REPORT OF THE

WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY

St. John's Canada
20—22 April 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 TERMS OF REFERENCE

In accordance with the ICES Resolutions adopted at the 86 th Statutory Meeting, the Working Group on Fisheries Acoustics Science and Technology (Chair: Dr. F. Gerlotto, France) met in St John's, Newfoundland, Canada, on the 20-22 April 1999 to:

a) Review methods for estimating mean Target Strength (TS) in relation to spatial density statistics of scatterers,

b) Report on the impact of fish avoidance on the results of fisheries acoustics, particularly:
   - the effect on TS
   - the effect on biomass estimation
   - the effect on species identification

c) Review the development of acoustic methods and tools for *in situ* observation of fish behaviour

d) Review the application of acoustic techniques to bottom trawl surveys.

e) Select a format for exchanging data and software

2 MEETING AGENDA AND APPOINTMENT OF RAPPORTEUR

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

The following agenda was adopted:

Session 1: Review methods for estimating mean Target Strength (TS) and the application of acoustic techniques to bottom trawl surveys

Session 2: Report on the impact of fish avoidance on the results of fisheries acoustics and review the development of acoustic methods and tools for *in situ* observation of fish behaviour

Session 3: To select a format for exchanging data and any other matters.

A list of participants appears as Appendix A. Reports of progress submitted by some of the countries represented at the meeting are appended in Appendix B.

3 DISCUSSION OF ICES STRATEGIC PLAN

Ole Arve Misund outlined the latest version of the ICES Strategic Plan to members of the Working Group, emphasising proposed areas of particular relevance to the Group.

'In addressing the science under-pinning its mission, ICES had identified five core objectives. These are:

- Understanding the physical and biological functioning of marine ecosystems.
- Understanding and quantifying human impacts on the marine environment.
- Developing the science of integrated marine living resource management.
- Advising regional agencies on the sustainable use of living marine resources and the protection of the marine environment.
- Co-ordinating and supporting interdisciplinary, national and international marine science programmes'

Priority areas for the WGFAST working group were identified within the first objective:

- 'Describe, understand and quantify the variability and state of the marine environment in terms of its biological, physical and chemical components.
- Develop a classification system and map marine habitats of coastal areas, continental shelves and slopes, and the open ocean
- Develop our knowledge of the life history, stock structure, dynamics and trophic relationships of living resource populations'

and within the fourth objective:

- 'Provide sound, credible, timely, peer reviewed and integrated scientific advice on fishery management and the protection of the marine environment requested by client Commissions, Member Countries, and partner organisations'

4 SESSION 1 -REVIEW METHODS FOR ESTIMATING MEAN TARGET STRENGTH (TS) AND THE APPLICATION OF ACOUSTIC TECHNIQUES TO BOTTOM TRAWL SURVEYS

4.1 John E. Ehrenberg. Scattering density estimation, *in situ* target strength measurement and single echo isolation

Uncertainty in the individual fish backscattering cross section is one of the main sources of error in acoustic abundance estimation. A variety of in situ target strength measurement techniques have been developed. The split beam method provides the estimate of the average backscattering cross section that has the lowest variance and bias of the techniques developed to date. All of the *in situ* techniques assume that the echoes from the individual fish have been isolated. However, the currently used echo isolation techniques are not perfect and accept some overlapping echoes as single echoes. An analysis and simulation of the three currently used techniques for echo isolation has been carried out. The study has shown that the performance of the echo isolation techniques is affected by the selection of the bandpass filtering in the echo sounder and the signal to noise ratio. The echo isolation method based on pulse width measurements provides the best performance of the currently used techniques. The second best performance is achieved by the phase variation measurements and the third is the use of the correlation coefficient for the echo envelope. The pulse width and phase variation methods perform best when the receiver filtering is matched to the transmitted pulse. Performance can also be optimised by adjusting the single echo criteria as a function of the signal to noise ratio. The use of wideband signals (such as the FM slide or chirp) provides a means to achieve both good range resolution and good signal to noise ratio and thereby results in better single echo isolation. Tracking of the targets from ping to ping can also be used to isolate single echoes.

The discussion following this paper considered which TS should be used for populations with mixed sizes or orientations, the effect of range on the various single echo isolation methods and horizontal ass well as vertical reduction of the pulse. It was noted that the combination of phase variation and pulse width does not improve results as much as might be anticipated because they are both depressed by the same variables.

4.2 Howard Nes

Dealing separately with the information received from the four quadrants of a split beam sounder, it should be possible to compute the most likely pulse from any depth and any direction. Comparison of the observed with the expected can provide an error term for each quadrant.

4.3 John K. Horne and Michael Jech, Quantifying Variability in Fish Backscatter: Integrating Theory and Empiricism

Variability in backscatter cross section among conspecifics and among successive returns from individuals is a universal trait of acoustically detectable organisms. Amplitudes of returned echoes are influenced by physical factors associated with the transmission of sound through a viscous fluid, and by biological factors associated with the location, reflective properties, and behaviour of a target. Numerous empirical and theoretical backscatter models were used to predict echo amplitudes and to increase understanding of the scattering properties of fish and invertebrates. These authors used a Kirchhoff- ray mode (KRM) model to predict backscatter from aquatic organisms as a function of species, length, aspect, and acoustic wavelength. To quantify accuracy and precision of the method, model predictions have been compared to *ex situ* measurements of several marine and freshwater fish species. Species-specific KRM models permit the examination of the combination of geometric scattering frequencies with the inverse approach; the effect of digital image resolution on predicted backscatter amplitudes; The ability to discriminate targets based on signal-to-noise ratios; and the effects of acoustic size choice on accuracy of population abundance estimates. The integration of backscatter models with empirical measures formed a logical approach to understanding the biological scattering of sound.

4.4 David N. Maclennan and Paul G. Fernandes, Acoustical Definitions, Units and Symbols

There is a long standing problem over definitions, units and terminology in fisheries acoustics which needs to be resolved. This presentation explored these issues and, as a basis for discussion, proposed some rules aimed at a more consistent approach in the acoustical literature. There is a particular need for clearly identified names for the many acoustical quantities which need expression in our work. Some of the names suggested might be considered rather indigestible, but nevertheless they form a consistent and logical set. The WGFAST Working Group may wish to consider whether a new initiative is required to put these matters on a more formal and generally agreed basis.

As a basis for discussion, the following rules for symbols describing key acoustical quantities were proposed.

1. Linear cross-sections begin with the Greek letter 'sigma' σ.
2. For linear volume coefficients:
   2.1 The first letter is always 's' (scattering) with:
   upper case 'S' for quantities in SI units (i.e. m^{-1}) :
   lower case 's' for quantities in other units (seldom required but included for the sake of completeness)

   2.2 The second letter is always subscripted 'v' (volume) with
   upper case 'V' for quantities based on acoustic cross-sections
   lower case 'v' for quantities based on backscattering cross-sections

3. For linear area coefficients
   3.1 The first letter is always 's' (scattering) with:
   upper case 'S' for unscaled quantities (m^2 / m^2)
   lower case 's' for quantities in 'units' (e.g. m^2 / n.mi.^{2})

   3.2 The second letter is always subscripted 'a' (area) with:
   upper case 'A' for quantities based on acoustic cross-sections
   lower case 'a' for quantities based on backscattering cross-sections

4. For logarithmic measures, the second letter is NOT subscripted, otherwise the same case-sensitive rules apply.

The proposed names and symbols are listed in the Table reproduced as Appendix C.

4.5 Arnaud Bertrand and Erwan Josse. Acoustic estimation of longline tuna biomass

French Polynesia EEZ is located in an important longline fishing ground for albacore (*Thunnus alalunga*), yellowfin (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*). Longline tuna abundance estimation using fishing catches is biased especially when hook depth does not coincide with habitat optimal depth. To avoid catchability problems an acoustic direct tuna abundance estimation was performed in the French Polynesia EEZ with a 38 kHz echo-sounder working down to a depth of 500 m. Several biases can influence individual tuna targets selection i.e. threshold effect, multiple target acceptance risk, beam width effect or target detection restriction at depth. Influence of bias appears limited, and comparison with experimental longline catches shows that selected acoustic targets appear representative of longline tuna distribution. A density of 1.33 fish per km^2 i.e. about 33.8 kg of tuna per km^2 was measured. Such a density estimate is slightly superior than that based on tuna catches, as the whole tuna habitat range is not prospected by most professional longlineing.

4.6 Noel Dîner, Corrections on school geometry and density descriptors. Use of the algorithm on actual school detections

In 1998, a special algorithm was perfected dedicated to the correction of geometric and energetic descriptors extracted from school echo-traces. This algorithm was established on simulated images and gives generally very accurate results. Nevertheless, it seems necessary to operate this algorithm on school actual detection. This exercise has been conducted according to two main approaches:

- on well indidualized schools, detected by the same echo-sounder; by varying the processing threshold, it is possible to change the detection angles and thus the correction amplitude; but normally the corrected descriptors must remain unchanged.
- on schools detected simultaneously by two echo-sounders with very different directivities; after correction, the descriptors must be the same for each school.

On actual detection, the corrections do not seem to offer the same level of accuracy as that reached on simulated data. This is mainly due to the variability encountered in the echo-traces, resulting from complex shapes and varying internal densities.

The comparison between 2 very different directivities - 16° and 5.7° - was not always easy to operate as the equipment give very different echo-traces. Nevertheless, it can be concluded that:

- it is better to use narrow beam echo-sounders : in this way a greater number of traces can be processed with an acceptable accuracy.
- corrections concerning length appear quite often more accurate than those for volume back scattering strength,
- each time, it is necessary to observe the "Nbi" values : when they are lower than 1.5, the accuracy drops down and it seems better not to operate the algorithm.

4.7 John Simmonds, François Gerlotto, Paul Fernandes and David MacLennan. Observation and extraction of three-dimensional information on fish schools

The presentation described the performance, calibration and use of a 90-deg sector scanning sonar for the collection and extraction of information on the 3D structure of fish schools. The equipment, which consisted of a 455 kHz 60 beam sector scanning sonar linked to a PC was described briefly. The specific calibration problems of a high-frequency instrument with multiple beams was discussed and calibration data from on-axis and beam shape measurements were presented. The deployment of the instrument for data collection at sea and the data collection methods were described, along with examples of the data. A three-dimensional data processing algorithm was presented along with results of reconstruction from selected schools. The statistical properties of within school data were discussed along with indications of the precision of internal structures that could be evaluated using the sonar.

4.8 Holliday, D.V., Acoustical Monitoring of Sub-Meter Scale Vertical Structure in Plankton

During June 1998, three six-frequency, Tracor Acoustic Profiling Systems (TAPS-6) were deployed in an upward looking mode on mid-water moorings in East Sound at Orcas Is., WA. Each TAPS-6, located at the corners of a 300 m triangular array, collected data from 12.5 cm intervals in the upper 10 m every minute. This acoustical monitoring of thin scattering layers and aggregations revealed a complex, dynamic distribution of zooplankton and fish. This contribution focussed on the interpretation of data collected during a short interval of the 9 week deployment. Data from an eight frequency TAPS-8, used in a cast mode from a research vessel anchored nearby, and ancillary data on the local physical environment was discussed to set the context for the observed biological distributions.

4.9 Helge Bodholt, The effect of temperature and salinity on split-beam target strength measurement (presented by Howard Nes)

In situ target strength measurements are performed at many different places and at different times around the year. The water temperature and the water salinity vary. The effect of this on the accuracy of a split-beam target strength measurement was discussed. The speed of sound is the fundamental parameter, and both temperature and salinity have influence on this. Three transducer parameters are important in this connection: Angle sensitivity, Beamwidth and Transducer gain. Simrad has specified default values for each transducer type. The default values are based upon transducer measurements in a water tank with fresh water at the temperature 17 degrees Celsius. The sound speed is here 1 473 m/s. In the sea, the sound speed varies, and consequently the transducer parameters vary. These variations are caused by the law of physics and are therefore common for all transducers, and an adjustment of the settings according to the current sound speed can be made. In addition each transducer type may show changes in impedance and sensitivity when the temperature changes.

5 SESSION 2: REPORT ON THE IMPACT OF FISH AVOIDANCE ON THE RESULTS OF FISHERIES ACOUSTICS AND REVIEW THE DEVELOPMENT OF ACOUSTIC METHODS AND TOOLS FOR IN SITU OBSERVATION OF FISH BEHAVIOUR

5.1 Ian H. McQuinn, A Review of the Effects of Fish Avoidance and Other Fish Behaviours on Acoustic Target Strength, Species Identification and Biomass Estimation

A comprehensive review was presented, arranged under the following headings:

1) Orientation
    a) Circadian

i) Tilt Angle

- conduct surveys either in the daytime or at night
- measure and model the day/night influence to correct for the bias, e.g. *in situ* TS measurements, orientation distributions
- tilt angle tags

b) Physiological State

i) Tilt Angle

- conduct surveys at a fixed time of the year for inter-annual comparability

2) Avoidance

a) Vessel

i) Tilt angle, Dispersion, Herding

- reduce vessel stimuli, i.e. reduce the speed and/or the size of the vessel; design quieter vessels; eliminate deck lighting; modification to the vessel to reduce certain frequencies
- conduct the survey at times of the year when fish are less susceptible, i.e. during spawning; when fish are distributed in deep water
- monitor and measure avoidance response, i.e. target tracking, multi-beam sonar, stationary monitoring buoys, Doppler technology

b) Predator

i) Tilt angle, Gas Release

- monitor avoidance response: target tracking, multi-beam sonar, Doppler technology

3) Social Aggregation

a) Density

i) Shadowing

- apply a correction for the extinction cross section where applicable

b) Configuration (See SGETC report)

i) Pattern

- develop a data bank of species configurations
- use multi-beam sonar to better describe school shapes and dimensions

4) Distribution

a) Vertical

i) Acoustic Dead Zone

- apply a correction for the ADZ where applicable
- reduce the pulse length and the beam angle
- lower the transducer closer to the seabed
- avoid surveying when fish are in the surface dead zone

b) Horizontal

i) Survey Area

- requires a detailed knowledge of the seasonal distribution of the target species
- requires a knowledge of the factors which affect distribution, i.e. prey species, temperature regimes, physiological state

- conduct survey when population is relatively concentrated

5) Migration
   a) Vertical
      i) Tilt Angle

- *in situ* target strength data
- avoid active vertical migration periods, e.g. dawn and dust

      ii) Swim bladder volume

- model the effects of changing pressure, e.g. cage experiments, pressure tank experiments)

   b) Horizontal
      i) Non-stationary
      - avoid conducting surveys in a migratory situation
      - measure the average migration rate and apply a correction

- conduct the survey orthogonal to the migration direction

5.2 Andrew Brierley and Paul Fernandes, An autonomous echosounder for deployment on Autosub-1

Autosub-1 is an Autonomous Underwater Vehicle (AUV) which has been developed over the past ten years by the National Environment Research Council (NERC) of the United Kingdom. Under the NERC sponsored 'Autosub Thematic Programme', the British Antarctic Survey and the Marine Laboratory Aberdeen have a joint project (Under Sea Ice and Pelagic Surveys – USIPS), which aims to use Autosub-1 as a platform for acoustic surveys. AUVs provide a means to sample otherwise impenetrable environments including: near surface; under sea-ice; and the deep sea. AUVs may, in addition, facilitate sampling at times when conventional research vessels can not operate, e.g. during bad weather. As the use of AUVs becomes more routine, they are likely to provide large savings in operating costs compared to conventional platforms.

This presentation described how a standard Simrad EK500 echosounder was adapted for autonomous use in the Autosub-1. The sounder has two split-beam transducers, operating at 38 and 120 kHz. Data is archived onto a local portable PC across the ethernet using the software 'Echoview'. The sounder is controlled from the ethernet or serial ports by the local PC. The sounder, local PC and control circuits (to monitor voltage, water and temperature) are housed in an aluminium casing rated to 1000 psi. The power is supplied by a battery pack containing 168 manganese alkaline cells; this battery pack is housed separately. The local PC is remotely controlled by a remote PC via a microwave link, operating at 2.4 GHz.

The system will be trailed on Autosub in April this year and used in earnest in the North Sea herring acoustic survey in July. The objectives are to collect additional acoustic data to enhance the survey's precision, to look at surface schools and to investigate aspects of vessel avoidance by herring.

5.3 François Gerlotto, INFOBANC: a method for measuring school movements

An omnidirectional sonar system has been used for the measurement of school movements during studies carried out in Venezuela and the Ivory Coast. Avoidance was studied by examining the location of schools at 30-second intervals, and making comparisons with a 'natural', drifting vessel. Infobancs software has been developed that can measure the speed between one sonar image and the next, and can thus generate data on school speed of movement and direction.

5.4 Mariano Gutiérrez T., Distribution and behaviour of anchovy (*Engraulis ringens*) before, during and after El Niño 1997–98

Anchovy (*Engraulis ringens*) is the most abundant marine species in the southeast Pacific within the cold Humboldt Current. Warm oceanographic phenomena such as El Niño can seriously affect this fish both in its distribution and in abundance. It can especially affect the north-center stock, which is more abundant than the southern one. In Peru, the distribution and abundance of anchovy is assessed mainly using acoustic techniques. During El Niño 1997-98 a decrease in the biomass of anchovy as well as a change of its population structure were detected, as were alterations in behaviour. The biomass of this marine resource, which in early 1997 was estimated as 9.5 million tons, dropped to 1.2 million tons between August and September 1998. However, thanks to the return of normal environmental conditions since late 1998, the abundance of this species is recovering quickly. From the analysis of the studied information it is concluded that during warm periods anchovy moves partially to the south and takes refuge in the central coastal area; also, its abundance drops due to the lack of food. On the other hand, during cold or normal periods, the distribution projects to the north and towards west and the biomass increases. For this reason, the largest landings in the 1983-99 period have been during the normal or cold periods

5.5 Jacques Massé, Acoustic images recording changes in fish behaviour

Images of cod, whiting and haddock were used to demonstrate that demersal species could become pelagic; under these circumstances bottom trawl surveys would not sample the full population. Similar occurrences were observed with herring and sprat. Conversely herring could be seen close to the seabed, where a bottom trawl survey would be appropriate. An image of cod showed fish that were within bottom trawl range for 3 or 4 minutes of the observation period, but completely out of range for another 25 minutes of the same period.

Other Working Group Members reported similar near-bottom aggregations – known to contain spent fish. A wider length range had been recorded for fish close to the bottom and the suggestion was made that such mixed populations may not spawn as effectively as single size populations. Elsewhere post-spawning fish that normally came up off the bottom to feed had not done so, suggesting unusually low food resources. Changes in behaviour were reported by a number of Members; some changes had made populations difficult to recognise acoustically. Jaques Massé requested that more similar observations should be sent to him by email, and he will report back to next year's WGFAST meeting.

5.6 Rudi Kloser, Measurement of TS bias due to fish behaviour and target selection

TS was measured from a towed body, either lowered vertically or towed slowly. Data from the towed body on pitch, roll, depth, conductivity, temperature, 12, 38 and 120 kHz sounders were combined with GPS and vessel log by means of the vessel's data acquisition system.

Orange Roughy have wax-ester filled swim-bladders, and a 35 cm fish has a target strength approximately equivalent to a myctophiid. Compression of the Orange Roughy swim-bladder with depth increases the resonant frequency and three frequency separation performs better at depth.

The towed body was towed at 700 – 750 m depth, drifting over the bottom with the calibration sphere suspended in situ. The escape reaction observed at the towed body approached fish helped in their identification. Identified targets were plotted in colour on top of a black and white echogram to show their relationship to the seabed and each other as a quality check for target selection. By separating TS values from different situations such as the margin of school, the drift experiment and individuals that were clearly escaping, it was possible to demonstrate that escaping individuals had a TS 3dB lower than those around a school, as a result of fish diving towards the seabed.

WG Members suggested that this technique of studying the location of selected targets, to refine the selection process, could be further enhanced with target tracking.

5.7 Patrick Schneider, assessing the relationships between oceanographic parameters and fish distribution: first results

Hydroacoustic data together with simultaneously collected oceanographic data from four surveys were collected in two areas: the Catalan Sea and the Adriatic Sea. Data was sampled from a 38 kHz dual beam transducer using echointegration and TS data were also sampled.

The most important finding of this analysis – though based on preliminary results – is that, using the presented method, relationships between the occurrence of fish and oceanographic parameters can be detected and analysed numerically. Especially with respect to the resolution of the data, the survey design is important. Data on further parameters, such as fluorescence and the general hydrographic situation (TS diagrams, e.g.) as well as possible avoidance reactions of the fish must be considered to achieve a more profound understanding. Finally, the method provides a good basis for further statistical analysis of the data. This includes especially the application of Generalised Additive Models (GAMs) as a tool for describing interrelations of various parameters and their effect on the dependent variable.

5.8 Gordi Swartzman, Fish behaviour relative to plankton distributions

Near-shore fish and plankton distribution in the California Current System were studied using the relationship between echoes at 38 and 120 kHz alongside data on temperature, salinity, fluorescence and current, with data from Mocness, Anchovy and Methot nets. Looking at four comparable transects fish and plankton distribution was found to be inconsistent on and offshore. Analytical methods used included:

a) binning, non-parametric regression, correlation, e.g. spectral analysis, patch density vs. environmental variables such as bottom depth, temperature, lateral current flow and
b) distance-based, proximity of plankton patches to fish schools.

A modified Ripley's K was used from the edge rather than the centre of schools. Error bounds were set using a Monte Carlo type simulation of random schools so that empirical school locations could be assigned to clustered, dispersed and random categories.

5.9 Gordi Swartzman, Cluster analysis

A poster was presented describing cluster analysis (the analysis of data with the object of finding natural groupings within the data either by hand or with the aid of a computer). Cluster Analysis and examples of its use with fisheries data were illustrated.

5.10 Gordi Swartzman, About Generalized Additive Models (GAMs)

The Generalized additive models (GAM) discussed in this poster are a generalization of generalized linear models. They are generalizations of multiple linear regression. GAMs are nonparametric regression methods which model the dependent variable as an additive sum of unspecified functions of covariates and, if desired, their interactions.

The poster described both inappropriate use of GAMs, and also their potential for Acoustic Studies. If the primary interest of the investigator is in abundance trends and how they are related to spatial and environmental conditions, GAM is totally appropriate, because, after all it is the trend in the mean abundance that they are concerned with (but trends and spatial autocorrelation can be related). Unlike various classification methods (which GAM is not) GAM cannot be applied directly to the question of fish school classification, but rather can be used after classification to relate different species distributions to spatial, temporal and environmental factors as well as to each other (i.e. species associations in space). They bear a major advantage over correlation and linear regression methods of not assuming a specific functional form for the relationship, and therefore allowing for general associations (e.g. temperature preferences or acceptable salinity or depth ranges for a species).

5.11 Gary Melvin, Application of multibeam technology to fish school mapping and 3-D visualization

This presentation examined the use of multibeam sonars. The developmental 8M2000 multibeam sonar had been used . While no calibration was available for this equipment at present, some progress had been made towards achieving this. Some progress had also been made towards a post processing capability, and it is possible to select one beam or a group of beams for viewing. A NSERC proposal has been submitted which aims to develop a Windows-based multibeam editing package both for the bottom and the water-column.

6 SESSION 3: TO SELECT A FORMAT FOR EXCHANGING DATA AND ANY OTHER MATTERS

6.1 Dave Heatley & Ian Higginbottom, A proposal for generic extensions to the HAC standard format for hydroacoustic data

SonarData have undertaken an assessment of the utility of the HAC format as a data exchange format from their perspective as a software developer. They find that the format offers a strong foundation for data exchange but that version 1.0 fails to meet their criteria of forward/backward compatibility and fails to provide a data structure that is independent of the data source. These limitations of the HAC format can be overcome by the addition to the format of new "generic" tuple types as defined in their paper. The generic tuple types will allow ping based data from any source (e.g. EK500, Biosonics DT4000, a "dB difference" or even a thermometer) to be written to the one tuple format.

They also recommend consideration of the following additions/modifications for the next revision of the standard:

- add a file naming convention that ensures that HAC files can be sorted into chronological order on the basis of an ASCII sort
- define the CHAR data type and preferably adopt the Unicode character encoding format to allow for Asian language characters

- allow the use of meta-data files so that integration regions and other user defined structures can span across data file boundaries
- fix problems with recording transducer geometry and transducer platform' geometry.

With these recommended modifications, they believe that the HAC format will reach its potential to become a powerful tool for data exchange. Without them they believe that it risks becoming just one of many data formats that will need to be supported by software developers.

6.2 Yvan Simard , Ian McQuinn , Noel Diner and C. Marchalot, 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

A new multi-channel multi-echosounder hydroacoustic data format, called the HAC format, was proposed two years ago to store, in a standard way, the high-resolution data produced by various types of echosounders, present or future, and the auxiliary information required for their proper interpretation. This responds to a need of various research organisations around the world for constructing self-contained multi-channel hydroacoustic data banks, with non-degraded information, under an adaptable unique structure that can accommodate the developments in this field. The characteristics sought for a standard data format by the fisheries acoustic community and the premises at the origin of this development were recalled and the view of the acoustic world from the HAC perspective was presented. The HAC format is presently used by several fisheries acoustics software tools from various developers around the world, to handle single to multi-channel raw and edited data as various as those produced by multi-frequency, split- or dual-beam echosounders, multi-beam sonars or virtual echosounders. The HAC has an internal structure where the information is grouped and encapsulated in functional units called tuples. This offers a large spectrum of possibilities to accommodate many developments while keeping the binary file structure simple and related information grouped. This versatile HAC format is young. It can be upgraded regularly to respond to the continuous creativity that has always characterised the fisheries acoustic community. Its development would have to be co-ordinated by a user's group to keep the format growth harmonious and conform to its original philosophy. A new version of the HAC format including the recent developments and user's enhancements is on its way and the update notes will be available soon.

6.3 Howard Nes, Data Exchange Formats – a Simrad view

The advantages of a simple system for data exchange were stressed. A comparison was made with the development of GPS output from the original basic data to a far more complex requirement for specific information, and it was suggested that more modest demands could be made from an acoustic data exchange format.

A simple method for detecting machine reading order, details of number and time representation and the use of understandable letter codes were advocated.

6.4 Dan Wiggins, Portable data formats

While it is accepted that the HAC format is well suited for archival, other objectives may suggest a different format for data exchange. A data exchange format needs to be able to accommodate new developments, such as 3-D data. A number of pre-existing, cross-platform tools exist that can be used for data handling e.g. matlab, ArcView, SPSS, and data may be shared over networks, so that file structure is unimportant, only the data are important.

The use of SQL was recommended because it is written in plain English, it has the advantage of universal support and an ISO standard. It has become the foundation of big business and is therefore likely to remain stable. It operates with mid-processed data, meta-data, when there is not the need to examine raw data. SQL has the advantage of speed, flexibility and ease, allowing 'what-if' scenarios and fast recalculation, and output for example to GIS packages.

7 OTHER TOPICS

7.1 Len Zedel, Application of Doppler sonar to fish detection

A Doppler sonar system, the RD Instruments 307 kHz Workhorse unit was evaluated for its performance as a means of detecting the motion of individual fish. Testing was undertaken in the Institute for Marine Dynamics' clear water towing tank (7 m deep, 200 m long, 12 m wide). Styrofoam spheres in a variety of sizes from 2.5, to 12.5 cm diameters were positioned alone and in target arrays of up to 27 spheres. The Doppler sonar was attached to a tow carriage and moved at known speeds over the target arrays. Performance was evaluated on the basis of spatial resolution and speed accuracy. Spatial resolution in target amplitude analysis was complicated by the pulse pair transmissions characteristic of broad-band Doppler processing. For this operating mode, spatial resolution in backscatter amplitude is restricted by the total time required to transmit the code pulse pair (typically 50 cm in profile depth). Speed estimates are formed through an autocorrelation process that recovers the full bandwidth spatial resolution but the instrument only provides velocity output in 20 cm depth bins. It was not possible to use velocity data to identify target locations: target locations were identified using echo amplitude and signal autocorrelation. Depending on the system configuration, single ping estimates of (horizontal) velocity had a standard deviation as low as 10 cm - approaching the theoretical limit of the broad-band technique. When targets of different speeds were present simultaneously in a sample bin, speed estimates tended toward the average of the two speeds: the resolved speed in this case appears to be weighted by the target size.

7.2 John Anderson, Acoustic seabed classification

A project to examine seabed types was initiated following the crash in cod stocks. The need to know about juvenile cod distribution meant that there was a need to have information about seabed type because juvenile cod were found to be dependent upon habitat type for predator avoidance. Older juveniles hide amongst cobbles, whereas larger juveniles (3-4y) and adults no longer have this habitat dependence. Young cod are known not to live on muddy bottoms so these bottom types are also used to identify where fish will not be found.

The system used for seabed classification was the QT Seaview System. The end product was the distribution of 8 bottom types. A digital acoustic fish detection system has now been added to the programme.

7.3 ICES Report No. 209 – Research Vessel Noise

The recommendation in this report that 'at 11 knots vessel noise should be less than ...' could be misinterpreted – and its meaning though to be that the vessel could be noisier at speeds other than 11 knots. For this reason a supplement would be sent out to all purchasers of the report, amending this to 'all survey speeds up to and including 11 knots ...'.

8 REID, D. REPORT ON THE STUDY GROUP ON ECHO TRACE CLASSIFICATION

The Study Group met on 29 April, 1999 for the last time, to review editorial changes to its final report. The meeting was chaired by D. Reid, who reported on its progress to the WGFAST.

The report of the meeting is attached at E.

9 SUMMARIES

9.1 Target strength

The echogram provides a two-dimensional (2-D) view of scatterer aggregations which occupy three-dimensions (3-D) in space and change over time. Thus, the echosounder measurements provide 2-D spatial observations of a 3-D variable and may only approximate reality by generalisation (e.g. mean values). For example, only when the dimensions of the school sizes are small relative to the inter-school spacing (point processes) will the variability intrinsic to the observational method become insignificant relative to the variability in the physical dimensions measured. Therefore, one must be mindful of the limitations of the vertical echosounder data to precisely measure school parameters and select appropriate analysis tools to avoid misinterpretation of the many potential measurement artefacts.

Uncertainty in target strength (TS) is one of the biggest sources of error in abundance estimation using echo integration. Therefore, an accurate and precise distribution of backscattering cross-section is a critical factor in the estimation of the probability density function (pdf) of animal abundance from an acoustical survey. The mean backscattering cross-section is necessary to estimate the mean abundance, but the entire pdf is required to account for this component of variance in the abundance estimate.

TS can be measured from animals in their natural state and environment (in situ), through controlled experimentation (e.g. caged fish), or estimated from multivariate scattering models. The desirability of in situ TS measurements stems from their inherent inclusion of many difficult to obtain and mostly uncharacterised variables such as distributions of scatterer density, sound speed, orientation, size and shape.

In situ TS measurements can be made using single-, dual-, and split-beam echosounders. Single-beam measurements require indirect estimation of the TS pdf via deconvolution of an ensemble of uncompensated TS measurements and the transducer beam pattern. Due to their enhanced ability to remove the beam pattern effect from single-target echo signals, direct measurements of individual TS can be obtained from both dual- and split-beam systems. Of these two direct measurement techniques, the split-beam method is less susceptible to noise and therefore provides the most accurate in situ TS.

Since overlapping echoes can be falsely identified as single echoes, isolation of echoes from single-scatterers is the primary obstacle to measuring in situ TS. Methods based upon pulse width, phase, and echo correlation were evaluated individually by simulation. The performance of each method was a function of the signal-to-noise ratio (SNR). The best echo isolation performance is achieved using the pulse width measurements. The second best isolation is achieved using the phase measurements.

Echo isolation can be improved by matching the echo sounder bandpass filter to the transmitted pulse, employing isolation criteria that varies with signal-to-noise ratio, increasing resolution (beam-width and range), increasing the SNR, target tracking, and by utilising multiple-frequency detections. Employing a coded signal and matched-filter processing will increase both the SNR and the range resolution.

In a separate set of simulation and empirical studies, the combination of pulse width and phase methods were evaluated for rejecting unresolvable targets. In high SNR situations, the effectiveness of the combined pulse width/phase algorithms were shown to be limited by constructively interfering signals originating from scatterers which are separated in radial range by integer multiples of a half-wavelength. Therefore, the effectiveness of a split-beam echosounder system to reject echoes from unresolvable scatterers is significantly improved by combining the synchronised signals from two or more adjacent split-beam transducers of different frequencies which are not integer multiples of each other.

9.2 Behaviour

1) The work of the WGFAST has confirmed that fish behaviour is one of the most important potential sources of bias in fisheries acoustics, from several points of view:

   a) directly, due to the existence of relationships between the spatial position of fishes, the stimuli produced by the research vessel and the characteristics of the individuals, due to avoidance reactions.

   b) indirectly, on species identification through the avoidance of fishing gear, etc,

   c) randomly, by the existence of adaptive functions related to the environmental changes

2) The main characteristics of fish behaviour as studied through acoustics may be:

   a) Predictable (tilt angle, shadowing, etc)

   b) Species specific (school shapes, migrations, ...)

   c) Responsive (induced by environmental variability)

3) These characteristics allow new insights into the dynamics of fish stocks, and contribute to such innovations as automatic species identification, recognition of stock status (cluster, schools) etc. Moreover, some behavioural characteristics are highly favourable to acoustic surveys:

   a) aggregative behaviour (decrease sampling effort, multi-species mixing)

   b) fish identification

   c) trophic relationships, etc.

4) Acoustics may provide to itself, as well as to other research fields valuable information about behaviour, which allows to correct the acoustic data and sampling strategies in real time. Moreover, it is able to provide to other areas of fisheries biology a unique data source on fish behaviour in relation to:

   a) catchability and availability to fishing gear

   b) reactions relative to the environment

   c) monitoring of behavioural changes

   d) the definition and following of populations (stocks)

   e) adaptation to exploitation

   f) trophic relationships

5) Acoustic methods and instruments presently exist which allow for an exhaustive spatial and temporal observation which, thanks to dynamic 2D and 3D visualisation:

a) the unbiasing of sonar data

b) the detailed description of spatial behaviour in relations to any environmental element.

10 RECOMMENDATIONS

10.1 Target strength recommendations

The WGFAST did not consider that a new Study Group on TS problems was needed at the present time. Nevertheless, continuing research on TS problems should be strongly encouraged with a view to substantial progress being made towards better knowledge of TS importance in acoustic biomass estimation, fish behaviour studies, remote observation and classification of sonar targets. .

Specifically WGFAST recommends:

- Incorporation and application of equipment (hardware and software) improvements e.g. coded signals, matched filtering, multifrequency measurements, amplitude-based techniques, etc.
- Continued development and evaluation of in situ measurement techniques for acoustic stock assessment using analysis, simulation and real data.
- Evaluation and application of in situ target strength measurement for species ID and behaviour studies (avoidance, diel migration etc.)

10.2 Behaviour recommendations

WGFAST recommends that behaviour be studied along three lines:

- Adaptation of fisheries acoustics to monitor and quantify fish behaviour effects on biomass estimation
- The use of acoustic observation of fish behaviour to help understand fish stocks
- The development of new methods, tools and modelling to resolve fish behavioural effects on biomass estimation

10.3 Data exchange formats

The WGFAST recommends that:

- The HAC format be adopted by the ICES community as the common data exchange format for the next five years
- The HAC format and information be made available through a web page under the responsibility of the ICES secretariat
- A group of experts be created to develop the next versions of HAC that could take into account the major observations pointed out during the meeting.

10.4 Special topics

- **Fish avoidance**

  The FAST W.G. recommends a special topic be organised to consider and quantify the effect of fish avoidance on acoustic data collection and abundance estimates. A small group of experts leaded by Geoff Arnold will work by mail and present at the next FAST meeting the state-of-the-art on this point.

  Justification: the FAST W.G. agreed that fish avoidance is one of the most important fish behaviour characteristics producing bias on acoustic data. The effect appears both on the TS, the species identification, and the echo integration results. According to the results and recommendation of the group, the way how to consider the theme "fish avoidance" in the future will be defined during the next meeting

Acoustic bottom classification

The FAST recommends a special topic be organised during the next meeting on the bottom type classification and visualisation and the effect of bottom type on fish population structure and behaviour.

Justification: it appears that fish behaviour is in a large part related to the conditions of the environment. One particular point is the role of the bottom type on the distribution of stocks. It exists acoustic tools which provide direct classification of bottom type and allow to link precisely the fish abundance and the type of bottom. These tools and the potential improvement they bring to fish stock survey will be evaluated.

10.5 Other recommendations and information

WGFAST also recommends that a Theme Session be held on Priorities for the next decade in Fisheries Acoustics.

The WGFAST should meet at the RIVO, Vermuyden, Netherlands between 17 th-25 th, April 2000. It was noted that the current arrangements, whereby sessions are run in parallel by the WGFAST and Fisheries Technology and Fish Behaviour Working Groups, prevent interchange between the two groups, other than at the Joint Meeting, and that attendance at the latter was weakened by holding it at the end of the week. A review of timing of the two meetings was recommended.

The Chair of WGFAST (François Gerlotto) agreed to stand for that post for one further year, after which Yvan Simard indicated that he would be willing to take over the position.

Members were reminded of the ICES Symposium on "100 Years of Science under ICES" : Helsinki, Finland, 1-3 August 2000. Convener: Dr E. D. Anderson (USA).Call for papers, Pre-registration Form and Preliminary Programme

Also the ICES Symposium on ."Acoustics in Fisheries and Aquatic Ecology" : Montpellier, France, 10-14 June 2002 Co-Conveners: Dr F. Gerlotto (France) and Dr J. Massé (France). Co-sponsors: Acoustical Society of America, UK Institute of Acoustics, Société française d'acoustique.

Further details of both can be found at the web-site:

http://www.ices.inst.dk/informat/about.htm

11 CLOSURE OF WGFAST MEETING

The Chair thanked the local hosts at St John's, Newfoundland, for their hospitality, and closed the meeting.

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APPENDIX B – NATIONAL PROGRESS REPORTS

Acoustic activities 1998 - Progress Report of Denmark.

Jens Pedersen, Bo Lundgren, J. Rasmus Nielsen, Torben F. Jensen, and Karl Johan Stæhr.
Ministry of Food, Agriculture and Fisheries
Danish Institute for Fisheries Research (DIFRES)
North Sea Centre
P.O.Box 101
DK-9850 Hirtshals
Denmark

I) Standard surveys

Three standard acoustical surveys were performed:

1. A survey on the herring *(Clupea harengus)* in the Skagerak and adjacent waters in the North Sea and Kattegat in July with R/V Dana. This survey is a part of the International Herring Survey in the North Sea coordinated by ICES. Contact: Jens Pedersen, jp@dfu.min.dk.

2. Two surveys during March-May in the Sound between Denmark and Sweden to monitor the migration of the Rügen herring *(Clupea harengus)* stock with R/V Havfisken (supplemented with sampling of acoustic and biological data wit R/V Dana in May). The objective of the project is to provide background information for evaluation of possible environmental impacts of the construction of the Sound Bridge between Denmark and Sweden including possible changes in the distribution and migration patterns of the herring in the Sound. Contact: J. Rasmus Nielsen, Bo Lundgren and Karl Johan Stæhr, rn@dfu.min.dk, bl@dfu.min.dk, kjs@dfu.min.dk

1) Special field investigations

3. One survey with R/V Dana in December to investigate the conditions for the recruitment of cod *(Gadus morhua)* in the Baltic was performed. The survey included by measurements of the distribution and density of juvenile cod in relation to hydrographical and biological conditions in the Central Baltic Sea using hydroacoustic and trawl sampling methods. This survey is part of the EU CORE and STORE projects. Contact: Rasmus Nielsen, rn@dfu.min.dk and Bo Lundgren, bl@dfu.min.dk .

4. Two surveys to measure swimming activity and swimming speed of individual saithe (*Pollachius virens*) by tracking with a split beam echo sounder were carried out in May and November in the Northern North Sea with R/V Dana. The diurnal swimming activity and speed is calculated by the use of a newly developed program. The swimming speed of the individual fish is corrected for the water current velocity measured by an ADCP during the survey. This survey is part of the EU CORMA project. Contact: Jens Pedersen, jp@dfu.min.dk.

I) Laboratory investigation

An experiment to measure the target strength of juvenile gadoids was continued. The experiment was carried out in the large 2000 m^3 experimental tank in Hirtshals using a 120 kHz EY500 split beam echo sounder. To check the presence of single fish in the beam and approximate tilt angle of the fish the experiment was complemented by video monitoring. Contact: J. Rasmus Nielsen, rn@dfu.min.dk, and Bo Lundgren, bl@dfu.min.dk.

Establishment of an experimental design of a combined wideband (appr 100-200 kHz), a split beam and a video system in the experimental tank in Hirtshals. The purpose is to obtain pulse spectra from juvenile gadoids. The system comprises a RESON wideband transducer system with a transmitter and a receiver as well as a SIMRAD EY500 split beam system. The videosystem consists of two high resolution under-water video cameras running in non-interlaced mode connected to two videograbbers. An image capture and analysing software system to track position and attitude angles of the fish in the beam is being developed. Pilot tests of the overall system have been performed. Contact: Bo Lundgren, bl@dfu.min.dk and J. Rasmus Nielsen, rn@dfu.min.dk

1. Other activities.

New methods to stratify survey data with regard to depth contours are being tested.

This work is carried out in cooperation with the ConStat company, North Sea Centre. Contact: Jens Pedersen, jp@dfu.min.dk, and Torben F Jensen, tfj@dfu.min.dk.

Evaluation of previous acoustic surveys to optimise the allocation of trawl catches in relation to the distribution of age and size classes in the survey area is done. Contact: Jens Pedersen, jp@dfu.min.dk,

Work is done to describe the distribution of single fish in layers using point process methods. This work is made in cooperation with the ConStat company. Contact: Jens Pedersen, jp@dfu.min.dk,

Development of an international database for the acoustic and biological data from the international acoustic survey for herring (*Clupea harengus*) in the North Sea and west of Scotland is carried out. The database server is placed in the North Sea Centre. This work is part of the EU HERSUR project. Contact: Karl-Johan Stæhr, kjs@dfu.min.dk, and Peter Faber, pf@dfu.min.dk.

National progress report 1999/Acoustic activities

Iceland

Routine acoustic assessment surveys of summer spawning Icelandic herring and capelin were carried out in Icelandic waters in 1998. In May 1988, Iceland participated in a coordinated multi-national acoustic assessment of stock abundance and observations of the migrations of Atlanto-Scandian herring in the Norwegian Sea and adjacent waters. In June/early July an acoustic survey was carried out of the migrations of these herring into the Icelandic economic zone east and north of Iceland. This area was surveyed again in late July but no herring located. A short assessment survey of blue whiting, aggregating at the continental shelf southeast and south of Iceland, was carried out in July.

A contract for the building of a new research vessel was signed in February 1998. This is a trawler type multipurpose research vessel, mainly intended for fisheries research and environmental studies in Icelandic and adjacent waters. The maximum length of the vessel is 70 m and the width is 14 m. At the designing stage, measures were taken to keep the underwater radiated noise as low as practically possible, e.g. by using diesel-electric propulsion, low-noise propeller and extra sound insulation. A large drop-keel will be installed, housing all main acoustic transducers. The vessel is to be delivered in autumn 1999.

Country report: ICES Fisheries Technology Committee Working Group on Fisheries Acoustics Science and Technology Annual activities Report - April 1999

United Kingdom

Fisheries Research Services, Marine Laboratory Aberdeen, Scotland.

The marine laboratory continues with its programme of acoustic surveys for herring in the North Sea1 and west of Scotland2. Last year, these were conducted in July by the new RV Scotia1 and the MFV Kings Cross3. Data from other nations involved in the co-ordinated North Sea herring acoustic survey were combined to estimate the total biomass of the stock1. Acoustic data were also collected during the International Bottom Trawl Surveys in the North Sea and off the west coast of Scotland2.

The EC project on geostatistics came to a successful conclusion with the acceptance for publication of the final report as a book in the Blackwell Science Fish and Fisheries Series1,3. A number of EC funded projects continue, looking at the use of multibeam sonar (AVITIS)1,3, the analysis of spatial structure in fish populations (CLUSTER)2, and near seabed investigations1,4. A number of new projects have started including an EC funded project on multivariate analyses of trawl data (MIQUES)1 and an internally funded project looking at the timing of mackerel migration2. A NERC funded project (USIPS)3 looking at the application of an AUV (Autosub) to acoustic surveying was also started this year. MLA has recently acquired the software "Echoview" and will be using it for the first time during the USIPS project and then later in the July surveys for herring.

Contacts:

1	John Simmonds	simmondsej@marlab.ac.uk
2	David Reid	reiddg@marlab.ac.uk
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4	David MacLennan	Maclennan@marlab.ac.uk

ICES Fisheries Acoustic Science and Technology Working Group 1999 Progress Report

British Antarctic Survey - United Kingdom

Acoustic studies were carried out on the RRS James Clark Ross during a one-month cruise to the South Atlantic during the austral summer 1998-1999. This was the fourth year of a five-year programme aimed at a fuller understanding of inter-annual variation in the South Georgia pelagic ecosystem. Using a Simrad EK500 sounder with split beam 120kHz and 38kHz, and single beam 200kHz hull-mounted transducers, integrated and raw data were logged over a LAN to a Sun workstation. For the first season we also logged data to a pc using SonarData's EchoLog package and viewed the results using EchoView. While these two systems were used in parallel, SonarData's EchoConfig programme became our primary method for sending command files to the EK500. The sounder was calibrated at South Georgia using the target sphere method. The cruise included a large scale acoustic and oceanographic transect from a point north of the Antarctic Polar Frontal Zone to the South Georgia shelf, and a series of shorter transects to survey two areas on the edge of the shelf. Throughout the latter transects, targeted and regularly spaced plankton hauls were carried out, in support of our investigations into the identification and classification of acoustic targets in the mesoplankton and smaller nekton.

Bottom Classification

The EK500 operating at 38, 120 and 200 kHz was run aboard RRS James Clark Ross during ROV deployments from the vessel in Marguerite Bay, western Antarctic Peninsula. The ROV was equipped with video and stills camera systems, and was used to investigate differences between benthic communities in areas exposed to ice berg scour and sheltered areas. First and second bottom echoes were logged ping by ping from each frequency (where depth allowed) using SonarData Echolog_EK software, and viewed using Echoview. Attempts will be made to analyse the acoustic data from regions of differing bottom type (mud, rock, scoured, sheltered) as identified by the ROV, to develop an acoustic sea bed classification scheme. (Contact asbr)

Contacts:

1. Inigo Everson icv@bas.ac.uk
2. Jon Watkins jlwa@bas.ac.uk
3. Cathy Goss cg@bas.ac.uk
4. Andrew Brierley asbr@bas.ac.uk

ICES

Fisheries Technology Committee

Fisheries Acoustics Science and Technology Working Group

Annual Activities Report - April 1999

USA

NOAA NMFS / AFSC, Seattle, WA

The Alaska Fisheries Science Center continues work on the stock assessment of pollock and whiting in the North Pacific. Research projects include in situ target strength measurements including those collected with a lowered transducer system, variance estimation using geostatistics, and the use of an acoustic buoy for examination fish avoidance to vessel and trawl noise.

Contact: Chris Wilson, chris.wilson@noaa.gov.

NOAA / NMFS Woods Hole, MA

The Northeast Fisheries Science Center (NEFSC) conducted a fisheries acoustic survey on Atlantic herring in the Gulf of Maine and Georges Bank regions during late-August through early October of 1998. Sampling operations included systematic surveys and in-situ TS experiments using EK500, omnidirectional sonar, midwater trawls, and underwater video. Laboratory TS experiments are currently being planned for this summer. The NEFSC, Maine Department of Marine Resource, Canadian Department of Fisheries and Oceans, and the herring fishing industry have worked cooperatively in a series of acoustic data working workshops and planning meetings in preparation for the 1999 herring acoustic survey.

Contacts:

1. Bill Michaels at William.Michaels@noaa.gov or
2. Mike Jech at j-jech@whsunl.wh.whoi.edu.

NOAA / NMFS / SFWC, San Diego, CA

The Antarctic Ecosystems Research Group at the Southwest Fisheries Science Center continues work on stock assessment of krill and fish off the Antarctic Peninsula, off the coast of Southern and Central California, in the Gulf of California, and recently in the Ligurian Sea. Primary research projects include ecosystem approaches to fisheries management, predator- prey interactions (whale-krill, penguin-fish/krill, and seal-fish/squid/krill), uncertainty in echo integration techniques, enhanced methods for in-situ target strength measurements, multi frequency techniques for taxa identification and delineation, and velocity measurements of fish and zooplankton aggregations with acoustic Doppler current profilers.

Contact: David Demer, ddemer@ucsd.edu

Marconi Aerospace (formerly Tracor), San Diego, CA

Recent work within Marconi's Analysis and Applied Research Division has been focused in four areas: (1) adaptation of the multifrequency TAPS zooplankton instrument for long-term monitoring in relatively shallow water environments; (2) development of methods for examining the emergence and re-entry of benthopelagic zooplankton and micronekton from and to the seabed; (3) examination of methods for determining shapes and physical properties of zooplankton in situ; and (4) processing of acoustical data obtained from arrays of sonobuoys to determine dive patterns for sperm whales. Marconi scientists also participated in the collection acoustical data designed to describe zooplankton distributions in the TIES project in the Chesapeake Bay; in the LOOPS program of research in Mass Bay; in a project which examined post-larval shrimp and other zooplankton in the Ogeechee River (GA) estuary; and in the Thin Layers program in East Sound at Orcas Is, WA. Copies of several recent publications can be obtained from the contact listed below.

Contact: D.V. Holliday at holliday@tracor.com.

Scripps Inst. of Oceanography / Marine Physical Lab / UC San Diego

A new instrument -OASIS (Optical-Acoustic Submersible Imaging System) has been developed for three-dimensional acoustic tracking of zooplankton with concurrent optical imaging to verify the identity of the insonified organisms. OASIS also measures target strengths (TS) of freely swimming zooplankton and nekton of known identity and 3-D orientation. The system consists of a 3-dimensional acoustic imaging system (FishTV), a sensitive optical CCD camera with red-filtered strobe illumination, and ancillary oceanographic sensors. The sonar triggers the acquisition of an optical image when it detects the presence of a significant target in the precise location where the camera, strobe and sonar are co-registered. Acoustic TS can then be related to the optical image, which permits identification of the animal and its 3-D aspect. The system was recently deployed (August, 1996) in Saanich Inlet, B.C., Canada. Motile zooplankton and nekton were imaged with no evidence of reaction to or avoidance of the OASIS instrument package. Target strengths of many acoustic reflectors were recorded in parallel with the optical images, triggered by the presence of an animal in the correct location of the sonar system.

Contact: Jules Jaffe, jules@mpl.ucsd.edu.

NOAA / GLERL and the University of Michigan

The NOAA Great Lakes Environmental Laboratory and the University of Michigan's Cooperative Institute for Limnology and Ecosystems Research continue work on acoustically assessing predatory-prey spatial and temporal interactions in North American Great Lakes and coastal estuaries. The Trophic Interactions in Estuarine Systems (TIES) project on Chesapeake Bay, USA measures biological and physical characteristics of the ecosystem over a wide range of spatial and temporal scales. Data are used to investigate biological-physical interactions, trophic-level connections, and to bioenergetically model fish growth and habitat preference. Fish abundance, distribution, and biomass are mapped at high spatial resolution throughout the bay for all seasons. Additional acoustic projects include modelling and measuring species- specific backscatter to quantify the relative importance of biological (length, aspect) and physical (carrier frequency) factors that influence echo amplitudes from single fish and aggregations of conspecifics.

Contacts:

1) Steve Brandt, brandt@glerl.noaa.gov
2) John Home, home@glerl.noaa.gov
3) Michael Jech, jjech@whsunl.wh.whoi.edu

Woods Hole Oceanographic Institution

The active-acoustics bioacoustics group at WHOI has continued a broad range of activities- laboratory measurements, theoretical modelling, and field measurements. The laboratory research involves measurements of acoustic backscatter, sound speed, and density of zooplankton. Theoretical modelling includes development of scattering models for the forward and backward directions and classification algorithms in the spectral and temporal domain. Field research includes use of the new towed system BIOMAPER-11 to survey Georges Bank off New England. Other field research involves in situ target strength measurements of zooplankton using a ROV.

Contact: Tim Stanton, tstanton@whoi.edu

Cornell University

A research team with scientists from Cornell University, the Woods Hole Oceanographic Institution, and Louisiana State University continue multi-frequency acoustic and video remote-sensing surveys to assess diapausing populations of *Calanus finmarchicus* in the Gulf of Maine as part of the US GLOBEC Georges Bank Program. Broad-scale survey cruises conducted in early and late autumn each year are used to estimate survivorship of the diapausing *Calanus* and the scale-dependent spatial coupling of *Calanus* and its principal invertebrate predators. The results from these field studies also will be used as input to coupled physical-biological models to examine how physical transport processes in the Gulf of Maine interact with *Calanus*' seasonal and diel vertical migration behaviours to seed Georges Bank with new recruits each winter.

Contact: Chuck Greene, chg2@cornell.edu

APPENDIX C – LIST OF SYMBOLS, NAMES AND DEFINITIONS FOR ACOUSTICAL QUANTITIES

K indicates a constant multiplier to scale s_v or s_V in a non-SI unit should that be required.

Symbol	*Name*	*Defining equation*
σ_{bs}	Backscattering cross-section	$\sigma_{bs} = [\, r^2 I_{bs}(r) / I_0 \,]$
σ	Acoustic cross-section	$\sigma = 4\pi r^2 [\, I(r) / I_0 \,] = 4\pi \sigma_{bs}$
TS	Target Strength	$TS = 10 \log_{10} (\sigma / 4\pi)$
S_v	Volume backscattering coefficient	$S_v = \Delta\sigma_{bs} / \Delta V$
S_V	Volume scattering coefficient	$S_V = \Delta\sigma / \Delta V = 4\pi S_v$
s_v	Scaled volume backscattering coefficient	$s_v = K S_v$
s_V	Scaled volume scattering coefficient	$s_V = K S_V = 4\pi s_v$
S_a	Area backscattering coefficient	$S_a = {}_{d1}\int^{d2} S_v \, dx$
S_A	Area scattering coefficient	$S_A = {}_{d1}\int^{d2} S_V \, dx = 4\pi S_a$
s_a	Nautical area backscattering coefficient	$s_a = (1852)^2 S_a$
s_A	Nautical area scattering coefficient	$s_A = (1852)^2 S_A = 4\pi s_a$
Sv	Log volume backscattering coefficient	$Sv = 10 \log_{10} (S_v)$
SV	Log volume scattering coefficient	$SV = 10 \log_{10} (S_V)$
sv	Log scaled volume backscattering coefficient	$sv = 10 \log_{10} (s_v)$
sV	Log scaled volume scattering coefficient	$sV = 10 \text{Log}_{10} (s_V)$
Sa	Log area backscattering coefficient	$Sa = 10 \log_{10} (S_a)$
SA	Log area scattering coefficient	$SA = 10 \log_{10} (S_A)$
sa	Log nautical area backscattering coefficient	$sa = 10 \log_{10} (s_a)$
sA	Log nautical area scattering coefficient	$sA = 10 \log_{10} (s_A)$

APPENDIX D

Study Group on Echo Trace Classification

Report of the final meeting 19 April 1999, St Johns, Newfoundland, Canada

1. Opening of the meeting

The meeting was chaired by D. Reid, A Brierley was appointed rapporteur. A full list of participants is attached

2. Background

The terms of reference for SGETC as agreed at the FAST meeting (Woods Hole, USA, 1996) and approved at the ICES Annual Conference, Reykjavik, Iceland, September 1996 were:

Address and document aspects of fish aggregation, distribution and classification including:

i. Methods of classifying echo traces

ii. Comparison of the performance of these methods

iii. The effect of fish behaviour on the precision of classification

iv. The scope for integrating existing research programmes

The study group will report to the April 1999 meeting of WGFAST and to the Fishing Technology Committee at the 1999 Annual Science Conference

2.2 The general background to this study group was presented in the report of the first meeting of the SGETC in Hamburg, 15-17 April 1997. The structure and layout of the report was determined at the second meeting of SGETC in La Coruna, Spain, 16 - 18 April 1998.

3. Organisation of the meeting

The meeting was organised to review the completed draft sections of the report, consideration of these and the discussion and implementation of any further work for the completion of the final report. The sections agreed for the report at the La Coruna meeting and the section collators are given below.

A. Appropriate school descriptors (D. Reid)
B. Single and Multi-Beam Sonar (F. Gerlotto)
C. Wide band & Multi frequency sounders (DN MacLennan)
D. Post Analysis procedures (G Swartzman & D Reid)
E. Data visualisation and analysis software (A Castellon)
F. Data exchange formats (I McQuinn)
G. Model simulations to provide beam correction parameters (N. Diner)

As agreed in La Coruna this meeting was intended solely as an editorial meeting. No actual presentations were made. Instead, the completed draft sections were collated and then circulated to all contributing authors prior to the meeting. Authors were requested to read and critically appraise the drafts for substantive scientific issues. Copy editing will be carried out following the St Johns meeting.

This report is intended to detail any substantive changes to the submitted drafts. The full texts will not be included.

3.1 Standard set of appropriate descriptors for echo trace classification

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

The examples of environmental variables should be expanded
The definitions of perimeter and perimeter roughness should be consistent with each other and with the relevant figure.
The potential for harmonising the symbology between this chapter and that on beam pattern corrections
Seabed parameters were dependent on sea state
"fish" should be changed to "fish and plankton" throughout

3.2. Single and Multi-Beam Sonar

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

The problems of lateral range in the presence of stratification should be emphasised
The possibility of using "bottom bounce" for near surface observation should be mentioned
The differences between the medium term and long term potential for sonar should be described.

3.3. Wide band & Multi frequency sounders

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

Mention should be made of cepstral coefficients for frequency description in wide band.
Mention should be made of parametric arrays although little use has been made of this approach.

3.4. Post Analysis procedures

This section was made up of 7 sections:

Point processes (P Petitgas & M Soria)
Geostatistics (P Fernandes)
Generalized Additive Models and clustering techniques (G Swartzman)
Neural Networks (S Georgakarakos & J Harabolous)
Discriminant Analysis (A Brierley)
Bayesian Approaches (C. Scalabrin, Y Simard & G Swartzman)

Point Processes

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

The text contained too many caveats
The rationale for using NEXT neighbour rather than NEAREST neighbour needs to be emphasised
A section on limitations would be appropriate
provide method for downloading the software described
provide guide to which references are for experts and beginners

Geostatistics

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

More emphasis could be given to the potential to map many variables e.g. school size.

Generalized Additive Models

The text was agreed as being substantially complete and acceptable. No further points were raised

Clustering techniques

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

This section is brief but this reflects the, to date, minimal use of this technique in echo trace classification. Given that the subject is well documented in the primary literature, it was agreed that the section should remain unaltered.

Neural Networks

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

The section provides a very good appraisal of the technique for species ID, but that the potential for other types of classification.

Discriminate Analysis

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

A few other references to applications in classification were identified for inclusion
An example of the analysis output would be useful

Bayesian Approaches

This section has not been completed. C Scalabrin has agreed that the text will be available by mid-May. The chairman has requested T Hammond (CEFAS, Lowestoft, U.K) to provide assistance.

3.5. Data visualisation and analysis software

This section is largely complete, however the text has not been made available as yet due to sea commitments. It is expected that it will be delivered by early May.

3.6 Data exchange formats

A text was provide on the Canadian .hac file format. Following discussion it was agreed that while data exchange formats were an appropriate topic for discussion by the SG it was note relevant to the CRR, as the situation was still unclear on standardisation. The chairman thanked I McQuinn for his work and apologised for not including the text.

3.7 Model simulations to provide beam correction parameters

The text was agreed as being substantially complete and acceptable. A small number of points were raised:

It should be stressed that the corrections give a more accurate mean distribution of school parameters rather than explicitly correcting each individual school.
The observation that most of these corrections are required because we are observing 3D objects using a 2D system should be emphasised

4. Other substantive changes

4.1. Elements for inclusion in "Introduction"

It was agreed that a number of elements should be included in the introduction to the report. These elements were mainly aimed at items which were applicable to a number of the report sections. These should include:

An overview of the function and value of the subjects covered in the report, particularly species identification and the provision of better information to allow modelling of fish distribution for survey designs studies.
The importance of retaining a view of the biological nature of the objects being studied.
The problems of studying a 3D phenomenon using a 2D methodology
Need for a standard data format
The medium and long term goal for this type of work

4.2. Order of the chapters

Data visualisation and analysis software
Appropriate school descriptors
Model simulations to provide beam correction parameters
Post Analysis procedures: classification
- Clustering techniques
- Artificial Neural Networks

Post Analysis procedures: spatial layout
- Point Processes
- Geostatistics
- Generalised Additive models

Single and Multi-Beam Sonar
Wide band & Multi frequency sounders

5. Recommendations

5.1. It was agreed that the report was substantially complete. All remaining editorial work would be carried out by the chairman in consultation with the contributing authors. The chairman agreed to produce a final draft of the introduction following the lines given in 4.1. This would be combined with a short Executive Summary. It was further agreed that the sections on post analysis procedures should include an overview. A first draft of this was completed during the FAST meeting by the chairman and G Swartzman. A second draft will be prepared and circulated to the contributing authors in May 1999.

5.2. The group recommended that the terms of reference remained unaltered, and that no further meetings are required. The SGETC reported to the April 1999 meeting of the WGFAST and will also report to the Fishing Technology Committee at the 1999 Annual Science Conference.

5.3. All further contributions should be sent to the chairman before the end of May 1999. No further submissions will be accepted after this time. It is intended to submit the completed report to ICES in June 1999 for consideration as a Cooperative Research Report.

6. Closure of the meeting

6.1. The chairman thanked the hosts, Memorial University of Newfoundland and the Department of Fisheries and Oceans, Canada and particularly Steve Walsh and George Rose for their support in ensuring a trouble free meeting. The chairman also thanked the participants for their efforts and submissions and also for the enthusiastic participation in the meeting.

List of Participants.

David Reid, UK (Chairman)

John Anderson, Canada
Andrew Brierly, UK
Dave Demer, USA
Noel Diner, France
Paul Fernandes, UK
Stephane Gauthier, Canada
Francois Gerlotto, France
Ian Higginbottom, Australia
Van Holliday, USA
Rudy Kloser, Australia
Bo Lundgren; Denmark
David McLennan, UK
Ian McQuinn, Canada
Gordon Schwartzmann, USA
John Simmonds, UK
Valerie Tonard, France