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REPORT OF THE

WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY

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1 TERMS OF REFERENCE

In accordance with the ICES Resolutions adopted at the 87th Statutory Meeting, the Working Group on Fisheries Acoustics Science and Technology (Chairman: Dr. F. Gerlotto, France) met in Haarlem, Netherlands, on the 10-14 April 2000 to:

a) evaluate the impact of fish avoidance on fisheries acoustic data;

b) consider the bottom classification methods using acoustic signal applied to survey design and data processing;

c) review the progress and evolution of the standard data exchange format;

d) review the proposal of standardisation of acoustical definitions, units and symbols;

e) discuss and organise experiments with the objective to find and verify new Target Strength (TS) conversion formulas for Baltic herring and sprat.

WGFAST will report to the Fisheries Technology and Baltic Committees at the 2000 Annual Science Conference.

Other points:

- suggestion of a candidate for new chairman;
- WGFAST web address
- Report from the organisers of the Symposium 2002 on Fisheries Acoustics (Montpellier, France)

2 MEETING AGENDA AND APPOINTMENT OF RAPPORTEUR

The chairman opened the meeting and Cathy Goss of the British Antarctic Survey, Cambridge, UK, was appointed as rapporteur.

The following agenda items were adopted:

Session a “Fish avoidance”

Session b “Seabed classification”

Session c “Common data format”

Session d “Acoustic definitions, units and symbols”.

Session e “TS of Baltic herring”

Session f1 “New methods and techniques”

Session f2 “Survey methods in ecology and fisheries acoustics”

A list of participants appears as Appendix A.

3 SESSION A “FISH AVOIDANCE”

3.1 G. Arnold Fish avoidance and fisheries acoustics

This author prepared a summary of avoidance effects, these were condensed into a table, reproduced here as Table 1. Observed reaction distances had been included in Co-operative Research Report (209). Typical vessels provoked a reaction in fish between 100 and 200 m distant, whereas noisy vessels caused an effect up to 400 m. Recent observations have been made on herring & sprat (Misund & Aglen, 1992) between 50 - 375 m, on herring (Misund, 1996) from 25 - 1000 m and on haddock (Ona & Godø, 1992) at 200 m (depth < 200 m).

Key research questions were identified:

- Is noise always the key stimulus?
- What is the relative importance of threshold noise level or rate of change of noise intensity?
- What noise level does the fish actually experience? (importance of signal to noise ratio)
- Are the detection & avoidance thresholds in Co-operative Research Report No. 209 correct?
- How important are habituation and/or learning?
- How do reactions vary with season (maturity stage)?
- How important is natural behaviour?

A list of references had been prepared, see Appendix B.

3.2 P. Fernandes An investigation of fish avoidance using an Autonomous Underwater Vehicle

An Autonomous Underwater Vehicle (AUV) Autosub-1 was deployed 200-800 m ahead of the research vessel Scotia on eight transects in water 60-180 m deep, during an acoustic survey of herring in the North Sea. In comparison to the 68 m Scotia, Autosub-1 is small (torpedo shaped, 7 * 1 m) and extremely quiet (propelled by electric motor). Autosub-1 was equipped with the same type of 38 kHz scientific echosounder as Scotia, and gathered equivalent acoustic data before the research vessel arrived. If fish avoided the Scotia, we expected that it would detect fewer fish than Autosub-1.

The experiment required two major assumptions: i) that the AUV did not cause avoidance itself, and ii) that the noise produced by the Scotia during the experiment (at 3 knots) was representative of survey speed (10 knots). Avoidance of Autosub-1 by herring is minimal: passing unprecedently close to a school, the vehicle caused only the localised school compression that is typical on close approach of predators. Noise ranging measurements show that the noise generated by Scotia at 4 knots is not significantly different from that at 10 knots.

The amount of fish detected by the research vessel was not significantly different from that detected by the AUV. Scotia is very quiet, having been built to guidelines intended to limit noise emission. Our data show that for such vessels avoidance is not a source of bias.

3.3 F. Gerlotto Some observations on fish avoidance in several seas

Fish school avoidance was studied in several areas in the Mediterranean and Caribbean seas and the inter-tropical Atlantic. The measurements were made using both a vertical multibeam sonar RESAO SeaBat 6012 and an omnidirectional sonar SIMRAD SR240. Reactions of avoidance in most of the areas were observed, but the avoidance scheme was different from one area to the other. The conclusions of the author are:

- avoidance may be an important source of bias in fisheries acoustics
- it varies depending of a number of factors
- there are tools that are able to measure this bias during the surveys (e.g. multibeam sonar)

3.4 C. Wilson Consideration in the analysis of acoustic buoy data to investigate fish avoidance

Acoustic data were collected with a free-drifting acoustic buoy containing an echosounder operating at 38 kHz to investigate fish avoidance reactions to vessel noise. Field experiments with the buoy were conducted on walleye pollock (*Theragra chalcogramma*) in the Gulf of Alaska during March 1998 and in the Bering Sea during August 1999. Work with the buoy was also conducted on Pacific hake (*Merluccius productus)* off the west coast of the United States during July-August 1998. The purpose of the fieldwork was to investigate whether these species exhibited behavioural responses to the research survey vessel, *Miller Freeman,* when it was free-running at the standard survey vessel speed of 11-12 knots. The vessel made repeated passes by the buoy during each buoy deployment. Each pass began (and ended) about 2 km away from the buoy and passed within about 5-10 m of the buoy (i.e., CPA; closest point of approach). The analysis of the data is currently in progress. Preliminary results suggest that neither walleye pollock nor Pacific hake exhibited strong, consistent avoidance responses to the vessel noise.

The work with the buoy in the Bering Sea included efforts to determine whether walleye pollock exhibited a *consistent* avoidance reaction during free-running passes by the buoy with a large, relatively "noisy" factory-trawler vessel. These results facilitated interpretation of the earlier results for the *Miller Freeman*.

An analytical procedure called superposed epoch analysis (Prager and Hoenig 1989, Trans. Amer. Fish. Soc: 118: 608-618; Prager and Hoening 1992, Trans. Amer. Fish. Soc: 121:123-131) was used to determine whether significant trends occurred in the buoy nautical area scattering coefficient (s_A) estimates. Superposed epoch analysis (SEA) is a nonparametric technique for conducting significance tests of association in autocorrelated time series. Time-series of the buoy data were created by appending all buoy passes together within a given deployment. The SEA tests were performed to determine whether significant associations occurred between particularly low s_A estimates, and the CPA times between the buoy and vessel during a deployment. Results of the epoch analysis tests were highly dependent on the width of the window that was used to define the CPA portion (and non-CPA portion) of the buoy time series.

3.5 R. Vabö Effect of fish behaviour on acoustic estimates of NS herring

Day/night abundance differences were recorded over 8y. The differences were possibly related to behaviour through vessel avoidance, tilt angle distribution, and depth-dependent TS variations.

Within their wintering area, herring were found deep during the day, 200-400 m, but at night they relocated to 50-400 m. In the outer fjord they were found deeper still, therefore acoustic data were separated on geography.

At present a single, length-dependent only TS relationship was used. However a new relationship is needed that will introduce swim bladder compression with depth and tilt angle variations. The tilt angle distribution may be ascertained from photographs.

TS in the upper layers has been found to be unimodal at night in the top 100 m. In contrast, deeper records (100-200m), were found to be bimodal and strongly influenced acoustic biomass estimates. During the daytime, the TS distribution was bimodal for both shallow and deep recordings.

Split beam TS estimates from single fish were averaged over several pings, in order to look for depth dependency (in a very variable dataset) predicting what would happen to a swimbladder compressed according to Boyle's law. However, the actual data showed less compression – possibly due to a smaller reduction in area than that predicted.

The conclusions of this work were that the TS showed high variability, a high TS compared with current value was required and that TS showed only weak depth dependency.

4 SESSION B "SEABED CLASSIFICATION"

4.1 J. Breslin ECHOplus. A digital seabed discrimination system

ECHO*Plus* is a new digital device which allows a standard single beam echo sounder, navigation and chart plotting system to be used as a complete seabed classification system. Seabed classification tools can be used for a variety of applications concerned with the protection, development and monitoring of fisheries resources. The following projects requiring seabed classification have been carried out: mapping of sediments associated with herring spawning grounds, clams, eels and juvenile lobsters, mapping of mussel beds prior to and after channel clearance, identification of seabed sediments during International Bottom Trawl Surveys and the monitoring of dredge-spoil dumpsites. Acoustic techniques have the advantage over mechanical and visual methods for seabed classification because the data can be achieved remotely when the vessel is underway.

ECHO*Plus* uses the backscatter information from the first echo to characterise the seabed roughness and reflection information from the second echo to characterise seabed hardness. To avoid contamination of the backscattered energy with energy that has been reflected from below the transducer, only the tail of the first echo is used in the analysis. Two theories to describe the physical mechanism behind the second echo are described. Both theories agree that the harder the seabed the more energy appears in the analysis window and so the debate has no practical bearing on the design of the ECHO*Plus* system and in particular the choice of analysis window parameters. Although not independent, roughness and hardness together are a reliable indicator for seabed discrimination.

ECHO*Plus* has two separate frequency channels to exploit the difference between the acoustic properties of the seabed, which can vary significantly as a function of the frequency used. Automatic frequency compensation is achieved by using wide band low loss front-end hardware together with frequency estimation software. A digital time varying gain or amplitude factor proportional to the water depth is applied to the digitised voltages within the system in order to compensate for losses in energy as a function of depth. The ECHO*Plus* outputs are automatically scaled within the system to compensate for changes in pulse length and power level so that the roughness and hardness outputs for the system will remain centred on the same values as long as the seabed remains unchanged. Real time examples of ECHO*Plus* serial and parallel outputs are presented.

4.2 J. Anderson Seabed classification comparing submersible and acoustic techniques

Seabed habitats were defined based on submersible observations in Placentia Bay, Newfoundland. Habitats included: mud/silt, sand/gravel, cobble, rock, boulder, bedrock. When macroalgae occurred it was classified into different density classes: sparse, moderate and dense. Submersible identification of these marine seabed habitats was used to develop a set of calibration sites for a QTC VIEW digital acoustic classification system. Following calibration of the acoustic system, in Placentia Bay, Newfoundland, seabed classification was carried out within Bonavista Bay, Newfoundland. A single submersible dive consisting of two transects over approximately 1.5 km distance within the classified area was carried out to independently validate the acoustic seabed classification. There was a close association between marine habitats observed from the submersible with seabed classification by the acoustic system. Overall, hard bottom habitats represented 88% and 83% of all submersible and acoustic classifications, respectively. Gravel habitats accounted for 12% and 10% while dense macroalgae accounted for 8% and 5%, respectively. Small and large-scale variability in seabed habitats occurred for both classification systems.

5 SESSION C “COMMON DATA FORMAT”

5.1 Y. Simard Report of expert group

Appended as Appendix C

6 SESSION D “ACOUSTIC DEFINITIONS, UNITS AND SYMBOLS”.

6.1 D. MacLennan and Paul Fernandes Acoustic definitions, units and symbols

Revisions were presented of the definitions, units and symbols proposed by these authors at the previous session of this WG for the basic quantities used by workers in the field of fisheries acoustics. Their paper on this topic is reproduced at Appendix D

6.2 J. Dalen: Terminology in fisheries acoustics

The fisheries acoustics related scientists at the Institute of Marine Research (IMR), Bergen supported the initiative taken at the 1999 FAST meeting in St Johns, as well as the following work which has been done and that still to be done. To meet the need of more concrete contributions than just verbal comments during the discussions at the meeting a paper was presented. Where agreement and understanding were clear, reference was made to the contribution by MacLennan and Fernandes to this meeting (item 6.1), but where this was not the case, special comments and proposals for new expressions, notations and definitions were added. While the previously mentioned contribution concentrated on terms related to the scattering processes, this author suggested that the sound source and sound propagation related fields should also be incorporated.

Alterations and extensions of the "primary quantities" given in MacLennan and Fernandes was by a list of comments according to their list of names, definitions, and symbols.

6.3 Discussion and recommendations topic d

It was suggested that a letter should be sent to the Journal of the Acoustical Society of America describing current situation on this topic – and that the information should also be presented at the Annual Science Conference at Bruges meeting. This should be considered as an interim standard – a starting point for a study group to review periodically.

A high percentage of this topic was not controversial and it was anticipated that this interim standard could be produced by the end of the week.

7 SESSION E “TS OF BALTIC HERRING”

7.1 F. Arrhenius: The target strength conversion formula of Baltic herring (*Clupea harengus*)

In the application of acoustic fish abundance estimation, the target strength (TS) of the fish is an important parameter for the conversion of integrated acoustic energy to absolute fish abundance. Variability in acoustic estimates can be ascribed to several causes. High precision and comparability of acoustic measurements of isotropic standard targets are documented and verified. The main problem appears in the quantitative interpretation of acoustic echoes revived from targets of unknown reflecting characteristics. The same fish or school could produce very different acoustic echoes. The differences can be associated with pure stochastic reasons or with more systematic phenomena joint with behavioural reactions, controlled by basic biological rhythms and functions.

One of the most important factors influencing the final results is related to TS conversion formulas. By convention the TS conversion is expressed as the averaged function of fish length. The actual TS constants applied since 1983 for

Baltic Sea acoustic surveys are in reality the North Sea herring properties. A short review on the influence of biological sampling and TS conversion formulas to the results of acoustic estimations was presented.

7.2 J. Dalen The Baltic Herring TS

A change in TS for clupeoids was recorded over 13 years. 4 surveys per year carried out over the past 5 years, have been considered. The TS relationship published by Foote in 1987 has been used in the past: 20 log l -71.9, derived from 4 *in situ* measurements. However, modifications according to specific surveys are needed. Large variations had been found in estimated TS since then due to the relationship between scattering properties and frequency, physiological and environmental factors, fish swimbladder size and shape changes according to depth and tilt angle. The 20 log L -B_{20} relationship is only appropriate for the geometric scattering zone, but is used for smaller fish. Thus there is a need for a new B_{20} to reflect ‘all impacts’ from physiology, behaviour and environmental factors. It was considered that the effect on biomass estimates of using the measured lipid content rather than an average will result in an overestimate. Depth variation was used to fit a compression model, but there was still a lot of variation at each depth. Swimbladder tilt angle, tilt angle variation, depth, GSI and swimming speed were all compared for each assessment time period, for 6 months, showing the potential for larger variations within year than between year.

Using all this information, the constant term should be 4-6dB higher (i.e., stock numbers will be lower).

7.3 F. Arrhenius, M. Cardinale, and N. Håkansson: Spatial and temporal small scale variability of area backscattering strength values (Sa-values) in the Baltic Sea

The dynamics of schooling behaviour of pelagic fish during 24-hours was investigated using data from acoustic experimental surveys in the Baltic Sea. We analysed patterns of temporal distribution at small scale and diel dynamics of vertical migrations of pelagic fish. The area investigated was surveyed over 4 transects forming a square with sides equal to 12 nautical miles. The entire area was ensonified repeatedly 4 times during the 24 hours. The survey was conducted for three days, two consecutive days, 3 and 4 October and the last, one week apart, 11 October 1995. Fish abundances were statistically different among transects, laps and days but without any defined trend in space or time indicating a process of dispersion of fish mainly by horizontal migration or immigration into the area. Pelagic fish were dispersed in the night at the surface and aggregated during the day at the bottom. They aggregated fast at dawn and dispersed slowly at dusk.

7.4 O. Misund TS of herring by the comparison method

The comparison method has various advantages, it is made *in situ*, and can be used on dense schools. A research vessel records a fish school and then instructs a following purse seiner to catch within an extensive aggregation. The aggregation selected needs to be evenly dispersed. The fishing vessel collects net data. By scaling the catch to a square nautical mile, a TS is calculated that gives the measured Sa. The sigma that is calculated varies over an order of magnitude, and the value for b_{20} that is derived is -71.8 but has very large range. Depth, density and seasonal dependence within this range were examined. The main cause of variation was thought to be the movement of herring in or out of the net between shooting and closing of the net.

7.5 Andrzej Orlowski: Acoustic studies of spatial gradients in the Baltic: implications for fish distribution

Year by year acoustic methods play a more important role in studies of fish group behaviour in relation to environmental factors, and are becoming a promising tool in creating new standards in research on marine ecosystems. The paper presented two new approaches to treating acoustic, biological and hydrological data, collected during surveys from significantly large spatial units of the ecosystem. Both methods are designed to study the spatial structure of abiotic and biotic factors. In the first case, the method for estimation of vertical gradients in basic environmental factors, corresponding to the main range of fish occurrence, was defined and applied to characterise fish distributions for daytime and night-time, in various seasons (spring, summer, and the autumn) and years (1983-1996). In the second case, the method of matrix macro-sounding, correlating acoustic and hydrological data, was improved and employed to examine horizontal gradients in fish distribution due to associated environmental structure. Some applications of the method for short-term and long-term studies were shown and discussed.

(Published in ICES Journal of Marine Science 56; 561-570, 1999)

7.6 I. Svellingen: Calibration

The presentation described some results from calibration of split-beam transducers for *in situ* and experimental target strength measurements. Also, results from calibration of a submersible transducer were shown. When using submersible transducers, measurement of the transducer performance at different depths were found to be essential, and in particular in the depth range where target strength measurements are undertaken.

Calibration of split-beam transducers for *in situ* target strength measurement has been carried out for more than 10 years. Vessel calibrations are normally made in fjords at about 50–100 m depth, with a distance to the sphere of about 25 meters.

Experimental target strength measurements are often done in a tanks or pens, and hence it is necessary to perform a standard-target calibration at rather short range. Improved calibration results were obtained with the modified software in the echo sounder.

It has been observed that inhomogeneous water masses near the surface may affect the angle measurements in EK500, probably because interference on the main signal affects the zero-cross detector in the echo sounder. A wrong measured angle will in turn affect the compensated target strength readout, TSC.

However, under good conditions we feel that we are able to perform standard-target calibration of split-beam transducers with an accuracy of +/- 0.2 dB for the actual settings.

If pulse duration or bandwidth is changed, the sounder should be recalibrated with the new settings.

7.7 M. Jech Three dimensional visualisation of fish morphometry and acoustic backscatter

A goal of fisheries acoustics is to estimate the length frequency distribution of the organisms being surveyed. Empirical measurements of backscatter alone do not ensure the accurate conversion of acoustic target size to organism length. Theoretical acoustic models of fish are needed to explain variability in backscatter measurements, to improve estimation of target size, and to improve target recognition and discrimination among types of acoustic targets. In this paper steps were outlined to obtain an anatomically accurate representation of a fish's body and swimbladder, and the predicted backscatter by an individual using a Kirchhoff ray-mode model. Backscatter predictions were made as a function of fish length, carrier frequency, and angle of insonification. The author’s digital morphology representations were expanded to include fish roll and tilt, and the Kirchhoff ray-mode model was extended to predict backscattering at any spatial orientation. The three dimensional backscattering surface (ambit) allowed visualization and quantification of the effects of behaviour on echo amplitudes and prediction of acoustic backscatter measurements obtained by non-vertically looking sonars or multibeam technology.

7.8 Simard Y. and J. Horne Capelin TS: when biology blurs physics

Capelin (*Mallotus villosus*) is an important circumpolar forage fish in northern latitudes, which is preyed upon by a large variety of fish, birds and marine mammals as the main input in their annual energy budget. Despite its widespread distribution and large ecological importance, very little is known about its sound scattering characteristics at various acoustic frequencies. To help fill this gap, the geometric properties of the fish and its swimbladder, an important contributor to target strength (TS), were investigated from a sample in the St.Lawrence estuary. A sample of about 300-400 live fish was obtained from a shore trap in June 1999, and immediately put in a large thermo-isolated container filled with filtered sea water and brought to the aquaculture facility of the Maurice-Lamontagne institute. The fish were maintained at constant temperature overnight, in a semi-closed circulation system allowing 20% water renewal. A subsample of 45 fish, from 12 to 16 cm total length, were radiographed to investigate the geometric characteristics of the swimbladder and sound backscattering characteristics. Batches of 5 to 8 fish were extracted from the tank with a dip net, put in a small bucket and brought to the X-Ray lab., where they were anesthetized with CO_2 saturated water. They were then immediately X-Rayed in a X-Ray Mammograph MAM-CP (Transworld X-Ray Corp., Film konica medical film 24x30 cm CM-H), on both lateral and dorso-ventral views. They were then measured, dissected, sexed; their maturity stage was determined, and presence/absence of food in stomach was noted. Fish body and swimbladder silhouettes were contoured by hand from the X-Ray photographs. The silhouettes were scanned to produce 150 dpi bitmaps that were subjected to image analysis to extract the swimbladder and body cross-section areas, from dorsal and lateral views. Their co-ordinates were also digitized for input to a backscattering model exploring the effect of fish shape on the backscattering strength as a function of acoustic frequency, length and tilt angle.

Results showed that the swimbladder has similar cross-section in both lateral and dorsal views. Because of the larger lateral body cross-section, the swimbladder represented only 5.5 ±1.1 % of lateral body cross-section while it was 8.2 ±1.8% of the dorsal body cross-section. The swimbladder cross-section is related to the fish total length but this relation varies up to ±40% for a given length. Variability in individual swimbladder cross-sections is as large as the cross section change for a given fish between a dorsal view and a head view (i.e., tilt angles of 0^o to 90^o). The variability in shape parameters is paralleled with changes in the modelled backscatter patterns. The TS versus frequency relationship exhibits substantial peaks and troughs, notably in the range of acoustic frequencies commonly used in fisheries acoustics (~38-200kHz).

8 SESSION F1 “NEW METHODS AND TECHNIQUES”

8.1 F. Gerlotto The latest version of AVITIS multibeam sonar system

AVITIS stands for ‘Analyse et Visualisation Tridimensionnelle des Images Sonar’. The objectives of the development of this system were:

1) Avoidance measurement
2) School typology
3) School behaviour

Evidence of fish school avoidance was obtained with AVITIS which can be used to analyse the distribution of fish schools from 0 to 70 m to the side of the survey vessel. The use of the multibeam sonar SEABAT 6012 (Reson) was described, including the connection diagram and choice of a calibration sphere (24.8mm suitable for the frequency: 455 kHz). The results of calibration were presented. The sonar image is generated by 60 beams, of 1.5° each giving a total beam of 90°. Recording from a vertical line beneath the vessel to sea surface, the beam pattern in the perpendicular direction was 15° and the maximum range is 100 m (in any direction), pulse length: 0.06 ms, pixel length: 4.5 cm. The SBI Viewer consists of software for extraction and analysis of the data, school characteristics, 3D-Echogram. The limitations of multibeam acoustics were identified as:

- Lateral lobes
- Maximum range
- Signal/noise
- Fish tilt angle
- Problems in biomass estimate
- Problems with real time analysis because of the volume of data collected

The conclusions were that the application of 3D acoustics could fulfil the objectives of increasing the understanding of:

- fish behaviour
- school typology
- evaluation of avoidance
- Species identification
- 3D spatial distribution
- Shallow water areas
- Near boundaries acoustics (bottom and surface)

In shallow waters, multibeam acoustics can aid bottom location, establish fish echo characteristics and avoid the multiple reverb problem of standard echosounders.

8.2 G. Melvin Advances in the application of multibeam sonar to fish school mapping and biomass estimates

A summary of research activities and results from a program to investigate the application of multibeam sonar to 3-D fish school mapping and biomass estimates was presented. The presentation began with a review of the background which lead to the adoption of the Simrad SM2000 multibeam sonar as a tool for the investigation. Until recently, no post processing capabilities were available for the system and data storage was restricted to an internal format which required conversion. Through funding from the National Hydroacoustic and the National Research Council software, editing tools and backscatter algorithms were developed to beamform and display beamformed data into 3-D space, overlay single beam echosounder data, isolate and export individual beam amplitude, and collect and display real-time beam amplitude from the serial port. The latter development overcame a cumbersome approach to calibrating the system. Early calibration studies of the multibeam system clearly demonstrate (low signal to noise ratio) the need to calibrate (using standard balls) in a deep water facility and in the far field. All data display and analysis were done after the fact in that the data were converted and displayed on a separate workstation. In 1999 the system, the SM2000 software and hardware were modified to produce a real-time data stream, which could be captured and processed on the fly. The software is now complete and testing is scheduled for May of 2000. Once finished the system will be able to provide real-time 3-D display of observations. The calibrated system will then be used to provide near real-time dimensions of fish schools and estimates of biomass.

8.3 J. Dalen A short introduction to SODAPS 950: a sonar data processing system

The SODAPS data processing system is designed for logging, monitoring, post-processing and visualisation for use with the Simrad SF950D sonar system. Operating at 95 kHz the sonar has 32 beams of 1.7°, giving a coverage of 45°. Interfaced to pitch and roll sensors, the system can be monitored by beam, school, map and echogram windows. Data are pre-processed to discard noise and non-targets, and post-processed to scrutinise and interpret data to determine schools and from these fish abundance and school area to abundance relationships. Monitoring and control is also carried out through the software. An example of use of the system in Namibia was described, and it was noted that the system can provide important data such as speed course and aspect angle of the fish in addition to school area and intensity.

8.4 E. Bethke Calibration in open seas

Calibrations were carried out in Scapa Flow, Scotland. Calibration in the open sea was needed because of the lack of suitable sheltered sites on German coast. A two-part programme procedure written in Delphi enter particulars of vessel and sounder. This automatically reads settings from the Simrad EK500 sounder, i.e., before calibration and new settings are displayed. The programme begins measurement in the same way as the Simrad lobe programme, colouring squares in blue as measurements taken across beam, press compute to obtain results. The basic calibration formula takes the minimum of the calculated values. Data obtained were comparable to those from lobe. The differences between the new programme and the lobe progamme provided by Simrad were discussed.

8.5 P. Roux Multiscattering in a school of fish: fish counting in a tank

This study used multiple scattering in a reflecting cavity to count fish in a tank. Using 1 cm long striped bass as targets, echoes from sound emitted in two shots by an omni-directional transducer were compared from an empty tank and one containing fish. The results of 100 shots were averaged and the average scattering due to the fish was computed by subtracting the scattering from the tank away from the tank plus fish. Using 400 kHz sound and different numbers of fish to estimate a target strength relationship it was possible to count fish in a tank using multi-scattering theory; this may have applications for fish counting and for target strength measurement.

Problems with high fish densities were not encountered until densities were increased above those encountered in the wild.

Backscattering was recorded from all surfaces of the fish; the influence of the surface was nearly zero.

WG members thought that the technique was complimentary to other methods of TS measurement.

9 SESSION F2 “SURVEY METHODS IN ECOLOGY AND FISHERIES ACOUSTICS”

9.1 G. Swartzman Plankton patch and fish shoal distribution in California Current Ecosystem

Pacific hake and Euphausia pacifica were the dominant species studied on a triennial survey off the west coast of the USA. Using 38 and 120 kHz sounders, parallel transects out from the coast with 10-nautical-mile separation, a depth limit for plankton recording of 250 m and collected over the years 1990-1995, were examined from south to north. The study compared a non *el nino* year (1995) with the *el nino* in 1998. An adcp was used to characterise current that might influence distribution especially of plankton. Data analysis and synthesis was by defining regions. And the question was posed: can transects be considered as replicates? GAM was applied to fish school biomass as a function of depth, bottom depth, slope and plankton biomass within 1 km. There were as many occasions when fish were associated with prey as when they aren't. At the shelf break overlap between fish and plankton was consistent over a very wide area, and that was a phenomenon that was not necessarily true elsewhere. This was seen during two very different years.

9.2 G. Swartzman, Ric Brodeur, Jeff Napp, George Hunt, David Demer and Roger Hewitt Synthesis of fish-plankton acoustic data near the Pribilof Islands AK over 6 years

The objective of this study was to relate the spatial distribution of juvenile pollock to prey (zooplankton) and predators (birds & larger fish). Using EK-500 acoustic data collected at 38, 120 and 200 kHz between September 1994-1999. Concurrent CTD, fluorescence, bird count data were collected over 4 transects (multiple passes) near a major pollock nursery area. Analysis used the FishViewer software for multi-frequency acoustic data viewing, both by transect and data fusion (including isotherms, surface environment and birds).

Thresholded data at 38 kHz were used to locate fish shoals by aggregation morphology.

A connected component algorithm generated a table of shoals and patches with attributes (location, shape, backscatter and environmental). A modified Ripley's K was used to look at distribution of plankton patches around fish clusters (using the distance from edge of shoal instead of point to point distance), and generalized additive models (GAM) were used on binned data.

When plankton densities were low clustering was found, and a significant increase in fish shoal density occurred with increase in plankton patch density for the intermediate plankton density range. Diel migration of plankton was observed during the study, which also demonstrated the importance of the thermocline as a barrier to fish distribution.

9.3 R. Kieser Echo integration threshold bias and its effect on estimating a diminishing fish stock

Pacific hake in the Strait of Georgia on the West coast of Canada have been surveyed acoustically for almost 20 years. Spawning aggregations of hake are recorded to about 300 m depth and in recent years have been more frequently observed as single fish echo traces. This change has prompted the author to investigate a possible echo integration threshold bias that could result in under estimating hake biomass or the extent of this stock. The investigation uses two different models: The effective equivalent beam angle described by Foote (1991) and Reynisson (1996) and a signal processing based simulation. The latter is an extension of the model used by Kieser et al. (2000) to describe the systematic split-beam angle measurement bias that was observed at low signal to noise. The second model provides a more accurate description of the echo integration and thresholding processes and includes fish density and noise parameters that are not included in the effective equivalent beam angle. Results from the effective equivalent beam angle model generally agree with those published by Reynisson (1996) and indicate that echo integration threshold bias effects need to be considered for Pacific hake (TS~-35 dB) that are observed below 250 m as single fish. First, results from the simulation model were presented and a detailed comparison between both models was proposed.

Foote K.G. 1991. Acoustic sampling volume. J. Acoust. Soc. Am. 90(2):959–964.

Kieser R., Mulligan T. and Ehrenberg J. 2000. Observation and Explanation of Systematic Split-beam Angle Measurement Errors. Aquatic Living Resources, accepted for publication.

Reynisson P., 1996. Evaluation of threshold-induced bias in the integration of single-fish echoes. ICES J. of Mar. Sci. 53:345–350.

9.4 M. Gutierrez The EUREKA method for survey design in Peru

The EUREKA Survey is a co-operative effort by fishermen to participate in marine research with relatively low cost for each participant as an alternative to an expensive and slow acoustic cruise. The Peruvian Marine Institute (IMARPE) created EUREKA Surveys to quickly monitor the distribution and abundance of fish and in this way support the management of the fisheries. The main target of EUREKA Surveys has been the anchovy.

The main objective of a EUREKA survey is to collect useful field data within the fishing season, and to determine if it is possible to continue fishing, by providing information about abundance and distribution in order to acertain whether the fishery had depleted stocks.

A EUREKA Survey consists of an acoustic sweep of the whole coastal zone of the Peruvian Sea. Usually more than 30 fishing ships participate in this type of survey. The covered area is usually from 0 to 100 nautical miles offshore along about 3,000 km of coastline. Each ship makes 2 parallel transects of 100 nautical miles. The scientific team on each ship is composed of 3 scientists who take notes of the presence of fish every 1 or 2 nautical miles on the echosounder. All ships carry out purse seine fishing in order to collect individuals for biological sampling, including the measurement of length and weight for studies of age and growth. The surveys also collect oceanographic data. The data is collated in the headquarters of IMARPE and final report is ready after 2 or 3 days of the end of the survey.

Advantages:

- It is quick and cheap for IMARPE because costs are covered by fisherman;
- The size and number of samples are large enough to ensure confidence in the results of the biological and oceanographic analyses;
- Recommendations for management of the fisheries is based on direct measurements and observations;
- Provides knowledge of the fishing grounds and permits regulation of the fishing effort;
- GIS and Argos give confidence in the geographical distribution.

Disadvantages:

- A large number of observers reduces the reliability of the acoustic part of the survey because of their different levels of skill;
- The type and features of sounders is highly variable and the data processing is difficult because of different interpretation by each observer;
- It is not possible to perform echointegration, although VPA models are used to estimate the abundance;
- Lamentably, sometimes a rebellious attitude of captains occurs, who refuse to help the scientists. Technical problems on board ships can affect the whole survey.

9.5 B. Lundgren. *et al.* An experimental set-up for possible hydroacoustic discrimination of fish species by analysis of broadband pulse spectra combined with image processing.

A large experimental tank was used for new studies on hydroacoustic discrimination of fish species by analysis of broadband pulse spectra. The techniques are at an early stage of development and have used analysis of echoes from free swimming fish using image processing.

10 RECOMMENDATIONS

10.1 Recommendations Terms of Reference item (a) Fish avoidance and fisheries acoustics

According to the Terms of Reference item (a), a synthesis on fish avoidance was given by G. Arnold.

Four communications were presented:

- P. Fernandes and A. Brierley. *An investigation of fish avoidance using an AUV*
- C. Wilson. *Consideration on the analysis of acoustic buoys data to investigate fish avoidance*
- R. Vabö. *Effect of fish behaviour on acoustic estimates of NS herring*
- P. Brehmer and F. Gerlotto *Some observations on fish avoidance in several seas.*

These five documents and the discussions led to several conclusions:

- Fish avoidance is recognized as one of the major sources of bias in fisheries acoustics;
- Silent vessels demonstrate their ability to reduce fish avoidance;
- Tools exist that can “evaluate” in real time the bias due to fish avoidance (multibeam sonar, AUV, etc.);
- Stable patterns may exist in fish behaviour that can be observed during biological cycles (day/night, winter/summer, etc.) in certain circumstances and areas;
- The acoustic data could be corrected by the bias value in the above circumstances;
- Habituation may bias repeated experiments in local areas.

The WGFAST recommends the study of:

- the effect of hydrodynamic waves generated by vessels;
- the use of multi frequency and wide band methods;
- the development of acoustic Doppler measurement;
- the modelling/measuring of avoidance behaviour;
- the reaction of fish to ultra sounds;
- to explore/adapt the technical possibilities (AUV) to observe and measure the fish behaviour.

The effect of pressure waves at frequencies higher and lower than the published hearing limits of fish will be considered during a special topic of the joint session.

10.2 Terms of Reference item (b) bottom classification methods

Two communications were presented at the meeting:

- \- John Breslin. ECHOplus. A digital seabed discrimination system
- \- John Anderson. Seabed classification comparing submersible and acoustic techniques.

The main applications of seabed classification are:

- Mapping the habitat
  i. demersal species (recruitment)
  ii. spawning areas (demersal and some pelagics)
  iii. study of any animal (fish, lobster, shelfish) depending on the substratum
- Assessment: covariate for stock mapping
- Fisheries development/commercial exploitation
- Macroalgae and seagrass beds
- Conservation and management

It appeared that not all the techniques and evolutions of seabed methods and techniques were presented at the WGFAST, particularly the use of multibeam sonar and multi frequency soundings. It was stressed also that the seabed classification was of interest to the FTFBWG, and a synthesis was presented at the Joint Session. A recommendation on this item from the Terms of Reference is presented in the Joint Session Report.

10.3 Terms of Reference item (c) Data Exchange Format

- The WGFAST acknowledged the report from the HAC group;
- It recommends posting the HAC information on the WGFAST web site;
- It appeared that the technical nature of the discussions made it difficult to have them by mail. A meeting of the HAC group is needed prior to the WGFAST meeting. A HAC session will be organised on Monday 23rd April 2001, in Seattle;
- The group required a chairman to help to organise the discussions: D. REID accepted the chairmanship of the HAC group.

10.4 Terms of Reference item (d) acoustic definitions, units and symbols

Two written contributions were presented at the meeting:

- MacLennan and Fernandes Acoustic definitions, units and symbols
- J. Dalen Terminology in fisheries acoustics

After discussion of the issues it appeared there was substantial agreement on a standard and consistent approach to acoustical terminology appropriate to fisheries work. In particular, there was not very much difference in the guidelines proposed by the authors noted above.

The WG requested D. MacLennan, P. Fernandes and J. Dalen to consider a joint note taking account of the opinions expressed in the WGFAST discussions. This note will be published in the first instance as a letter to an appropriate acoustic journal.

10.5 Terms of Reference item (e) TS of Baltic herring

The synthesis of the documents presented and the discussion show that:

- There is evidence of the existence of cycles and trends in the main ecological characteristics of the Baltic herring which must lead to changes in the anatomical, physical and behavioural parameters influencing the TS values. There is a consensus that the TS equation used until now should be revisited;
- Mean target strength depends on two types of component, some of them are rather easy to measure, and a good relationship can be found with the TS values. Others present a high variability that no method can help to reduce. Therefore it is important to recognise those factors where knowledge and measurements would significantly improve the estimation of abundance;
- A significant number of data already exist which could help to measure the effect of the main factors and their importance;
- Some new models could greatly help to evaluate the magnitude of the effects of the main factors;
- There is need of some particular experiments to better understand the meaning of the TS values and their variability.

The WGFAST recommend a study group to be created, under the responsibility of Frederik Arrhenius, with the objectives:

1) To prepare and disseminate as soon as possible a protocol for TS measurements on the Baltic herring, based upon the state of the art and especially the recommendations of the CRR (on TS measurements, 1999), adapting these recommendations to the special case of the Baltic sea. (*A draft of this document possibly to be submitted at the next ASC*);
2) Meanwhile establish a list of the main factors affecting the herring TS and study the effects through comparative analysis and measurements on various herring stocks (e.g., Baltic and Norwegian spring spawning herrings);
3) Collate the existing information and measurements on herring TS;
4) Apply modelling methods on the case of the herring and compare their results to the existing information;
5) From the databases available from the WGFAST members, measure the variability of TS in situ under various conditions (day-night, winter-summer, etc.);
6) Encourage experimental measurements through conventional and non-conventional methods.

The study group will give an annual report to the WGFAST. After 3 years and considering the results of its works and the improvements in the understanding of the meaning of the TS, the S.G. will conclude its works proposing guidance for the development of better parameterised herring-TS relationships.

Suggested names of members: F. Arrhenius, A. Orlowski?, B. Lundgren, E. Bethke, E. Goetze, I. Svellingen, J. Horne, M. Jech, K. J.Staehr (so far).

11 SPECIAL TOPICS FOR 2001

Several special topics were proposed or arose as conclusions of the works of the WGFAST.

11.1 Acoustic methods of species identification

This special topic would aim to review current techniques and address a long-standing problem in fisheries acoustics.

Justification. Species identification was highlighted as one of four main sources of error in acoustic surveys (WGFAST report 1998). The identification of echo traces is essential for abundance estimation from acoustic surveys. Currently, echo traces are identified by sampling, usually trawling. However, not every echo trace can be sampled and therefore subjective decisions are often required to attribute a trace to species. Usually these decisions are based on experience of echo characteristics. Increasingly there are new techniques that may aid this process: these include multifrequency applications and broadband techniques, as well as more traditional echo trace classification school descriptors.

11.2 Ecosystem studies based on acoustic survey data.

The WGFAST recommends a review of papers on ecosystem studies based on acoustic survey data, with the objective of organising a theme session in a future ASC on this problem in collaboration with a WG that is specialised in ecology. Convenors: D.Reid and J. Horne.

Justification: *There is a need for ecosystem research for fish stock assessment. The use of acoustics for providing data in this field is increasing. This fact leads to two observations:*

1) Acoustics is not always deployed by specialists, and the correct interpretation of the results is not always guaranteed. Connection between the ecologists using acoustics and the FAST would help to prevent this problem;
2) The use of acoustic data in “non conventional” research (i.e., for other purposes than abundance estimates) opens new fields for these techniques and methods. Adapting them to the particular needs of these new users is important, and requires that technicians and methodologists be aware of their needs.

11.3 Special topic to evaluate the effect of fish avoidance during surveys

Review the results and analyses of routine surveys where fish avoidance was monitored. All countries are asked to make observations of vessel avoidance behaviour by fish, using sonar and echo sounders to do so. Whenever an opportunity occurs, observations should be made and the details recorded on a specially prepared log sheet.

Justification:

Nowadays specific instruments are able to evaluate and measure the avoidance reactions of the fish during a survey. These tools could bring important improvement in the abundance estimates by acoustics.

12 CLOSURE OF WGFAST MEETING

FAST web address: see the report of the J.S.

Symposium 2002: A report of the activities of the Steering Committee was presented to the FAST and approved. It was suggested that Dr Furusawa from Japan be contacted and asked to be a member of the steering committee. The chairman transmitted a message from the Steering Committee of the Shallow Water Acoustic Symposium (Seattle, September, 1999), who suggested that a special session be organised during the 2002 Symposium devoted to the particular problems of acoustics in shallow waters. The scientific communities working in shallow water areas and in the Great Lakes will be contacted respectively by F. Gerlotto and J. Horne.

New chairman: Yvan Simard (Institut Maurice Lamontagne, Canada) accepted the chairmanship of the WGFAST.

Next meeting. It will be organised in Seattle WA, USA in April 2001. The FAST will meet on 24 and 26–27 April. The HAC group will meet on 23rd April. The Joint Session will meet on the 25th.

The present Chairman of WGFAST (François Gerlotto) was thanked for organising the meeting for the past three years.

The chairman thanked the local hosts at Haarlem, Netherlands, for their hospitality, and closed the meeting.

Table 1. Summary of the effects of various fish behaviours on the accuracy and precision of acoustic survey results, with an indication of their severity and resolution status.

			Direct Effect			Severity of effect		Resolution Status		
Behaviour	Type	Acoustic Characteristic	TS	Species ID	Biomass Estimation	Accuracy (Bias)	Precision (Variability)	Tractable	Work Progressing	More Research
Orientation	Circadian	Tilt Angle	✓			(*****)			✓	
	Physio. State	Tilt Angle	✓	✓		(***)				✓
Avoidance	Vessel	Tilt Angle	✓			(**)		✓		✓
		Dispersion	✓		✓	(****)			✓	✓
		Herding			✓	**			✓	✓
	Predator	Tilt Angle	✓				*			✓
		Gas Release	✓			(*)				✓
Social Aggregation	Density	Shadowing			✓	(***)		✓		
	Configuration	Pattern		✓			***			✓
		Ground Truthing (selectivity)		✓			****			✓
Distribution	Vertical	Dead Zone			✓	(*)		✓		
	Horizontal	Survey Area			✓	(***)		✓		
Migration	Vertical	Tilt Angle	✓		✓	(*****)			✓	
		Swim Bladder Volume	✓			(***)		(✓)	✓	
	Horizontal	Non-Stationary			✓	***(***)		✓		

* On a scale 1 to 5, ()=negative

APPENDIX A – LIST OF PARTICIPANTS

WGFAST participant list 2000, Haarlem, Netherlands		
Lars Andersen	Norway	
John Anderson	Canada	
Geoff Arnold	UK	
Frederik Arrhenius	Sweden	
Eckhard Bethke	Germany	
Guillermo Boyra	Spain	
John Breslin	Ireland	
Andrew Brierley	UK	
James Churnside	USA	
Jeff Condiotty	Simrad USA	
Bram Couperus	Holland	
John Dalen	Norway	
David Demer	USA	
Noël Diner	France	
Paul Fernandes	UK	
Catherine Goss	UK	
Eberhard Götze	Germany	
John Horne	USA	
Michael Jech	USA	
Erwan Josse	France	
Olavi Kaljuste	Estonia	
Bill Karp	USA	
Robert Kieser	Canada	
Chris Lang	Canada	
Jacques Massé	France	
Dave MacLennan	UK	
Ole Arve Misund	Norway	
Ron Mitson	UK	
Hans Nicolaysen	Norway	
Kjell Olsen	Norway	
Heikki Peltonen	Finland	
Dave Reid	Scotland	
Philippe Roux	France	
Yvan Simard	Canada	
Haakon Solli	Norway	
KarlJohan Staehr	Denmark	
Frank Storbeck	Holland	
Ingvald Svellingen	Norway	
Gordon Swartzman	USA	
Mats Ulmestrand	Sweden	
Chris Wilson	USA	

APPENDIX B - REFERENCES ON FISH AVOIDANCE AND FISHERIES ACOUSTICS. G.P. ARNOLD

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APPENDIX C – COMMON DATA FORMAT: 2000 PROGRESS REPORT

Y. Simard[1], I. McQuinn[1], N. Diner[2], J. Simmonds[3], I. Higginbottom[4]

1: Department of Fisheries and Oceans, Maurice-Lamontagne Institute,

Mont-Joli, Québec, Canada

2: *Ifremer, Centre de Brest, Brest, France*

3: FRS Marine Lab., Aberdeen, Scotland, U.K.

4: Sonar Data, Hobart, Australia

Introduction

In 1999 at the meeting held in St. John's, Newfoundland, the FAST WG adopted the ***HAC*** standard data format for raw and edited hydroacoustic data (Simard et al. 1997, 1999) as the common format for exchanging fisheries acoustics data and for comparing processing algorithms within the ICES community. A group of experts including FAST members and representatives of hardware manufacturers and a private software company was assigned the responsibility of coordinating the development of the format. This included the examination of proposals to introduce new information in the ***HAC*** environment and the definition of a generic set of tuples for echosounders that were not covered by the already defined tuples* of this upgradable format. The coordinating committee has worked by e-mail during the year and encountered difficulties in efficiently exchanging the highly technical details of this format and in agreeing on proposals presented for its future development. The committee held a special working session during the present FAST meeting and agreed on the following points. A representative of Simrad was present as observer.

Decisions of the group of experts

A Generic set of tuples for undefined echosounders.

To easily introduce data from various echosounders that have not already been defined by specific tuples in the ***HAC*** format, it was decided at the 1999 FAST WG meeting to define a set of tuples that could describe the common fields of information that a "generic" echosounder should have. The coordinating committee wants to stress that these generic tuples must only be used for the exchange of data collected from echosounders that are not presently described by tuples that are accepted by the committee and from echosounders that will not be described by specific tuples. These tuples are not intended to be used to acquire new data in the ***HAC*** format from new scientific echosounders. A new group of tuples must be defined for each new scientific echosounder for this purpose. The ***HAC*** format philosophy is based on the identification of the attributes of specific echosounders by specific tuples mirroring the various settings offered by the manufacturer which defined the parameters under which the data was collected and to which the users are accustomed to.

A provisional Generic echosounder tuple (tuple no 900) has been defined by the committee and its description will be finalised within the next month, after the committee members have revised the various fields of information.

A Generic channel tuple (tuple no 9000) to be associated with the Generic echosounder tuple, according to the ***HAC*** rules, has also been defined and its description will be available at the same time.

The ping tuple to associate to the Generic channel tuple that was chosen by the committee (see below) is the Standard ping tuple U-32 (tuple no 10001) defined in the ***HAC*** version 1.0 (Simard *et. al*. 1997). It's "sample value" field will be upgraded by the definition of additional data ranges to use with the new types of data samples introduced in the Generic channel tuple. The Ping tuple U-16-angles (tuple no 10031) was also chosen by the committee for storing split-beam angle data associated with the Generic echosounder and channel tuples.

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* Tuple: a labeled group of bytes encapsulating special type of information in the ***HAC*** format, which forms the basic structure of this format and that gives the format its upgradability and versatility property. Tuples belongs to tuple families or classes that groups the information by themes. Unique numbers, varying from 0 to 65535, identify each tuple. The ***HAC*** co-ordinating committee has to allocate these numbers to prevent any "collision" in the tuple usage by various groups around the world and to agree on the definition of the various fields of information they contain.

The rules for allocating tuple numbers and accepting new tuple definitions: the basic tuples and the optional tuples of the common data format

To ease the use of the ***HAC*** format by various software developers requiring the addition of new tuples, and to facilitate the work of the coordinating committee, the tuple classes were divided in two groups. A first group is the basic tuples classes for which any tuple addition will require a thorough examination and a unanimous agreement by the coordinating committee. Tuples numbers will be allocated temporarily to the applicants during their definition and debugging period for a maximum of 14 months, after which they will be retired if the committee has not accepted their description. (See below; the committee will meet annually to resolve outstanding issues). A second group is the optional tuple classes that concern auxiliary information or secondary level of data analysis. For these classes, the committee will allocate tuple numbers at the request of the users, on presentation of a short justification and objectives of the tuple by the applicant. In addition there is a need to define the minimum tupples required to define the minimum needs of a ***HAC*** compliant file.

The Basic tuple classes are: Position tuples, Navigation tuples, Platform attitude tuples, Echosounder tuples, Channel tuples, Ping tuples, Threshold tuples, Environmental tuples for sound speed profiles, Opening and closing file tuples, End of file tuples and the HAC signature tuple.

The Optional tuple classes are: Mission and project tuples, Event marker tuples, Edition tuples, Classification tuples, Environmental tuples except sound speed profiles, Private tuples, and Index tuples.

The minimum tuples in a *HAC* file are: Position tuples, an Echosounder tuple, a Channel tuple, Ping tuples, a Threshold tuple, Opening and closing file tuples, an End of file tuple and the ***HAC*** signature tuple.

Revision of the list of tuple numbers defined or in use.

A list of the tuple numbers defined or in use by the various groups in our community has been circulated and examined by the committee. Some discrepancies relative to the defined standard (Simard et al. 1997) were noted for the type of binary formats used for some fields in a few tuples types and one change was noted for one tuple type. The committee will supervise the correction of these problems. The current list of the additional defined tuple numbers in use will be issued at the same time as the definition of the Generic tuples and will include the definitions of the added basic tuples and the addition of some details to specific fields. Since the initial definition of the ***HAC*** version 1.0, the following tuples numbers were added to the list of defined tuples or in use: 39, 300, 301, 3000,3001, 5000, 5001, 10039, 10119, 12000, 12005, 12010, 12050, 12051, 12052, 12053, 12100, 13000, 13500, 14000, 65397, 65406.

The Private tuples

The ***HAC*** Committee examined the role and objective of the tuple class named “Temporary and private tuples” in the HAC version 1.0 report (Simard *et al*. 1997). It was decided that this tuple class would be better identified as a Private tuple class because temporary tuples will now exist outside of this category, namely during the definition and debugging of the new tuples belonging to all other tuple classes.

The committee decided that private tuples shall be used only to store information that do not belong to the other tuple classes, such as information necessary for the operation of certain software packages. The committee firmly opposes the use of this tuple category to store acquisition data or to introduce a new format inside the ***HAC*** standard data format. Consequently the space occupied by private tuples in a *.hac file shall be very small in comparison to the other tuples that a *.hac file must contain. The committee underlined that to comply with the ***HAC*** format a file must contain a minimum number of tuple categories identified above (see also Simard et al. 1997). To introduce new types of data in the ***HAC*** format, the above mentioned procedure to introduce new tuples must be followed.

A new private tuple, number 5397, was defined (Table 28).

The inclusion of Lidar data

Some users expressed their will to use the ***HAC*** standard data format to store Lidar data profiles, in order to compare these measurements with simultaneous acoustic measures. The ***HAC*** format was initially defined only for hydroacoustic data but the committee did not oppose its use for Lidar data, especially if it is for comparisons with the acoustic data. In such a case however, specific tuples must be defined for these Lidar instruments. These include a specific Echosounder tuple, a specific Channel tuple, and possibly a specific Ping tuple if the Standard ping tuple U-32 cannot be used. These tuples will be ratified by the HAC committee.

HAC compliance and *HAC* compatibility

The committee discussed the meaning of these two labels.

A data file is defined as ***HAC*** compliant if it conforms to the ***HAC*** syntax rules, contains the minimum required ***HAC*** tuples described above using the exact tuple format described (Simard et al 1997).

A software application tool is defined as ***HAC*** compatible if it can read and use a minimum number of commonly used basic tuples. These tuple numbers are: 20, 100, 200, 900, 1000, 2000, 9000, 10000, 10001, 10100, 65516, 65517, 65534 and 65635.

The composition and working of the *HAC* Committee

The ***HAC*** Committee will consist of a maximum of 9 members with a majority of WGFAST member institutions, and representatives of fisheries software suppliers and fisheries sounder manufacturers. The normal composition will consist of one representative from each organization or institution and an additional nominated chairman from within the ***HAC*** Committee. The ***HAC*** Committee can ask for participation on a non-voting basis of any other experts, accepting this on a majority basis.

The ***HAC*** Committee will meet annually at WGFAST

The ***HAC*** Committee will try to comment on ***HAC*** related proposals through the year, but in the event of conflict will resolve this at the ***HAC*** Committee annual meeting.

All technical matters to be raised at the ***HAC*** Committee will be circulated two months in advance of the annual meeting. Non attending representatives must either accept the ***HAC*** Committee decision or provide a written request or response, and authorize an alternate member to represent their interests.

Unresolved issues may be referred by any member of the ***HAC*** Committee through the ***HAC*** Committee Chairman to the FAST Committee.

Other changes to *HAC.*

The need for precise referencing of the location of the transducers in three dimensions, on different platforms, was mentioned and postponed to further exchanges of the HAC co-ordinating committee. This includes the horizontal polar orientation of the transducer on the platform, namely for the split-beam transducers. The codes for various ***HAC*** data production tools were added to the appropriate field of the ***HAC*** Signature tuple.

Communicating the status of *HAC.*

The need of a Web site to rapidly and easily access updated ***HAC*** information was reiterated and the HAC committee welcomed the offer of the use of the FTFB-FAST web site to hold this information.

References

Simard, Y., I. McQuinn, N.Diner, and C. Marchalot. 1999. The world according to ***HAC***: summary of this hydroacoustic standard data format and examples of its application under diverse configurations with various echosounders and data acquisition softwares. ICES-Fisheries Acoustics Sciences and Technology meeting, St. John's, Newfoundland, Canada, 20–22 April 1999, Working paper. 14 pp.

Simard, Y., I. McQuinn, M. Montminy, C. Lang, D. Miller, C. Stevens, D. Wiggins and C. Marchalot. 1997. Description of the ***HAC*** standard format for raw and edited hydroacoustic data, version 1.0. Can. Tech. Rep. Fish. Aquat. Sci. 2174: vii + 65 pp.

Echosounder tuple

An echosounder is defined as a group of channels. The echosounder tuple contains the information that is common to all channels of the group. The echosounder tuple is machine specific; the tuple type code is therefore specific to the machine. If several machines are operated simultaneously, then several echosounder tuples will exist. (The range of values reserved for encoding the echosounder tuple type are 100–999). ***}***

Table 26. **Generic Echosounder tuple** to used with echosounders for which no Echosounder tuple will be described or has been described in the ***HAC*** standard data format.

Echosounder tuple for echosounders that do not fit in the already described echosounder tuples of the ***HAC*** standard data format, version 1.0 (Simard et al. 1997), updated with the Ossian Echosounder tuple (tuple no 301) and the Ines-Movies Echosounder tuple (tuple no 300). The ***HAC*** version 1.0 includes the Echosounder tuples for the Biosonics Model 102 or similar analog echosounders (tuple no 100) or the Simrad EK500 echosounder (tuple no. 200). Do not use the Generic Echosounder tuples for any of those described echosounders neither for a new echosounder that will be described by a new specific Echosounder tuple in the ***HAC*** format.

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
0	Tuple size	4	ULONG	Tuple data size: […- 4 giga] bytes	byte	[…- 4 giga]
4	Tuple type	2	USHORT	Tuple type code: **900**. This is the tuple type code for the generic echosounder.	unitless	900
6	Number of software channels	2	USHORT	Number of software channels associated with this echosounder.	unitless	[1 - 65535]
8	Echosounder document identifier	4	ULONG	Unique identification number for the echosounder document (i.e., the group of channels). The channels are tied to the echosounder by the echosounder document identifier, which is repeated in the channel tuples.	unitless	[0 - 4294967296]
12	Sound speed	2	USHORT	Mean sound speed. **N.B.** Sound speed and sound speed profiles could also be computed from environmental tuples. A value of **0** (zero) means that the sound speed is not available.	0.1 m s^{-1}	[0.0 - 6553. 5 m s^{-1}] In water: [1450.0 - 1550. 0 m s^{-1}]
14	Ping interval	2	USHORT	Interval between 2 pings. If it is a multiplexing echosounder that triggers the various transducers in sequence, the ping interval recorded here is the master trigger interval. A value of **0** (zero) means that the ping interval is not known or varies. In that case the interval is obtained from the time difference between the pings.	0.01 s	[0.00 - 655.35 s] (= up to 10.92 min)
16	Ping mode	2	USHORT	Ping mode: **0** = off, the echosounder is in the passive mode **1** = normal, the echosounder is in the active mode **2** = not available	unitless	[0 - 65535] EK-500 options [0, 1, 2]

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
18	Space	2	USHORT	Space to allow the next field to be aligned on an address that is a multiple of 4.	untiless	0
20	Remarks	X4	CHAR	Character string comment. This field could be used to store the echosounder brand, its properties and the serial number.	ASCII char.	variable
…	Tuple attribute	4	LONG	Attribute of the tuple: **0 =** original tuple, e.g., nothing special to mention **1** = edited tuple Other attributes could be labeled by a code (e.g., tuple data quality). Negative codes should be used for special cases.	unitless	[-2147483648 to +2147483647]
…	Backlink	4	ULONG	Tuple size: varia (X4) bytes	byte	[… – 4 giga]

{ Channel tuple

This tuple type is machine- and channel-specific; the tuple type code is therefore related to the machine and to the hardware and software channels and. Virtual channels can exist (e.g., an echo-classification channel that combines the information from four other channels), and they would have their own tuple type code. This tuple type should include an image of the machine settings and calibration parameters for the given channel. Besides the four fields common to all tuples, the 3 following fields are required: the software channel identifier, the echosounder document identifier, and the sampling rate. (The range of values reserved for the channel tuple type fields is 1000–9999.) **}**

Table 27. Generic Channel tuple for the Generic Echosounder.

Channel tuple for the Generic Echosounder. Do not use this Channel tuple for any other described Echosounder tuples (tuples no 100, 200, 300 and 301) of the *HAC* standard data format, version 1.0 (Simard *et al.* 1997), updated with the Ossian Echosounder tuple and the Ines-Movies Echosounder tuple, neither for a new echosounder that will be described by a new specific Echosounder tuple and Channel tuples in the *HAC* format.

Offset (byte)	**Field**	**Length (bytes)**	**Format**	**Content**	**Encoded units**	**Limit range**
0	Tuple size	4	ULONG	Tuple data size: [… 4 giga].	byte	[… - 4 giga]
4	Tuple type	2	USHORT	Tuple type code: **9000.** This is the tuple type code for the Generic Channel tuple.	unitless	9000
6	Software channel identifier	2	USHORT	Unique identifier for this software data channel This identifier must be unique for the whole file in order to associate the pings to their proper parent channel. **N.B.** This is not the hardware number.	unitless	[0 - 65535]
8	Echosounder document identifier	4	ULONG	Identification number for the parent echosounder document (i.e., the group of channels) to which this data channel belongs. It is the echosounder document identifier field of the echosounder tuple.	unitless	[0 - 4294967295]
12	Sampling rate	4	ULONG	Digitization rate for this channel. If not available, it can be obtained computed from the sound speed divided by 2 and the result multiplied by the no of samples per metre.	sample s^{-1}	[0 - 4294967295 sample s^{-1}]

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
16	Type of data sample	2	USHORT	Type of data sample: **0** = Volts **1** = Sv (Volume scattering strength in dB) **2** = TS (Target strength of single targets in dB) **3** = Off axis mechanical angles of single targets **4** = power in dB re 1 Watt **5** = $(\text{Volts})^2$ **6 …** following are averages over the sample interval **10** = averaged Volts **11** = averaged Sv (Volume scattering strength in dB)* **12** = averaged TS (Target strength of single targets in dB)* **13** = Off axis mechanical angles of single targets **14** = averaged power in dB re 1 Watt **15** = averaged $(\text{Volts})^2$ Others to be defined. *Note that the average must be computed in the linear domain.	unitless	[0 - 65535] Presently: [0-6, 10-15]
18	Time varied gain mode	2	USHORT	Time-varied gain (TVG) applied for this channel: **0** = 20 log R TVG **1** = 40 log R TVG **2** = 30 log R TVG XXXXX= value of the XX log R TVG used, e.g., a value of 28 means that a 28 log R TVG is used. **N.B.** This TVG is applied from a min. range up to the TVG max. range field of the Generic Echosounder tuple. When the TVG max. range is null or smaller than the blanking up to range value, no TVG is applied. See relevant fields in the Generic Echosounder tuple.	unitless	[0 - 65535] Presently for the Biosonics 102: [0,1, 2 or XXXXX]
20	Blanking at TVG max range	2	SHORT	The gain operating mode after the TVG max. range is reached **0 =** normal mode, the gain is maintained constant at the value reached at the TVG max range. **1 =** blank at range mode: the gain drops to zero at the TVG max range **2** = not available	unitless	[0 - 65535]
22	TVG min. range	2	USHORT	The range from which the TVG is applied. TVG is computed from the transducer face and applied from the min. range up to the max. range. Before this TVG min. range the gain is either maintained constant at the initial value (in normal mode) or at to zero (in the blank mode). A value of **0** means that no TVG is applied to the data.	0.1 m	[0.0 - 6553.5 m]

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
24	TVG max. range	2	USHORT	The range up to which the TVG is applied. TVG is computed from the transducer face and applied from the min. range up to the max. range. After this TVG max. range the gain is either maintained constant at the value reached at this range (in normal mode) or dropped to zero (in the blank at range mode). A value of **0** means that no TVG is applied to the data.	0.1 m	[0.0 - 6553.5 m]
26	Blanking up to range	2	USHORT	Blanking range from the transducer face up to which the receiver output is blanked to zero or the range at which the data started to be collected. A value of **0** means that no blanking up to range was used.	0.1 m	[0.0 - 6553.5 m]
28	Transceiver channel number	2	USHORT	Hardware channel number from which the data are coming. It is convenient to use the same channel numbers as from the echosounder. A value of **0** means that the transciever channel number is not available. **N.B.** This field is not the software channel number.	unitless	[0 - 65535]
30	Space	2	USHORT	Space to allow the next field to be aligned on an address that is a multiple of 4.	unitless	0
32	Acoustic frequency	4	ULONG	Acoustic frequency. A value of **0** means that the acoustic frequency is not available.	Hz	[0 - 4294967295 Hz] Fisheries acoustics range: [100 - 1000000 Hz]
36	Installation depth of transducer.	4	ULONG	Installation depth of transducer relative to the sea surface. A value of **42949672.95** means that the installation depth of the transducer is not available.	0.01 m	[0.00 - 42949672.95 m] Working range: [0.00 – 10000.00 m]
40	Alongship offset relative to the attitude sensor	4	ULONG	Alongship distance between the transducer center and the reference point of the attitude sensor in the fore and aft direction of the platform. Negative values are on the aft side of the reference point of the attitude sensor.	0.0001 m	[0.000 – 429496.7295 m] Working range: [0.0001 – 200.0000 m]
44	Athwartgship offset relative to the attitude sensor	4	ULONG	Athwartship distance between the transducer center and the reference point of the attitude sensor in the fore and aft direction of the platform. Negative values are on the port side of the reference point of the attitude sensor.	0.0001 m	[0.000 – 429496.7295 m] Working range: [0.0001 – 200.0000 m]
48	Vertical offset relative to the attitude sensor	4	ULONG	Vertical distance between the transducer center and the reference point of the attitude sensor in the fore and aft direction of the platform. Negative values are below the reference point of the attitude sensor.	0.0001 m	[0.000 – 429496.7295 m] Working range: [0.0001 – 200.0000 m]

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
52	Alongship angle offset of the transducer face	2	SHORT	Mechanical angle of the transducer face relative to the horizontal in the alongship plane of the platform. Negative is below the horizontal and 0 degree is in the fore direction. A value of **[–3276.8]** means that the alongship angle offset of the transducer face is not available.	0.1 degree	[-3276.8 to +3276.7 degree] Working range: [-360.0 to +360.0 degree]
54	Athwartship angle offset of the transducer face	2	SHORT	Mechanical angle of the transducer face relative to the horizontal in the athwartgship plane of the platform. Negative is below the horizontal and 0 degree is in the starboard direction. A value of **[–3276.8]** means that the athwartship angle offset of the transducer face is not available.	0.1 degree	[-3276.8 to +3276.7 degree] Working range: [-360.0 to +360.0 degree]
56	Rotation angle of transducer	2	SHORT	Mechanical angle of rotation of alongship axis of transducer relative to alongship axis of platform. Negative angle are clockwise rotation. A value of **[–3276.8]** means that the rotation angle of the transducer is not available.	0.1 degree	[-3276.8 to +3276.7 degree] Working range: [-360.0 to +360.0 degree]
58	Alongship angle offset of the main axis of the acoustic beam	2	SHORT	Mechanical offset angle of the main axis of the acoustic beam of the transducer relative to the vertical in the alongship plane of the platform. Negative is in the aft direction. Zero (0) is perpendicular to the transducer face. A value of **[–3276.8]** means that the alongship angle offset of the main axis of the acoustic beam is not available.	0.1 degree	[-3276.8 to +3276.7 degree] Working range: [-20.0 to +20.0 degree]
60	Athwartship angle offset of the main axis of the acoustic beam	2	SHORT	Mechanical offset angle of the main axis of the acoustic beam of the transducer relative to the vertical in the athwartship plane of the platform. Negative is in the port direction below the horizontal. Zero (0) is perpendicular to the transducer face. A value of **[–3276.8]** means that the athwartship angle offset of the main axis of the acoustic beam is not available.	0.1 degree	[-3276.8 to +3276.7 degree] Working range: [-20.0 to +20.0 degree]
62	Absorption of sound	2	USHORT	Absorption of sound (α) in the propagation medium. A value of **[655.35]** means that the absorption of sound is not available.	0.01 dB km^{-1}	[0.00 - 655.35 dB km^{-1} Practical range: [0.00 - 300.00 dB km^{-1}]
64	Pulse duration	2	USHORT	Duration of the transmitted pulse. A value of **0** means that the pulse duration is variable or not available.	0.1 ms	[0.0 ms - 6553.5 ms]
66	Bandwidth	2	USHORT	Transceiver specific bandwidth. A value of **0** means that the bandwidth is variable or not available.	0.01 kHz	[0.00 - 655.35 kHz]
68	Calibration source level	2	USHORT	Source level (SL of the sonar equation). A value of **0** means that the source level is not available.	0.01 dB µPa @ 1 m	[0.00 to 655.35 dB] Practical range: [150.00 - 250.00 dB]

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
70	Transducer shape	2	USHORT	**0**= not known **1=** oval (which includes circular transducer) **2=** rectangular	unitless	[0 – 65535] Presently: [0 - 2]
72	3 dB alongship beamwidth of the transducer beam	2	USHORT	Half power (3 dB) beamwidth of the transducer beam in the alongship plane. A value of **0** means that the 3 dB alongship beamwidth not available.	0.1 degree	[0.0 - 6553.5 degree] Practical range: [1.0 to 50.0 degree]
74	3 dB athwartship beamwidth of the transducer beam	2	USHORT	Half power (3 dB) beamwidth of the transducer beam in the athwartship plane. A value of **0** means that the 3 dB athwartship beamwidth not available.	0.1 degree	[0.0 - 6553.5 degree] Practical range: [1.0 to 50.0 degree]
76	Two-way beam angle	2	USHORT	Two-way beam angle (10 log ψ) in dB for this transducer. **N. B.** For circular transduecers, the two-way beam angle is related to the directivity index (DI = 10 log the beam pattern factor (i.e., expected value of b$^{2)}$) by the equation DI = - 10 log ψ = -DI + 7.7 dB. A value of **0** means that the two-way beam angle is not available.	0.01 dB	[0.00 to 655.35 dB] Practical range: [10.00 - 50.00 dB]
78	Calibration receiving sensitivity	2	SHORT	Calibration receiving sensitivity (VR of the sonar equation) of the transducer for this TVG-amplified data channel. **<u>N.B.</u>** This includes all through receiver gain. A value of **0** means that the receiving sensitivity is not available.	0.01 dB v /µPa @ 1 m	[-327.68 to +327.67 dB] Practical range: [-200.00 to - 100.00 dB]
80	SL+VR	2	SHORT	Sum of the calibration source level (SL of the sonar equation) and the receiving sensitivity (VR of the sonar equation) of the transducer for this TVG-amplified data channel. **<u>N.B.</u>** This includes all through receiver gain. This field is the identical to the value obtained by summing the two seprate fields. A value of **–327.68** means that the SL+VR is not available.	0.01 dB v µPa @ 1 m	[-327.68 to +327.67 dB] Practical range: 0 to 100.00 dB]
82	Bottom detection: minimum level	2	SHORT	Level for the bottom detection in the units selected in the above field “Type of sample data ”.	0.01 volts, (volts)^2, Watts or dB	For all units: [-327.68 to +327.67] Practical range: [2.50 to 15.00 volts] [6.25 to 225.00 (volts)^2] [-150.00 to 0.00 dB]

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit range
84	Bottom window	4	ULONG	Minimum depth for bottom detection window.	0.01 m	[0.00 - 42949672.95 m] Working range: [0.00 - 999.99 m]
88	Bottom window max.	4	ULONG	Maximum depth for bottom detection window in m. For the CH1 software this is also the maximum depth up to which data will be acquired.	0.01 m	[0.00 - 42949672.95 m] Working range: [0.00 - 999.99 m]
92	Remarks	X4	CHAR	Character string comment, up to 30 characters. This field could be used to store the transducer serial number.	ASCII char.	variable
…	Tuple attribute	4	LONG	Attribute of the tuple: **0 =** original tuple, e.g., nothing special to mention **1** = edited tuple Other attributes could be labeled by a code (e.g., tuple data quality). Negative codes should be used for special cases.	unitless	[-2147483648 to +2147483647]
…	Backlink	4	ULONG	Tuple size: 104 bytes.	byte	[… - 4 giga]

Table 28. Definition of the Private tuple no 65397.

This is a new Private tuple that uses a field identifying the organization to which this private tuple belongs and which has the definition of the fields it contains. It has the advantage of preventing possible collisions in non concerted use of the private tuple by various groups.

Offset (byte)	Field	Length (bytes)	Format	Content	Encoded units	Limit Range
0	Tuple Size	4	ULONG	Tuple data size: variable	bytes	[6 - 4 giga]
4	Tuple Type	2	USHORT	Private tuple 1 type code: 65397	unitless	65397
6	Organization	2	USHORT	Code identifying the organization that controls the format of the data section of the tuple. Codes are allocated by the ***HAC*** co-ordination committee and described publicly. **Organisation code** DFO-Maurice Lamontagne Institute 1 BioSonics 2 Simrad 3 HTI 4 IFREMER 5 SonarData 6 Others to be added.	unitless	[0 - 65535]
8	Data	multiple of 4 bytes		Space for data, structure to be determined by user with restriction that total length must be a multiple of 4 bytes.		
…	Tuple attribute	4	LONG	Attribute of tuple: 0= original tuple 1= edited tuple Other attributes could be labeled by a code (e.g., tuple data quality). Negative codes should be used for special purposes.	unitless	[-2147483648 to +2147483647]
…	Backlink	4	ULONG	Tuple size: variable (multiple of 4 bytes)	byte	[16 - 4 giga]

APPENDIX D - DEFINITIONS, UNITS AND SYMBOLS IN FISHERIES ACOUSTICS

by

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Introduction

At the 1999 FAST meeting in St Johns, we presented a paper on “Acoustical definitions, units and symbols”. This addressed a long-standing problem of inconsistent terminology and parameter definition in fisheries acoustics.

During the discussion of these matters in the Working Group, the need to make progress towards adopting consistent rules was recognised. It was agreed that further consultation of members and other interested parties should be done with a view to the development of guidelines which would be generally acceptable to workers in fisheries acoustics. We then prepared a draft proposal which was circulated last November with a request for comments. The proposal was sent to all on the FAST mailing list and to some others known to be active in the field.

There were only three replies to the November circular. The fact that few responded is not necessarily disappointing. Hopefully it indicates there is already a good degree of consensus on what FAST might adopt as recommended guidelines. We have amended our earlier suggestions to take account of the constructive views expressed by correspondents, and a revised draft proposal is presented in this paper.

Primary measurements

Table 1 contains a list of the most important acoustical parameters together with their definitions in the form of equations. Derived parameters like the Target Strength are not measured directly. They are determined by numerical evaluation of the defining equations. To do that requires measurements of or assumptions about a primary set of quantities. Different sets of primary quantities might be selected for this purpose, however, we have adopted the set listed below. Thus evaluation of the equations in Table 1 requires the following quantities to be measured or otherwise determined. They are normally expressed in the SI units shown in the square brackets:

r	Distance of the measurement position from the target [m]
θ,φ	Spherical polar angle coordinates of the measurement position. The target is at the origin and the transmitted wave propagates in the direction (0,0) [deg.]
I_{inc}	Intensity of the transmitted wave at the target [Watts m^{-2}]
$I_{scat}(r,\theta,\varphi)$	Intensity of the scattered wave at the measurement position [Watts m^{-2}]
$I_{bs}(r)$	Intensity of the backscattered wave, equal to $I_{scat}(r, -\pi, 0)$ [Watts m^{-2}]
z	Distance along the propagation path of a plane wave [m]
$I(z)$	Intensity of a plane wave as a function of distance along the propagation path [Watts m^{-2}]
n	Number of targets per unit volume [m^{-3}]
V	Volume occupied by a scattering medium or nV discrete targets [m^3]

Naming conventions

The first requirement is to adopt a set of names which are unique for each quantity having a 7specific physical definition. Furthermore, quantities which are scaled by factors other than powers of 10 should have different names, like degrees and radians in the case of angles. Given a non-confusing and widely accepted set of names, the symbols are less of a problem, or at least those which have dimensions. In that case, SI units are the norm with 10^n scaling factors as needed. On the other hand, it is not necessary to cover every quantity which might be expressed with non-decadal scaling. The need is to include those which are often used in fisheries acoustics, to eliminate any risk of confusion.

We start with the concept of scattering by a small target as a direction-dependent phenomenon. Therefore, the most general name "acoustic cross-section" should be reserved to describe the scattering over all directions, measured bistatically, and the related symbol should have a functional form such as $\sigma(\theta,\varphi)$ or $\sigma(\mathbf{r})$.

It follows that other cross-sections relating to specific directions or with no directional dependence should have different and less general names. Their symbols should be written as σ followed by subscripts which describe the context. In the case of the "backscattering cross-section" (σ_{bs}), this is in line with current practice. In the case of the pseudo-isotropic cross-section ($= 4\pi\, \sigma_{bs}$), rather general names have been used in the past and it is often symbolised by σ with no subscripts. We feel something more specific is needed. The term "spherical scattering cross-section" is suggested as being appropriate to the isotropic assumption in the definition of this quantity. The isotropic assumption almost never holds in practice, hence the term "pseudo-isotropic" mentioned above.

Volume scattering is not a big issue. The "volume backscattering coefficient" is well understood as $s_v = \Sigma\sigma_{bs} / V$ where the sum is taken over all the discrete targets in the volume V, or $s_v = \Delta\sigma_{bs}/\Delta V$ in the case of a continuous scattering medium. The SI unit (m^{-1}) is the norm for s_v and 4π scaling is seldom if ever used.

Area scattering is more of a problem. Being dimensionless, this quantity is more difficult to express clearly when non-decadal scaling is applied. A naming convention is essential to distinguish the various scaled versions. By analogy with the volume case, the unscaled quantity is the "area backscattering coefficient" which is defined as the integral of s_v over a range interval. The most commonly used scaled coefficient is the one implemented in the Simrad EK500 echosounder. The relevant scaling factor is $4\pi\ (1852)^2$; for historical reasons, the nautical mile enters the calculation (1 n.mi. = 1852 m). In the absence of a better idea, we have called this scaled quantity the "nautical area scattering coefficient". That is a rather long expression, but in practice it could be contracted to the acronym NASC.

So far we have discussed linear measures only. There are the corresponding log measures to be considered as well. The name and definition of "target strength" are cast in tablets of stone; absolutely no need to change anything there. In the case of volume and area scattering, we suggest the log name should simply be the linear name with "strength" substituted for "coefficient". This covers the important case of the "mean volume backscattering strength" or MVBS which is well known as $10 \log_{10} (s_v)$.

Symbols

We suggest that the following conventions should be adopted. To a large extent they correspond to current practice.

- Linear measures have symbols beginning with
  (1) σ for cross-sections
  (2) Lower case Roman 's' for volume and area coefficients

- Log measures have symbols beginning with a capital Roman letter

- The final subscript letters (the case is immaterial) indicate the context e.g. bs for backscattering. They are not normally relevant to the particular quantity or the units of measurement.

- In the case of area scattering only, the subscript case is significant. s_a and s_A refer to the area backscattering coefficient and the NASC respectively.

Biomass estimation

Perhaps the most important application of acoustics in fisheries research is the estimation of the density or abundance of biological targets. It is essential to be clear about the formulas used to convert the acoustical measurements to biological quantities. Consider the simple example of a layer between depths z_1 and z_2 below the transducer. ρ is the density of targets expressed as the number per unit surface area of the layer. ρ is proportional to s_a and inversely proportional to $\langle\sigma_{bs}\rangle$, the expected backscattering cross-section of one target. $\langle\sigma_{bs}\rangle$ is so written to denote an expected value rather than a mean, since it is determined indirectly from the size distribution of fished samples and empirical equations relating the Target Strength to fish length. Equivalent formulations may be written in terms of s_a or s_A, $\langle\sigma_{bs}\rangle$ or $\langle\sigma_{sp}\rangle$ with the appropriate scaling factor. Some examples are, with the units of ρ in square brackets:

$\rho = s_a / \langle\sigma_{bs}\rangle$ [m^{-2}]
$\rho = 10^6\ s_a / \langle\sigma_{bs}\rangle$ [km^{-2}]
$\rho = s_A / \{4\pi \langle\sigma_{bs}\rangle\} = s_A / \langle\sigma_{sp}\rangle$ [$n.mi.^{-2}$]

Discussion

During the correspondence about earlier versions of the proposal, it was noted that formulas for the scattering cross-section should include the acoustic absorption coefficient. This has now been incorporated in Table 1. The absorption coefficient α (measured in dB m^{-1}) has been used in preference to β (measured in nepers m^{-1}) so that our definitions correspond to those recognised by acoustical oceanographers (Medwin and Clay, 1998).

There has been much work recently on the echo statistics of fish schools. Various measures of the school echoes are needed for classification purposes, in particular, a measure of the total echo strength returned by the school. It has been pointed out that previous versions of Table 1 concentrated on point targets. They did not cover the case of distributed targets like fish schools which are sampled over many pings.

The total echo strength is generally determined from measurements of s_v over the area of the school as observed on the echogram. If the transverse width of the beam is taken into account, we can integrate s_v over the sampled volume. The result is a quantity with the dimensions of area i.e. the same as a cross-section. We suggest this quantity is called the "aggregate backscattering cross-section", σ_{ag}. In the case of a school consisting of multiple discrete fish, σ_{ag} can be defined simply as the sum of σ_{bs} over all the targets in the insonified volume. For a plankton patch where the scattering is more continuous, σ_{ag} is better expressed as the integral of s_v. In either case, we suggest that the aggregate backscattering cross-section as defined here is a suitable measure of the total scattering strength in the context of echo-trace classification studies.

Conclusions

The names proposed for key quantities relevant to fisheries acoustics, together with their definitions and suggested symbols are summarised in Table 1. The list in Table 1 is not intended to be exhaustive. The need is to include all those which frequently appear in the literature pertaining to fisheries acoustics. As is the normal practice in physical descriptions, names should be chosen to avoid confusion between different quantities, and in each case the quantity is defined by an equation which shows how it is determined from primary measurements. The units follow from those of the quantities in the defining equation. SI units are normally adopted as is generally required in formal publications. It is necessary to allow for non-SI units in a few cases, in particular when a non-SI unit is needed to conform with current practice in the field.

While the scheme presented here is not the only one which might be considered as a standard, we suggest it is a consistent approach which overcomes the main problems with current practices in acoustical terminology.

Members of FAST are invited to consider this proposal. If substantive agreement can be obtained, it is suggested that the proposal (or a modified version thereof) should be adopted by FAST as recommended guidelines to be followed in fisheries acoustics publications.

Reference

Medwin, H. and Clay, C.S. 1998. Fundamentals of Acoustical Oceanography. Academic Press, New York, 712pp.

Table 1

Preferred names, definitions and symbols for parameters related to acoustic scattering

Symbol	*Name*	*Defining equation*	*Units*
α	Acoustic absorption coefficient	$\alpha = 10 \log_{10} \{I(z) / I(z+\Delta z)\} / \Delta z$ (I is measured in the absence of biological scatterers)	dB m^{-1}
$\sigma (\theta,\varphi)$	Acoustic cross-section	$\sigma (\theta,\varphi) = [r^2 I_{scat}(r,\theta,\varphi) 10^{\alpha r/10}]/I_{inc}$	m^2
σ_{bs}	Backscattering cross-section	$\sigma_{bs} = [r^2 I_{bs}(r) 10^{\alpha r/10}]/I_{inc}$	m^2
σ_{sp}	Spherical scattering cross-section	$\sigma_{sp} = [4\pi r^2 I_{bs}(r) 10^{\alpha r/10}]/I_{inc}$	m^2
σ_s	Total scattering cross-section	$\sigma_s = \int_0^{2\pi} \{ \int_0^{\pi} \sigma(\theta,\varphi) \sin \theta \, d\theta \} \, d\varphi$	m^2
σ_e	Extinction cross-section	$\sigma_e = \{\Delta I(z)/\Delta z - \alpha \ln(10)/10\}/\{n I(z)\}$ (I is measured in the presence of biological scatterers)	m^2
σ_a	Absorption cross-section	$\sigma_a = \sigma_e - \sigma_s$	m^2
σ_{ag}	Aggregate backscattering cross-section	$\sigma_{ag} = \Sigma\sigma_{bs}$ (sum taken over all targets in volume V)	m^2
s_v	Volume backscattering coefficient	$s_v = \Sigma\sigma_{bs} / V$	m^{-1}
s_a	Area backscattering coefficient	$s_a = \int_{z1}^{z2} s_v \, dz$	(m^2/m^2)
s_A	Nautical area scattering coefficient (NASC)	$s_A = 4\pi (1852)^2 s_a$	$(m^2/n.mi.^2)$
TS	Target Strength	$TS = 10 \log_{10} (\sigma_{bs})$	dB re $1m^2$
S_v	(Mean) Volume backscattering strength	$S_v = 10 \log_{10} (s_v)$	dB re $1m^{-1}$
S_a	Area backscattering strength	$S_a = 10 \log_{10} (s_a)$	dB re 1 (m^2/m^2)
S_A	Nautical area scattering strength	$S_A = 10 \log_{10} (s_A)$	dB re $1(m^2/n.mi.^2)$