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REPORT OF THE

WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY

La Coruña, Spain
21–23 April 1998

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1 TERMS OF REFERENCE

In accordance with C. Res. 1997/2:13 the Working Group on Fisheries Acoustics Science and Technology (Chairman: Dr. F. Gerlotto, France) met in La Coruña, Spain, on 21-23 April 1998 to:

a) review the results of the questionnaire on sources of uncertainties in acoustic surveys.,

b) identify the outstanding problems in acoustic stock assessment and assess to what extent they can be resolved by further research;

c) review the progress of the Study Group on Echo Trace Classification.,

d) consider the related research in acoustic stock assessment.

2 MEETING AGENDA AND APPOINTMENT OF RAPPORTEUR

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

The following agenda was adopted:

Session A: to review the progress of the Study Group on Echo Trace Classification and to consider the related research in acoustic stock assessment;

Session B: to review the results of the questionnaire on sources of uncertainties in acoustic surveys and to identify the outstanding problems in acoustic stock assessment and assess to what extent they can be resolved by further research;

Final Session for a general discussion, to elaborate conclusions and to make recommendations.

3 SESSION A - STUDY GROUP ON ECHO TRACE CLASSIFICATION: RELATED RESEARCH IN ACOUSTIC STOCK ASSESSMENT

3.1 Traynor, J. Improvements in *in situ* target strength measurements of walleye pollock *(Theragra chalcogramma)*

The results of recent target strength (TS) measurements of walleye pollock from the North Pacific were presented. Results were shown using a lowered-transducer system which allowed the transducer to be moved closer to the target fish thus reducing the well-known bias of *in situ* target strength measurements due to range-dependent noise thresholds. Comparisons of measurements using a conventional system with the transducer mounted on the research vessel and this system were also presented. The Alaska Fisheries Science Center currently uses a target strength-to-length relationship

$$TS=20\log_{10}(L)-66.0$$

where L = length in centimetres,

to scale echo integration information to estimates of fish density. Caveats regarding the limitations of *in situ* target strength measurement techniques were presented and suggestions for appropriate conditions for such measurements were provided.

In discussion the recognition of similar limitations were confirmed by others, and it was noted that smaller fish have even greater restrictions, but lower directivity. Attention was drawn to the problem of making TS measurements under different conditions from survey conditions e.g. night versus day, and the applicability of these measurements to survey results.

3.2 Demer, D.A., Soule M.A. and Hewitt, R.P. A multiple-frequency method for potentially improving the accuracy and precision of *in-situ* target strength measurements

The effectiveness of a split-beam echosounder system to reject echoes from unresolvable scatterers, thereby improving the measurements of *in-situ* target strengths (TS) of individuals, is dramatically enhanced by combining synchronized signals from two or more adjacent split-beam transducers of different frequencies. The accuracy and precision of the method was determined through simulations and controlled test tank experiments using multiple standard spheres and 38 and 120 kHz split-beam echosounders. By utilizing the angular positional information from one of the split-beam transducers, additional corresponding TS measurements were shown to be obtainable from a juxtaposed single-beam transducer. Both methods were utilized to extract *in-situ* TS measurements of Antarctic scatterers simultaneously at 38, 120, and 200 kHz. The ultimate efficiency of the multiple-frequency technique is shown to be limited by phase measurement precision, which in turn is limited by the scattering complexity of targets and the receiver bandwidth. Imprecise phase measurements also result in significant beam-compensation uncertainty in split-beam measurements. Differences in multi-frequency TS measurements provided information about the identity of constituents in a mixed species assemblage. The taxa delineation method has potential, but is limited by compounding measurement uncertainties at the individual frequencies and sparse spectral sampling.

3.3 Acker, W., Wiggins, D. and Burczynski, J. Digital Transducer, Advanced Technology and New Applications

BioSonics, Inc. new digital SONAR architecture offers many advantages over older analog designs. By digitizing the signal at the transducer element, rather than several hundred feet of cable away, cable-coupled noise is eliminated. This results in a typical system self-noise figure of 4 dB.

The digital architecture features extremely high accuracy: samples are gathered at a rate in excess of 41 kHz (yielding a spatial resolution of ±9 mm) and with an accuracy greater than 0.03% per sample. This architecture also features a very wide instantaneous dynamic range (greater than 132 dB). This allows simultaneous capture of extremely small echoes (as from a single plankton specimen) and large echoes (such as the bottom echo), with no loss in detail or threat of signal saturation.

The digital SONAR transducers are available in a wide range of frequencies (from 38 kHz to 1 MHz) and beam angles (from 10 to 200 nominal beam angle), in single, dual, or split beam configurations. In addition, the split-beam configuration can operate as a dual or single beam transducer. This flexibility in transducer configuration supports use in a variety of applications: biomass estimation, layering effects, target strength measurements, bottom classification, sediment monitoring, and more.

All digital samples are stored directly to the controlling computer's storage medium (e.g.: hard disk, external storage device, remote network drive). This computer is a standard Ante ITm-based Personal Computer, running a standard operating system such as MicroSoftTM Windows 95. All software is fully compatible with Windows 3. 1 / Windows 95 / Windows 98.

The discussion centred on the interaction between the systems described and other analysis software. The willingness of the producers to adopt standard formats, as soon as the community agrees, was re-affirmed. The importance of precise bottom detection was agreed, and the possibility was raised of incorporating image analysis techniques to provide bottom tracking where other algorithms fail.

3.4 Soule, M.A., and. Barange M., New Developments in single target recognition using split-beam echsounders

New Windows NT-based software has been developed that adds three new filters to the present Simrad EK500 single target detection algorithms for Target Strength (TS) estimation. The software utilizes complex sample data derived from the channels of an EK500 split-beam receiver via a digital demodulation process. The processed data is used to produce a TS histogram, an 'echo-chart' of accepted single target echoes, a fish behaviour window and a raw data display which identifies the response of the different algorithms to potential targets on a ping-by-ping basis.

The new filters are based on the assumption that the echo amplitude in each of the four quadrants of a split-beam echosounder will be equivalent for single targets but will vary due to interference effects when overlapping echoes are received. In addition to using phase stability as a single target discriminator, FISH also tests for:

Channel amplitude differences within the 6dB limits of the received echo

Sample slippage between channels

The expected maximum peak amplitude channel

Beam phase differences between port and starboard half-beams

Target range separation

Initial tests under controlled conditions showed that overlapping echoes, accepted as single on the basis of phase stability criteria, could be successfully rejected by using the additional algorithms.

A field trial was carried out on gobies which were present both dispersed through the water column and aggregated in a dense layer. Of 1462 targets accepted by the EK500 single target detector, only 189 were accepted by FISH. Most of the targets accepted by the EK500 system were recorded in the area were the fish were densely aggregated, while FISH rejected most of them as not genuine single targets. The TS peak value was the same for both systems when the TS distributions were compared, but a 'shoulder' of higher values accepted by the EK500 had been rejected by FISH. More data will be collected in the near future to further compare both systems.

The group acknowledged that the technique described here would be most beneficial when used in conjunction with the lowered transducer approach of Jim Traynor. It was pointed out that the example chosen for this study could have particular problems caused by perturbation of the echoes as they passed though the dense fish layer. This provided a separate reason for adopting the lowered transducer method.

3.5 Mitson, R., and Simmonds, J. Design and noise performance of a new Scottish Research Vessel, 'Scotia'

There has been concern for many years about the effects of underwater noise radiated by research vessels. FAST set up a Study Group to look into this and their recommendations were published as ICES Co-operative Research Report No. 209 in 1995. Scotia is the first vessel to be planned and built since that report was completed so it is of interest to see the results of her noise-ranging results and trials. ICES Report 209 makes recommendations based on published work about fish hearing and avoidance reaction to noisy vessels. A distance of 20 m was chosen, beyond which the most sensitive of fish should not react to vessel noise. A graph for the maximum allowable vessel noise for this purpose was produced and was used in the specifications for this new vessel. At echo-sounder frequencies the recommendations were based on a fairly typical survey practice at the time of towing a transducer astern of the vessel at 15 m from the propeller. The speed of 11 knots was chosen because it was around the maximum possible for most vessels without noise becoming a problem.

Scotia has a fairly conventional layout. Noise reduction techniques were used throughout the vessel and in the propeller design. The result is a vessel with a noise signature meeting the ICES Recommendation with minor deviations. Of particular interest is the change between 10. 7 knots and 11.1 knots. Normal rate of fall-off beyond 1 kHz is 20 dB per decade, due to propeller cavitation, but there appears to be another influence here. It is believed to be the self-noise of the stern-thruster tunnel. However, Scotia does not rely on a towed transducer, she has a drop keel which places the transducer about 45 m ahead of the propeller.

Results from noise measurements when towing a pelagic trawl showed that, as expected, the noise levels increased by about 15-20 dB. The drop keel improved the echosounder performance significantly under severe weather conditions.

3.6 Kloser, R., Ryan, T., Koslov, T. and Sakov, P. Species identification in deep water using multiple frequencies

In order to reduce the biases in acoustic assessment, relative methods had been used for six years for the assessment of deep water populations, a deep towed body being used in preference to hull-mounted acoustics. A large reduction in stocks was recorded over the assessment period. It was known that Orange Roughy assessment was highly sensitive to small changes in species composition, and recently Whiptails and Morids have become increasingly important, at the expense of Orange Roughy. Both of the increasing species have swim bladders, and a small error in the estimation of these two would contribute a large error to the biomass estimate. The fish were sampled using a Midoc, multiple opening and closing trawl, and in 1996 a first deployment was made of a three-frequency sounder operating at 120 kHz (split beam), 38 kHz and 12 kHz. Discrimination between gas-filled sphere targets using multiple frequencies increases with depth, and the scattering from Orange Roughy was found to be equivalent at all three frequencies, but the other species dominated at 38 kHz or 12 kHz. Software was developed to produce a composite echogram using all three frequencies, with each frequency having a characteristic colour. The resulting charts showed a characteristic appearance for all three species, and this was used for discrimination and in conjunction with target strength to apportion the stock.

3.7 Wilson, C.D. Field trials using an acoustic buoy to measure fish response to vessel and trawl noise

A free-drifting acoustic buoy was constructed to evaluate the response of fish to vessel and trawl noise. The buoy contained an echosounder and split beam transducer operating at 38 kHz, and other instrumentation to facilitate the remote operation of the buoy. Performance of the buoy during field trials in 1997-1998 was excellent. Field experiments with the buoy were conducted in the Gulf of Alaska during March 1998 to investigate whether aggregations of walleye pollock (*Theragra chalcogramma*), exhibited behavioural responses to noise generated by the research vessel, *Miller Freeman*, during routine acoustic-trawl stock assessment survey operations. Preliminary results suggested that the fish did not exhibit dramatic responses to vessel noise generated during several runs of the vessel past the buoy. However, a more thorough examination of the data are in progress to verify these initial observations. Further work is planned to better understand whether the presence of vessel noise under different environmental conditions and life history stages of the fish may cause a response in walleye pollock which could potentially bias abundance estimates generated during stock assessment surveys.

It was suggested that an escape reaction from the ship by the fish would also be detectable as a wave of higher numbers ahead of the ship. Future studies might include passive listening during avoidance tests, and the use of the buoy for TS measurements. Reductions in S_A values could result from changes in tilt angle as well as avoidance.

3.8 Marchallot,C. Movies +

Movies + is a software system developed at IFREMER, France, having a wide range of capabilities. Data may be acquired from Ossian, Simrad or BioSonics sounders. Data files are organised by day or by launch, time-based or ping-based with more than one sounder or channel. The Canadian HAC format has been adopted, having a special ping tuple with supplementary location data. Pointers are used so that files can be read in either direction. Replay of several files at once is permitted and includes scrolling and oscilloscope displays. Echointegration can be by shoal or selected area and can generate 40 parameters. Editing, importing and checking operations are facilitated. Calibrations are assisted by maximum echo detection. The FishView module is based on ARCView

The software has familiar Microsoft Windows95 architecture, 32 Mbyte Pentium being the recommended hardware. The design is object oriented, written in C++. A licence is available for 50 000 F, or 20 000 F for a research laboratory or 10 000 F for French users

3.9 McQuinn I., Raymond A. and Lefebvre L. The influence of the CIL on the distribution of Western Newfoundland herring in Autumn

The objectives of this study were to study the causes of the interannual variability in herring distributions, and to improve the delineation of the acoustic biomass survey area, and the allocation of sampling effort. These herring show some association with the 50-60 m depth contour, but this varies from year to year. Large interannual variations in their relative densities along the coast have also been observed; some years they were concentrated in a few strata, some years they were spread out over almost the entire coast.

There was a major change in the temperature regime of the coastal areas, from relatively warm surface waters in 1995, to extremely cold conditions in 1997, with an associated difference in the herring distributions. It was hypothesised that variations in the distribution of the cold intermediate layer (CIL) may have caused these variations in herring distribution. The CIL (£ 2 deg. C) is the dominant water mass in the Gulf of St. Lawrence and is produced by winter cooling of the top 150 m followed by the summer warming of the top 50 m. It was suspected that wind forcing was responsible for the differences in the observed surface water temperatures. In 1995, the dominant wind direction the week before the survey was from the southwest. These SW winds created a shoreward movement of the warm surface waters through Echman transport, and a down-welling effect, thus lowering the CIL.

Looking at the proportion of the herring echoes per depth layer (5-20, 20-50, 50-60, 60-100 m), most of the backscatter was found between 20-50 m in 1995. The association with the available temperatures shows a bias towards warmer temperatures, avoiding areas of temperature below 5 deg C. At 60 m, the proportion of backscatter was reduced in general, and reduced proportionally in the middle strata, with a higher proportion in the northern strata, were water temperatures were warmer. Although the few herring outside the depth contour were all in relatively cold water, they were mainly restricted to above 2.5 deg C.

In 1997, the dominant winds in the week preceding the survey were from the north, producing a net offshore movement of the warmer surface layer, and an upwelling of the cold (0-1 deg C) CIL water into the coastal areas. The proportion of backscatter increased in the 5-20 m and 50-60 m depth layers in 1997. At 5-20 m, herring appeared to have avoided the coldest temperatures. Between 20-50 m, there was less backscatter in the middle strata, and an increase in the southern and northern areas where the water was warmer. Between 50-60 m, the herring were found exclusively in the northern and southern areas. There was therefore a displacement towards the north and the south with respect to 1995, where warmer waters were available at all depths. We conclude that northern Gulf herring show avoidance of the CIL in coastal waters in autumn, and that the presence of the CIL in coastal areas was influenced by the dominant wind direction.

It was noted in the discussion that the overall abundance was lower in the colder year. It was suggested that it may be useful to examine salinity in any follow-on studies.

3.10 Ona, E. and Svellingen, I. High resolution target strength measurements in deep water

High resolution target strength data can only be claimed valid in situations where it can be safely shown to be much less than one target per pulse volume. Many fish species occur in densities and at depths where this demand hardly can be met with standard, hull-mounted survey transducers. This paper describes a new and simple method for obtaining such data with some examples of target strength and target tracking data obtained in deep water at three different cruises. The system used is the Simrad EK-500 split-beam echo sounder, connected to an oil-filled ES38D, pressure insensitive transducer, on cable lengths from 400 - 800 m. The TST (target strength transducer) was lowered as a probe the desired depth, often inside, or only 10 m above the fish layer, with the research vessel stationary, or slowly drifting. For maximising the number of detections per fish, the echo-sounder was operated at maximum pulse repetition frequency, and the data recorded on the BEI (Bergen echo integrator system) and on a PC. Recordings shown were from three different species, small myctophid fishes at 200 - 400 m, hake (*Merluccius carpensis*) at 200 - 400 m, and herring (*Clupea harengus*) at 50 - 400 m. The two first were recorded from R/V "Dr. Fridjof Nansen" outside Namibia, and the latter were recorded from R/V "Johan Hjort" in Vestrålen, northern Norway. High quality target strength estimates can often be obtained spending one to two hours per target strength station.

The discussion centred around the need for TS measurements that are appropriate, in terms of conditions and behaviour and reflect the relevant modes of the TS distribution. The importance was stressed of differentiating between variations in measurements on a single fish and between-fish variation, and including an estimate of the TS variance in the final result.

3.11 Lundgren, B. Single fish TS tracking

TS studies have been carried out by observing single fish with a 120 kHz sounder and a camera. Individual cod from size classes 7 – 10 cm were tracked, and TS measurements plotted against angle from the beam axis. In spite of the narrow size range, an unexpectedly wide range of TS values were recorded (range 10dB); 15 - 19 cm fish gave similar results.

It was suggested that this finding was not unusual, and that the size range would predict a greater range than that found.

4 SESSION A - STUDY GROUP ON ECHO TRACE CLASSIFICATION: PROGRESS

4.1 Reid, D. Report on the Study Group on Echo Trace Classification

The Study Group met on 18 - 20 April, 1998. The meeting was chaired by D. Reid and a report written by R. Aukland. The report of the Group will be published separately. A summary of the subjects to be covered, and discussion of those that will be excluded, follows. It was decided that the term school would not be rigidly defined, and it was suggested that it should be used interchangeably with object.

4.1.1 Reid, D. School Descriptors. These would be at the school, ESDU or geographical region level, and defined in terms of height, width and energy by each user

4.1.2 Gerlotto, F. Single and Multi-beam SONAR. This will include omni-directional and side-looking equipment.

4.1.3 MacLennan, D.N., Brierley, A.S. and Holliday, D.V. Wide-band and multi-frequency sounders. This section will incorporate the results of the questionnaire that has been circulated on this topic.

4.1.4 Swartzman, G. Analysis Procedures. Including:

- point processes - Pettigas, P. and Soria, M.
- geostatistics - Fernandes, P.
- GAM and clustering techniques - Swartzman, G.
- neural networks - Georgakarakos, S. and Harabolous, J.
- discriminant analysis - Brierley, A.
- Bayesian approach - Scalabrin, C., Simard, Y. and Swartzman, G.
- correspondence analysis - Pettigas, P.

4.1.5 Castellon, A. Data visualisation and analysis software. This section will include the information obtained from the questionnaire that had been circulated to members.

4.1.6 McQuinn, I. Data Exchange Formats.

4.1.7 Diner, N. Model simulations to provide beam correction parameters.

4.1.8 Reid, D. Comparison of image analysis methods. A CD of image datasets, contributed by group members, had been collected and converted to a common (simple binary) format and circulated to members of the Study Group. None of the recipients had been able to perform any analyses however, because of difficulties in converting the images back into their preferred formats. It was decided that contributors would not be likely to perform these analyses within a useful time period, and that this project would be better suited to a separate workshop, allowing the rest of the topics covered in the report to be published within the original schedule.

This experience of data exchange problems led members to propose an investigation into the utility of the HAC data exchange format and its implementation.

A workshop was proposed to carry out blind trials, to delimit schools and to extract selected objects, in order to compare different approaches.

4.2 Discussion session A

The echogram scrutiny exercise carried out by members of the herring group was felt by some not to belong in the report, since this concerned the performance of six groups of users in a single situation, while the rest of the report concerned general, universally-applicable issues. Others thought that this scrutiny experiment was important because it highlighted problems, the roles of subjective and objective methods, and also represented an attempt to define schools. However the consensus was that it should be excluded from the main report because it was a small scale exercise and the rest of the study consisted of comprehensive collections of methodologies. The study had attracted a lot of interest because it concerned a real, practical exercise, and because its results highlighted the over-riding importance of adequate haul information and training in order to achieve consistent results from echogram scrutiny. The study will be published as a separate paper.

A requirement was noted for multispecies identification from echotrace classification, but species recognition had been explicitly omitted from the objectives of the study group.

Ecological change evidenced by acoustic studies was also considered to be an important topic relevant to the group, but would be included in future studies and was outside the useful remit of the present report.

The adoption of a common format for acoustic data exchange had been discussed at the Wood's Hole meeting of FAST two years earlier, and the benefits of adopting the Canadian (HAC) system had been recognised then. The representatives of two major manufacturers of acoustic systems had agreed at that time that this action would be beneficial to the community. The only other formats that might be used for data exchange were the very basic binary stream adopted for the image exchange exercise, and this had not been taken up by any of the groups that might have completed the analysis, and the BI-500, which does not include sample data. It was therefore decided to promote the HAC format by circulating the latest documentation that had been made available by Ian McQuinn; the consensus was that it should be appraised by as many users as possible.

5 SESSION B SOURCES OF UNCERTAINTIES IN ACOUSTIC SURVEYS: OUTSTANDING PROBLEMS IN ACOUSTIC STOCK ASSESSMENT

5.1 Simmonds, J., Toresen, R., Pedersen, J., and Goetze, E. ICES Co-ordinated surveys of North Sea Herring: Inter-calibration of participating vessels

It was recommended by ICES that the acoustic survey participants should utilise as many opportunities as possible for inter-calibration during the 1997 surveys. In order to minimise the effect of spatial and temporal variability of herring abundance, the exercises were intended to be inter-ship calibrations, with the vessels running the same course at the same time. Since such an arrangement required some extra time for cruising, which inevitably reduced the coverage of the sampling area to some extent it was important to plan this efficiently. It was decided that pairwise inter-calibrations would be more efficient than trying to organise all vessels to be together at the same time, and it was judged to be acceptable to carry out up to two inter-calibrations per vessel.

The first inter-calibration was carried out at about 57E 40' N by 0E E by *G.0. Sars* and *Walther Herwig III* on the morning of 1 July. Due to severe weather *Tridens* was unable to reach this location in time, and could not participate as planned. The inter-calibration was carried out throughout the entire survey day, during which no fishing took place.

The second calibration carried out between *Walther Herwig III* and *Dana* after the completion of the first inter-calibration. During 2 July *Walther Herwig III* sailed eastward and contacted the *Dana*. The inter-calibration was carried out in the morning of 3 July at a position 57E 45' N and 06E 00' E about 30 Nm south west of the Norwegian coast.

The third inter-calibration was earned out between *G.0. Sars* and *Scotia* on 16 July at about 60E 45' N 30E W. There was no need for a fourth inter-calibration because *Scotia* carried out both Scottish surveys using the same equipment for both cruises.

G.0. Sars and *Scotia* were found to have the same performance. The ratio from the calibration from the *Walther Herwig III* and *Dana* was not significantly different from unity, but indicated a slightly lower sensitivity on the *Walther Herwig III. G.0. Sars* and *Walther Herwig III* gave a ratio of 0.76, however the accuracy of this factor, and how it should be applied are currently uncertain. The weather was poor during this inter-calibration and there was evidence for signal loss on the *Walther Herwig III,* not seen on the *G.0. Sars,* which has a keel system for the transducer. Further investigation is needed to establish if the reduction is weather dependent.

5.2 Olsen, K. Behavioural impact on TS-fish length equations

Simple regressions of TS to length that imply a single relationship for all behaviours or species need to be replaced by a relationship that shows TS as a function of length, tilt angle, depth and biological condition.

A demonstration of the importance of these factors was provided by the results of an experiment using a submerged transducer that recorded the behaviour of fish as a survey vessel passed above it. The S_A values dropped dramatically with the passage of the vessel, then recovered. Even in deep layers the S_A values dropped by one third to a quarter of their former levels as the vessel passed.

A study of the effect of tilt angle, using encaged fish showed that this factor varies according to the size of fish because of the different directivity patterns of small fish compared to large fish. Thus it was concluded that behavioural observations are needed in order to select an appropriate TS for a survey. ADCP records from herring have shown that this technique could provide a record of vertical movement of a fish concentration during a vessel's passage above it.

The discussion that followed this presentation offered a number of approaches to solving the problems raised. Interpretation of fish behaviour from ADCP records would require ping by ping analysis. Experiments had been carried out in the past to survey undisturbed fish by using transducers towed to the side of a vessel, using an otterboard. That comparison showed that the greatest reaction to survey vessels occurred below the keel. Observations of undisturbed fish might be made from helicopters as an alternative strategy. If complex behaviour patters can be studied it might be possible to compensate for these by modelling. TS reduction with depth can be modelled using tilt angle and time of day to find swim bladder compression.

It was noted that the observations of the fishes reaction to the passage of the survey vessel implies that a vessel term needs to be included in the TS function. However field observations suggest that fish reactions to survey vessels are highly erratic. Multibeam sounders could provide an alternative technique for behavioural observations.

5.3 Ona, E. and Svellingen, I. Improved calibration of split beam echo sounders

During the first year of target strength data collection in the EU project "Acoustic properties of fish and their exploitation in classification schemes for fish stock assessment" a number of calibration-related problems was encountered, mainly due to the short ranges used in the experiment. Since the TVG within the echo sounder was digital, the only limit which was focused on at the start of the project was the nearfield effects, estimated to be limited to 3-5 metres at the operating frequencies used. As the expected variations in average target strength for a fish over the season was about 1 to 2, or at most 3 dB, due to changes in swimbladder size, the accuracy of the calibration was essential. It was also believed, from nearly 6 years of experience of vessel calibrations, that the calibration accuracy of the Simrad EK-500 was between 0.1 to 0.2 dB when performed according to standard procedures (Bodholt *et al.* 1989, MacLennan and Simmonds 1992; Foote *et al.* 1987; Foote 1982). Vessel calibrations are however in Norway made in fjords at about 50 - 100 m depth, with the sphere at 20 m or more, and at moderate ping rates (Foote *et al.* 1987). Variations of 0.5 dB magnitude have over the years been observed between survey periods on some vessels, but these deviations have generally been explained by either temperature differences or by the weather conditions during calibration. The earlier experienced deviations from expected accuracy are reported in Ona *et al.* (1996) and in Zhao (1996). In this presentation, data and results were given on the calibration problems, and how they were solved and controlled during the last two years. The starting point of the echo pulse needs to be defined for accurate range determination, as was reported at last year's meeting, otherwise this could contribute significant bias. Using a special version of the EK500 with a 2 cm digitising distance, a new method of range measurement and a high ping rate the bias was reduced to an acceptable level. A dramatic improvement in accuracy at 18 kHz was obtained when a new optimised copper sphere was introduced (64mm). Before this change was made it was thought that ringing may have depressed efficiency.

It was noted that a 3dB increase in TS would be found during gonad development, and suggested that gonad somatic index needed to be included with swim bladder index, ambient pressure, mean and standard deviation of tilt angle as terms in a model to describe fish TS.

In discussion it was noted that the first resonance for the 38.1 tungsten carbide sphere was around ka 7, which meant that 18 kHz would fall down in the Rayliegh scattering region, explaining the requirement for a large sphere to give satisfactory results.

5.4 Masse, J. and Petitgas, P. How to combine data base of schools? Proposal from the CLUSTER EC Project

The database of schools derives from a number of contributors, with the objective to examine changes in fish aggregation that are dependant on environmental parameters. Biomass parameters are recorded per school, together with species composition variables, numbers of schools, numbers of clusters and number of schools per cluster. The smallest unit of description is the school, and other items may be included such as other acoustic information e.g. bottom type. After defining schools, characterisation is followed by stratification into horizontal areas. The school file contains 25 parameters, and the ESDU file acoustic parameters plus environment, substratum, topology, STD data, weather etc. and species information.

The effect of threshold was considered; for example between -60 and -50 dB many schools would be lost, so -60 dB was selected.

For image analysis the Marine Laboratory, Aberdeen Group use -70 dB, and they examined the effect of varying this, in combination of one- or two-stage closures (removal and replacement of the outer ring of pixels of an object) and compared the width, height, S_V and pixels in order to select the optimum procedure.

Using Movies + for school selection was compared with manual selection and Movies + was found to be effective and much faster. Movies + was also compared with Optilab for this purpose and Movies + performed well.

Apparent school length against school depth has been examined by both IFREMER and IEO laboratories, and the minimum fell along the predicted line.

5.5 Fernandes, P. Errors in the B1500 scrutiny process: use your pings

An error has been observed in the BI500 scrutiny process that is caused by a maximum size limit imposed on the vessel-log (VLOG) file. At a typical 10 knots, 5-nautical-mile segments will last for 30 minutes i.e. cover 1800 one-second pings. The size limit for the VLOG file is 1000 pings and if the ping number exceeds this some pings are lost. The magnitude of the resulting error depends on ping to ping variation and the size (horizontal extent in pings) of school relative to the sampled volume (hence range). For large schools at long range ping to ping variation is likely to be small due to beam overlap. Large schools at short range would show greater ping to ping variation.

To detect the problem it is necessary to examine pings whenever the ping file exceeds the VLOG file. Access to the first 1000 pings of the ping file is straightforward, but a new method of access is needed for the whole of the file.

It was noted in the discussion that the software was developed ten years earlier when capacity was limited and scrutiny needed to be fast. More pings were needed for school characterisation than for survey (when autocorrelation makes more frequent samples redundant).

The error described would be most important in situations where a small number of schools contain all the biomass.

5.6 Diner, N. Corrections on school geometry and density approach based on acoustic image simulation

Models of simulated schools have been used to determine the intrinsic variability in echo traces due to beam pattern effect. This work concerns only morphometric and energetic parameters which can be extracted from echo traces.

It appears that the difference, dRS, between school density and processing threshold is a key parameter which directly influences the detection angles concerned. Relationships, taking into account dRS, and also Nbi, the relative school length image compared to the beam width, have been established for the calculation of length and density corrections. In most cases corrected values are obtained with errors less than 5 % for length and 0.5 dB for density (reverberation index), provided that the value of Nbi is 2 or more. When Nbi is less than 1, it seems impossible to apply appropriate corrections. The school energy does not need any correction. To avoid detection through the side lobes, it is recommended that too low threshold values are avoided. However this setting must be determined so that dRS values are greater than 10 dB. Thresholds between - 60 and - 65 dB seem suitable, at least for schools with the Rv values commonly encountered in the Bay of Biscay.

The discussion considered situations when the proposed method would be appropriate, noting that the schools considered were all ellipsoid and of even internal density. A prerequisite was for schools to be larger than the beam.

5.7 Arrhenius, F. and Bethke, E. Intercalibration of the S_A values between R/V *Argos* and *Solea*

When more than one ship are engaged on an acoustic survey, the performance of their equipment should be compared by means of an inter-ship calibration. In 1994 and 1996, in the Baltic Sea, the result of the intercalibration of acoustic equipment indicate that there may be a systematic difference between the German R/V *Solea* and the Swedish *Argos* and Polish *Baltica*. Therefore, an intercalibration experiment was conducted, on three consecutive nights, between R/V *Solea* and *Argos* in October 1997. The result showed that a side-shifted transducer (20-60 m) on the German R/V *Solea* gave 1.4 - 2.5 times higher S_A-values than the hull-mounted transducer used by R/V *Argos*. The two R/Vs *Argos* and *Solea* produce different noise in the water. Generally, there is a tendency for the noise made by the larger ships, like *Argos*, to be higher. This reaction is also dependent on the water depth and distance of the ship. However, we did not found any simple explanation, but the impact of noise from the ships seems to be an important factor to be taken to account. The explanations and a simple conversion factor can not be done at this stage, so further investigation of the present data set and future research work is necessary.

5.8 MacLennan, D.N. and Simmonds, E. J. Discrimination of Fish and Seabed Echoes

The investigation of seabed detection problems, as reported to the 1997 FAST meeting, has continued with further measurements using the tower frame apparatus at the Loch Duich field station on the West Coast of Scotland. The tower is 10 m high with a split-beam transducer at the top and a fish cage at the bottom. In experiments with various densities and sizes of gadoids in the cage, echoes from the vicinity of the seabed have been studied over hard and soft ground. The latter is the natural mud bottom of the Loch while the hard ground has been constructed by depositing 10 tonnes of stones at the experimental site. The effect of a bottom slope may be simulated by rotating the transducer. It was found that rotations up to 6 degrees gave useful results. At larger angles, the echoes from the frame structure become too large.

A suite of MATLAB programs has been developed for the analysis of echo-amplitude and phase data. The phases are used to determine the apparent target direction as two split-beam angles (SBAs). It has been found that the SBA is not necessarily an accurate indication of the target direction. Echoes from fish aggregations and the seabed appear to have quite different characteristics in this respect. When the seabed echo is detected with few interfering targets above, the SBA is an accurate indication of the seabed slope and, assuming the slope does not change over a short series of pings, the SBA is highly correlated. On the other hand, the SBA from fish echoes are highly variable and the ping-to-ping variation is essentially random. Furthermore, when the seabed echo is transmitted through a substantial density of fish, the interference can change the SBA, although the ping-to-ping correlation of the seabed SBA remains superior to that of fish aggregations.

Records from acoustic surveys on various research vessels have been studied to provide comparable results at full scale. When there are few fish, the correlation between the fore-aft SBA and the seabed gradient is optimum just after the first seabed echo and then it declines. But when there are dense aggregations in the bottom zone, the bottom detection algorithm may fail to detect the true seabed. Examples were given to illustrate this problem. The performance of the EK500 algorithm has been studied using a software simulation of the decision rules.

The implications were discussed of poor recognition of the bottom slope under a fish school for the accuracy of information that comes from the bottom of a thick school.

5.9 Simmonds, E.J. and MacLennan, D.N. High Frequency Calibration Problems

Recently there has been a demand for spheres suitable for calibrations at high frequencies, around 0.5 MHz or more. However, the accuracy of the standard target method at such frequencies is unclear. This paper described an experimental investigation of the high frequency calibration problem with particular reference to the SEABAT sonar whose frequency is 455 kHz. Tungsten carbide (WC) is a popular choice of material for standard targets because it is hard, dense and resistant to corrosion., but most of the experimental work on standard targets has been done at low frequencies, below 100 kHz. As the frequency increases, the form function becomes highly variable around certain frequencies due to resonance of the sphere, so a solution is to select a flat part of the curve and choose sphere sizes accordingly. At sizes over 24 mm the form function doesn't have any flat parts, so spheres of 12.7 mm, 16.0 mm and 24.8 mm were tested. Using pairs of spheres, comparisons were made of the amplitudes, but the theoretical predictions did not agree well with the differential TS measurements. There was a discrepancy of 0.7 dB in the case of the two smaller spheres and about 1.4 dB in the comparison of the larger spheres. These discrepancies are rather more than can be explained by the standard error on the observations. In order to use a detector instead of the sphere to search for sharp nulls, the detector needs to be in exactly the same location as the sphere. Measured results fitted the form function closely, nulls being found where expected. At present it seems that any of the tested spheres may be suitable as calibration targets for 455 kHz sonars. But to ensure confidence in the use of these spheres, the discrepancy in the differential TS measurement needs to be explained. It is proposed to conduct a further series of experiments with this aim in mind.

Self-reciprocity was suggested as a possible method for measuring system gain, but this had not been tried.

5.10 Bertrand, A., Josse, E. and Massé J. *In situ* acoustic Target Strength measurements of Bigeye (*Thunnus obesus*) and Yellowfin tuna (*Thunnus albacares*) by coupling split beam echosounder observation and sonic tracking

A research program was carried out in French Polynesia to study tuna behaviour using acoustics and fishing experiments. Acoustics is the most important technique for the study of tuna behaviour and abundance estimation, but target strength estimates are particularly imprecise at the present time. In this study, 4 yellowfin tuna (*Thunnus albacares*) and 2 bigeye tuna (*Thunnus obesus*) of 4 to 50 kg weight were individually caught, identified and equipped with ultrasonic tags for telemetry experiments. While tracking the fish, simultaneous underwater acoustic data were recorded with a split beam echo-sounder in order to estimate their *in situ* acoustic target strength. It was observed that target strength was stronger when the fish were diving than when they were ascending toward the surface. This can be explained by the variation in tilt angle of the swimbladder. A target strength bias according to depth was also observed.

5.11 Williamson, N. J. Temperature dependence of a Simrad 120 kHz split beam transducer

At the Alaska Fisheries Science Center, the 38 and 120 kHz split beam transducers are mounted on the end of a centerboard on the research vessel, the NOAA Ship *Miller Freeman*. When the centerboard is fully extended, these transducers are 4 m from the hull and 9.15 m below the water surface. The systems are calibrated before, during, and after both the winter and summer field seasons. The sphere calibration techniques described in the Simrad EK500 v5.20 Operator Manual and the ICES calibration manual by Foote *et. al.* (1987)are employed. The 38 kHz system has remained relatively stable during the six years that it has been used. Water temperature seems to have no effect on transducer characteristics. The same is not true for the 120 kHz system. Since its first use in the winter of 1997, the system has been calibrated 12 different times in both the Seattle area and at locations in Alaska, using a 23 mm copper sphere and the EK500 v5.20 roms. The results of these calibrations were presented. Water temperature at the transducer depth was measured using a Seabird CTD profiler. Distance of the sphere from the transducer ranged from a minimum of 20.3 m to a maximum of 28.3 m. The data reveal a significant relationship between system sensitivity and transducer temperature. TS transducer gain (as defined in the calibration section of the EK500 manual) increases with water temperature. A clear monotonic increase in gain from 3.4 to 11.6 degrees C was observed of approximately 2.5 dB.

It is not known whether this temperature dependence is inherent in the design of the transducer or symptomatic of a faulty transducer. Any information about the temperature sensitivity of other transducers, particularly at 120 kHz would be appreciated.

Other members of the group reported similar changes in calibration with temperature at this frequency ranging from 6 dB over 22, down to 1dB. Changes in impedance measurements made on a transducer that had undergone chilling were also reported.

6 SESSION B SOURCES OF UNCERTAINTIES IN ACOUSTIC SURVEYS: RESULTS OF THE QUESTIONNAIRE ON UNCERTAINTIES IN FISHERIES ACOUSTICS

6.1 Notes on Report

The report is included as Appendix C. Numbers in parentheses throughout these notes refer to sections of the report.

Attention was drawn to particular important errors in each of the categories:

1. Acoustic signal

   1.1 120 kHz generated much larger errors in on-axis calibration than 38 kHz

   1.2 Equivalent beam angle: it was noted that the programme 'lobe' supplied by Simrad will not measure changes in beam angle. Also that transducer sector failure in a split-beam sounder only results in lower sensitivity and is not apparent on the target strength (TS) display, resulting in an oval beam shape.

2. Sampling strategy

   2.1 General sampling precision: 38 kHz errors in this category were important and well estimated, but 120 kHz had generated fewer responses

3./4. Fish discrimination and fish behaviour

   4.2 Fish TS: of the errors in these groups there was an overwhelming bias introduced by estimates of both maximum and mean TS.

For 38kHz, TS errors (1.7), general sampling precision (2.1) and discrimination between fish species were highlighted, and for 120 kHz additional physical absorption (1.5) by shadowing and the bubble layer were known areas of uncertainty, although it was recognised that insufficient dynamic range was a historical problem.

6.2 Discussion

Losses through physical absorption were thought to be very important losing up to a half of the echo energy around sea-state 4-5, and keels were acknowledged to be an important solution for this problem. Absorption within schools is known to occur when thickness exceeds 10m. Following recognition of this effect, herring estimates may be elevated by 10%. Shadowing was considered to be important by several members and it was noted that a reset would need to be completely filled with fish in order that this effect was not confounded by dilution of S_A by clear water. (1.5)

A significant difference was pointed out between absorption coefficients depending on which formula is used to estimate this: Fisher and Simmons or François and Garrison - the latter is considered most appropriate. (1.4)

The importance of linked net data to determine species proportion was raised, errors in this estimate could be as important as errors in TS. (3.2)

Ways of categorising the list of errors were discussed, such as into solved versus unresolved or human error versus equipment failure, in order to highlight which issues need most work.

The inclusion of response to catastrophic change should not be included in the list of errors, and instead can be seen as a topic that can be addressed using acoustic methods. (4.4) Diurnal/circadian change can be viewed in the same light (4.3).

Major problems remaining were seen to be related to behaviour rather than acoustics, and include avoidance, TS, boundaries between schools and the seabed, species proportion and discrimination. Resolving these will require new resources. Most members of the group experienced all of these problems, although fish avoidance and attraction varied in the level of importance of its contribution to error budgets. These topics were thought to be suitable for a joint meeting between the FAST and FTFB Working Groups. (3./4.)

Various approaches were suggested for increasing the level of understanding of avoidance including studies using newer quieter vessels for comparison with older vessels, and the provision of advice to others outside the group about the significance of this topic. (4.1)

The importance of tabulating data on errors, providing a system of quality control for assessments. A system is required that will document survey conditions such as noise levels, weather conditions, changes during surveys such as propeller damage etc.

7 OTHER TOPICS

A Symposium on Fish & Plankton Acoustics is planned for June 10-14 2002 at Montpellier, with J Massé and F Gerlotto as convenors.

A conference on Shallow Water Acoustics is planned to be held in Seattle in 1999.

Participants were reminded of the forthcoming Theme Session at the ICES Annual Science Conference: Variation in the Pattern of Fish Aggregation: Measurement and Analysis at Different Spatial and Temporal Scales and Implications. Convenors: F Gerlotto and D Reid.

The ICES Five Years Plan had been circulated and was described to Members of the Working Group who were requested to send comments by e-mail to P Stewart. The main changes will be the need to plan further ahead, and that there may be opportunity for joint study groups and new study groups.

Comments to stewartpam@marlab.ac.uk

8 RECOMMENDATIONS

The WGFAST should meet at the Memorial University Fisheries and Marine Institute, St. John's, Newfoundland, Canada between 17-25 April 1999 to consider and encourage studies on:

a) The impact of fish avoidance on the results of fisheries acoustics, particularly:

- the effect on target strength
- the effect on biomass estimation
- the effect on species identification

Ian McQuinn will lead a group and produce a report on the state-of-the-art to be presented in 1999 at the WGFAST

b) The development of acoustic methods and tools for *in situ* observations of fish behaviour

c) Consider the application of acoustic techniques to bottom trawl surveys

d) consider the effect of spatial distribution of fish on TS measurements, through the invitation of a keynote speaker on this topic.

e) The group will also:

  a) Following the recommendation of FCT in 1996 circulate through FAST e-mail forum data exchange formats for analysis.

  b) Propose the following theme sessions for the Annual Science Conference:

  - Evaluation of species assemblages from marine resource surveys
  - Behaviour affecting data in Fisheries Research
  - Consider the application of acoustic techniques to bottom trawl surveys

c) Final drafts for the Echo Trace Classification Report would be prepared by November so that a final version can be available for editing immediately before the WGFAST meeting in April, to be then published as a Co-operative Research Report between April 1999 and September 1999.

Justifications.

a) The results of the questionnaire on uncertainties in fisheries acoustics demonstrated that the present weak points in the fisheries acoustics methods are mainly related to fish behaviour, in three areas:

- the effect of fish movements and behaviour on the results of TS measurements and TS values *in situ:* TS remains the keystone of fisheries acoustics and it is essential to have a clear idea of the effect of behaviour on this value, from two aspects: on the variability of values during the measurements of a single fish; and on the statistical variability of TRS *in situ*

- the effect of fish behaviour on species identification. Here too, there are two facets to the effect of fish behaviour: on one hand it may bias the result of fishing samples (fish avoidance, escapement, etc.) and on the other hand it can help indirect identification (when fish behave in a particular way, it may lead to their identification, e.g. through school typology, etc.).

- the effect on fish biomass evaluation: fish behaviour may bias the evaluation, mainly due to fish and school avoidance, but also by changing mean TS values, or through shading, etc.

Special attention on these points is a priority, in order to deliver more accurate results.

b) Considering that fish behaviour is one of the most important sources of bias in fisheries acoustics, it is important to be able to observe and understand in order to evaluate its effects. Acoustics is one of the few techniques that is able to perform direct observation and quantitative measurements on fish *in situ*. Developing tools for this purpose is considered important by the fisheries acoustics community, in order to quantify the impact of behaviour on survey data.

c) Acoustic methods permit the measurement of fish biomass very close to the bottom. In addition, survey design and statistical tools have been developed, which could help with the analysis of bottom trawl surveys. These methods suffer from many biases, the most important being the fact that the relationship between the catch and the actual population density and distribution, which is supposed to be constant, may vary according to fish vertical distribution and behaviour. The main potential contribution of acoustics to bottom trawl surveys is to evaluate the representativeness of the catch compared with the actual fish distribution. Fish avoidance, escapement, and the vertical distribution of demersal fish could be documented by acoustic methods and the biases evaluated. The methodology of the links between the two techniques requires developmental research.

d) Another important source of uncertainties that arose from the analysis of the questionnaire is that TS measurement are strongly influenced by the spatial density statistics of scatterers. No simple way of correcting this fact exists. The WG. concluded that a first step would be that a keynote speaker be invited to address the WGFAST in 1999 on the subject 'optimum methods for estimating the mean target strength in relation to spatial density statistics of scatterers'. J. Ehrenberg or D. Farmer will be asked if they will speak on this topic.

e) A general format for exchanging data and using software for echo classification and analysis was agreed as indispensable during the WGFAST, Woods Hole, 1996. Several formats were submitted. A final choice should be done no later than 1999. All the potentially usable formats will be considered by the FAST community during the current year and the selection of the universal one will be done at the 1999 meeting. This selection is required by the manufacturer to produce a translator from their own formats to the common one.

9 CLOSURE OF WGFAST MEETING

The chairman thanked the staff of the Instituto Español de Oceanografia, A Coruña for their hospitality, and closed the meeting.

APPENDIX A: NATIONAL PROGRESS REPORTS

A. DENMARK

Ministeriet for Fødevarer, Landbrug og Fiskeri

Danmarks Fiskeriundersøgelser

Afdeling for Fiskebiologi

ICES Working Group on Fisheries
Acoustics Science and Technology
A Coruña, Spain, 21-23 April 1998

Acoustic activities 1997 - Progress Report of Denmark

Jens Pedersen, Bo Lundgren, Torben F. Jensen, Karl-Johan Stæhr and Rasmus Nielsen

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 Skagerrak 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 co-ordinated by ICES. Contact: Jens Pedersen, jp@dfu.min.dk.

2) Two surveys during February-April and one survey during October-November in the Sound between Denmark and Sweden to monitor the Rügen herring *(Clupea harengus)* stock with the R/V *Havfisken.* The objectives of the project is to provide background information for the evaluation of possible impacts of the construction of the Sound Bridge between Denmark and Sweden related to possible changes in distribution and migration patterns of herring *(Clupea harengus)* in the Sound. Contact: Karl-Johan Stæhr, kjs@dfu.min.dk.

3) One survey with R/V *Dana* in January to investigate the conditions for the recruitment of cod *(Gadus morhua)* in the Baltic was supplemented by measurement of the distribution and density of juvenile cod *(Gadus morhua)* in relation to hydrographical and biological conditions using hydroacoustic and trawl sampling methods. This survey is a part of the EU CORE-project.

Contact: Rasmus Nielsen, rn@dfu.min.dk.

II) Special field investigations

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

III) Laboratory investigation

An experiment to measure the target strength of 0-group (5-10 cm) cod *(Gadus morhua)* was carried out in the large 2000 m^3 tank in Hirtshals using an 120 kHz EY500 split beam echo sounder. To check the size and approximate tilt angle of the fish the experiment was complemented by video recording. Contact: Rasmus Nielsen, rn@dfu.min.dk, and Bo Lundgren, bl@dfu.min.dk.

IV) Other activities

New methods to stratify survey data with regard to depth contours are tried out. This work is made together with ConStat. Contact: Jens Pedersen, jp@dfu.min.dk, and Torben F. Jensen, tfj@dfu.min.dk.

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

Work has been done to describe the distribution of the position of single fish in layers using point process methods. This work is made together with ConStat.

Contact: Jens Pedersen, jp@dfu.min.dk.

Development of an international database for acoustic and biological data obtained during the international acoustic survey for herring *(Clupea harengus)* in the North Sea and west of Scotland. The project is a part of the EU-project HERSUR.

Contact: Karl-Johan Stæhr, kjs@dfu.min.dk.

B. GERMANY

Progress report 1997
Federal Research Centre for Fisheries, Institute for Fisheries Techniques, Hamburg
(contact: bethke.e@metronet.de egoetze@metronet.de)

1. International Surveys

<u>RV "Walther Herwig" 183;</u> March-April 1997
International hydroacoustic survey on atlanto-scandian herring in the Norwegian Sea from 62EN - 68EN off the Norwegian coast
<u>Participation Acoustic Survey Norwegian Sea</u> RV "Argos", first part <u>RV "Walther Herwig" 186-</u>, June-July 1997
ICES co-ordinated Herring Survey in the North Sea "Walther Herwig" covered the south-eastern part of Div. IVb. Hydroacoustic intercalibrations with "G. O. Sars" and "Dana".
<u>RV "Solea"</u> 414. September-October 1997
ICES co-ordinated survey on herring and sprat stocks in the Baltic
The working area of "Solea" was the Western Baltic (ICES sub-div. 21-24)

2. Special investigations

<u>RV "Solea"</u> 415- October 1997
Joint investigations with the Swedish RV "Argos" in the Baltic. Catch comparison, intercalibration and investigation of fright reactions with a side shifted towed body were carried out.

3. Acoustic equipment

RV "Walther Herwig"
Echosounder EK 500 with hull mounted transducers for 18 kHz (single beam) and 38, 120 kHz (split beam). In bad weather situations and looking in a greater depth also a towed body VD500 (38 and 120 kHz split beam) is used.
RV "Solea"
Echosounder EK 500 with a transducer 38-26 (single beam) installed in a towed body. The 120 kHz channel is working with a hull mounted transducer.

On both vessels the Bergen-integrator B1500 is used for the registration and analysis of acoustic data.

4. Technical developments

Signal and image processing software system "Khoros" running on a SUN workstation. Software is written to load BI500 data to the image processing system, edit the data and convert the format of the images (logarithmic to linear and vice versa). The use of powerful tools provided by the program for further investigations is possible now.

C. UNITED KINGDOM

British Antarctic Survey, Cambridge.

Acoustic studies were carried out on the RRS James Clark Ross in three months of sea time in the South Atlantic during the austral spring and summer 1997-1998. Using a Simrad EK500 sounder with split beam 120 kHz and 38 kHz, and single beam 200 kHz hull-mounted transducers, integrated and raw data were logged over a LAN to a Sun workstation. The sounder was calibrated on three occasions at South Georgia and once at King George Island (Antarctic Peninsula) using the target sphere method. Surveys included large scale acoustic and oceanographic transects between Stanley, Falkland Islands, South Georgia, the South Sandwich Islands and the Antarctic peninsula. Throughout the cruises targeted fishing was carried out in support of our continuing investigations into the identification and classification of acoustic targets in the mesoplankton and small nekton range.

In October 1997 comparative zooplankton studies were carried out using acoustics in conjunction with a Longhurst-Hardy Plankton Recorder and Optical Plankton Counter at sites on and off the South Georgia shelf. Contact Jon Watkins or Andy Brierley for more details.

A group of geneticists joined the ship during November and December to collect material for studies of the genetics of larval fish, krill and other zooplankton from widespread sites between the Falkland Islands, the Scotia Arc and the Antarctic Peninsula. Acoustics were used to locate suitable fishing targets, and provided a valuable record of the distribution of targets in relation to local oceanographic conditions throughout this extensive survey. Contact Cathy Goss or Andy Brierley for more details.

In January and February 1998 two rectangular areas on and off the shelf to the north of the island of South Georgia were surveyed using acoustics, nets and oceanographic measurements. These box surveys were the third in a series that are being repeated each year for at least five years in order to study inter-annual variation in krill and other zooplankton in relation to oceanography. Contact Jon Watkins or Cathy Goss for more details.

D. USA

Progress Report
APRIL 1998

The Alaska Fisheries Science Center continues work on stock assessment of pollock and whiting in the North Pacific. Keywords: stock assessment, target strength, acoustic buoy, lowered transducer system. Contact: Chris Wilson, chris.wilson@afsc.noaa.gov

The Antarctic Ecosystems Research Group at the Southwest Fisheries Science Center continues work on stock assessment of krill. Keywords: predator-prey interactions, uncertainty in echo-integration techniques, target strength, multi-frequency methods, acoustic doppler. Contact: David Demer, ddemer@ucsd.edu

The Northeast Fisheries Science Center continues its examination of the impact of predation on larval and early demersal juvenile Atlantic cod and haddock. Keywords: US Globec, EK500, plankton. Contact: William Michaels, William_Michaels@noaa.gov

The Naval Research Laboratory, Stennis Space Center, continues investigations on the low frequency backscattering characteristics of schools of swimbladder bearing fish. Keywords: biological modelling of fish distributions, theoretical modelling of school-scattering, simulations, and measurements. Contact: Woody Nero woody, nero@nrlssc.navy.mil

The Southeast Fisheries Science Center is continuing hydroacoustic stock assessment activities on sharks, small pelagics, and reef fish. Keywords: multifrequency, reef studies, zooplankton. Contact: Walt Gandy, Walt_Gandy@noaa.gov

Tracor's programs in bioacoustics currently involve projects in three areas: (1) the use of multiple frequency acoustical sensors to study vertical structures in zooplankton with sub-meter dimensions; (2) improvements and extensions of inverse theory and applications, related to transformation of volume scattering strength data to estimates of biomass and size spectra for zooplankton; and (3) the application of high resolution acoustical methods in problems in benthic ecology. We continue to work with Richard Pieper at USC and a number of other scientists in processing, interpreting and publishing data from the BITS mooring off Southern California and deployments of our TAPS technology in the Arabian Sea (on a SEASOAR), on Georges Bank (on a SEASOAR), in the Bering Sea (on a CTD), in estuaries and fjords (bottom mounted, upward looking) and elsewhere with various modes of deployment. Additional information on our activities, as well as some data and information relevant to technology of interest to FAST WG members are now available on the World Wide Web at "http://www.aard.tracor.com" in the section on Ecosystems Research. Contact: D. V. Holliday, holliday@galileo.tracor.com.

Woods Hole Oceanographic Institution Scientists continue their work on acoustic surveys of zooplankton. Keywords: acoustic scattering models, laboratory measurements of zooplankton target strengths, acoustic surveys

Contacts: Tim Stanton, tstanton@whoi.edu and Peter Wiebe, pwiebe@whoi.edu.

The NOAA Great Lakes Environmental Research Laboratory has taken over and expanded much of the acoustic work of the Great Lakes Center at Buffalo State College. They continue work on pelagic fishes in east coast estuaries, lakes and rivers and continue their work on using Acoustic data to support spatially-explicit ecological models and Geographic Information Systems to assess predator-prey relationships and fish production. Key words: acoustic buoy, multifrequency acoustics, ecological modelling, fish scattering models.

Contact: John Horne, horne@glerl.noaa.gov.

E. France

Progress Report, April 1998

Fisheries acoustics activities in France are mainly developed by two Institutes: IFREMER and ORSTOM

- ORSTOM.

The institute counts with 7 scientists (full time) for marine acoustics, 3 scientists(mid time) for fresh water acoustics, and 4 technicians. The main activities are focused on:

⇒ stock assessment (Indonesia). The field activities in the Java sea are completed and a final report is being published. A PhD thesis on the relationships between ecology, fishery and fish structures distribution (schools and TS) will be submitted in September, 1998, by an Indonesian student.

⇒ Habitat and trophic relationships. The relationship between tuna aggregation and scattering layers are studied in the Atlantic Ocean (program PICOLO, description of tuna preys spatio-temporal behaviour) and the Pacific Ocean (Tahiti, description of the pelagic habitat of tuna). Results on tune TS, and tuna prey distribution were published.

⇒ Sardinella school typology and behaviour. A comparative study for *Sardinella aurita* school typology and behaviour is undertaken in Senegal, Ivory Coast and Venezuela. Results allowed to define a school typology related to this species. The relationships between school avoidance and fishing pressure is studied. Results on the effect of meteorological events were presented.

⇒ Shallow water acoustics. This is performed mainly in co-operation with the Caribbean Acoustic Network (Cuba, Mexico, Venezuela, Costa Rica, Colombia, USA). Results on stock evaluation and TS at short distances are being published.

⇒ European projects. ORSTOM is involved in AVITIS (elaboration of a multibeam sonar system for fisheries acoustics) and CLUSTER (school and aggregation studies).

⇒ Surveys: done with the two ORSTOM research vessels in the Pacific (R/V Alis: 4 surveys) and Atlantic (R/V Antea,: 7 surveys) oceans, plus surveys aboard small crafts and fishing vessels.

⇒ Equipment deployed: Simrad EK500 (38 and 120 kHz) and EY500 (38 and 120 kHz); Biosonics 102 and DT5000 (120 kHz); Simrad sonar SR240 (24 kHz); Reson sonar Seabat 6012 (455 kHz); TAPS (Tracor); acoustic tags; OSSIAN (38 and 120 kHz)

- IFREMER.

Développements technologiques

- **Projet MOVIES+**: un nouveau logiciel est en cours de développement à l'IFREMER. Il va remplacer l'ancien MOVIESB, mis au point il y a 10 ans, dont il va reprendre les différentes fonctionnalités en les complétant. Il sera compatible avec les sondeurs numériques comme OSSIAN Simrad EK500 ou Biosonics. Il permettra l'archivage des données au nouveau format *.HAC défini par nos collègues canadiens. La version 1 qui comporte toutes les fonctionnalités de MOVIESB, est opérationnelle depuis le début 1998.

- **Système SABRINA**: le nouveau N.O. THALASSA a été doté d'un système temps réel d'analyse du bruit rayonné par le navire. Il permet en temps réel une analyse spectrale du bruit du navire, dont les niveaux relatifs peuvent être comparés à des niveaux de référence. Le niveau d'émission de tous les équipements de détection acoustique peut également être contrôler en temps réel.

Campagnes effectuées dans le cadre des recherches halieutiques:

La campagne **PEGASE** destinée à évaluer la répartition et l'abondance des petits pélagiques dans le Golfe de Gascogne a été effectuée en juin 1997 à bord du nouveau navire océanographique THALASSA. Cette campagne était plus particulièrement destinée à évaluer le stock d'anchois et récolter le maximum de données environnementales afin d'en étudier le déterminisme du recrutement. C'était la première campagne d'évaluation acoustique réalisée à bord de ce nouveau navire où un ensemble important de systèmes informatiques a été élaboré pour stocker et traiter en temps réel les données acoustiques, environnementales et de navigation.

Deux campagnes acoustiques ont été réalisées à bord du navire océanographique L'EUROPE:

PELMED destinée à évaluer les stocks de petits pélagiques dans le Golfe du Lion (Méditerranée) et récolter des données environnementales liées en particulier à l'anchois et à la sardine.

ERYTHREE afin d'étudier les ressources halieutiques potentielles en Mer Rouge le long de la côte érythréenne.

Programme européen CLUSTER:

L'ensemble des données acoustiques a été stocké et analysé grâce au logiciel MOVIES et donnent lieu en partie aujourd'hui à des analyses particulières par bancs dans l'optique du programme européen CLUSTER. Dans ce même cadre, un effort particulier a été consenti pour tenter la normalisation des données acquises par différents équipements acoustiques.

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APPENDIX C: SOURCES OF UNCERTAINTIES IN ACOUSTIC SURVEYS: RESULTS OF THE QUESTIONNAIRE ON UNCERTAINTIES IN FISHERIES ACOUSTICS

The relative importance of sources of variability in acoustic surveys

FAST WG 21-23 April 1997

Following ICES recommendations to the FAST WG in 1997 a questionnaire concerning perceptions of uncertainties in the quantitative use of acoustics in fisheries and plankton observations was developed. The terms of reference for the questionnaire were:

> that a questionnaire be circulated to members of the working group to compile a synthesis of opinion on sources of uncertainty in acoustic surveys. The questionnaire should be structured to provide information under the following categories; Acoustic Signal, Sampling Strategy, Fish Discrimination, Fish Behaviour.

Originally it was intended that the questionnaire should be circulated by August and the results collated in the New Year. However, this was delayed and the questionnaire was circulated to all FAST members in December 1997, (a copy of the questionnaire is included as Annex A to this report). Participants were requested to estimate the magnitude of errors under a fairly extensive catalogue described under the four major categories given above. The complete list of errors and their definitions are given in Table 1. Reminders were issued in February and in late March. A total of 24 responses were received, sixteen for systems operating at 38kHz , seven at 100 / 120kHz, a single response for the multi-frequency (MAPS). The two sets of single frequency responses were collated to provide two summaries of random and systematic errors. The MAPS Multi-frequency system provides a completely different approach and the complete response for this system is included below. The respondents were requested to give numerical estimates of variability, an indication of the quality of this information and provide general comments. The original intention was to give different weighting to the results based on the quality of the data supporting the numerical values, however, often the differences between guesses and real data were small and the in most cases categories were either mostly guesses or mostly based on calculated values. For 38kHz 140 values were guesses, 33 were estimated from a small range of values, 3 were from CVs and 8 from estimated confidence intervals. For 100/120kHz 47 values were guesses, 8 were from a range of values, 5 from CVs and 5 from confidence intervals. The quality of the data and the general comments supplied by participants are collated in Tables 2 and 3 for 38kHz and 100/120kHz respectively. As the results were predominantly based on intelligent guesses the absolute values are not particularly reliable, however, it is felt that the relative values of each estimated error does provide a good guide of its importance. The summarised numerical results expressed as relative random errors and relative biases are given in Figures 1 and 2 for 38kHz and Figures 3 and 4 for 100/120kHz. The results for the MAPS system are given in Table 5. The names affiliations and contact details of all who responded are detailed in Table 6.

The conclusions of the study provided a consensus of agreement that the sources a variability could be separated into two groups:

Group 1 Major sources of variability

Target strength, both baseline mean values and behaviour related variability.
Species composition, estimated by direct discrimination or by numerical proportions.
Spatial distribution sampling precision.

Group 2 Secondary important sources of variability

Behaviour related change, diel change, catastrophic change
Avoidance,.
Local mean target strength
Location of the stock
Stock migration or movement
Target discrimination near boundaries
Additional absorption, surface bubbles, dense schools
System calibration at higher frequencies

Conclusions

The results of this study point to several areas of primary development; a) improved methodology to investigate local mean target strength, b) improved acoustic classification and species identification techniques, c) improved biological sampling or alternative identification methods, and d) methods for collecting additional information to reduce the variability of acoustic estimates of abundance at a location.

Table 1 A Description of the Sources of Errors

1Acoustic Signal	**This group covers all aspects of the measurement that affect the value of the measured signal**
1.1 On axis Calibration	The combined uncertainties due to estimation of the transmit and receive sensitivities of the sounder system by standard target or other method, including uncertainties in the standard sphere or hydrophone, system transfer functions, bandwidth and temporal stability due to thermal change or ageing .
1.2 Equivalent beam Angle	The uncertainty due to the value of the equivalent beam angle, the measurement of the two angles of the beam width, or the area of the beam, due to mounting, temperature effects due to use, or to water changes.
1.3 Time varied Gain Range	Uncertainties due to incorrect matching of gain profile in the instrument and the propagation in the water due to sound velocity variation or instrument settings.
1.4 Time varied gain Attenuation	Uncertainties due to incorrect implementation of absorption factor in the TVG function or due to uncertainties in the correct factor to use or the correct temperature and salinity values.
1.5 Additional physical absorption	Extra variable losses due to weather dependent bubbles or other absorbing material between the transducer and the targets of interest, or shadowing effects within a school.
1.6 Motion related losses	Losses in signal due to the misalignment between transmit and receive beams due to motion
1.7 Baseline Fish Target Strength Value	Uncertainties in the mean target strength value used on the survey if derived from a standard value or standard equation, or the error in the mean if the Fish Target Strength is measured during the survey (for errors due to fish sampling see below).
1.8 Measurement of target physical size	Uncertainties in measurement of shoal size or fish size due to beam shape, for example where the beam is smaller than the fish or the shoal.
1.9 Equipment mistakes	Errors introduced because important aspects of the equipment or processing software designed were not known by the operator and not originally described by the manufacturer.
2 Sampling Strategy	**All aspects of uncertainties due to the limited data collected on the survey.**
2.1 General Sampling precision	The errors associated with estimating the mean acoustic area back scattering strength in an area due to the limited sample.
2.2 Error due to motion	The impact of the space time interaction between the motion of the stock, random or migration, and the motion of the vessel carrying out the survey.
2.3 Errors in local mean target strength	Errors in fish size in the catch leading to the incorrect mean target strength applied locally, and errors due to fishing gear size selectivity.
2.4 Errors in fish proportions	Errors in the estimation of one species due to uncertainties in the split by species from catch sampling data and fishing gear species selectivity.
2.5 Errors due to location	Errors introduced by the incorrect choice of area due to unpredictable location of the stock, i.e. missing population.
3 Fish Discrimination	**All errors introduced due to the uncertainties of target identification.**
3.1 Discrimination between Fish other targets	The errors due to the separation of fish from plankton layers or bubble layers, including errors in fish target strength if measured during the survey.
3.2 Discrimination Between Fish Species	The errors due to incorrect fish species recognition.

3.3 Discrimination between Plankton Species	The errors due to incorrect species allocation in plankton.
3.4 Discrimination between targets and seabed or surface	The errors introduced due to incorrect allocation of fish and boundary echoes from for example the seabed due to proximity of the seabed, sea surface or any other boundaries.
4 Fish Behaviour	**All other fish behaviour related errors not described above.**
4.1 Fish Avoidance or Attraction	Error in number of targets observed due to the presence of the survey vessel.
4.2 Fish Target strength	Variation in target strength caused by the presence of the survey vessel.
4.3 Diurnal/Circadian change	Variation in target strength or availability of the targets to the survey due to changes in behaviour over a 24 hour period.
4.4 Response to Catastrophic change	Variation in abundance due to behavioural changes due to major weather events or any other influence which provides change that occurs over significant proportions of the survey period.

Table 2 Comments on error sources at 38kHz. Source of error, numbers and quality of responses (G=guess, R=range of values, C=CV & F=Confidence Intervals) and comments.

1Acoustic Signal		
1.1 On axis Calibration	10R1C	Based on range of SV gain values from calibrations using standard spheres. Occasional large changes seen, sometimes the cause is not known, sometimes due to loss of a transducer quadrant.
1.2 Equivalent beam Angle	4C2R3 F2G	Based on measurements with full monitoring of angles and also with angles derived from Eklobe program. Some include changes following mounting of the transducer.
1.3 Time varied Gain Range	11G1R	Based on sound speed chosen to match temp-salinity profiles, but in deep water and long pulse lengths the error is larger than for shallow waters. Approximate temp dependant changes during survey.
1.4 Time varied gain Attenuation	6G1R	Based on a mean alpha chosen to match temperature-salinity profiles, numerical processing giving over and underestimation in different parts of survey. Bias in absorption from equations, unknown.
1.5 Additional physical absorption	7G2R	Sometimes ignored as shadowing regarded as negligible (Furusawa et al, 1992); Transducers on the centre-board minimises bubble problem (Ona and Traynor, 1990); Novarini-Bruno (1983) eqn gives effects < 0.01 dB but not checked; The problem is small some absorption from bubbles reduced due to the use of a towed body. Main problems are for hull mounted transducers. In some cases a correction is made to the SA-values due to bubble attenuation. This is done by judging the echo-grams by eye, and may be biased either way, but rather more likely to be an underestimate. The errors given are only valid for those parts of the survey where correction has to be made.
1.6 Motion related losses	7G1R	Rate of motion not measured but best guess of rotation rate from Fig 8.14 in MacLennan and Simmonds (1992). In an other case it is based on the mean pitch and roll of the vessel and the associated water depth.
1.7 Baseline Target Strength Value	7G3R	20logL-66 Traynor (1996); 0.5 dB error possible, herring equation has been used for anchovy, probably estimated TS too high; 1 dB error possible measured single fish TS has resulted in to low biomass estimates. Comparison of VPA and acoustics was used to estimate the TS in use. Based on in situ measurements, carried out during the surveys. Range of values depend on the validity of methods for single target discrimination being unbiased. Unknown – similar to cage measurements error not known. The TS used is based on measurements made in Norway.
1.8 Measurement of target physical size	1G	Schools : depending of the size of the schools, individual fish : size measured in,.
1.9 Equipment mistakes	10G	Assumed negligible. Wrong beamwidth used on 1 occasion. Assumed negligible TVG in the uppermost 30 m,. Error due to TVG-start time. Corrected for transducer sector failure.
1.10 Any additional factors	2R	Dynamic range problems – newer equipment less prone to these problems. Vessel noise requiring changes in threshold setting in integration. Previously saturation on EK400 but not now with the EK500, errors species-dependent
2 Sampling Strategy		
2.1 General Sampling precision	4C4F4 G	Based on Williamson & Traynor (1996); 1-D EVA; 5 nmi spacing 20 nmi spacing. The level depends on species 10/5 nmi spacing. Based on several repeated measurements , Redfish is distributed evenly over a very big area (SA-values in the range 2-200) Typical survey CV ±(10-25%) Based on acoustic numbers calculated by geostatistics.
2.2 Error due to motion	10G	Small with short survey; small area; timed to minimise migration but some transects are over 300 nmi long. North-south migration minimal; E-W transects short . Assume that there is a 10% turnover rate on the ground being, Unknown – migration of stock possible .

2.3 Errors in local mean target strength	7G1C	Based on fish size errors. Problems trying to sample centre and bottom of aggregations difficult when several year classes mixed. Negligible for large fish, bigger errors for pre-recruits (due to gear selectivity) depending on species and correct form using literature relationships. More difficult when several year classes mixed. Not significant if big the small fish are normally at different locations. Insignificant where the length distribution of the fish is very even over the whole area, and the fishing gear is designed to be able to catch even smaller fish. Can be significant due to trawl selection in surveys, when juvenile and adult capelin mix to a variable degree. Likely bias towards catching younger fish.
2.4 Errors in fish proportions	9G1C	In some cases catches (by weight) are almost 100%, Probably small depending on species (specific gear catchability) not considered a problem. Generally the target species is dominant, the major problem is when the target species has a low variability. Orange Roughy have a low TS compared with many of the other species, making species proportions important. Based on proportion of stock with poor identification. Tendency NOT to allocate when in doubt.
2.5 Errors due to location	4G3R	Geographic distribution consistent year to year; inshore area (< 70 m) not surveyed. Negligible but does depend on species (inaccessible fish ashore, on the surface, close to the bottom.) recent survey design changes remedied this problem. Experience has shown that occasionally the results from a survey must be discarded. The main problem has been in covering the whole distribution area. There is a hope fish found by industry outside the survey area. Not a problem if the full coverage is coast to coast. Migration across ICES stock lines is a recent problem
3 Fish Discrimination		
3.1 Discrimination between Fish and other targets	6G1R	Jellyfish a big problem in south-east shelf area the main problem is plankton. Macrozooplankton a "minor" problem off California Mostly insignificant, but can be troublesome during night time. The problem is more or less solved by either surveying only during daytime or discarding night time data. Solved by thresholding
3.2 Discrimination Between Fish Species	11G2R	Mostly caused when several species are together. Myctophid "contaminants" relatively occasionally giving small problems but more severe below 350-400 m,. Probably progress may possible with a systematic classification of aggregations compared to identification catches. Discrimination of fish species is not often a problem during herring surveys. This problem actually sets the lower limit of echo integration of the redfish. Problem is severe because of low ts of target species. Discrimination of fish species is hardly a problem during capelin surveys.
3.3 Discrimination between Plankton Species	1G	Not often applicable. Threshold used to exclude plankton.
3.4 Discrimination between targets and seabed or surface	11G1R	Proximity to seabed may sometimes lead to errors. Some schools missed very occasional seabed counted. Pollock are found in midwater far off seabed flat bottom combined w/ good weather and gives no problems. Bottom backstep too small and about 10% of targets are in non-surveyed surface region especially at the shelf break or in sharp bottom gradients. The majority of whiting are in midwater well off bottom In some locations the herring reaches very close to the shoreline and the ship can not reach the limits of distribution. The oceanic redfish is located well away from boundaries, such as bottom and surface. The capelin is usually located well away from boundaries, such as bottom and surface.
4 Fish Behaviour		
4.1 Fish Avoidance or Attraction	7G2R	Not known but may sometimes influence the measurements but more likely, due to noisy charter vessels. Could be important depending on species, biological conditions, time. If fish are found deep the effect is not really known. Pollock are found 300-600 m below vessel and the influence is assumed negligible; The oceanic redfish is mostly observed at 150-350 m. Single-fish traces are predominant and no avoiding reaction has been observed. Some investigations are in progress.

4.2 Fish Target strength	5G1R	For pollock 300-600 m below vessel assumed negligible; investigation in progress since vessel (is noisy. Tilt angle changes assumed negligible. Sailing at different speed during trawling, with no noticeable effect on the target strength values.
4.3 Diurnal/Circadian change	6G1R	24 hr/day survey; availability is unchanged; no observed vertical migration; no dispersion at night; For daytime only survey not a problem depending on species (for example, herring and anchovy) Coinciding diurnal (diel) variation in SA and TS have been observed and taken into account.
4.4 Response to Catastrophic change	6G1R	Where the weather is usually fairly good at the time of the survey there are no obvious signs. For pollock 300-600 m below vessel good weather almost all the time This problem depending on species and location. For the Atlantic fish they may need at least 48 h to recover a balance situation, in Mediterranean sea, 12 h are often enough. Sometimes bad spells of weather may cause the capelin to change its behaviour or distribution. Difficult to quantify, but schools seem to recover fast, aggregations are generally similar between years and areas.
5 Any Additional Errors	1F	Possible problems due to timing of a survey with changes in maturity state.

Table 3 Comments on error sources at 120kHz, Source of error, numbers and quality of responses (G=guess, R=range of values, C=CV & F=Confidence Intervals), quality of estimate and comments.

1Acoustic Signal		
1.1 On axis Calibration	3R2C1F	Based on SV gain measurements variation in repeated calibrations within any year. The problems are thought to be predominantly due to instabilities versus temperature
1.2 Equivalent beam Angle	2G1R	Temperature dependent effects detection at short range. Due to variant temperature and sound speed given by manufacturer.
1.3 Time varied Gain Range	1C2G1F	Instrumental TVG measured and accounted for in software. Due to differences in the assumed and the actual sound velocity profiles .
1.4 Time varied gain Attenuation	3G	Due to differences in the assumed and the actual sound velocity profiles. Small errors in amplitude unimportant in riverine methods
1.5 Additional physical absorption	3G	Bubbles obscure fish tracks, dependant on strength of surface winds highly appreciable or negligible depending upon the weather surface noise or bottom integration and some shadowing
1.6 Motion related losses	2G	Highly appreciable or negligible depending upon the weather (measurements stopped in rough seas) Tendency to ensonify targets off axis due to ship motion, although we use a very stable platform
1.7 Baseline Target Strength Value	2G1R1F1	This doesn't effect abundance based on counting trajectories Unknown distributions of acoustic impedance and orientation. TS reference (fish encaged) insitue (increasing with depth) Actual TS will mostly be lower that baseline TS, although there is a tendency to undersample smaller TS's
1.8 Measurement of target physical size	1G	beam dimension too small at short ranges.
1.9 Equipment mistakes	3G	Operator fatigue in manual recognition of targets highly appreciable or negligible depending version. Errors in setting can be + or - but we are always learning
1.10 Any additional factors	1G	Boundary reflection multi-paths causes wrongly counted echoes
2 Sampling Strategy		
2.1 General Sampling precision	2C	This error is best reduced with better knowledge of the target species distribution
2.2 Error due to motion	3G	Fixed-location therefore no errors. Efforts are made to survey at a time when fish are not migrating
2.3 Errors in local mean target strength	2G1R	The selectivity or inefficiency of fishing gear. This doesn't effect abundance based on echo counting. Catch selectivity unknown and not used: Under-sampling, especially of low density aggregations which may have different size distributions, is still a problem. In the worst case where assume mean size of krill may vary by ± 6.8 mm (from Watkins et al 1990)
2.4 Errors in fish proportions	2G	Sometimes single stocks, sometimes mixed species N/A we use the commercial catches
2.5 Errors due to location	2G	All fish pass through beam on way up river. Unknown seasonal migration. We think we know the population distribution fairly well, but surprises do happen.
3 Fish Discrimination		
3.1 Discrimination between Fish and other targets	3G1R	Sometimes the system counts floating debris. Problems due mainly to myctophids and possibly squid can be improved by playback with different threshold. Small bias from addition of non-fish backscatter Occasional vessel wakes obscure fish tracks.

3.2 Discrimination Between Fish Species	3G	Sometimes incorrect count of non-target resident fish. Tendency to underestimate the target species when species identification is "uncertain".
3.3 Discrimination between Plankton Species	1F1G1R	Due mainly to other euphausiids and salps not used Small bias due to the small TS of plankton Bias arising from classifying everything as krill
3.4 Discrimination between targets and seabed or surface	2G	Boundary reverberation obscures fish tracks, especially at longer ranges. Unknown for semipelagic species, it doesn't take many rocks to increase a biomass estimate.
4 Fish Behaviour		
4.1 Fish Avoidance or Attraction	2G	For fixed location no survey vessel. Unknown not detected during the surveys. Although fish can be "herded" by a vessel, avoidance is more prevalent.
4.2 Fish Target strength	1R2G	Effects due to changes in orientation are not observed. TS is mostly reduced when aspect is off axis.
4.3 Diurnal/Circadian change	2G2F	Salmon closer to bottom during daylight. Due to migration above minimum detection range; mostly corrected by surveying only during day. Survey only conducted at night .
4.4 Response to Catastrophic change	3G	Salmon closer to bottom during stronger currents induced by tidal effects downstream this aspect has been observed but not really measured. Poor environmental conditions may reduce availability, but good conditions will not increase population size.
4.5 Any additional factors	1G	Pink salmon shoal together, making echo counting difficult

Table 4 the Maps system

Errors	Value	S or B	F,C, R or G	Comments
1Acoustic Signal				
1.1 On axis Calibration	1.2	S	R	Surface Reciprocity / Standard Hydrophone
1.2 Equivalent beam Angle	1.02	S	C	Varies with environment. Due principally to corrections for temperature and salinity profiles in some environments. Can be corrected in post processing if data are available.
1.3 Time varied Gain Range	1.01	S	C	
1.4 Time varied gain Attenuation	1.01	S	C	
1.5 Additional physical absorption	1.01	S	F	
1.6 Motion related losses	1.02	S	G	
1.7 Baseline Target Strength Value	2	Assymetric	G/R/C/F	Complex. Nulls deeper than peaks. Depends on the species, do not have TS vs f and size for many species or shapes. estimates of size and abundance comparable to, or better than the result of net or pump sampling. TS required at several freqs., errors ave
1.8 Measurement of target physical size	1.01	S	F	for those species that we have studied extensively (ca 25)
1.9 Equipment mistakes				
1.10 Any additional factors				
2 Sampling Strategy				
2.1 General Sampling precision				Depends on where and when. Patchiness in the plankton
2.2 Error due to motion				can be the controlling error.
2.3 Errors in local mean target strength				Concerned about TS changes with molting, but no firm data
2.4 Errors in fish proportions				
2.5 Errors due to location				
2.6 Any additional factors				
3 Fish Discrimination				
3.1 Discrimination between Fish and other targets				Not usually difficult, based on the target strength spectrum
3.2 Discrimination Between Fish Species				
3.3 Discrimination between Plankton Species				Not yet quantified, but often possible based on size and net

Errors	Value	S or B	F,C, R or G	Comments
				or pump hauls
3.4 Discrimination between targets and seabed or surface				Little difficulty at range resolutions now approaching 10 cm
3.5 Any additional factors				Bubbles can mask echoes from weaker targets near surface (ca 2 m), but are readily identified due to spectral response
4 Fish Behaviour				
4.1 Fish Avoidance or Attraction				None noticed at a mooring over ca 5 yr., but we still worry.
4.2 Fish Target strength				
4.3 Diurnal/Circadian change				
4.4 Response to Catastrophic change				
4.5 Any additional factors				

All of the errors associated with undersampling in space and time relative to the temporal and spatial scales present, especially when the plankton are distributed on scales smaller than the physical oceanography apply. Errors are important, but less a problem in plankton work than in fish work, because at present its not required to enumerate the total amount of plankton in the sea with these methods. The problem is usually one of understanding the relationships between the distributions of ocean physics and plankton abundance and size / species. In other words, the main use of the plankton acoustics instrumentation has so far been to unravel processes on scales of a few km down to a few cm, not to estimate population biomass. In time, sampling can be as often as every two minutes (in some modes and for some sensors) so aliasing is not presently a big problem for those modes. A cast, however, say multiple casts at the same station to depths of ca 100 m, can take 0.5 hr. In that, mode, temporal aliasing can be a problem , especially in areas with internal wave fields.

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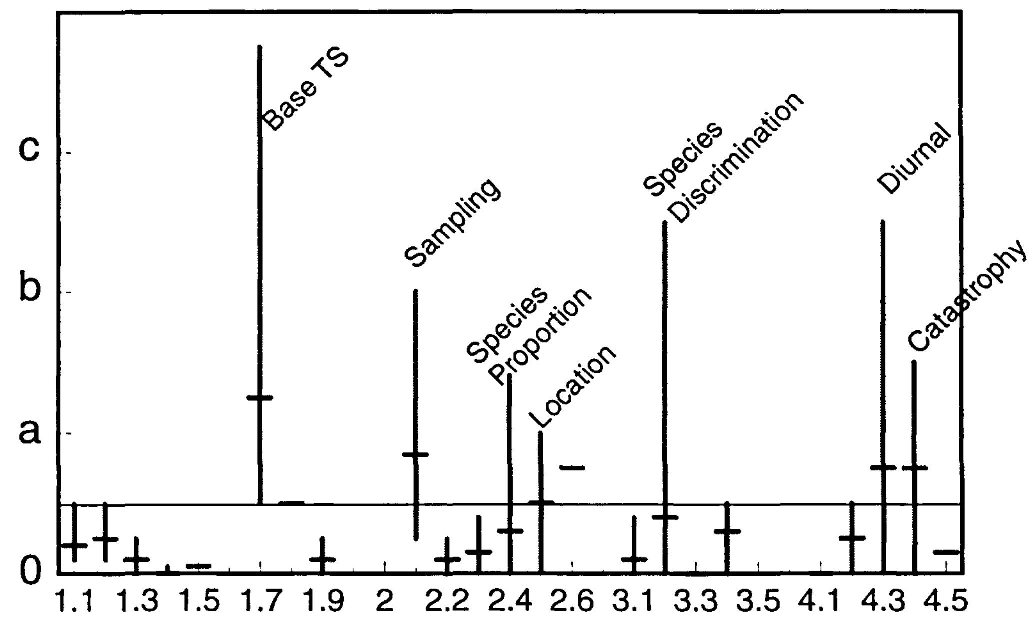

Figure 1. Relative magnitude of random error components in acoustic measurements at 38.kHz.

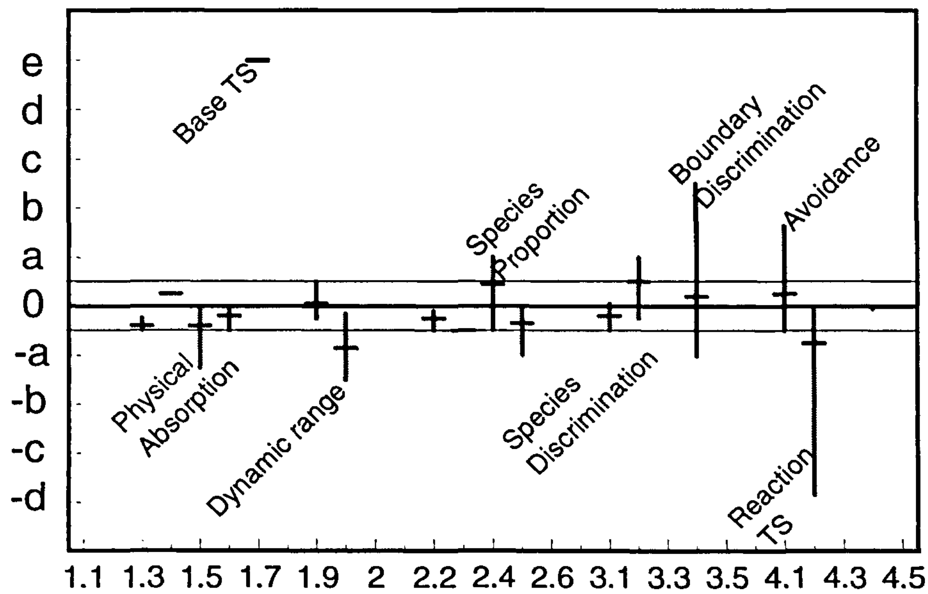

Figure 2. Relative magnitude of bias error components in acoustic measurements at 38 kHz.

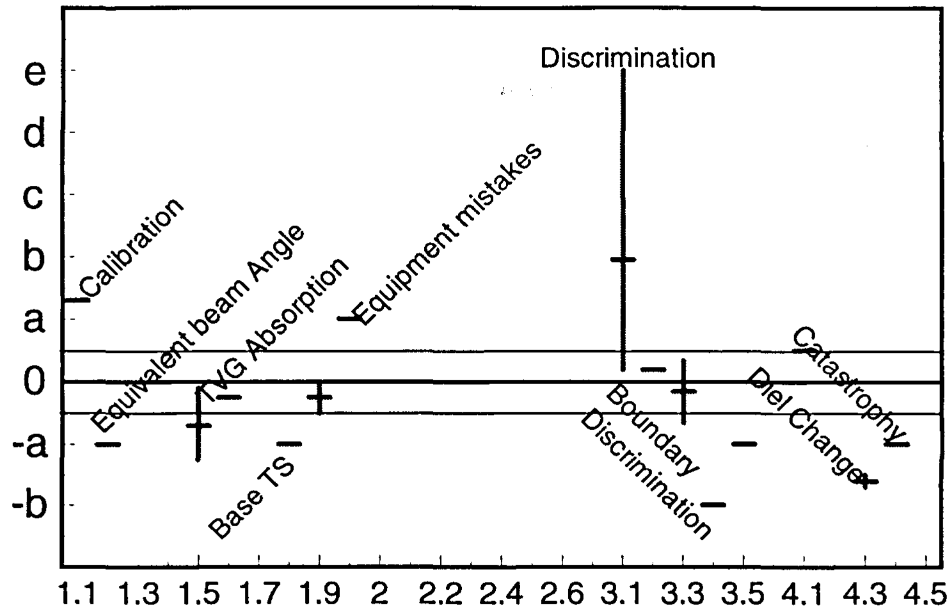

Figure 3. Relative magnitude of random errors in acoustic measurements at 100/120 kHz.

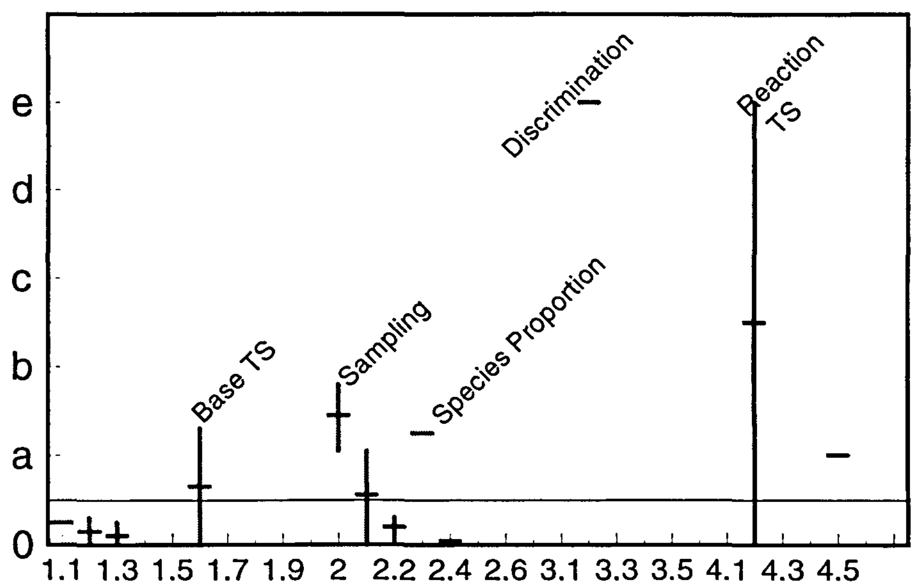

Figure 4. Relative magnitude of bias error components in acoustic measurements at 100/120 kHz.