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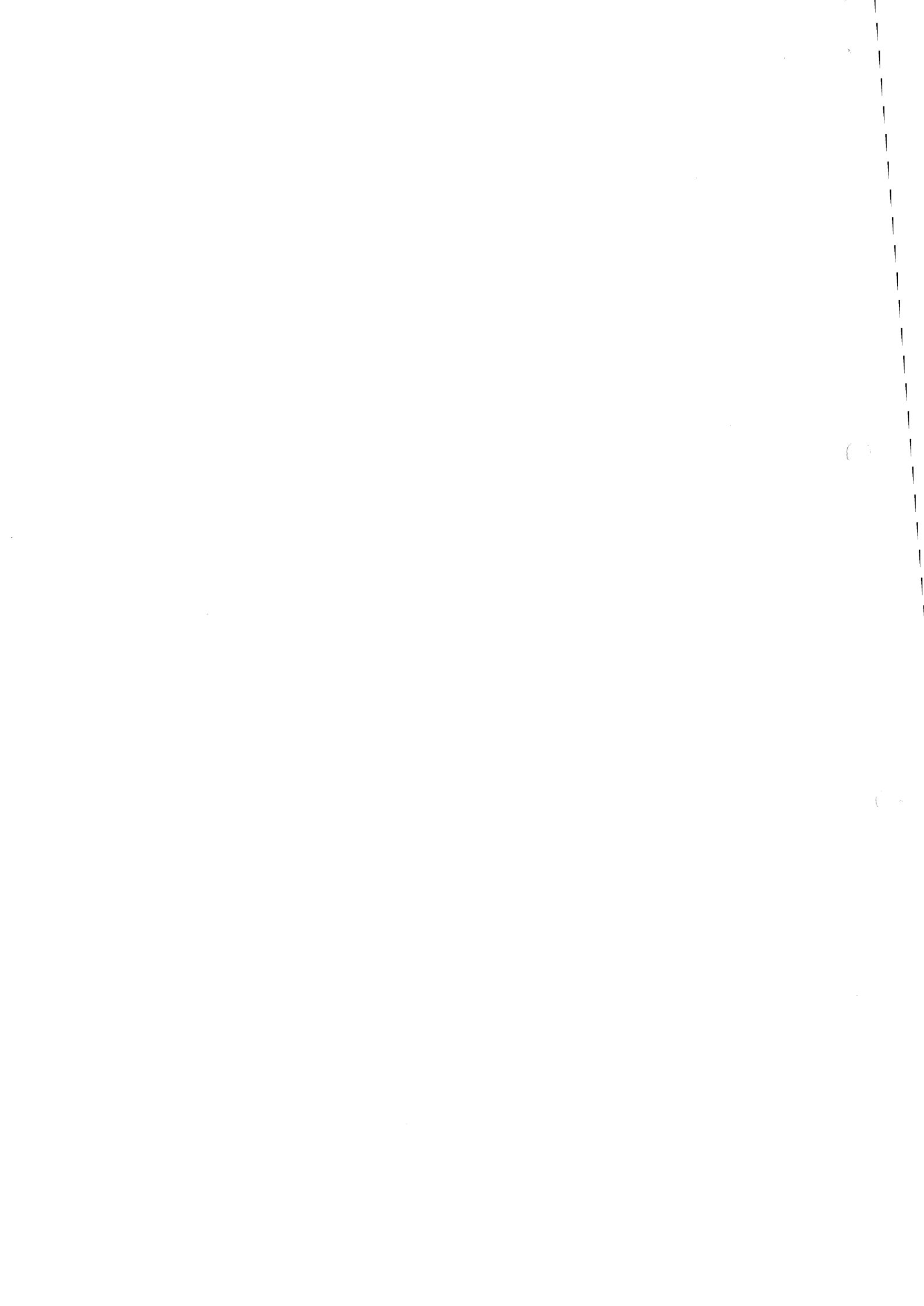
International Council for  
the Exploration of the Sea

C.M. 1988/B:50  
Fish Capture Committee

Report of the Working Group on Fisheries  
Acoustic Science and Technology (FAST)

Ostend, Belgium, 20-22 April 1988

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## 1. INTRODUCTION

### (i) Participants

A list is given as Appendix 1.

### (ii) Terms of reference

In accordance with C. Res. 1987/2:4, there was a joint session of the Working Group on Fishing Technology and Fish Behaviour (FTFB) with the Working Group on Fisheries Acoustic Science and Technology (FAST) in Ostend, Belgium on 20 April 1988 to discuss matters of common concern.

In accordance with C. Res. 1987/2:5, the FAST group met under the chairmanship of Professor K Olsen on 21-22 April. The particular topics considered were:

- (a) methods of measuring fish target strength (TS);
- (b) the design of acoustic surveys and data analysis for stock estimation purposes.

## 2. OPENING OF THE MEETING

The chairman welcomed all participants to the meeting and proposed an agenda.

## 3. ADOPTION OF THE AGENDA: APPOINTMENT OF A RAPPORTEUR

The agenda was adopted and Mr R B Mitson of the MAFF Fisheries Laboratory, Lowestoft, UK was proposed and accepted as rapporteur for the FAST working group meeting.

## 4. PROGRESS REPORTS

### CANADA

Newfoundland: St John's; Department of Fisheries and Oceans

Six acoustic surveys to determine distribution and/or biomass were carried out on capelin, cod, redfish and herring in this area. Surveys of these species will continue in 1988.

Development of the dual-beam system HYDAS-2 continued with extensive field trials of the analogue sub-system. Major problems were due to the transducer sensitivity to propeller noise, torque imbalance in the towing cable and bending stress at its underwater towing termination point. Steps have been taken to correct these problems. The development contract for an acoustic Data Editing System (HYED) was completed in January 1988. Software to interface this system to an HP1000 has been written and the system is being used to examine and edit data from several surveys.

A frame for acoustic calibration has been developed and field tested. It allows a hydrophone to be remotely positioned on the acoustic axis of a survey transducer whilst the latter is under water in its towed vehicle. SL and SRT can be measured with the system located on the research vessel. A similar, but smaller, frame for use with standard targets is being considered.

Scotia-Fundy:

Bedford Institute of Oceanography

Surveys were carried out for mesoscale haddock distributions and field tests of TS algorithms for ECOLOG I. A joint trawl/acoustic survey for pollock took place on the Scotian shelf. During March 1988 the spawning stock of haddock was surveyed in Brown Bank area. This cruise also included tests of BRUTIV, a vehicle for carrying a low-light-level TV camera for fish species identification, and tests of a data acquisition system for ECOLOG II in survey mode. There will be a replica of the pollock survey during 1988.

St Andrew's Biological Station

Herring surveys continued in Chedabucto Bay during the winter of 1987/88.

An acoustic data acquisition system has been assembled using a Simrad EK50 echo-sounder, a QX525 preprocessor and an IBM-compatible PC. The latter will record acoustic data plus Loran C on Bernoulli disks. Data are processed on the PC to calculate acoustic back-scattering coefficients and geographic positions of fish traces identified on echograms. This system has been used to map and quantify large and small concentrations of herring.

Pacific: Nanaimo Biological Station

MASS programme (Marine Survival of Salmon): Acoustic methods are providing complementary data to seine net catches made on the migration routes of sockeye salmon:

- (a) stationary sonar observations recorded on time-lapse VCR;
- (b) concurrent side-looking echo-sounder observations;
- (c) mobile echo-sounding;
- (d) vertical casts with a horizontal transducer being slowly lowered.

There were two surveys to assess summer and winter distribution and biomass of adult herring in the Hecate Strait. An acoustic assessment was

made of the spawning distribution of hake off Vancouver Island. A 'user system' for echo-integration has been successfully operated with minimal technical support since July 1987.

#### DENMARK

##### (i) Acoustic surveys

Surveys have been conducted in the North Sea east of 3°E in August 1987 and in ICES division IIIa in August-September 1987. The surveys have been extended to provide a more general picture of the abundance of several fish stocks.

There has been cooperation with Sweden in the Bohuslen archipelago and with FRG in the western Baltic, in both cases with mobile equipment.

##### (ii) TS measurements

Tests on a calibration method for the split-beam echo-sounder have been performed.

##### (iii) Data collection and analysis system

A new system for integrated collection and analysis of signals from a split-beam and two single-beam echo-sounders has been specified and the split-beam data collection and analysis parts of it are operative. A full system is expected to be operational for the 1989 season.

#### FRANCE

(i) IFREMER and ORSTOM are carrying out their usual surveys in the Gulf of Gascoyne, Senegal and Mauritania in cooperation with those countries.

(ii) Methodological studies include horizontal and vertical observations of fish in relation to the passage of vessels. The quantitative aspect of this work has been taken into account when considering data.

There have been exploratory studies on plankton at six frequencies between 28 and 200 kHz.

Studies of shoals have been made monthly in the Caribbean since November 1987.

Fish reaction to nets has been studied by means of towed omnidirectional sonar. There has been further application of acoustic methods in tropical areas including measurements of the TS of fish. Some studies of signal processing have continued.

(iii) Technological improvements include work on a four-frequency echo-sounder (28-200 kHz), on a multi-frequency echo-sounder with a trial of frequencies between 70 and 140 kHz, and improvements to the visualization of colour echo-sounder signals were obtained using an IBM PC with colour printer.

#### ICELAND

Routine acoustic surveys were carried out in autumn and winter 1987/88 on the Icelandic stocks of herring and capelin for management purposes.

A further study of the reaction of herring to an approaching research vessel was attempted. Due to 'unfavourable' behaviour as well as equipment failure this had to be abandoned. Another experiment is planned for next winter (1988/89).

Some TS measurements on herring and cod were carried out in January 1988 with an ES400 split-beam echo-sounder. All available information from the ES400 parallel data output was recorded. Processing of the data is well under way.

In view of the recent experience gained in TS-measurements with our ES400, it is planned to sample TS-data when possible on all our acoustic surveys.

#### NORWAY

Projects which are underway are arranged by application area.

#### Aquaculture

A system is being developed for estimating the size and quantity of penned salmon.

#### Behaviour

Reaction of fish to the passage of a research vessel or catching gear is being studied both by off-vessel echo-sounders and by trawl-mounted sonars.

#### Freshwater fish

A PC-based echo-integrator system has been developed. This aims to address applications where system portability is a major requirement. Freshwater fisheries are thus the most likely application area.

### Krill

Data on Euphausia superba, collected in a collaborative project with the British Antarctic Survey, are under analysis.

### Marine fish

Fish TS are being measured in situ with a split-beam echo-sounder. This is an on-going study.

The depth dependence of TS is being studied by measurements on encaged aggregations of cod and herring.

Morphometry of swimbladders continues to be pursued for use in modeling TS.

Absorption of sound by fish aggregations is being measured for layers and school formations.

An expanded transducer with two operating modes, distinguished by beam width and equivalent angle beam, is being designed.

### Trawl sampling

Representation of sampling by trawl is being extended by means of trawl sonar.

### Zooplankton

A system for size classification and abundance measurement of zooplankton is in its fifth year of development. This aims to examine animals of sizes 1-50 mm. Eleven discrete frequencies, from 27-710 kHz, are used. A prototype is being tested at sea and also calibrated.

New projects have been started to:

- (i) estimate the abundance of fish in schools by sonar;
- (ii) build a deep-towed acoustic system for surveying fish, particularly near bottom slopes and irregularities;
- (iii) process and present echo-integrator data, and other research vessel data, for use in abundance estimation work.

SPAIN: Instituto Espanol de Oceanografia (IEO)

During 1987, routine acoustic surveys were carried out covering all the Spanish continental shelf (between France and Portugal in the Atlantic and from Gibraltar to France in the Mediterranean). These surveys were on the stocks of sardine and anchovy for management purposes and also for evaluation of the rest of the coastal pelagic stocks. During 1988, we are

trying to extend these surveys, on the coast of France in the Atlantic and in the Mediterranean, to cover all the area occupied by the sardine and anchovy stocks.

In 1987, a fourth acoustic survey (the first was in 1980) was carried out in the Gulf of Guinea as part of the CEECAF cooperative project.

The experiments in TS measurements were not performed during 1986 and 1987 but it is planned to work in this field again in 1989. There will also be a project to work on the sardine stock of the Balearic Islands in the Mediterranean. It is a stock with an annual catch of 1 000 tonnes, exploited by 10 purse-seiners, concentrated in a reduced area well delimited and studied by VPA methods from 1980 and regularly evaluated by acoustic methods from 1982.

#### SWEDEN

The yearly international acoustic survey was carried out during October in the Baltic. The survey is coordinated by a Planning Group within the framework of ICES. In the 1987 survey, three countries participated, Sweden, GDR and Poland. The objectives of the survey were to estimate the abundance of herring and sprat stocks.

Acoustic methods of integration and echo-counting are frequently being used in fresh water for assessment purposes.

Acoustic surveys are carried out yearly in Angola with a local research vessel. The project is a joint venture between Angola and Sweden.

#### UNITED KINGDOM

British Antarctic Survey, Cambridge

The field work phase of the krill TS study has been completed.

Analysis of the 38 and 120 kHz data from krill surveys is continuing.

Estimates of krill distribution and abundance were made in the vicinity of South Georgia.

The design of a new towed transducer body is complete.

MAFF Fisheries Laboratory, Lowestoft

A survey of spawning herring was carried out in the central North Sea at the end of August 1987 from RV CLIONE. The survey will not be continued in 1988 because no ship is available.



In the Celtic Sea an extensive survey of plankton was carried out from RV CIROLANA, using 38 and 120 kHz systems with both transducers in one towed body. The QD echo-integrator was run in sequencing mode. Data have yet to be analysed.

Improvements to the acoustic calibration tank facility include a new anechoic lining attached to movable boards which are supported by floats at the surface and weighted at the bottom. Calibrations from 10 to 320 kHz have been carried out with an accuracy of  $\pm 0.2$  dB. The beam patterns of transducers can be measured in 0.1 degree steps. The tank is used frequently by universities and commercial companies under a hiring arrangement.

The laboratory took part in an acoustic calibration inter-comparison exercise organized by the UK National Physical Laboratory, Teddington. The purpose was to check on calibration standards throughout the country. Results may be published later.

It may be of interest to note that the UK National Physical Laboratory offers a service for the calibration of hydrophones from very low frequencies up to some tens of MHz.

A tag for measuring fish tilt angle has been designed and constructed using hybrid microelectronic techniques. The five prototypes will use an electrolytic sensor and the complete package is a cylinder 10 mm in diameter and 50 mm long. Operation is by transponding mode at 300 kHz carrier frequency and a maximum interrogation rate of 8 per second is possible.

The new research vessel CORYSTES recently completed commissioning trials and was delivered to the laboratory on 31 March. CORYSTES is 53 m in length and has a beam of 12.8 m. She is equipped with a Simrad acoustic survey system and other echo-sounders/sonar, etc.

The first research cruise used the MAFF 300 kHz high resolution sector scanning sonar to observe the behaviour of acoustically-tagged fish. The tilt tag was also tested satisfactorily.

DAFS Marine Laboratory, Aberdeen

Surveys of herring were carried out in the northern North Sea in April 1987, in the Clyde and in the Orkney, Shetland and Buchan areas in July 1987. The latter survey was in conjunction with the Norwegian research laboratory in Bergen. In addition, a survey of herring and mackerel was conducted in November in ICES division IVa. During these

surveys, data were collected in individual sample format for each transmission and with 0.5 m range definition.

Data collection and analysis is now based on an IBM-compatible system using a commercial data-base and spreadsheet (SMART) for all the analysis from the integrator readings to the final results. Approximately 8 000 lines of program have been written to produce a menu-driven analysis system.

Dual-beam data on herring were collected during July in the Orkney, Shetland and Buchan areas. Problems were encountered in getting the transducer close enough to the large concentrations to obtain a reliable number of single echoes.

A side-scan system has been implemented using existing echo-sounders at 120 kHz with a 1 degree by 50 degree transducer in a towed body. This system was used for examining shellfish grounds in the Firth of Forth.

Routine measurements (bi-annual) of survey transducer beam patterns continue and, so far, no long-term changes have been found.

Experiments are continuing on the extinction effects of dense fish aggregations.

USA

Northwest and Alaska Fisheries Center (NAFAC)

The Pelagic Resource Assessment Subtask of RACE at the NAFAC has, during the last year, conducted two large-scale surveys of spawning pollock, initiated a programme of at-sea monitoring of depth effects on the transducer, TS and echo-integration system calibration and stability, and has tested a computer board-level echo-integrator.

A survey of spawning pollock, in the international zone of the Bering Sea and along a portion of the Alaska peninsula, was conducted during February 1987. The total survey area amounted to about 40 000 n.m<sup>2</sup> and some 3 000 n.m. of trackline were steamed; spacing of the parallel transects was about 40 n.m. A similar survey was conducted during March 1987 in Shelikof Strait, between Kodiak Island and the Alaska peninsula. Again, the target species was spawning pollock. The survey area amounted to about 4 000 n.m<sup>2</sup> over which about 1 200 n.m. of transects were run. Some in situ TS data were collected in Shelikof Strait.

An at-sea procedure designed to monitor the stability and calibration of the TS and echo-integration system and the effect of depth on the transducer has been initiated. Total system stability and calibration are measured by suspending a copper ball of known TS from extension rods

attached to the towed body containing the transducer. The ball is suspended at about 30 m below the transducer. The whole unit is then lowered through a series of incremental depths while simultaneous dual-beam and split-beam TS analyses of the returns are made and integration channel voltage measurements are automatically collected. These data allow determination of the position of the ball in the beam and thus the transducer directivity factor for each measurement. Transducer depth effects are reflected as apparent changes in the TS of the ball with depth, while total system stability is measured by repeatability of the measurements over time (i.e. weekly or bi-weekly tests). Six sets of measurements have been collected over the last 5 months but thorough analyses are not yet complete.

A prototype computer board-level echo-integrator produced by BioSonics Inc., Seattle was tested for reliability, ease of use and operation during recent surveys. Although several shortcomings were noted, mainly improper thresholding of bottom following intervals, the overall opinion of the unit was favourable. Correction of the problems noted are currently being addressed by the manufacturer.

Dr Bill Karp reports that papers for inclusion in the Proceedings of the 1987 Symposium on Fisheries Acoustics have been selected. He has written to most of the authors and should have completed this by the end of April.

## 5. TARGET STRENGTH

The measurement of TS continues to be a subject of great interest and importance. A paper describing further development of the calibration method of Degnbol and Lewy (1987) gave details of the procedure for calibrating the echo level and the directivity compensation function. In addition, the performance of the phase detection has to be included and needs new procedures for the calibration of phase to angle conversion. Using the method gave reproducibility at any point in the directivity pattern to within  $\pm 0.1$  dB. However, to achieve this result it was necessary to collect data well outside the angular range used in practice.

A summary of methods for measuring fish TS was given. These may be classified as in situ or ex situ. Direct or indirect means are employed to remove transducer beam pattern effects from measurements. The problem with in situ measurements is the uncertainty in knowing what is the target and with the fish ex situ the behaviour may be abnormal. However, despite

the variability in methods and conditions under which the published TS data were obtained the variability in results is quite small.

The measured TS of small herring, having a mean length of 9.4 cm, was examined from a vessel travelling at 9 knots, 5 knots and with the vessel stopped. Dynamic TS may be dependent on species, length, depth, condition and behaviour of the fish. In this experiment there was a tendency for the indicated size distribution to increase as the speed of the ship dropped. There were also some illustrations of TS changes with depth from a colour printer record.

The criteria for echo selection in the split-beam ES400 echo-sounder are unsatisfactory and the beam compensation is inadequate. Differences were found between the use of ES400 and EK400 transmitters. A system was calibrated by means of standard target transects through the beam. Phase compensation was applied and the system was used when the ship was drifting over a distribution of cod. TS values of -35 to -55 dB were recorded. The tail at the lower end of the TS distribution had also been seen with haddock, especially in the -30 dB range.

A method of making in situ mean TS measurements in small schools uses an EY-M echo-sounder with wide beam transducer to obtain Sv and a wide-angle camera for fish density estimates. TS is then calculated from the expression  $Sv = 10 \log pv + TS$ .

An experiment using the 70 kHz EY-M echo-sounder in the Caribbean was described. This work used a net cage of 30 m diameter with many transducers facing upwards. Fish were caught in nets set close to the beach and remained in them for some days. Because of the fish being in ventral aspect assumptions were made about shape factor. Video records of distribution were made, including some from a balloon looking vertically down to the cage. The main purpose of the work was to study the internal structure of schools. It is clear that schools cannot be considered as single homogeneous structures and that the sampling variance of acoustic data obtained on a single school has to be considered. There are completely empty volumes within some schools.

Comparison of fish TS distributions by dual-beam method and otter trawl catch distributions for cod and haddock continue. As individual fish go through the beam at 100 m or more there are several successive pings which allow the calculation of an average TS. Results show that this can be obtained for large numbers of fish to allow comparison with other published results. Differences are not statistically significant.

An experiment to determine in situ TS of fish in Lac Annecy was made using an EY-M (70 kHz) plus AGENOR integrator and a 400 kHz dual-beam system plus integrator. The size distribution of the fish was not known (probably about 20-25 cm) but there were 3-4 dB differences per layer between the two systems. The squared integrated voltage from the systems showed quite good agreement.

Some discussion was centred around the problem of defining fish TS. It is difficult to think of it as a stable figure in all circumstances. There is not sufficient known about the biological/physiological aspects which are probably more important in some species than others. Although the literature has been reviewed there is not much known about these factors. It seems that a TS value for a particular species may be appropriate in a given stock at a particular time of year. There are still a number of species for which no TS is known. Despite all the probable causes of TS variation, data from diverse sources fit well.

## 6. SURVEY DESIGN AND DATA ANALYSIS

One paper was given on this subject. The point was made that acoustic surveying of fish has much in common with other types of survey and the errors in collecting and analysing data are likely to be similar. Account must be taken of the geographical area to be covered and the resources available for the survey. An a priori knowledge of historical information of stock location or relative densities should be used before deciding on a particular strategy.

It was suggested that a random number generator be used to determine movement from area to area. Random track spacing should also be used with nearly parallel lines. It is important to decide if species are identifiable from the echo traces. If they are, the species should be separated and allocated. The fact that a stock is randomly distributed does not automatically decree that random sampling is used.

A situation was reported when herring could be sampled only in the early morning. During the night they were much too close to the surface and during the day too close to the sea bed. This type of problem has to be related to the design of surveys.

## 7. PLANKTON ACOUSTICS

The new topic for the working group, of acoustic sizing and abundance of plankton, was first addressed by a description of the MUFAP system being developed in Norway. This aims to deal with organisms from 1-50 mm

in size and has 11 frequencies from 27-710 kHz. Frequencies are sampled serially from a stack of ring transducers.

A Multi-frequency Acoustic Profiling System (MAPS) was described which has 21 discrete frequencies from 100 kHz to 10 MHz. This was developed in the USA about 12 years ago as a research tool to investigate very high frequency back-scattering. It has proved to be of great value in examining zooplankton from 20-50  $\mu\text{m}$  to 10 mm in size. Results are computed near real time. Arrangements are being made to bring MAPS, and the scientists who have developed it, to Europe in 1989 for a joint project with the MAFF, Lowestoft laboratory in the Celtic Sea.

## 8. GENERAL MATTERS

A constant vigilance is essential to ensure that acoustic systems perform correctly. The working group was reminded of this by a reference to an apparent difference in performance of a transducer with depth. Checking was done by the suspension of a standard target below the towed body housing the transducer and holding it at each depth interval for 90 minutes. For a nickel transducer, the SL + VR increased steadily with depth. A ceramic transducer showed the same effect until detergent was used to wet the face. After being lowered to 60 m then cycled to 30 m, a constant performance was obtained.

There was a proposal that situations arise where the present transducer designs are inadequate, particularly where the fish are in deep water. For example, the split-beam transducers are smaller than some previous 38 kHz designs. Thought is being given to making use of the maximum aperture space available and optimizing all parameters.

Sound absorption has been measured in dense concentrations of herring in a deep fjord with a flat bottom. A reduced output from the echosounder prevents the integrator from locking onto the bottom echo and allows measurement of the bottom back-scattering signal. At approximately 200 fish per  $\text{m}^3$  the reduction was 3 dB in bottom signal. On the edge of a school, fish were found to be 2-8 per  $\text{m}^3$  by measurement from a 330 kHz scanning sonar.

Acoustic density estimates of pollock showed that 80% of the stock were contained in one small area. Net samples yielded independent estimates but 9% of these came from an area where no pollock were acoustically detected. Although there is good overall agreement between the trawl and acoustic abundance estimates the sources of variation and bias in the two methods are very different and need to be explored.

## 9. RECOMMENDATIONS

It is recommended that the working group should meet in 1989, on a date to be decided, in Dublin, Ireland, to consider in particular:

- (i) effect of threshold on the conversion factor used in echo-integrator surveys;
- (ii) separation of the fish-related and instrumentation parts of the conversion factor;
- (iii) survey design and data analysis.

It is recommended that a joint session of the FAST and the FTFB working groups should be held during the 1989 meeting to discuss, in particular, avoidance reactions to survey vessels and gear.

The working group recognizes the important effect of survey design and data processing on the results of surveys. The working group recommends that a report be prepared which reflects the best of present practices and techniques used in the design and data analysis of echo-integrator surveys. (A questionnaire will be circulated during the summer of 1988 and sent to all working group members prior to the date of the next meeting.)

## REFERENCE

- DEGNBOL, P. and LEWY, P., 1987. Interpretation of target strength information from split-beam data. International Symposium on Fisheries Acoustics, June 22-26, Seattle, Washington, USA. 13 pp. Unpublished mimeograph).





APPENDIX 1 List of participants in the FAST Working Group

<u>Country</u>	<u>Name</u>	<u>Area</u>
Belgium	F Delanghe J Van Hee	
Canada	D Miller L Dickie P Boudreau W Lear	St John's Dartmouth "
Denmark	P Degnbol E Kirkegaard	Hirtshals Charlottenlund
Faroes	B Joensen	
Finland	P Suuronen	
France	P Freon F Gerlotto E Marchal R Person J Sacchi	Brest
Iceland	P Reynisson	Reykjavik
Norway	J Dalen K Foote H Hovgard J Jacobsen O Misund K Olsen E Ona	Bergen " Tromso Bergen
Spain	P Oliver	
Sweden	O Hagstrom	Lysekil
United Kingdom	D Bone I Everson C Hood D MacLennan R Mitson J Simmonds J Watkins	Cambridge " Lowestoft Aberdeen Lowestoft Aberdeen Cambridge
USA	D V Holliday	San Diego

