Fish Capture Committee

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REPORT OF THE
WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY

Aberdeen, Scotland

17 June 1995

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK-1261 Copenhagen K Denmark

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TERMS OF REFERENCE

In accordance with C Res 1994/2:9 the Working Group on Fisheries Acoustics Science and Technology (Chairman: Mr E J Simmonds, UK) met in Aberdeen, Scotland, 17 June 1995 to:

a) review the conclusions of the ICES International Symposium on Fisheries and Plankton Acoustics (Aberdeen, 12-16 June 1995) to identify the most important and productive areas for future research;

b) consider and comment on the report of the Study Group on Target Strength Methodology;

c) consider and comment on the 1994 ICES Workshop on Hydroacoustic Instrumentation.

OPENING OF THE MEETING AND APPOINTMENT OF RAPPORTEUR

The chairman opened the meeting and Dr P Fernandes of the SOAFD Marine Laboratory, Aberdeen, Scotland, was appointed as rapporteur. The agenda was adopted.

HYDROACOUSTIC INSTRUMENTATION WORKSHOP REPORT

The report from the Hydroacoustic Instrumentation Workshop was submitted by Mr H P Knudsen, Norway. This workshop took place at the headquarters of the British Antarctic Survey, Cambridge, UK, from 3-5 May 1994. Questions regarding the report were invited. The report was commended and a vote of thanks was conveyed to Mr Knudsen.

PRESENTATION OF THE REPORT FROM THE STUDY GROUP ON TARGET STRENGTH METHODOLOGY (LED BY MR E ONA, NORWAY)

Introduction

A meeting of the Study Group on Target Strength Methodology took place on 8-10 June 1995, immediately prior to the symposium. Substantial work was carried out on the report and it is now in its final draft stage. An offer was made to distribute draft copies amongst interested parties with the intention of incorporating any alterations or additional comments prior to completion. The final report will be presented at the ICES Statutory Meeting in September this year.

The history of the Study Group was briefly outlined. Since its inception in 1992/1993, the group has met three times and has had extensive communication by mail. A point regarding the aims of the group was stressed in that its coverage was restricted specifically to techniques for fish and micronekton (mostly krill).

Contributors

The principal contributors to the manuscript were acknowledged. These were listed according to their inputs:

Dual beam:	Dr J Traynor	Alaska Fish Sci Centre, USA
Single/split beam:	Mr E Ona	Inst of Marine Res, Norway
	Dr L Rudstam	Cornell Bio Field Station, USA
	Dr P Reynisson	Marine Res Inst, Iceland
	Dr H Solli	SIMRAD Subsea A/S, Norway
Biology:	Dr I Everson	British Antarctic Survey, UK
	Dr J A Jacobsen	Fish Res Centre, Faroe Isles
	Dr D Miller	Fish and Oceans, Canada
Single fish recognition criteria:	Dr M Barange	Sea Fisheries Inst, South Africa
	Mr M Soule	Sea Fisheries Inst, South Africa
	Mr H Nes	SIMRAD Subsea A/S, Norway
Deep measurements:	Mr R Kloser	CSIRO Marine Labs, Australia
	Mr J Dalen	Inst of Marine Res, Norway
Miscellaneous inputs throughout:	Mr E J Simmonds	SOAFD Mar Lab, UK
	Dr D V Holliday	Tracor Applied Sci, USA

Report Contents

An outline of the proposed contents of the report was then presented. The contents, by chapter, will be as follows:

1 Introduction
2 Definition and Terms
3 Single Beam
4 Dual Beam
5 Split Beam
6 Single Target Recognition Criteria
7 Biological Sampling
8 Summary of Other Methods
9 Discussion

A number of points were then made with regard to specific chapters. In Chapter 2 (Definitions and Terms) explicit justification for measuring Target Strength (TS) is given by the requirement for abundance estimation to obtain an unbiased measure of the average acoustic cross section of the fish. This is as opposed to the acquisition of average length from TS, an objective that is not a concern of the report. A detailed definition of TS is given which can be summarised by the property of a fish manifested by its ability to reflect and scatter acoustic energy, due to both physiological and behavioural effects.

The true TS distribution of fish targets may often be different to the measured TS distribution. Chapters 3, 4 and 5 describe the system types available for TS estimation and what their effects are on the measured TS. Each of these chapters is divided into the same sections:

1 Calibration
1.1 On Axis
1.2 Beam
2 Removal of Beam Effect
3 Effect of Noise
4 An Example in Detail

Chapter 6 deals with single target recognition criteria. It describes the current algorithms and the errors associated with their use under situation-specific conditions. Important points with regard to the algorithms performance include variations in pulse length criteria, phase jitter and fish density. This was highlighted as one of the most important sections in the report. Reference was made to a number of papers presented at the FAST WG and ICES Statutory Meeting in 1994, which included an interesting analogy to military tactics in radar avoidance, illustrating the problem succinctly.

Chapter 7 details the measurement of biological samples and the sampling errors that may occur. Chapter 8 provides a summary of other *in situ* or ex-situ methods. These include fish tracking, fish counting, multi-frequency applications and deep water towed systems. Finally, the discussion in Chapter 9 deals with the comparative analysis of errors and relates this to the expected biological variability. This chapter is yet to be completed.

A peripheral detail that the report is dealing with pertains to the departure from point source targets. This may occur when the target is large relative to the beam at close ranges, or when the array is large relative to the target. In addition, concern about TVG effects on the pulse at distances between 1 and 2 near-field edges was expressed. Consequently, the report aims to set distance limits for measurements. However, a comment from the floor indicated that even in near-field conditions, calculations for its correction can be applied. These problems will be addressed in the discussion, although it was highlighted that this should take the form of only the briefest of notes, so as to ensure completion of the document on time.

The report also identifies two main areas on which attention should be focused in the future. These were: education, with specific reference to the availability of courses in TS measurements; and the effects of vessel noise on fish tracking.

Report Status

The report is in its final stages. It requires retyping and redrawing of figures. There will then be some editing and incorporation of selected comments. It is hoped that it will be presented to the ICES Fish Capture Committee at the 1995 Statutory Meeting and then published as an ICES Cooperative Research Report.

Discussion

During the ensuing discussion it was apparent that some confusion was evident as to the purpose of the report. It was clarified by stating that the report was a methodological approach to measuring the TS of single target point sources, and ultimately it is aimed at the novice user as a comprehensive manual for that purpose. The extensive and detailed description of how to obtain "ground-truth" biological samples was questioned, but was justified by consensus. The problem of near field observations will be briefly noted and should not concern the average user as this is obviously a specialised field, although it was mentioned that such measurements had been reported on during the symposium. The absolute definition of TS was put to question with reference to its dependence on so many local and temporal conditions. Although this was acknowledged, it was stressed that the physical definition of TS is important as an explicit measure, which should not be equivocated due to the complexity caused by the variety of dependent parameters.

DISCUSSION OF THE ICES INTERNATIONAL SYMPOSIUM ON FISHERIES AND PLANKTON ACOUSTICS

Target Strength - (led by Dr J Traynor)

Review of contributions

There were a total of 34 papers dedicated to TS in the symposium; for the purposes of this discussion these were divided by discipline according to Table 1. Some concern was expressed for the potential abuse of TS measures beyond the capabilities of current methodology. This point was made with particular reference to the problems with algorithms for single target recognition criteria. It was reiterated that current algorithms only work well at low densities and short ranges. Target tracking was noted as a relatively new application which provides two very useful applications. There is the obvious use in behavioural studies, but it also assists in ensuring the isolation of single targets and a variety of fish aspects resulting, in improved TS measurements.

Table 1. Target strength contributions at the ICES International Symposium on Fisheries and Plankton Acoustics, June 1995, Aberdeen, Scotland

	Marine fish	Plankton	Freshwater/Rivers	Total
Tracking	2		3	5
TS	10	4	3	17
Methods	2			2
Swimbladder/models	2	4		6
Low frequency	2			2
Ecology			2	2
Total	18	8	8	34

The emphasis on zooplankton TS had been on modelling and frequency dependence. It is not clear of the consequences of such work and most of the issues are not fully resolved. No new techniques had been demonstrated for swimbladder modelling although a couple of new species had been studied. Wideband systems (including the 10 kHz "chirp" system) were of particular interest as they may provide real potential for improving resolution and overall TS measurements. However, some concern was expressed as to whether these measures provide appropriate TS values for echo-integration.

The group was warned of the dangers of working with single beam derivations of TS. The common feeling that the techniques work as well as multi-beam systems is a dangerous assumption, particularly for inexperienced personnel.

Discussion

The discussion that followed centred on two main themes: wideband and low frequency systems; and problems associated with single target recognition criteria. With regard to the latter, the group will obviously benefit from the TS methodology report described above. A few concerns were expressed as to the future utility of *in situ* methods in view of the current problems. The group was assured that despite the problems with *in situ* methods, the technique still provides very valuable information under stringent low density monospecific conditions with high signal to noise ratios (SNR). Even in the absence of a reasonable SNR, it was suggested that the problem could be alleviated using coherent signal processing. Improvements can be made by tracking fish and obtaining good representative biological samples.

A distinction was made, for clarity, between wideband or broadband systems that are centred around commonly used frequencies, and those centred around hitherto less utilised lower frequencies. Both fields have only recently begun to be more widely used, although their development dates back to Van Holliday's work in the late 70s. The same author pointed out to the group that more experience is needed in these fields, particularly for the lower frequency applications.

Despite their unfamiliarity, the lower frequency systems have many theoretical advantages because of the greater amount of information provided by the scattering models at the lower end of the frequency spectrum. In addition, the low frequencies have longer operating ranges, require little in the way of technological advances and can be used to study swimbladder resonance (and potentially, size). The latter is a subject of current research in Norway (Dr K Olsen, University of Tromso) where the effects of depth on herring swimbladder resonance are being examined.

The group was very enthusiastic about the potential for wideband applications in the future, although, as with any new techniques, questions regarding calibration, resolution and current availability of systems were raised. Influences such as doppler effects and body part resolution (eyes, otoliths, etc) may be important, and the phase linearity of the receiver also needs to be carefully addressed. One system already in use is the parametric source system. The development of future systems may require a more qualified definition of target strength. The current definition would limit the bandwidth to about 10 kHz where the resolution of the system is approximately three or four times the size of the target. The group was reminded that when dealing with wideband systems, the potential differences between rayleigh and geometric scattering should be taken into account.

Areas for future research

The frequency and size related TS of krill should be considered with the aim of developing recommended TS scaling factors.

A comparison should be made between single beam, multi-beam and split beam techniques for a variety of TS distributions to attempt to examine the validity of single beam procedures.

Surveys - (led by Dr I Hampton)

Report on an informal workshop on the estimation of variance in marine acoustic surveys

A workshop as titled above was held to take advantage of a number of visiting scientists in Cape Town on 5 August 1994. Papers were given by George Jolly, Pierre Petitgas, Alistair Murray and Ken Foote. The objective of the workshop was to compare design-based estimators of variance (from random sampling theory) with model-based estimators (from geostatistics).

A report of the workshop is available from Dr I Hampton which was summarised as follows:

1. Random sampling:

- Yields unbiased estimates of the mean and variance, irrespective of population distribution.
- No correction is necessary for the correlation between sample values (unlike in systematic sampling).
- Systematic surveys are more precise but the estimate of precision is generally biased if the random sampling estimator is used.
  Mathematically sound methods of estimating the variance from systematic surveys are needed because, despite its limitations, this type of survey design continues to be popular.

2. Geostatistics:

- The estimates of variance are made from a model of spatial structure, not from the actual data.
- There are various meanings of geostatistical estimators of variance (according to transitive and intrinsic theory).
- There is a need to include an objective analysis of the uncertainty associated with the modelling of parameters. These may only be small errors.
- It is useful for pre-stratification on the basis of expected differences in spatial distribution.
- There is a concern over the complexity and non-robustness of the technique.
- Its use as a mapping tool is accepted.

3. Conclusions:

- There was no consensus on all issues, but at least the problems were identified clearly.
- There was disagreement as to whether the geostatistical estimators of variance were generally more "realistic".
- Geostatistics techniques will not necessarily give a more precise estimate of the mean.
- Geostatistic techniques break down in the presence of strong periodicity.

Discussion

The discussion was initiated with a reminder to the group that most of the issues presented had been dealt with at the workshop on the applicability of spatial statistical techniques to acoustic survey data, held in Reykjavik, in September 1991. The group was reminded to refer to the resultant report (Anon, 1993) and to Simmonds *et al.* (1992) for a review and definitions of terms. Specific reference was made to the difference between classical variance estimators, which estimate parameters of the population (in a statistical sense), and geostatistical estimators, which estimate the difference between the measure and what is actually present within the survey area. The two methods are actually incomparable because they deal with different parameters, however, the variances obtained are numerically equal, if a random survey is adopted. In the presence of autocorrelation and a non-random design, the two estimates are conceptually and numerically very different.

The discussion quickly reverted to a debate on the choice between random or systematic surveys. The group was reminded that the only issue of contention is the matter of variance estimation. Both strategies were accepted as giving unbiased estimates of the mean (except in the case of periodicity in the data which may cause bias in the systematic-centred approach; this is solved by introducing a random start point). All parties were agreed that in the absence of knowledge on the distribution of a stock a systematic survey would be better for mapping purposes.

The debate then became very specific to the requirements of the user: proponents of the systematic survey argued that it was more precise and in the absence of a need for variance estimates was, therefore, better; whilst those who required an estimate of biomass with variance argued that a random survey was better. One or two members believed that temporal fluctuations are such that a systematic survey is actually a random survey. The group was reminded that using a systematic survey will result in a biased estimate of variance if a random distribution is assumed. The discussion was concluded by reiterating that reference should be made to the publications referred to above.

Dr G Swartzman (University of Washington, Seattle, USA) has developed software which provides model and design based estimators of abundance and variance from survey data. He would welcome any communication to share experiences.

Areas for future research

The effects of local temporal change and stock migration on survey design and analysis.

Classification and Identification - (led by Dr Y Simard)

Review of contributions

Three fields of work being carried out in classification and identification were outlined:

1. Single targets, which may involve:

- Individual targets for tracking
- Layers of single targets for image analysis

2. School pattern, which will be affected by:

- The type of system used (single beam, multi-beam, sonar, etc)
- The behaviour of the fish
- The relative movements of fish, vessel and water mass

3. Identification/classification of set volumes (which may be of any size)

- Using multi-frequency methods to produce scattering models (mostly zooplankton)
- Or discrete frequencies and wideband systems

All classification methods must have high quality data input, and the effects of beam fanning may generate problems. The current statistics of classification methods are satisfactory, although the processes of validation are less so; these are prone to errors in gear selectivity and efficiency. The training data set upon which classification is based, should be at least $1/10^{th}$ of that of the sample, but this will ultimately depend on the number of samples.

Discussion

A distinction was made between classification methods which had been derived from experimental procedures (in cages for example) and those that had been performed on survey data. This was seen as analogous to caged and *in situ* measurements of target strength. The methods utilised should depend on the objectives of the classification; principally, whether to look at schools (or aggregations) or species within area's (ie sections 2, or 3, above).

In general, this subject was agreed by most members of the group to warrant specific attention, and was even remarked as being the "challenge of the decade". However, as was pointed out from experience in the French group "Echospace", it was difficult to obtain a consensus of opinion as to the specific line of investigation to focus on. One specific proposal was made, aiming to focus on school recognition criteria in image analysis techniques. This was believed to be too limiting, particularly at the exclusion of wideband species identification.

The chairman pointed out that to justify a Study Group would require very specific and well thought-out terms of reference allocated to a small team of interested individuals. The group concluded, therefore, that there should be a special topic on general "echo classification" for the next FAST WG; more specific studies could then be identified. This approach was endorsed by the chairman of the Fish Capture Committee.

Areas for future research

Fish shoal shape (see recommendations - section 7).

Behaviour - (led by Dr K Olsen)

Review of contributions

It was noted that behaviour was becoming more of an issue in many studies, although it was not clear that there had been any significant improvements in the knowledge obtained. Three areas of interest were identified:

1. Behavioural observations, such as:

- General patterns of behaviour in nature
- Avoidance
- "Scaring" experiments

2. New methods of behavioural observations:

- Echo tracking - a powerful tool when single targets can be resolved
- Multi-beam and scanning sonars
- Doppler sonars

3. Special contribution:

- The "Acoustic fish concentrator". This device was the subject of a presentation by Kudrjavtzev and Timin (VNIRO, Russia). It consists of a conical acoustic steering beam which is mounted on a trawl and increases its efficiency by scaring fish into the mouth. If this device is effective for scaring fish, what are the implications for avoidance in fisheries acoustics?

Future trends in research should look at avoidance problems more carefully, and attempt to determine the area specificity of the problem. The question of behaviour as related to target strength also needs to be addressed. The behaviour below the vessel whilst underway may be different to that whilst stopped and there is, therefore, a need for a tool to determine the aspect of fish. More *in situ* observations whilst underway will also be useful. The potential for Acoustic Doppler Current Profile (ADCP) work to study movement of targets whilst underway may be useful for this. This instrument has already been used in the study of plankton and the possibility of applying the same technique to fish should be investigated.

Discussion

The question of modelling behaviour was raised and there was some debate as to the complexity that models should assume. Some members argued that in order to achieve anything at all, models should, initially at least, be simple and generalised. References were made to the knowledge of fishermen who depend on years of experience for their livelihoods. They, in essence, model fish distribution relative to time of year, position and other environmental factors. Others argued that simple models are unrealistic and at best will be extremely location and time specific. In the presence of such complexity it

may be necessary to study behaviour by indirect means, such as looking at school shapes as indicators of behavioural patterns. The group was agreed that any work in this field would have to be specifically applied to survey conditions.

The use of ADCP was reiterated, although in its present form the geometrical problems associated with the four beam system must be taken into account. It may be prudent to modify existing designs to suit particular objectives. The use of side-scan sonar for tracking school speed relative to the vessel was also noted.

The status of the Joint Session with the Fish Technology and Fish Behaviour (FTFB) was put into question arising out of the obvious common interests in behaviour that the two groups share. The chairman of the Fish Capture Committee outlined two major points of mutual interest: the application of new tools to study behaviour; and problems associated with sampling methodology. Despite some members discontent with past joint sessions, many were keen to maintain it on the basis of providing different viewpoints and a more multidisciplinary approach. The point was made that at a recent symposium on the ecology of fish, not a single reference had been made to the use of acoustic techniques; it may be time to recruit specialists within the field and improve our understanding of behaviour in acoustic surveys.

Areas for future research

A more comprehensive review is required (see recommendations - section 7).

CONCLUDING DISCUSSION

There was some discussion as to the format of future FAST WG. Some members are unhappy with the format used in previous years because too much time is allocated to oral presentations. In addition, papers presented are often replicated at the statutory meeting. Some would prefer more time allocated to discussion and/or more interactive study, such as that which occurs in Study Groups such as the TS methodology group. However, others maintain that oral presentations are necessary when dealing with such a large group, and provided they are not taken as definitive reports (they could just present preliminary work) are still very useful. This is particularly the case for Study Group reports, as presentation at FAST results in peer review and often a more comprehensive piece of work, which may then go forward to the Statutory Meeting. They also provide a forum for raising new areas for intensive study.

A poster session was proposed, but was generally opposed because of its low status, poor communication capability, and the difficulty in obtaining funds to travel to FAST unless an oral presentation is being given. A balance between oral presentations and discussion was acceptable to all parties and shall be adopted for the next meeting. In addition, the use of poster presentations will be encouraged and facilities for posters will be requested at the next FAST WG.

The recommendations for the next FAST meeting were then put forward (see below). It was decided that the behavioural topic should encompass a broad range of all aspects of behaviour relating to acoustic surveys. More specific studies should then be identified next year.

WORKING GROUP RECOMMENDATIONS

The Working Group made the following recommendations:

1. The FAST WG should meet in Woods Hole on Wednesday 17 - Friday 19 April 1996 to:

a) Discuss echo classification methods and results including:

- Shoal parameters
- Evaluation and definitions
- Methods and problems
- Behavioural parameters
- Standardisation
- Signal classification
- Interpretation of echograms

b) Define behavioural aspects that affect acoustic surveys with the aim of identifying the most tractable problems.

2. The report of the Study Group on *In Situ* Target Strength Measurement Methodology should be published as a Cooperative Research Report after presentation at the Statutory Meeting.

CLOSURE

The chairman thanked the members of the Working Group and Study Groups for their efforts and contributions, and for their perseverance in maintaining acoustic concentration for six intense days in succession.

REFERENCES

Anon. 1993. Report on the workshop on the applicability of spatial statistical techniques to acoustic survey data. ICES Cooperative Research Report, 195, 87 pp.

Simmonds, E.J., Williamson, N.J., Gerlotto, F. and Aglen, A. 1992. Acoustic survey design and analysis procedures: a comprehensive review of current practice. ICES Cooperative Research Report, 187, 127 pp.