simrad, Horten, Norway, lars.nonboe.andersen@simrad.com

Published standard sphere measurements show that TS measurements from the EK60 show about twice the scatter that is observed with the EK500. Measurements are with alternate pings from both instruments on the same target sphere and with the same transducer. This suggests that differences in the internal data processing are responsible. The EK500 and the EK60 have similar architecture and both use 500 kHz to sample the incoming signal. However a major difference is that the EK60 uses a pulse length dependent minimum sample rate for subsequent internal processing and data storage. As an example a 1 ms pulse will be samples at 10 kHz in the EK500 while it is sampled at 4 kHz which corresponds to 1/4 of the pulse length or two Nyquist in the EK60. A lower sample rate for example will lead to a poorer definition of pulse height and timing which are critical for TS measurements and accurate definition of the TVG correction. In addition a lower sample rate will lead to increased distortions when non linear operations such as TVG or squaring of the signal are applied. These effects are believed to be negligible in both instruments for most measurements however simulation techniques will be used to explain the experimental observations and to look for potential exceptions. Areas of potential concern are calibration, TS measurement and resampling of its sample data.

8.5 Tim Ryan and Rudy Kloser. Improving the precision of ES60 and EK60 echo sounder applications

CSIRO Marine Research, P.O. Box 1538, Hobart, Tasmania 7001, Australia. Tim.Ryan@csiro.au.

Quantifying acoustic instrument measurement error (absolute and relative) is complex, and it is widely assumed that the calibrated sphere methodology will confine this relative error to within 0.2 to 0.5 dB. Two errors greater than this have been identified in the current generation of digital echosounders (EK60 and ES60). The first being variation in echo integration values of a calibrated sphere using Sv pixel array data (i.e. Q data). Under certain circumstances we have measured this variation to be as high as 3.9 dB and could be potentially higher. The impact of the variation on biomass surveys is discussed and will depend on a range of factors. Simrad have confirmed the variation and intend to provide an improved algorithm in their next release of the EK60 software. Secondly, a systematic error exists in Simrad ES60 echosounders. The error can be described as a ping indexed staircase function with an overarching triangle wave shape that has a period of 2 721 pings and peak-to-peak amplitude of 1 dB. We describe a simple method for removing this error using the transmit pulse.

8.6 John Simmonds. Spatial effort allocation for a complex survey objective

Fisheries Research Services Marine Laboratory, P.O. Box 101, Victoria Road, Aberdeen, Scotland, UK, AB11 9DB. j.simmonds@marlab.ac.uk.

In some situations advantage can be obtained by stratifying survey effort. However, if the survey has several a number of purposes of different importance, each with a different spatial distribution it may be to determine how best to design the survey. The presentation addresses a design of a multi-vessel survey used for the assessment of North Sea herring. The use of the data in the assessment is analysed to determine the sensitivity of the output information to the variability. The spatial contribution of variability is investigated. An appropriate stratification of the strategy is proposed and the potential benefits examined.

8.7 Discussion

Currently, acoustic biomass estimates are used mostly for management of individual stocks. In some cases, the acoustically-derived estimates of absolute biomass are used. In other cases, the estimates are used as relative indices of abundance, with or without consideration and or incorporation of age information. As fishery management strategies moves from single-species to ecosystem-based approaches, there is an increased need to obtain and use absolute abundance estimates. Acoustical survey methods are ideally suited to the task of providing abundance estimates for species in a wide range of trophic levels, and at the appropriate temporal-spatial scales necessary to characterize marine ecosystems. In this context, WGFAST discussed error in acoustical biomass estimates.

Historically there have been numerous studies investigating individual sources of error in acoustical surveys. Few studies, however, have attempted to examine the total survey error including random and systematic components of measurement and sampling error. The results of two such studies are tabulated below, where some components of uncertainty were considered independently:

▪ Estimated magnitudes of systematic and random sources of error (%)

* not explicitly considered - considered negligible

	Tesler (1989)		MacLennan and Simmonds (1992)	
Source of error	Random	Systematic	Random	Systematic
Physical calibration	-	±12 to ±26	±2	±5
Transducer motion	±3	-	-	0 to -30
Bubble attenuation	-	-12	-	0 to -90
Hydrographic conditions	*	*	±2 to ±5	0 to ±5
Target strength	-	±26 to ±41	±5	0 to ±50
Species identification	*	*	-	0 to ±80
Random sampling	*	*	±10 to ±40	-
Fish migration	*	*	-	0 to ± 40
Diurnal behavior	*	*	0 to -25	-
Avoidance reactions	*	*	-	uncertain
Integrator error	±5	-	*	*
Attenuation coefficient	-	±5	*	*
Time-varied gain	-	±10	*	*
Equivalent beam angle	±14 to ±20	-	*	*

More recently, to account for covariance of some error sources, components of the total survey error were estimated and their pdfs combined via Monte Carlo simulation analyses (Demer, 1994; Rose *et al*., 2000; and O'Driscol, 2004). This technique may overestimate the random measurement errors and does not elucidate the major sources of systematic error. Demer (2004) provided a more comprehensive review for random and systematic measurement errors in surveys of Antarctic Krill. This analysis treats some of the random errors as correlated, and highlights the major systematic errors, improving the analysis. At WGFAST this year, other presenters provided information on specific sources of errors in acoustical surveys including bubbles and thresholds (Goss), equipment errors (Ryan and Kloser, Kieser and Andersen), and spatial sampling errors (Simmonds). Chu *et al.* presented a report on errors in inversion methods for biomass estimation due to the diversity of the scattering targets and the complexity of the scattering process as well as the inherent non-uniqueness of the inversion techniques. An example of using a nonlinear inversion scheme on multi-frequency acoustical and physical environmental data in the Southern Ocean was presented along with guidance of reducing the estimate errors and improving the robustness of the inversion. Most of these studies provided methods for quantifying the error and improving the estimates provided.

Some questions were raised regarding the possibility of adaptive designs. A provisional analysis was presented which indicated that, in the presence of a strong mean variance relationship, there might be problems with adaptive strategies. Issues of survey design should be investigated further and will form one of the issues considered by the ICES workshop on Survey design and Analysis (WKSAD) which will meet later this year in Aberdeen. The concept of incorporating other information, either inclusive or not of an adaptive strategy will also be examined. Total uncertainty in acoustical and net sampling surveys is also the topic of a theme session planned for the ICES ASC in 2005.

There was also some debate on whether the applicability of uncertainty should be more relevant to an absolute estimate rather than a relative index. This was of particular concern to the choice and error associated with the target strength function, for example. Building on that example, it was noted that even with a relative index, conditions may change from year to year that, without incorporation of the correct uncertainty would render an index in one year not relative to a similar one the following year. The key as noted above is the incorporation of the correct measure of uncertainty. There was finally agreement that a relative index is likely to be subject to some error in most areas and that an absolute measure with an estimate of uncertainty is likely to be a better "relative" measure than one obtained by ignoring some of the errors. The move towards an ecosystem approach has some relevance in this debate. Comparing quantities of different types of animals will necessitate absolute measures. However, other "indicators" may need to be incorporated other than just the abundance, such as the spatial distribution and the relationship to environmental factors. With regard to the latter point, it should be emphasized, that the acoustic method is just one of a suite of techniques that provide pieces of the ecosystem puzzle. The group was reminded to use appropriate methods to detect the variety of processes, and to obtain more information for understanding the whole system rather than focusing on a single objective.

The extent to which uncertainty in surveys is investigated and reported remains an issue of debate. A purely objective pursuit of an absolute abundance estimate, with a measure of uncertainty, will deliver the best advice regarding the status of any resource. However, reporting estimates of uncertainty without confidence that the

uncertainty estimate is itself correct, is misleading. That is, misleading error analyses may cause more problems than an omission of error estimates.

The experience of the United States of America's National Marine Fisheries Services' Northeast Fisheries Science Center is relevant to this discussion. In the late 1970s, perhaps through political expedience, experiments were conducted there which drew serious doubt as to the accuracy of the acoustical technique for abundance estimation. This focus on measurement uncertainty, regardless of the studies' validity, rendered many people to perceive the technique as unreliable. This study effectively closed the acoustical survey programme in the region for over twenty years, despite recognition a few years later that the experiments were flawed. Therefore, some scientists who remember those years are still wary of reporting uncertainty. This is a political debate which is difficult to incorporate into a purely scientific arena. Nevertheless, it is of considerable concern to many in the community. Resolution of this debate will only come with very accurate and precise characterization of the sources of uncertainty in acoustical surveys, to ensure that their inclusion in survey reports is constructive.

Chair: John Simmonds, Scotland. j.simmonds@marlab.ac.uk.

9 Review of the Reports of the Study and Planning Groups

9.1 Study Group on Acoustic Seabed Classification (SGASC)

The Study Group met in Gdynia, Poland 18–19 April 2004. John Anderson presented the report of the study group to WGFAST. This was the second meeting of the study group and interest in the study group remains high, attracting 28 participants from eleven countries. A direct contact has been established with the Working Group on Marine Habitat Mapping (WGMHM) through Dr. Roger Coggan, (UK). A number of presentations were made by lead chapter authors based on the draft table of contents previously developed by the study group. Significant progress has been made towards the development and writing of a *ICES Cooperative Research Report* (CRR). Timelines were developed for writing and editing the CRR during the coming year. The study group plans meet next year to review and finalize the CRR. The report of the SGASC will be available in a separate ICES document.

9.2 Study Group on Collection of Acoustic Data from Fishing Vessels (SGAFV)

SGAFV held its first meeting at the Sea Fisheries Institute (SFI), Gdynia, Poland, prior to the 2004 meetings of ICES FTC working groups, WGFAST and WGFTFB. The meeting was Chaired by Dr. W. Karp (USA). Dr. Alex De Robertis (USA) acted as Rapporteur. Twenty-four scientists from seven ICES member countries and three observer countries attended the meetings. The Chair opened the meeting by thanking SFI and introducing those present. The Study Group then reviewed the agenda and discussed the goals of the meeting.
Major agenda items and meeting goals were agreed upon as follows:

- Review Terms of Reference (TORs),
- Review developments in the field,
- Develop outline for final report,
- Assign initial authorship responsibilities,
- Reach agreement on work to be completed before the next meeting of the Study Group,
- Recommend changes in the Terms of Reference if appropriate, and
- Identify major agenda items for 2005 meeting of SGAFV.

The Terms TORs for the study group were reviewed and discussed. Guidance provided for the SG includes the following summaries of the TORs;

- Review and evaluate recent and current research which involves collection of scientific acoustic data from commercial vessels (TOR a),
- Develop standardized methods and protocols for collection of acoustic data to address specific ecosystem monitoring, stock assessment and management objectives including: acoustic system calibration and performance monitoring, characterization of radiated vessel noise, comparability of results, survey design, biological sampling, data interpretation and analysis, and data storage and management (TOR b), and
- Prepare background material, guidelines, methods and protocols for possible publication in the *Cooperative Research Report* series (TOR c).

The SG proceeded to address TOR a. The Chair first provided an overview of presentations made on this subject during the 2003 meeting of WGFAST in Bergen Norway. This was followed by 10 presentations by SG attendees. These presentations addressed a broad range of topics germane to the SGAFV and each presentation was followed by stimulating discussions.

TORs b and c were then considered. The Chair initiated the process by presenting a draft outline for the final report of the SG. This provided a basis for extended discussions of the topics to be considered by SGAFV, the structure of the final report, SG member authorship responsibilities, and schedules for completing draft report chapters.
The SG reached agreement on the initial detailed outline of the final report, recognizing that changes would likely be made as the work proceeds. Lead authors were identified for most chapters and contributing authors were also identified for several chapters. It was agreed that lead authors would provide first drafts of chapters in advance of the 2005 meeting of the SG so that review and discussion could take place at the 2005 meeting. The Chair agreed to encourage SG members not present at the meeting to accept writing assignments.

After this discussion, SGAFV again reviewed the TORs and recommended minor changes to improve clarity. SGAFV identified the following agenda items for its 2005 meeting:

- Discuss recent developments in the field
- Review status of final report
- Review and recommend any necessary changes in the TORs
- Report to WGFAST and FTFB on progress and status

9.3 Study Group of Target Strength Estimation in the Baltic Sea (SGSEB)

Bo Lundgren, Chair, reported on the activities of the Study Group on Baltic Target Strength. SGTSEB has met three times, most recently in Bergen, June 2003. During this meeting the ToR's and work of the previous meetings were reviewed. The delayed report for 2002 was presented and finalised, and is available on the ICES website. It was also decided to work on establishing a TS-relation based on relatively few terms, expressing the influences of fish length, pressure (depth) and frequency. Influences from tilt distribution, fish condition and geographic area would be contained in the constant term until further knowledge has been obtained. The basis would be available data from surveys in the area. Activity continues by correspondence. A short form report of the 2003 meeting is also available on ICES website: http://www.ices.dk/iceswork/wgdetail.asp?wg=SGTSEB.

Terms of Reference 2004
The **Study Group of Target Strength Estimation in the Baltic Sea** [SGTSEB] (Chair: B. Lundgren, Denmark) will work by correspondence in 2004 to:

i) prepare a final report on the work of the Study Group for possible publication in the ICES *Cooperative Research Report* series; and
ii) make its draft report available by 31 July 2004 for the attention of the Fisheries Technology Committee and the Baltic Committee.

Present activities
Tomas Didrikas and Thomas Axenroth at Stockholm University, Sweden have sent a letter asking for available acoustic data combined with fisheries data to scientists at the various institutions around the Baltic Sea and has obtained positive answers from the following persons:
Datasets:
Lithuania/Sweden, Tomas Didrikas
Latvia, Guntars Strods
Sweden, Niklas Larsson
Denmark, Bo Lundgren
Germany, Eberhard Götze
Russia, Vladimir Severin

The plan is that Tomas Didrikas works up suitable data from the various datasets with a method similar to what was presented during the last meeting. At the moment, there are some difficulties since various datasets are recorded with different software, but Bo Lundgren and Helge Balk are working on a solution.

Reporting.
It is likely that it will not be possible to finalise a draft report by 31 July 2004 as stated in the ToR. The group will therefore issue an intermediate report to the Fisheries Technology Committee and the Baltic Committee at that date including a request to prolong the working period into 2005.

9.4 Planning Group on the HAC (PGHAC) common data exchange format

Laurence Berger reported on the progress of the Planning Group on HAC, a common data exchange format. Primary developments were: 1) the resignation of Dave Reid, UK, as Chair; 2) the nomination of Laurence Berger, France, as the new Chair of PGHAC; 3) the writing of a consolidated HAC specification by Ian McQuinn, Canada; and 4) the decision to conduct future business by correspondence. Dave Reid was thanked for his efforts to lead this important planning group since its inception. Laurence Berger was applauded for accepting the charge as new Chair. Ian McQuinn was applauded for his significant effort to create an up-to-date and amalgamated HAC document.

10 Recommendations

10.1 Terms of reference for 2005 WGFAST meeting

The discussion on the terms of references for the next WGFAST meeting resulted in the following recommendation.
Recommendation: WGFAST recommends that the Working Group on Fisheries Acoustics Science and Technology (Chair: D. Demer, USA) meets at FAO in Rome, Italy, from 19–22 April 2005 to:

a) examine works in the following research areas:
    i) Measurements of underwater acoustic energy and its effects on fish;
    ii) Technologies for remote species identification (low-frequency, Doppler, multi-frequency, broadband, data integration, optical sensors);
    iii) Alternative technologies (small-craft, buoys, ROV, AUV, gliders, fishing vessels, multi-beam sonar, acoustic cameras), with special attention to shallow water and near boundary assessments (coastal, riverine, demersal and epipelagic species, and bottom typing)
    iv) Target strength (modelling and measurements)
b) review the reports of the:
    i) Planning Group on the HAC (PGHAC) common data exchange format;
    ii) Study Group on Baltic Herring TS (SGTSEB);
    iii) Study Group on Acoustic Seabed Classification (SGASC);
    iv) Study Group on Collection of Acoustic from Fishing Vessels (SGAFV).

10.2 Terms of reference for 2005 WGFAST-WGFTFB Joint Session

In accordance with WGFTFB, the following themes were proposed for the 2005 Joint Session.
Recommendation: WGFAST and WGFTFB recommend that the two Working Groups (Chairs: D. Demer, USA, and N. Graham, Norway) meet for a Joint Session at FAO in Rome, Italy, on 21 April 2005 to review:

a) Advances in survey strategy, design, and gear (including observational techniques such as sonar, video, cameras, and longlines)
b) Techniques for validating multi-frequency acoustical species methods, with attention to appropriate time, space and scale (e.g. longlines, gill nets, plankton nets, survey trawls, CUFES, cameras, video, and u-tow)
c) Methods for integrating multi-disciplinary data to elucidate forcing functions of fish abundance and behaviour (e.g. environmental conditions, fishing pressure, and vessel noise)

10.3 Theme Sessions for the 2006 Annual Science Conference

In its continuing effort to contribute to the ICES Annual Science Conferences, WGFAST proposes the following theme sessions for the 2006 Annual Science Conference.

Recommendation: As the spatial structure of fish aggregations (school to population) and its dynamics can indicate adaptation to environmental conditions, characterization of this structure may provide information about stock status more efficiently and precisely than conventional indicators of catch and abundance. Therefore, WGFAST recommends that a Theme Session on the *"Spatial organisation and dynamics of fish populations as indicator of adaptation to the characteristics and dynamics of exploitation and the environment"* be established for the 2006 Annual Science Conference, with François Gerlotto, France, as one of the conveners. Contributions will be solicited on techniques for measuring and characterizing the distributions of fish aggregations, and relationships between their time-varying spatial structure and the associated environmental conditions, including exploitation activities.

Recommendation: Since ecosystem-based assessments are now required in most fisheries management strategies, WGFAST recommends that a Theme Session on "*Characterizing the requirements, observational technologies, and models for an ecosystem or ecosystem-based assessment*," be established for the 2006 Annual Science Conference with Dave Reid, UK, as a co-convener. Additional co-convener(s) to be determined. The theme session may be co-sponsored by FTC and LR.

10.4 2007 ICES Acoustics Symposium

The discussion on the 2007 ICES Acoustics Symposium resulted in the following recommendation.

Recommendation: WGFAST recommends that: an acoustics symposium be held at the Institute of Marine Research in Bergen, Norway in June 2007; it is co-convened by Egil Ona, Norway, Rudy Kloser, Australia, and David Demer, the United States of America; it is titled "*The 2007 Symposium on Fisheries Acoustics, Science and Technology*;" and it includes the following topic sessions:

1) Alternative platforms (small-craft, buoys, rov, auv, gliders, and ocean observation systems)
2) Species identification and multi-species assessments (low-frequency, Doppler, multi-frequency, broadband, and data integration)
3) Multibeam methods and applications
4) Target strength (modelling and measurement)
5) Passive acoustical observations and assessments
6) Uncertainty estimation (error analysis, calibration dynamics, and acoustic data validation)
7) Shallow water assessments (coastal and riverine)
8) Near boundary assessments (demersal and epipelagic species, and bottom typing)
9) Technologies for studying aquatic organisms (benthic and benthopelagic organisms, phytoplankton, protists, zooplankton, micronekton and mesopelagics).
10) Acoustic characterization and classification of aquatic habitats (pelagic and benthic environments)
11) The measurement of aquatic animal behaviour and its impact on assessments (tagging and tracking)

11 Miscellaneous

A generous offer was made by John Horne, USA, to host and maintain the WGFAST web site and list server for a minimum of two years (2005 and 2006). WGFAST gratefully accepted the offer and put John Horne in contact with the current web hosts: Lennart Edstroem, IMR (lennart.edstroem@imr.no; website: http://www.imr.no/) and Destry Wion, AKFSC (Destry.Wion@noaa.gov; list server). WGFAST is very appreciative of the significant efforts made by Lennart and Destry to host and maintain these sites, thereby facilitating easy and effective communications between WGFAST members.

A very attractive offer to host the 2006 meeting of WGFAST at CSIRO in Hobart, Tasmania was submitted by Rudy Kloser, Australia.

It was proposed that the 2007 meeting of WGFAST be limited to a one-day business meeting, and that it be held in Bergen, Norway in concert with the "*2007 Symposium on Fisheries Acoustics, Science and Technology*."
A proposal for exploring the possibilities of Lima, Peru, as the location for the 2008 meeting was submitted by François Gerlotto, France.

Paul Fernandes provided information on a Workshop on Survey Design and Data Analysis to be held in Aberdeen 21–25 June 2004. Relevant information is available on the ICES website.

12 Closure of meeting

On behalf of all members, the Chair thanked the local hosts at the Sea Fisheries Institute, Gdynia, Poland; specifically Tomasz Linkowski, Andrzej Orlowski, and the Secretariat, audio-visual and custodial staffs for their meticulous planning, generous hospitality, and comfortable and effective facilities. The meeting was then closed.

13 Annexes

Annex 1: Participants of the 2004 WGFAST Meeting in Gdynia, Poland

Last Name	First Name	Country	Email
Anderson	John	Canada	AndersonJT@dfo-mpo.gc.ca
Axenrot	Thomas	Sweden	thomas@ecology.su.se
Balk	Helge	Norway	helge.balk@fys.uio.no
Berger	Laurent	France	Laurent.Berger@ifremer.fr
Brierley	Andrew	UK	andrew.brierley@st-andrews.ac.uk
Boyra	Guillermo	Spain	gboyra@pas.azti.es
Burczynski	Janusz	USA	janusz@biosonicsinc.com
Chu	Dezhang	USA	dchu@whoi.edu
Condiotty	Jeff	USA	jeff.condiotty@simrad.com
de Theije	Pascal	Netherlands	detheije@fel.tno.nl
Demer	David	USA	david.demer@noaa.gov
De Robertis	Alex	USA	Alex.DeRobertis@noaa.gov
Didrikas	Tomas	Sweden	tomas@ecology.su.se
Diner	Noël	France	Noel.Diner@ifremer.fr
Dorn	Martin	USA	Martin.Dorn@noaa.gov
Eger	Kjell	Norway	kjell.eger@simrad.com
Fernandes	Paul	UK - Scotland	fernandespg@marlab.ac.uk
Gerlotto	François	France	fgerlotto@ifop.cl
Godlewska	Malgorzata	Poland	margogod@wp.pl
Gorska	Natalia	Poland	gorska@iopan.gda.pl
Goss	Cathy	UK - England	cg@bas.ac.uk
Grelowska	Grazyna	Poland	ggrel@wp.pl
Holliday	Van	USA	van.holliday@baesystems.com
Horne	John	USA	jhorne@u.washington.edu
Hotaling	John	USA	John.Hotaling@noaa.gov
Ignashkin	Nalezy	Russia	ign@pinro.ru
Jech	Michael	USA	michael.jech@noaa.gov
Josse	Erwan	France	Erwan.Josse@ird.fr
Karp	Bill	USA	bill.karp@noaa.gov
Kasatkina	Svetlana	Russia	ks@atlant.baltnet.ru
Kieser	Robert	Canada	kieser@pac.dfo-mpo.gc.ca
Kloser	Rudy	Australia	rudy.kloser@csiro.au
Knudsen	Hans P.	Norway	hans.knudsen@imr.no
Korneliussen	Rolf	Norway	rolf.korneliussen@imr.no
Larson	Niklas	Sweden	Niklas.Larson@fiskeriverket.se
Lebourges-Dhaussy	Anne	France	Anne.Lebourges.Dhaussy@ird.fr
Lindem	Torfinn	Norway	torfinn.lindem@fys.uio.no
Lipsky	Jessica	USA	jessica.lipsky@noaa.gov
Lundgren	Bo	Denmark	bl@dfu.min.dk
Macaulay	Gavin	New Zealand	g.macaulay@niwa.co.nz
Mazauric	Valerie	France	Valerie.Mazauric@ifremer.fr
McQuinn	Ian	Canada	McQuinnI@dfo-mpo.gc.ca
Michaels	Bill	USA	william.michaels@noaa.gov
Moszyski	Marek	Poland	marmo@eti.pg.gda.pl
O'Donnell	Ciaran	Republic of Ireland	Ciaran.O'Donnell@Marine.ie
Olsen	Kjell	Norway	kjello@nfh.uit.no
Orlowski	Andrzej	Poland	orlov@mir.gdynia.pl
Pauly	Tim	Australia	Tim.Pauly@sonardata.com
Pedersen	Audun	Norway	Audun.Pedersen@cmr.no
Pedersen	Geir	Norway	geir.pedersen@imr.no
Peña	Hector	Norway	hector.pena@imr.no
Pocwiardowski	Pawel	Denmark	ppo@reson.dk
Preston	Jon	Canada	jpreston@questertanget.com

Last Name	First Name	Country	Email
Reid	David	UK - Scotland	reiddg@marlab.ac.uk
Reynisson	Pall	Iceland	pall@hafro.is
Rosen	Shale	USA	srosen@gma.org
Ryan	Tim	Australia	tim.ryan@csiro.au
Scalabrin	Carla	France	carla.scalabrin@ifremer.fr
Schneider	Patrick	Spain	ps@wol.es
Severin	Vladimir	Russia	severin@atlant.baltnet.ru
Simard	Yvan	Canada	yvan_simard@uqar.qc.ca
Simmonds	John	UK - Scotland	J.Simmonds@marlab.ac.uk
Smith	Leon	Faroe Islands	Leonsmit@frs.fo
Stacey	Philip	UK-England	Phil.Stacey@ultra-scs.com
Stenersen	Eric	Norway	erik.stenersen@simrad.com
Stepnowski	Andrzej	Poland	astep@eti.pg.gda.pl
Strods	Guntars	Lativia	phoxinus@latfri.lv
Szczucka	Joanna	Poland	szczucka@iopan.gda.pl
Tegowaki	Jaroslaw	Poland	tegowski@iopan.gda.pl
Totland	Atle	Norway	atle.totland@imr.no
Walsh	Steve	Canada	walshs@dfo-mpo.gc.ca