C.M. 1992/B:5
Fish Capture Committee

Report of the Working Group on Fisheries Acoustics Science and Technology

Bergen, Norway, 17-18 June, 1992

ICES FAST Working Group Meeting 17-18 June, 1992

Bergen, Norway

Agenda

Wednesday 17 June, 1992

1. Opening of the Meeting: 0900

2. Welcome by our host.

3. Order of the Day and appointment of rapporteur

4. Presentation of Initial Plans for the 1995 Fish and Plankton Acoustics Meeting.

Morning Session 1: 0920-1030

5. Special Topic

5.1 Classification of acoustic signals

Simard, Y.
"Classification of Acoustic Signals- Review of methods"

Diner, N.
"Preliminary attempt of echo classification based on various school parameters "

Pederson, J.
"An attempt to classify fish by species using acoustic signals obtained by the split-beam echo sounder ECHOANN"

Coffee Break: 1030-1100

Morning Session 2:1100-1230

Goss, C.
"Comparison of plankton density estimates using 38 and 120 kHz echo sounders"

Karp, W.
" Allocation of trawl catch information during echo integration survey analysis - a source of variability in Gulf of Alaska pollock, Theragra chalcogramma, abundance and age composition estimates "

Survey Practices

Simmonds, J.
"A simulation study of survey strategies for structured populations"

Freon, P., Gerlotto, F. and Soria, M.
"Influence of the distribution functions on the estimate of mean biomass during acoustic survey data processing"

Lunch: 1230- 1400

Afternoon Session 1: 1400-1530

6. Initial discussion of recommendations

5. Continued

Target Strength Measurement

Kloser, R.
" Obtaining in situ target strength of deep sea fish (600-1200 m)"

Ona, E.
"On the possible use of acoustic Doppler current profilers for measurements of fish movement"

Arnold, G. P.
"The depth of neutral buoyancy in cod: vertical migration and systematic variation in target strength"

Coffee Break: 1530-1600

Afternoon Session 2: 1600-1730

Systems/technology

Dalen, J.
"Progress on deep-towed vehicle for fish abundance estimation"

Thursday 18 June, 1992

Morning Session 1: 0900-1030

Holliday, D. V.
"Acoustical Sensing of Zooplankton from a Mooring: A Progress Report"

Gerlotto, F, Freon, P. and Soria, M.
Video presentation

Gerlotto, F.
Report of ad hoc working group on spatial structures, Montpelier, May 1992.

Staehr, K-J.
"Acoustic location of mussel banks in the Limfjord"

Morning Session 2: 1100-1230

6. Recommendations

Report of the ICES Fisheries Acoustic Science and Technology (FAST) Working Group meeting 17-18 June, 1992, Bergen, Norway

1. Terms of reference

In accordance with C. Res. 1991/2:9 the Working Group on Fisheries Acoustic Science and Technology (Chairman: Dr J Traynor) met in Bergen, Norway from 17-18 June 1992 to:

a) evaluate the methodologies and results for in situ target strength measurements;

b) evaluate the methodologies and results for species and pattern recognition studies using procedures for classifying acoustic signals.

2. Opening of the meeting

The chairman opened the meeting and introduced Egil Ona, who welcomed members of the working group to Bergen on behalf of the Institute of Marine Research.

3. Order of the day and appointment of rapporteur

The agenda was adopted with the addition of three items announced by the chairman at the outset of the meeting. G. P. Arnold of the Fisheries Laboratory, Lowestoft, UK, was appointed rapporteur.

4. Presentation of initial plans for the 1995 fish and plankton acoustics meeting

John Simmonds (Marine Laboratory, Aberdeen; convener) presented outline plans for this meeting which would take place in Aberdeen during the summer of 1995. The planning committee was to include D. V. Holliday, W. Karp, E. Ona and D. MacLennan and suggestions were invited from members of the FAST working group for names of extra committee members, topics for discussion and methods of publication.

5. Presentation of special topic papers

5.1 Classification of Acoustic Signals

5.1.1 Simard, Y. Classification of acoustic signals - review of methods.

This paper reviewed methods of classifying mixed echoes in homogeneous groups by trophic level (plankton, micronekton, fish), size class, degree of dispersion or concentration, type of school, depth in water column and species, noting that information of this type was already used by fishermen in a wide variety of situations. Data could be acquired by a variety of hydroacoustic systems using

single or multiple frequency echo sounders, single or multiple transducers (dual-beam, split-beam, etc.) and recording a variety of ancillary information, which together determine the quality of the data. Attributes of echoes could be extracted by ping or groups of pings and a matrix constructed of qualitative and quantitative characteristics. Echoes could be classified by R-mode (dispersion, correlation between attributes), Q-mode (similarity between objects), RQ-mode (attribute and spacing) or by using probability models. Validation could be achieved by fishing, echogram reconstruction spatial representation or simulation. Methods in current use entailed multifrequency size sorting, school recognition and experimental classification studies but there were a number of major unsolved questions concerned with the adequacy of the acoustic data, the quality of ground truth data and methods of numerical classification. Questions related to the identification of echoes, the possible use of neural networks and the timescale within which echo classification might become a practical assessment tool.

5.1.2 Diner, N. Preliminary attempt of echo classification based on various school parameters

IFREMER had developed a software system (MOVIES B), which described echoes by a variety of morphological, temporal, spatial and energetic criteria. The system had been used during four oceanographic surveys in the Bay of Biscay during 1989 and 1990. A 38 kHz echo sounder was used with a TVG correction of 20 log R, a pulse duration of 1 ms and a sampling frequency of 7.5 kHz. The data set consisted of 29 descriptors from over 13,000 fish schools, 800 of which were identified with certainty. Eight species of fish - Sardina pilchardus, Sprattus sprattus, Clupea harengus, Engraulis encrasicolus, Micromesistius poutassou, Scomber scombrus, Trachurus trachurus and Capros aper - were identified by trawling. The data were analyzed by principal component analysis, a clustering technique and linear discriminant analysis. The principal component analysis employed three factors - a morphological descriptor, a bathymetric descriptor and an energy descriptor - each of which consisted of groups of several variables; together they accounted for 66% of the variability. Because of biological variability and the mutual presence of predator and prey it was not easy to achieve species identification by the chosen characteristics but separation of blue whiting and sardines from the other species was possible.

The discussion concentrated on changes in school shape during the acoustic surveys - known from other areas (eg North Sea herring) - to be very dynamic and changes in school shape between the acoustic surveys and the trawling surveys. It was suggested that additional discrimination could be achieved by working at two frequencies and that avoidance behaviour could also be included by using sonar observations.

5.1.3 Pederson, J. An attempt to classify fish by species using acoustic signals obtained by the split-beam echo sounder ECHOANN.

This paper concentrated on plans to identify characteristic acoustic properties of various species using a split-beam sounder. Four levels of question were identified: was it possible to visualize distributions in three-dimensions?; was it possible to identify diagnostic structures?; could pattern recognition techniques be used for identification?; and was it possible to carry out identification in real time? In discussion it was suggested that TS might be a useful additional variable and that because of problems of resolution the shortest possible pulse length should be chosen. It was also thought that the greatest difficulties would arise with mixed species and dispersed fish and that thresholding might also be a problem. Small targets (micronekton) might perhaps be resolved by positioning the transducer very close to them.

5.1.4. Goss, C. Comparison of plankton density estimates using 38 and 120 kHz echo sounders.

Three echo recognition projects were described for Antarctic krill, for which there is currently a substantial fishery. In the first, plankton echoes were recorded while a Longhurst Hardy Plankton Recorder was towed repeatedly through a patch of krill off Bird Island, South Georgia to obtain discrete samples at known locations. The results showed that Euphausia superba could be distinguished acoustically from E. frigida and Themisto gaudichaudii by the difference between Mean Volume Backscattering Strength (MVBS) at the two frequencies.

Repeated patch surveys over a 14 day period indicated a consistent size frequency distribution of E. superba and clear differences in the vertical distribution of swarms by day and night. By day krill were concentrated in small dense swarms from near surface to the bottom, typically compressed into a horizontal distance of less than 0.2 nautical miles; by night they were diffused homogeneously. Irrespective of time of day, there was a strong positive relationship between MVBS38 and MVBS120 at depths below 60 m. At shallower depths the value of MVBS120 was affected by aeration at higher wind speeds.

Visual inspection of echocharts obtained during a survey of the distribution and abundance of krill at distances of up to 60 miles from Bird Island, allowed the recognition of three types of trace which varied in horizontal and vertical extent and also echo intensity. Frequency distribution plots for the difference in MVBS at 38 and 120 kHz allowed the three types of trace to be identified as krill, small zooplankton and fish or squid.

Questions concentrated on the effects of multiple scattering within the swarms, the "grain" that might be produced on the night-time echograms by smaller copepods moving up into midwater, apparent differences in abundance between day and night and the possibility of combining the 38 and 120 kHz echograms by alternating the frequency on successive pings.

5.1.5 Karp, W. Allocation of trawl information during echo integration survey analysis - a source of variability in Gulf of Alaska Pollock, Theragra chalcogramma, abundance and age composition estimates.

Variability associated with the use of trawl samples for determining size composition was considered for echo integration surveys of walleye pollock abundance and age composition in the Gulf of Alaska in 1990 and 1991. The surveys were carried out in Shelikoff Strait, in a monospecific situation, using a 38 kHz echo sounder, equidistant parallel transects and opportunistic sampling with a midwater trawl. Variability was evaluated by calculating the estimates for randomly selected subsets of data and comparing the results with those obtained for the full set of samples. Age compositions and coefficients of variation for biomass estimates, which were unstable and relatively high, respectively, with small numbers of hauls, improved rapidly with the addition of extra samples.

Questions concerned uncertainties of area boundaries, errors in otolith reading and coefficients of variation for individual year classes, a big problem for Norwegian surveys where some year classes were only represented at a few trawl stations. In situations where there were similar length-frequency distributions at adjacent stations it was suggested that it might be appropriate to combine the data.

5.2 Survey practices

5.2.1 Simmonds, J. A simulation study of survey strategies for structured populations

This paper addressed the question of designing surveys for spatially correlated populations, in particular the problem of estimating mean abundance from four types of survey: a uniform random survey; a stratified random survey; a systematic survey with a random starting point; and a systematic survey with a centred starting point. The relationship between each survey strategy and spatial structure was investigated with simulated surfaces incorporating different degrees of spatial correlation. Three methods were used to generate the surfaces and, for simplicity, a one-dimensional surface was used consisting of a series of point values. Error variance was calculated both from sample means and with a variogram method. Results were applied to two acoustic surveys for herring, from which experimental variograms were calculated.

The results of the simulations showed negligible bias in the estimates of the mean for all surfaces and all survey strategies. Both mean and variogram methods gave comparable estimates of the error variance. More precise estimates of the surface mean could be obtained by using a stratified random or systematic survey in preference to a uniform random sample; the improvement in precision was dominated by the relationship between sample spacing and range of correlation. Stratified or systematic sampling was likely to

give the greatest benefit if sample spacing was small relative to the scale of auto-correlation.

In practice it was usually necessary to estimate the error variance of each survey. While this was usually straightforward for a uniform random sample there were difficulties and dilemmas with the other strategies. Ironically, the greater precision achieved with more even surveys was accompanied by greater problems in estimating the precision that was achieved. For acoustic surveys of herring, where the auto-correlation at the mean transect spacing was small, the estimate of variance was likely to depend mainly on the choice of variogram model. However, for both simulated and actual survey situations, whatever model was chosen, the estimated variance was significantly reduced from the value obtained using formulae assuming uniform random sampling.

Extensive discussion covered how actual survey data had been used, the nugget effect and the estimation of along transect variability. It was recognized that the estimate of autocorrelation using data from a systematic grid suffers from the small amount of information at sample spacing less than the distance between adjacent transects, but this will probably have only a small effect on the variance estimate. The author pointed out that it will probably not be possible in many situations to choose the "correct variogram", but the choice of a reasonable variogram will often result in a significant reduction in the variance estimate from that obtained using simple random sample statistics. The author states that "more even strategies lead to greater precision ... but probably greater problems in estimating precision". Many people in the audience felt that this paper was a very useful presentation of a complex topic in a manner that was more understandable for the acoustic survey practitioner.

5.2.2 Freon, P F, Gerlotto, F and Soria, M. Influence of the distribution functions on the estimate of mean biomass during acoustic survey data processing.

This paper considered errors in estimating mean biomass for very patchily distributed populations as a result of using inappropriate distribution functions. It was concluded that skewed distributions occurred by day and also at night and that the choice of distribution function could produce substantial differences in the estimate of the mean. The central limit theorem did not necessarily apply in all cases (infinite variance) and the convergence to the population mean with increasing sampling rate was very low. The arithmetic mean generally underestimated the population biomass except in those rare cases where huge schools were encountered; in such instances there was a large overestimate of biomass. Improved estimates might be achieved by fitting an appropriate function for each individual survey.

The paper generated a lively discussion which highlighted the contrast between the view it presented that mean biomass could not be estimated with any certainty and the previous paper which claimed that the variance about the mean could be estimated to within 5%. The problem appeared to be related to the size of the main patches in relation to the spacing of the transect lines.

Misund suggested that it would be appropriate to find the main patches first; Pierre Freon countered by emphasizing the difficulty of doing so in the tropics because of the small size of many patches. Egil Ona commented that he would have been very unhappy if removal of 5% of the observations had resulted in a major change in the estimate of the mean.

5.3 Target Strength Measurement

5.3.1 Kloser, R. Obtaining in situ target strength of deep sea fish (600-1200 m).

Australia, which was now an observer member of ICES, needed to make acoustic estimates of the biomass of the orange roughy, which was found in deep water around Tasmania. A fishery had started in 1987 and large catches (25 000 t) had been taken from the spawning grounds. The fish were slow growing, maturing at 20-30 years old and living as long as 140 years. They occurred in deep water on the slopes of sea mounts and the swimbladder was filled with wax esters so that TS was low.

A towed body system had been developed to avoid the acoustic dead zone at 800 m. It consisted of 2000 m of cable and a 750 kg cast iron body, which contained an EK400 38 kHz split-beam echo sounder and transmitter with pre-amplifiers (30 dB gain) for the returning signal. The current system transmits on the EK400 and receives the acoustic echoes on an EK500 system for analysis. The system had been calibrated roughly down to 1000 m using a copper sphere and preliminary results showed that it avoided most of the problems with a hull-mounted transducer. It had also been shown that the fish would avoid an underwater camera at 150 m range even with the camera lights switched off. A few TS measurements had been obtained which indicated an in situ value of -43 dB. This compared with estimates of -45 to -44 dB with dead specimens in the laboratory and a calculated value of -46.7 to -45 dB derived from a model produced by Ron Mitson. (Earlier New Zealand estimates had suggested values as high as -39 to -36 dB.)

Questions concerned the use of an air backed transducer, which accounted for changes of sensitivity with depth, and directivity of the split-beam system, which had not been completely measured.

5.3.2. Ona, E. On the possible use of Acoustic Doppler Current Profilers for measurements of fish movement.

A 150 kHz Acoustic Doppler Current Profiler with 4 beams at mutual angles of 30 degrees had been used to make some preliminary observations of the swimming speeds and directions of herring, capelin and blue whiting. Profiles of water speed beneath the research vessel showed layers with anomalous water current measurements that were consistent with schools of fish swimming at speeds of 15-30 cm s-1. Further work was needed on the technique but it had been shown that it could be used to track layers and gave realistic estimates of fish swimming speeds in the open sea.

The subsequent discussion indicated that estimated speeds of

fish relative to the water would still be correct even if bottom contact was lost and that they should not be significantly affected by movements of the tail provided the fish were insonified from above. The technique offered the prospect of testing Midtun's 'disc' hypothesis of current detection in large shoals of capelin, which had been observed to extend from midwater down to the bottom.

5.3.3 Arnold, G P. The depth of neutral buoyancy in cod: vertical migration and systematic variation in target strength.

The traditional hypothesis that fish with closed swimbladders were neutrally buoyant at all times of day and night and at all depths had been tested by examining the vertical movements of 24 individual cod (50-76 cm) in the southern North Sea. The fish had been tagged with transponding acoustic tags and tracked with sector scanning sonar for periods of up to 50 h and distances of up to 72 km. Three fish adapted to atmospheric pressure had been released at the surface; the others had been released at the sea bed after a period of confinement in a small cage, during which they had the opportunity to adapt or partially adapt to ambient pressure. The hypothesis was rejected because rates of ascent and descent over distances of 20-30 m were found to be faster than could be accounted for by either resorption or secretion of swimbladder gas and the maintenance of neutral buoyancy with changing depth. It was shown instead that many of the fish were negatively buoyant at the sea bed and only neutrally buoyant in midwater. The results indicated that large changes in target strength must inevitably be associated with vertical migrations of cod, which occurred systematically at both diurnal and semi-diurnal periodicities.

The paper was followed by a lively discussion of both the technique and the results. Egil Ona stressed the importance of recognizing that the TS of physoclist fish was indeed a very variable quantity.

5.4 Systems/technology

5.4.1. Dalen, J. Progress on deep-towed vehicle for fish abundance estimation.

A research programme was initiated in Norway in 1988 to develop a towed vehicle capable of observing fish at depths of 500-1500 on the continental slope and measuring their abundance acoustically at frequencies of 38 and 120 kHz. A 500 kg towed body had been developed which would operate at a depth of 400 m in order to: improve the acoustic signal-to-noise ratio; obviate problems with steeply sloping topography and improve spatial resolution; avoid signal attenuation caused by wind-induced bubbles in the upper layers; and give better TS measurements. Recent developments had included the use of 1500 m of low attenuation fibre-optic cable (2.8 dB km-1), the installation of an upwards firing transducer and the installation of the transmitter and front-end receiver of an EK500 echo sounder in the towed body with the transducer, which was oil-filled. The maximum data rate was 1.28 M bits s-1 from each

transducer with a total rate of 4 M bits s-1, which compared with a capacity of 32-100 M bits s-1 for the relevant microchip in the system.

In discussion Rudy Kloser asked whether any protection was provided for the transducer and was informed that it was installed in direct contact with the water. This method avoided air bubbles collecting behind a protective window, a problem previously encountered by the Norwegians. John Simmonds pointed out that, in addition to improving the signal-to-noise ratio, installing pre-amplifiers in the towed body avoided a major problem with cable and transducer impedance. Matching problems occur if the cable length was longer than about 1/8 of a wavelength (the wavelength of 38 kHz at the speed of light - the speed of electrical transmission in the cable).

5.4.2. Holliday, D V. Acoustical sensing of zooplankton from a mooring: a progress report.

This paper described the development of a pilot mooring for the Biophysical Interdisciplinary Trophic Studies (BITS) Programme, which had been deployed at a test site off Los Angeles in 100 m depth of water. The aim of the programme, which followed on from the earlier MAPS programme was to provide high-resolution long-term data on the abundance and distribution of zooplankton and micronekton. Transient events in the ocean were rarely detected, let alone quantitatively sampled, and yet they were probably of great significance in relation to understanding global processes such as climate change. The San Pedro basin, where the pilot mooring had been deployed, was highly dynamic with episodic El Nino events.

The pilot mooring was operated by two-way VHF telemetry accessible from the shore by public telephone; satellite communications were under investigation for future deployments. Initially the mooring would record air temperature, water temperature, surface light intensity, and wind speed. Water speed was measured with current meters and ADCP's would be added later. The operating period was 2-3 months and the basic sampling rate 50 kBytes per day; on board data storage was to be fitted. Zooplankton and environmental sensors were installed at various depths and the mooring incorporated bifrequency and multifrequency (8 frequencies between 100 kHz and 3 MHz) acoustic sensors together with a 165 kHz dual beam echo sounder to measure size distributions and TS of micronekton. A high-pass sound scattering model (J. Acoust. Soc. Am., 61: 375-77) was used to estimate the equivalent spherical radius of the zooplankton and thus their abundance. The Pacific mooring would be maintained until the end of the current El Nino event and it was intended to deploy the instrument on Georges Bank in the Northwest Atlantic as part of the GLOBEC programme. Proposed technical developments included methods of sampling dense thin layers of overwintering copepods, bulk optics for combined acoustic and optical sampling of zooplankton and the use of neural networks for analysing results.

It was commented in discussion that the mathematical models were very simple and only applicable in limited circumstances. One way of overcoming this problem might be to use independent estimates of size distribution to decide which model was appropriate in any particular situation.

5.5 Additional items

5.5.1 Gerlotto, F., Freon, P and Soria, M. Video presentation.

This interesting video showed the dynamic structure of a large school of schooling fish in Martinique from aerial and underwater pictures. There was a large dynamic vacuole in the middle of the school and avoidance was demonstrated to an inflatable boat and outboard engine. The shoal also split and rejoined in response to the passage of a towed lure made in the shape of a tuna.

5.5.2 Gerlotto, F. Report of ad hoc working group on spatial structures, Montpelier, May 1992.

Twenty scientists from eight (mostly Mediterranean) countries had attended this meeting entitled "Occupation of space by aquatic organisms as observed through acoustic methods". The discussion had been in French but there was a report in English and extra participants were invited for the next meeting which would be held in Toulon in June 1993. The 1992 meeting had been concerned with identification and classification of acoustic targets, and the impact of spatial structures on the estimation of abundance. Also considered were methods of processing acoustic data (artificial intelligence and synthetic aperture radar), school structure, environmental factors and the special problems of abundance estimation in shallow water.

5.5.3 Staehr, K-J. Acoustic localization of mussel banks in the Limfjord.

A preliminary attempt had been made to map acoustically the distribution of undersized mussels laid in the Limfjord in an area closed to fishing, using a 38 kHz echo sounder in a towed body. The acoustic maps showed good agreement with the known distribution of the laid mussels and also of catches. The next step was to devise a technique of quantifying the results.

Various suggestions were made in discussion including the use of a split-beam sounder, the ROXANN system and side-scan sonars. Possible advantages of working at higher frequencies were also discussed.

6. Working Group Recommendations

The Working Group made the following recommendations:

1) The Working Group recommends that its next meeting be held in Gothenburg, Sweden for two days during the week of April 19th, 1993. The Working Group also recommends that a joint FTFB-FAST Session meet for one day during the week of April 19th, under the chairmanship of William Karp, to discuss problems associated with near-bottom assessment. This session should be designed to address acoustic and bottom trawl techniques and develop recommendations for approaches that incorporate both methods.

2) The Working Group recommends that, following the conclusions of the ICES Symposium on Fish Behavior, attention be paid to the characteristics of fish behavior that may have impact on acoustic assessment, and particularly,

- fish reactions to survey vessels
- fish reactions to sampling gears
- behavioural patterns related to spatial structures and distributions, and
- behavioural patterns related to target strength.

The Working Group recognizes some of the recent developments in tag technology as being important to addressing some of these problems.

3) The Working Group recommends that a study group be formed under the chairmanship of Egil Ona to prepare a report (cooperative ICES report series) on methodology for target strength measurements with special reference to in situ techniques for fish and micro-nekton. A draft of this report should be distributed and discussed during the 1993 Working Group Meeting.

4) The Working Group, particularly in light of recent research findings, recognizes that the underwater radiated noise field from fisheries research vessels should neither un-necessarily impair the efficiency of instruments used for acoustic survey, nor disturb the natural distribution of fish in the vicinity of the vessels.

The Group feels that the noise control requirement for fisheries research vessels are stringent because the it limits the accuracy attainable in fish stock assessment surveys.

The Group recommends that studies be undertaken to determine the effects of vessel noise on natural fish populations. In addition, the Group feels that a study group should be established during the 1992 statutory meeting to describe accepted procedures for measuring vessel noise and to describe recognized methods to minimize vessel noise, for consideration by ICES countries, particularly for newly designed research vessels.

5) Following the resignation of the current chairman, the Working Group recommends that John Simmonds be requested to become the next chairman of the FAST Working Group.

7. Closure

The Working Group acknowledged the resignation of Jim Traynor from its chairmanship and recognized his contribution during the last four years. The Chairman thanked the host institute for its hospitality and expressed his appreciation to FAST Working Group members for their cooperation during the term of his chairmanship.

8. National Progress Reports

Appendix A.

Appendix A - National Progress Reports.

A.1 Australia

CSIRO Division of Fisheries Australia

Development

In July 1991 a deep sea towed body system that can obtain split beam in-situ target strength measurements to 1200m was commissioned. The system was calibrated twice during the year with a copper sphere to a depth of 800m and 1000m with no change in beam pattern observed. The dry end of the system is an EK500 with monitoring computers and electronics, the wet end contains an EDO split beam transducer rated to 1000m with a transmitter, preamplifier and pitch/roll, depth monitoring package.

A PC based data acquisition and processing system for the ping based EK500 ethernet data was developed and used to analyze survey data in October 1991. Plans are being made to convert this system to UNIX and add a data base under a collaborative project with the Australian Antarctic Division.

A new project has commenced to manufacture a portable deep-sea acoustic system that can be used off commercial trawl vessels in our fishery. The system will contain a winch, crane and portable laboratory to house the EK500 and associated electronics and computers. The existing towed body system is to be modified to enable it to be easily deployed and handled on these types of vessels. The system will need to perform echo integration at depths of 500-700 metres at 5-7 knots and obtain target strength measurements down to 1200 metres both with the vessel stationary and moving at 2-3 knots.

Surveys

In July '91 an acoustic survey was conducted of spawning orange roughy off the east coast of Tasmania using both the hull mounted and towed transducers. The towed transducer surveys were performed by towing the towed body to a depth of 600 metres. The data was processed in October showing a higher biomass for the towed body surveys. In-situ target strength data was obtained by vertically lowering and towing the towed body at a low speed, measurements of deep sea fish were obtained down to 1000m.

In February '92 a survey was undertaken of a deep sea 600-1300m mixed species ground that consisted of 35 hills off the south coast of Tasmania. The acoustic data was obtained by towing the towed body at depths of 500 to 900 metres at speeds of 5 to 7 knots virtually continuously for 10 days. In

situ data was collected on various species on those grounds down to 1200 metres and confirmed earlier measurements taken of spawning orange roughy.

Data was collected on in-situ target strength measurements of species from 100m to 1100m to determine species composition and abundance with a view to enhance our knowledge of the productivity of this region.

A.2 Canada

N.W. Atlantic Fisheries Centre, St. John's, Newfoundland

The group conducted six offshore acoustic surveys in 1991 comprised of three capelin biomass surveys, one redfish biomass survey, and two cod surveys, one a winter biomass survey of NAFO Division 2J3KL cod, the other a research oriented survey to assess the distribution and abundance of 2J3KL cod during the spring onshore migration. No inshore acoustic surveys were conducted in 1991.

Studies were conducted on herring and cod to assess target strength variability and the relationship between target strength and condition factor. Studies on fish counting techniques for cod were also undertaken in 1991.

A workshop under the Northern Cod Science Progam was held in August, 1991 to examine the feasibility of acoustic surveys in NAFO Division 2J3KL cod. The workshop recommended a move from 49kHz to 38 kHz to standardize with researchers in other countries carrying out gadoid acoustic surveys. A report was prepared to delineate procurement options for the 38kHz technology for offshore acoustic research and surveys.

Acoustic system development included the design of a gimbaled frame to accommodate a variety of towed body/transducer combinations for standard target calibrations.

Maurice Lamontagne Institute, Mt. Joli, Quebec

An acoustic cruise was conducted during May-June in Cabot Strait to study the summer migration of mackerel in the Gulf of St. Lawrence. A second cruise was completed in August in the northern Gulf of St. Lawrence on the aggregation dynamics of zooplankton, pelagic fish and whales in the region. A third cruise during November was directed towards estimation of herring on the west coast of Newfoundland. Systems used included a dual-beam Biosonics 103 (38 & 120 kHz), a single-beam Datasonics (120 kHz) coupled with the HDPS-9001 of Femto Electronics and, recently, a split-beam Simrad EK-500 (38 & 120 kHz).

St. Andrews Biological Station, St. Andrews, New Brunswick

Acoustic surveys of NAFO Div. 4WX herring in January 1991, December, 1991 and January, 1992 found only about one tenth the quantity from previous years. A drastic decline in stock size is only one possible explanation, others being changes in behaviour or in winter distribution. New survey methods are needed to elucidate this problem. The potential usefulness of a dual beam acoustic system is being tested during the regular groundfish bottom trawl surveys on the Scotian Shelf. Exploratory work on cod off Sydney Bight in January, 1991 showed good correlation between trawl catches and acoustic integrations during the tows.

Bedford Institute of Oceanography, Dartmouth, Nova Scotia

A 4-frequency acoustic backscattering system was deployed in September 1991 on a 12 day multidisciplinary zooplankton survey in the Gulf of Maine and the adjacent Scotian Shelf. Acoustics delineated centimetre-sized crustaceans and assisted direct BIONESS (multi-net) sampling. Intense siphonophore scattering hampered acoustics in some regions. Laboratory development of an 8-frequency deep towed sonar (1-50 MHz) has progressed with initial sea trials scheduled for August 1992.

Gulf Fisheries Centre, Moncton, New Brunswick

A herring acoustic survey was conducted in Chaleur Bay and Sydney Bight using a SIMRAD EY200 transceiver and 120-25 transducer. Herring observed in Chaleur Bay were generally in narrow bands parallel to shore while loosely aggregated schools were found at Sydney Bight.

Freshwater Institute, Winnipeg

A hydroacoustic study of northern shrimp (Pandalus borealis) diel vertical migration was executed off Labrador. The acoustic data were goundtruthed with a remote controlled opening/closing Tucker-type plankton trawl and a commercial shrimp trawl. Shrimp were observed to migrate upward after sunset to the lower limit of the thermocline. They descended rather quickly to the bottom at dawn. Nocturnal migration decreased the vulnerability of the shrimp resource to bottom trawls. Acoustic studies of Arctic cod (Boreogadus saida) schooling behaviour and predation by marine mammals and sea birds in Lancaster Sound (Canadian Arctic archipelago) were completed. Arctic cod distribution was highly contagious and fish densities in the schools occasionally exceeded 100 m^{-3}.

Sault Ste. Marie Laboratory, Sault Ste. Marie, Ontario

Fisheries acoustics surveys were conducted in the spring to quantify the biomass of fish migrating from tributaries

into Thunder Bay and Thunder Bay Harbour, Lake Superior. Results are under analysis.

Pacific Biological Station, Nanaimo, British Columbia

A new technique was developed to determine zooplankton abundance in large oligotrophic lakes. The system is capable of rapid acquisition and processing of large quantities of data for detailed determination of zooplankton production. When coupled with direct biological sampling, the technique provides improved information on zooplankton distribution in sockeye nursery lakes. It was used to expand coverage and enhance stock assessment information.

Hydroacoustic and trawl sonar equipment was used to examine the diel behaviour of rockfish (Sebastes) concentrations and their behaviour around the mouths of midwater and bottom trawls. It appears that the fishing vessel rather than the trawl may be the major factor influencing fish movements in response to fishing.

A Graphic Information System (GIS) was used to analyze digital echograms for fish schools and develop a school species index.

The fifth in a series of hydroacoustic cruises to estimate total herring biomass in two areas of major winter concentration was conducted. Night-time experimental hydroacoustic surveys to determine distribution and relative abundance of juvenile herring in the Strait of Georgia were conducted in October, 1990. A hydroacoustic survey of offshore Pacific hake distribution and abundance from the Canada/Washington border to Queen Charlotte Sound was completed. Hydroacoustic surveys were completed at three lakes in the Stikine/Taku watershed to determine survival of sockeye salmon fry outplanted from an Alaskan hatchery.

A.3 Denmark

The Danish hydroacoustic work has two main lines: monitoring surveys for fish stock assessment and research work for improving the use of the acoustical survey data.

Monitoring surveys

In 1991 Denmark participated in two ICES-coordinated surveys.

In July - August R/V DANA surveyed the eastern North Sea, Skagerrak and Kattegat in the joint survey for the pelagic fish species of the region.

In October Denmark participated in a German-Danish cruise with the German R/V SOLEA in the western Baltic and the Belt

Sea for herring and sprat.

Research work

In May a research project was started with the object of using image processing and pattern recognition techniques in order to extract more information from the acoustical signals, especially using three-dimensional structures for classifying disperse layers of fish.

In september R/V DANA made a cruise in which an attempt was made to study the distribution of fish (based on single fish echoes) in front of a trawl in relation to the selectivity of the trawl. Data were also collected for the above-mentioned project.

A.4 Faroe Islands

Three blue whiting surveys have been made in 1991. The first in January south off the Faroes and in international waters west of the British Isles, very limited amount of blue whiting were observed during the survey. The second survey covered the southern part of Faroese EEZ of postspawning blue whiting on its way northwards. The third survey covered the area north off the Faroes in the Norwegian Sea in August, where the 1989 year class dominated totally. These results were reported to ICES in 1991.

An acoustic survey on herring in Faroes waters in June yielded no reliable acoustic estimate due to very shallow distribution of the herring schools, but the area of distribution could be determined and areas of high and low density could be located in the Faroese EEZ during the survey.

A.5 France

Etudes menees par l'IFREMER

<u>Echo-integration, identification des detections</u>

Le logiciel MOVIES B etudie pour individualiser les bancs de poissons et permettre l'echo-integration par bancs est complete par un systeme qui definit pour chaque banc un certain nombre de criteres geometriques et energetiques.

Des recherches sont en cours pour trouver le systeme le plus fiable pour identifier l'espece constituant le banc a partir de l'analyse de ces criteres.

Le projet BIOMASS, mene dans le cadre du programme FAR avec des partenaires universitaires francais, le Marine Laboratory d'Aberdeen et le Marine Biology Laboratory d'Iraklion en Crete integre une partie de ces resultats.

Developpements de nouveaux sondeurs

- Les travaux sur le sondeur large bande poursuivent.

- Le sondeur multifaisceaux pour la peche developpe dans le cadre du projet HALIOS (programme EUREKA) a ete teste en mer a plusieurs reprises et ses resultats sont tres prometteurs, meme s'il demeure quelques problemes de visualisation.

- Le sondeur numerique developpe conjointement par IFREMER et la Societe MICREL est maintenant en phase d'essai sur des navires professionnels et de recherche halieutique ou sa souplesse d'emploi et les facilites apportees par le traitement numerique du signal sont tres appreciees.

Une campagne effectuee sur le N/O THALASSA a ete consacree a l'essai de ces differents sondeurs.

L'algorithme de determination de la nature des fonds sous-marins a partir de signaux emis par des sondeurs standard est maintenant au point.

Qualite acoustique des navires de peche

Le remplacement du N/O THALASSA tres age et particulierement bruyant, le souci de se doter d'un navire permettant de faire des recherches sur la peche a grande profondeur (avec la discretion acoustique que cela suppose pour ne pas affaiblir les performances des sondeurs) a amene l'IFREMER a etudier les causes de bruits rayonnes par les navires ainsi que les solutions retenues dans les autres pays ayant recemment lance des navires de recherche pour rendre ceux-ci suffisamment silencieux. Le souci de maintenir le cout de construction a un niveau raisonnable rend ce probleme particulierement ardu...

Evaluation acoustique de stocks

La gestion du stock d'anchois du Golfe de Gascogne a ete poursuivie en collaboration avec l'Espagne avec comme support une campagne en avril-mai.

Une deuxieme campagne s'est deroulee en octobre dans le golfe de Gascogne pour determiner l'abondance et la distribution des ressources pelagiques potentiellement utilisables pour des produits transformes type surimi.

Etudes menees par l'ORSTOM

La cooperation avec le Venezuela, Cuba et le Mexique, se poursuit. Il y a eu recemment une campagne d'echo-integration sur le merou dans le Yucatan. Des etudes sur l'influence du bateau dans l'evitement des poissons ont encore ete menees cette annee en Martinique et au Venezuela.

Au Senegal, outre les campagnes d'evaluation classiques, les travaux s'orientent vers les problemes de detection sur petits fonds.

Un programme d'evaluation de petits pelagiques se met en place en Mer de Java.

A Tahiti, outre les campagnes de marquage et des etudes de comportement, on etudie par echo-integration l'evolution des aggregations produites par les DCP.

Des etudes sont en cours a Brest sur les discriminations entre echos de poissons et echos de masses planctoniques, au moyen d'experimentations multifrequentielles.

Un groupe de travail francophone, dont le theme etait : "L'occupation de l'espace par les populations d'organismes marins : description et impact sur les evaluations acoustiques", s'est reuni en mai 1991 a Thonon-les-Bains ; il est ouvert a toute personne souhaitant y participer et se reunira de nouveau en mai 92.

A.6 Norway

Surveys

The acoustic systems EK500 and BI500, have been used on our research vessels for about 1000 survey days in 1991.

Development projects / Activities.

Sonar project

The goals for a development project sonar biomass estimation was somehow reduced in 1991, and redefined to use existing sonar hardware, the Simrad SA-950, but with improved data access. The sonar will be installed on G.O.Sars, summer 92. Further data interfacing on the Simrad SR-240 omni sonar have been made in 91. Contact persons: O.A.Midsund, A. Aglen.

Towed body project, phase 1 and 2.

Further development on the towed body concept is steadily progressing. The final goal is to install EK500 components in the towed body and transfer digital data on optical cable to the vessel. In 1991, successful testing and calibration on the ES38D, pressure stable split beam transducer have been made to 400 m. Experiments with resolving dense layers of fish at depth for in situ TS measurements have also been made. Contact persons: J.Dalen IMR, H.Bodholt, Simrad.

Mapping and charting module, BI500

The first version of the mapping / charting module for BI500 is now being tested, and further work will also involve more advanced tools and geographical software routines for

displaying and analysis of survey data.
Contact persons: A. Raknes, IMR, H. Naes, Simrad

Tracking of individual fish

Software using the detected single fish and connected angular data to track single fish in real time has been developed at IMR. Up to 32 fish can be tracked simultaneously, and data on fish "size", swimming speed, direction, vertical and horizontal movement are displayed and stored for further statistical analysis. The system, and results from using it under different conditions will be published on the Bergen Symposium on "Fish behaviour in relation to fishing operations", June 11 - 13, 1992.
Contact person: E. Ona, IMR.

Database development, IMR

IMR is now modelling a larger relational database to handle all our scientific data, i.e. hydrographical, chemical, acoustical and biological data. The database, Ingres V 6.3, will be operational in April this year, served by two HP 9000/mod750. The BI500 database, used during data collection at sea, will be modified so that all the tools developed for processing ashore, also could be used on board the vessels.
Contact person: E.Ona, IMR

Test system for EK500, the TAPF

In 1991 our instrument section developed a system for performing "dry measurements" on the EK500, simulating the input from a split beam transducer with four independent quadrants. Since Time, Amplitude, Phase and Frequency can be set with high precision, the preliminary name for the instrument is TAPF. Initial tests have been successful, and the results will be reported, probably through ICES.
Contact person: I.Svellingen or A. Totland, IMR

Geostatistics

Acoustical data to be analyzed by geostatistical methods were sampled on an experimental fjord survey in December. K. Foote, has from the summer 91, stayed in France, at Centre de Geostatistiqe, Foutainebleau, and will hopefully come back home and tell us how "precise" we are on our acoustic stock estimates.

Multifrequency

Multifrequency EK-500 data have been sampled on several surveys for different reasons, like for investigating target strength differences, attenuation differences and also for discrimination between plankton and fish.

The multifrequency plankton project has had a low activity in 91, mainly caused by financial problems. The future effort on this project at IMR will be determined during 1992.

Seismics and fish

In 1991 a project was commenced for further elucidation of harmful impacts on eggs, larvae and juveniles from different species. This also included sound pressure and acceleration measurements of the very near-field sound around air guns. The project will continue in 1992.

A.7 Spain

Instituto Espanol de Oceanografia (IEO)

Contact persons: Carmela Porteiro, Pablo Carrera and Rogello Abad

Two acoustics surveys were conducted by the IEO in the Spanish continental shelf:

1. **PELACUS** 0391 was carried out onboard R/V Cornide de Saavedra from 16/03/91 to 11/04/91. Its main objective was to assess both the sardine and the blue whiting stocks occurring in Spanish waters. The cruise covered the Spanish Atlantic and Cantabrian continental shelf down to 1000 meters depth.

A total of 2765 nautical miles were sailed with 1790 corresponding to the sample zig-zag and following a zig-zag track. The working area was divided into seven geographic zones and different depth strata for calculation purposes.

A Simrad echosounder EK-500 split beam 38 kHz was used after calibrating with a copper standard target. Vessel speed was 10 knots and acoustics signals were integrated over one nautical mile intervals.

Hydrographic parameters were recorded in 61 stations and 22 pelagic hauls were conducted for species identification.

2. The **ECOMED** 91 cruise was planned to assess the stocks of sardine and anchovy occurring in the Mediterranean Sea from Punta Europa (Gibraltar Strait) to Sete (Gulf of Lion). From 21/10/91 to 21/11/91, an area of 14352 squared nautical miles was surveyed by the R/V Cornide de Saavedra. This area was divided into 14 sectors and 3 depth strata for calculation purposes. Transects were done following a zig-zag track.

Acoustics signals from a Simrad echosounder EK-500 split beam 38 kHz were integrated over one nautical mile intervals. Species were identified from catches of 32 pelagic hauls.

A.8 United Kingdom - Scotland

Surveys of herring were carried out 1) in the ICES area VIa and 2) in Orkney Shetland and Buchan areas in July 1991. The latter survey was in conjunction with Norwegian Danish and Dutch fisheries research laboratories. During the VIa survey data was collected in individual sample format for each transmission and with 0.5m depth definition at 38 and 120kHz. For the Orkney Sheltand area data was recorded on Sun from EK500 echosounder at 38kHz. A second EK500 has been purchased and it is expected to equip future surveys with EK500.

Work on the automatic extraction of shoals has developed and the system has been transferred to Sun computer system. The echo sounder output is treated as an image and loaded into a Sun based system using Imaging Technology high speed image processing cards. Image processing techniques involving smoothing, edge enhancement, multiple binary thresholds, erosion and dilation are used to isolate and define the locations and shapes of fish shoals and the seabed from the image. Timing is dominated by data recovery and the association of adjacent pixels into connected objects. Typical image recovery and processing is less than 20 seconds for 512 acoustic transmissions. The objective of the work is to aid extraction of shoal statistics to assist with understanding of stock distribution and species recognition.

Work on survey design methods has continued using a series of simulations to investigate the precision of estimates with different survey methods. The results are encouraging and indicate that systematic designs have some advantages in survey precision. Use of geostatistical estimators for variance allows examination of survey strategies.

A.9 United Kingdom - England

British Antarctic Survey

A Simrad EK400 Echosounder had been used since 1983 for surveys of Antarctic Krill and fish on the R.R.S. 'John Biscoe'. Following the replacement of this ship by the R.R.S. 'James Clark Ross' the sounder was transferred in January 1992 to the Fishery Protection Vessel 'Falklands Protector'. Simrad 38 and 120kHz hull-mounted transducers had been installed on the 'Falklands Protector' and the EK400 was used in conjunction with BioSonics ESP post-processing software to supplement a bottom-trawl survey of fish around South Georgia. This was the fourth in an annual series of trawl surveys, but the first to carry a scientific echosounder. Hauls were made at a series of 83 stations randomly located within three bottom-depth strata. The integrator was operated in bottom-locked as well as surface-locked mode during fishing

and the results will be compared with catches which were weighed, measured, assessed for condition and used for otolith collections. Between fishing stations the sounder was run with the integrator in surface-locked mode. Using recent studies that demonstrate that krill can be separated reliably from other scatterers in our survey area by the difference between echoes at 38 and 120kHz, these between-station transects will be used to estimate the krill biomass for the area surveyed.

During the past year various studies were carried out on the interpretation of acoustic results obtained at 38 and 120kHz. We have examined acoustic results obtained during repeated surveys of a patch of krill, compared backscattering strength with a towed plankton sampler and studied targets separated by their appearance on echo-charts at these frequencies.

A study comparing simultaneous acoustic and photographic estimates of density of krill in swarms around South Georgia has been carried out. Photographic density was calculated from stereo photographs taken with a Camera Alive photogrammetric system. Acoustic density estimates were obtained using the BioSonics Integrator connected to the Simrad EK400 sounder. Preliminary analysis indicates that the photographic density of swarms at night was between 40 and 200 krill m-3 which is similar to the acoustic density estimates obtained utilizing the recent target strength values for krill given in Foote et al. (1990).

Next austral summer will be our first opportunity to use the Simrad EK500 on board the R.R.S. 'James Clark Ross'. Initially we plan to log the output from the integrator to a PC, while evaluating the various options for post-processing in the future. Surveys of krill, fish and zooplankton will be made in the Bransfield Strait and South Georgia areas, continuing to compare 38 and 120kHz results, and hoping to use 200kHz in future seasons.

Foote, K.G. Everson, I. Watkins, J.L. and Bone, D.G. (1990): Target strengths of Antarctic krill (Euphausia superba) at 38 and 120 kHz. J. Acoust. Soc. Am. 87(1), 16-24.