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REPORT OF THE WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY

Montpellier, France 28-29 April 1994

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Report of the ICES Fisheries Acoustics Science and Technology (FAST) Working Group Meeting 28-29 April 1994, Montpellier, France

1. Terms of Reference

In accordance with C Res 1993/2:9 the Working Group on Fisheries Acoustics Science and Technology (Chairman: Mr E J Simmonds) met in Montpellier, France, 28-29 April 1994 to:

a) review the progress of the study groups on Target Strength Methodology and Research Vessel Noise Measurement;

b) consider the combination of information obtained from fishing samples and acoustic measurements in the estimation of abundance, with the aim of identifying the sources and magnitude of errors.

2. Opening of the Meeting

The chairman opened the meeting and introduced P Fréon, who welcomed members of the working group to Montpellier on behalf of the Institute.

3. Order of the Day and Appointment of Rapporteur

The agenda was adopted. D G Reid of the SOAFD Marine Laboratory, Aberdeen, Scotland, was appointed as rapporteur.

4. Presentation of Report from the Study Group on Research Vessel Noise Measurement (Chairman Mr R Mitson, UK)

This report presented the findings to date of the vessel noise study group. The report is in the final draft stage. The main points of discussion are included below and the report is published as CM 1994/B:5.

4.1 Ambient noise

There are many gaps in the current state of knowledge. The most significant of these are:

- Knowledge of how ambient noise masks fish hearing (of vessels) or affects the threshold vessel noise level above which fish will react.
- Fish hearing and responses to infrasound (0.02-20 Hz).

There are a number of sources of ambient noise. The most important are:

- Shipping - Can be strong locally, and also present at long ranges (10-100 km), (20-100 Hz).
- Wind - Noise at 50-1,000 kHz.
- Thermal - high frequency (200 kHz and above).

- Site specific environmental.
  - animals
  - seismic - infrasound (0.02-20 Hz)
  - Seabed noise - gravel beds, rocks etc

4.2 Fish hearing

Hearing and responses to low frequency and infrasound are poorly documented. Infrasound (0.02-20 Hz) can be detected by some species and the intensity increases with decreasing frequency. There are some exploratory results but these are difficult to assess. Fish hearing is generally in the range 0.01-1 kHz. Sound in this range from trawls and sounders may scare fish. The main influence on fish is particle displacement not sound pressure. The lateral line does not appear to be involved in hearing, although it is involved in low frequency movement detection.

Size and age also have an effect. Norwegian studies have shown that the swim bladder acts as an amplifier, so the effects of air guns is more marked for larger fish.

Some vessels do produce noise at these frequencies and may have effects out to 500 m from the vessel eg *Thallasa*. *Corystes*, which is much quieter may only cause a reaction in fish within 10 m of the vessel. It should be noted that research has indicated that fish will react to noise only when it is above a certain threshold. Below this threshold the fish may hear the noise but do not react.

4.3 Vessels

As reported before, *Thallasa* is known to be noisy. *Corystes* has had much effort directed to reducing noise. This has resulted in a noise signature 10-20 dB down on other RV's. The effects of noise on vessel instruments should also be considered eg echo integration of noise from the vessel and variations in signal-to-noise ratio. There are known to be problems with variable pitch propellers, with different combinations of revs and pitch resulting in cavitation. Fixed pitch propellers are often most efficient, and hence quiet, at near to their maximum speed. Best compromise may be an adjustable pitch prop with settings for steaming and trawling.

4.4 General points

- There are no specific recommendations for retrospective noise improvements.

- Important for areas for annual maintenance:
  - Clean up propeller
  - Acoustic isolation of engines etc
  - Increased engine noise

  The report will include data on the variation of noise with time from *Corystes*.

- Comparison of fishing (FV) and research vessels (RV).
- Older FV's tend to be as noisy as the worst RV's
- Newer FV's come close to RV signatures.
- Recommendations for charter vessels will be similar to those for research vessels.

- Related subjects not covered in report.
  - Variation in fish responses from fishing areas to non-fishing areas
  - High frequency behavioural responses in fish

4.5 Noise Report Recommendations

- The noise signature for the vessel should be defined based on two criteria; the range of fish hearing (below 300 Hz), and appropriate acoustic instrument frequencies eg 38 kHz for acoustic surveys (above 300 Hz).
- Testing noise signatures.
  - Best to use a naval facility to determine noise signature, however this may be expensive
  - Technique developed at IMR Bergen. A hydrophone is mounted on a stationary barge. The vessel to be tested steams past at different ranges and speeds
- It is important to get noise data on a narrow band, and not to used averaged data.

The report will be completed for the ICES Statutory meeting in St Johns, September 1994.

5. Presentation of Report from the Study Group on Target Strength Methodology (Chairman Mr E Ona, Norway)

5.1 Terms of reference

To prepare a report with a view to publication in the ICES Cooperative Research Report Series on the methodology for target strength measurements with special; reference to *in situ* techniques for fish and micronekton.

5.2 Outline of report

The first draft of the report is in the final stages of preparation. The chapter outline given in the previous report is to be retained with some additions. The details of the chapters are given in Appendix B. The current state of progress by chapter is:

1.	Introduction	Complete
2.	Definitions and terms	Complete
3.	Single Beam echo sounders	Completed by June
4.	Dual Beam echo sounders	60% Complete
5.	Split Beam echo sounders	Almost complete
6.	Biological sampling	
7.	Brief summary of other methods, integration and catch controlled experiments and analytical methods	

This will be a summary only and will incorporate the previous Chapter 8 on specialised measurements; tracking; multifrequency methods; deep water towed vehicles/transducers.

8. Single fish recognition criteria - summary given below.

9. Discussion/Recommendations.

5.3 Summary of Chapter 8 - discussion covering single fish recognition criteria

1. General principles:
   - pulse length windows
   - phase jitter

2. Problems of multiple fish echoes being identified as a single target:
   - How are close targets separated/merged eg split and dual beam sounders use phase relationships
   - Discussion of the scale of this problem
   - Discussion of statistics and physics of this problem - - studies at IMR Bergen

5.4 General points

1. TS determination is very difficult for fish in very shallow water as TS is only viable when fish are seen as point target. In very shallow water fish is not point target.

2. The report will address the question of how valid are single fish targets taken from outside schools to fish in schools. This problem will also be addressed in a later paper.

3. When possible TS should not be assessed from skewed or bimodally distributed fish aggregations, as there is difficulty relating trawl to acoustic data.

5.5 Papers presented on TS determination

See Section 6.

Traynor, J. Target strength measurements of walleye pollack *Theragra chalcogramma* and whiting *Merluccius productus*.

Appenzeller, A. *In situ* seasonal changes in target strength from acoustical measurements in Lake Constance.

Huse, I and Ona, E. Experiments on measuring average TS for herring within dense concentrations.

Barange, M. and Soule, M.A. *In situ* determination of target strength in densely aggregated fish: some problems and practical solutions

Ona, E. Detailed *in situ* target strength measurements of 0-group cod.

Kloser, R. Investigations on the target strength of the deep water species orange roughy (*Hoplostethus atlanticus*) based on modelling and *in situ* measurements on schools and tethered fish.

Thorn, R. New developments in single beam target strength technology.

Misund, O.A. Target strength estimates of schooling herring and mackerel by the comparison method.

5.6 Timetable

The time table for the completion of the report will be:

First full draft: September 1994

6. Presentation of Papers

6.1 Traynor, J. Target strength measurements of walleye pollack *Theragra chalcogramma* and whiting *Merluccius productus*.

This paper repots on recent target strength measurements made on walleye pollack and Pacific whiting. Data were collected in situ using a Simrad EK500 echosounder with a split-beam 38 kHz transducer. Measurements on walleye pollack agree fairly well with the previously published equation.

$$TS = 20 \log (L) - 66.0$$

Measurements on Pacific whiting gave intercept results consistently lower than this suggesting a TS/length relationship of

$$TS = 20 \log (L) - 68.0$$

It is suggested that further work be carried out, possibly based on swim bladder morphology, to investigate this relationship.

6.2 Appenzeller, A. *In situ* seasonal changes in target strength from acoustical measurements in Lake Constance.

White fish and Perch populations in the lake were surveyed on a monthly basis, using and EK500 echosounder and 120 kHz transducer. Target strength and distribution data were recorded. Biological samples were made with trawls and gill nets. The surveys showed a migration pattern around the lake, varying from littoral to deeper waters. TS data gave unimodal distributions in February and March, becoming bimodal in June as the next year class was recruited. The dominance of the young fish then diminishes through to November.

6.3 Reynisson, P. Evaluation of the threshold effect on echo integration; a comparison of two methods.

This paper compares the results from direct measurements of the effect of threshold on the echo integration of oceanic redfish with calculations based on data on TS distributions and the directivity of the transducer. Calculations are presented for the correction of the echo-integral for different threshold values in different situations.

6.4 Huse, I and Ona, E. Experiments on measuring average TS for herring within dense concentrations.

Herring were studied while overwintering in a fjord in Norway. Concentrations of fish were examined using a trawl sonar, TV camera and an echosounder with a special split beam transducer designed for fish tracking. This allowed a comparison of integrator SA with the fish count from TV and sonar, tilt from the TV, and tilt and swimming speed and direction from the split beam. The herring migrate from 200 m in the day to 50 m at night, which would suggest changes in swim-bladder volume of 1/15 surface value, in the night, and 1/25 in the day. Fish distributions were mostly polarised in the day but showed very mixed angles at night.

6.5 Barange, M. and Soule, M.A. *In situ* determination of target strength in densely aggregated fish: some problems and practical solutions.

Researchers have shown concern over the fact that split-beam echo sounder systems seem to overestimate the target strength of pelagic fish. In this paper, evidence was presented to suggest that, at the densities that we generally encounter pelagic fish, *in situ* target strength is dependent on fish density. It was argued that the reasons for this effect are likely to be: a) the inability of split-beam systems to consistently resolve multiple targets when pelagic fish disperse into scattering layers; and b) the possibility that these systems may generate incorrect TS data due to a combination of the failure to resolve multiple targets and also over/under compensation due to erroneous phase information generated by closely spaced targets with the scattering layer. Although the reasons for the former are not yet well understood, it was suggested that the effect may be linked to some scattering properties of densely aggregated fish. A practical method to overcome the present limitations of the system was presented, using examples for the South African anchovy and pilchard populations. A preliminary *in situ* target strength expression for the South African anchovy was presented, and its impact on the time-series of hydroacoustic estimates of the stock size was compared with estimates using other assessment methods. Finally, the performance of a 38 kHz split-beam echo sounder system in relation to single target recognition was tested, and some results presented, to generate discussion on the ultimate causes that generate the effects above mentioned.

6.6 Ona, E. Detailed in situ target strength measurements of 0-group cod.

In situ target strength measurements of cod larvae have been made using a split beam echosounder. The two data sets are sampled in pure cod concentrations, one in Ullsfjord, North Norway, and the other in Parrisvatnet, a closed 270,000 m^3 salt

water basin used for the production of cod fry. The target strengths measured are compared with the target strength to length equation used for larger cod. The results from Ullsfjord are not significantly different to the equation for large cod (TS = 20 log L -68.0 dB). In Parrisvatnet the target strengths are slightly lower, but no recommendation is made to change the TS/L relationship for 0-group cod. Details of measurement procedures, biology and analysis are reported.

6.7 Kloser, R. Investigations on the target strength of the deep water species orange roughy (*Hoplostethus atlanticus*) based on modelling and *in situ* measurements on schools and tethered fish.

In situ target strength data of fish from 600 to 1,200 m were collected from a spawning aggregation of orange roughy located off the east coast of Tasmania in 1992. The target strength data shows many modes, none of which can be definitely and uniquely attributed to orange roughy. Dominant modes at -50 and -55 dB could be attributed to myctophid fishes that contain gas-filled swimbladders that were undisturbed by the acoustic towed body. Small modes at -44 dB and -31 dB were attributed to the macrourid, *Coryphaenoides subserrulatus* and morid, *Halagyreus johnsonii* sp. respectfully. The swimbladder of *H. johnsonii* is gas-filled, whilst that of *C. subserrulatus* contains a spongy gas-matrix. No evidence of a separate peak at -36 or -4.13 dB was found for the previously reported values of orange roughy target strength. Results from modelling and tethered experiments on orange roughy indicate that the possible target strength range for a 35 cm standard length fish is -43 to -53 dB. The dominant peak in the *in situ* data at -50 dB which ranges from approximately -48 to -53 dB and is associated with the myctophids is likely to be masking the orange roughy targets. It is concluded that the *in situ* target strength for a 35 cm standard length orange roughy is likely to be in the range of -48, the top of the *in situ* target strength values and -53 dB, the lower range of tethered measurements.

6.8 Thorn, R. New developments in single beam target strength technology.

This paper presented a new non-parametric technique for assessing TS using single beam echosounders, entitled Expectation, Maximisation and Smoothing (EMS). This technique is a deconvolution method. The results of the technique were compared to other deconvolution and dual beam techniques. EMS was shown to require fewer samples and would function with as few as 100 samples.

6.9 Misund, O.A. Target strength estimates of schooling herring and mackerel by the comparison method.

Some pelagic fish species in some areas have to be surveyed acoustically when schooling. Schooling fish will tend to have a more uniform behaviour, particularly in tilt angle, than looser aggregations. This will tend to result in a higher TS value than is found for individual fish. This study used the comparison method the determine the target strength for schooling mackerel and herring. The schools were first observed by echosounder and sonar and then captured in its entirety. This allowed a comparison of the echo-integration results and the actual biomass and length/frequency of the school, and hence the TS/L relationship of the fish in the school. The calculated constant for herring was -71.1 dB or 69.8 dB after correction for absorbtion. Both these values are higher than the standard clupeoid

value currently used for acoustic surveys. The constant for mackerel was -87.9 dB which is within the suggested range for this species.

6.10 Scalabrin, C. and Lurton, X. Fish shoals echo amplitude analysis

Aquatic biomass assessment is most often realised using the echo-integration method based upon the linearity principle which states that the echo energy is proportional to the target density. Hence, the echo amplitude envelope is usually admitted to be Rayleigh distributed.

The purpose of this communication is to present experimental echo amplitude PDFs from wild fish shoals. Many raw data were collected at sea during various fisheries acoustic surveys with a 38 kHz narrow band echo-sounder using a 1 ms pulse duration and a 8° vs 8° transducer. To our knowledge, such a variety of experimental data has not been systematically gathered and analysed yet. The empirical distribution of amplitude values from a shoal is computed after two major corrections: a) amplitude values corresponding to incomplete pings are removed systematically; and b) estimation of the sampling frequency for the echo peak in order to get statistically independent values (the original signal is over-sampled within one ping duration). Both correction methods are described and discussed.

The shoal amplitude PDF is then obtained by finding the theoretical distribution which best fits the empirical distribution, after corrections. Shoals from several species with different acoustic properties were selected and analysed. Although some of the obtained PDFs might fit a Rayleigh distribution law, a systematic exploitation of gathered data shows that it is usually not the case; better fits may be obtained with Pearson type I distribution. Another conclusion is that little useful knowledge can be extracted from the PDF analysis to discriminate among fish species. In order to improve fish species discrimination, spectral analysis of signals time envelopes were performed over the same data and the first corresponding results are presented.

6.11 Gerlotto, F., Freon, P., Soria, M., Cottais, P-H. and Ronzier, L. Exhaustive observation of 3D school structure using multibeam side-scan sonar: potential use for school classification, biomass estimation and behaviour studies.

The use of a multi-beam sonar used in the vertical plan as side-scanning sonar is presented. The data obtained are used in three different ways: a) for school classification using a set of statistical characteristics extracted from the result through image processing and pixel analysis; b) for school counting during acoustic surveys; and c) for behavioural studies, correlating the results with environmental data. The paper presents the methodology developed and some examples from a survey performed in western Mediterranean during a EEC/AIR project survey, in May 1993.

6.12 Swartzman, G. Relationship of fish school distribution in the Bering Sea to environmental factors.

Fish school parameters were derived from echogram data using image analysis techniques. A series of environmental parameters were also collected including vertical CTD data. Initial analysis used multiple bivariate plots, this was then enhanced using generalised additive models. The main areas of interest were defined by changes in thermocline structure, mainly controlled by the frontal systems in the study area. The most important school parameters were; school density, area and average energy. School mass was highest in shallow waters, below the thermocline. Ocean fronts affect the depth and size distribution of summer Bering Sea pollack schools.

6.13 Simard, Y. Combination of different types of information with acoustic data: some possibilities of spatial statistics.

This paper discussed a range of possible methods of combining continuous acoustic survey data with point trawl data and various auxiliary variables eg temperature, salinity, depth, light etc. This could be carried out using spatial statistics, and could lead to more accurate or less variable stock assessments.

6.14 Godø, O. and Totland, A. Effects of different trawl sampling strategies on acoustic abundance estimates of cod and haddock in the Barents Sea.

This paper compared two different methods for assigning trawl data to rectangles. The original method assigned a haul manually to the square. Unfished squares would be assigned to the nearest haul. The second (automated) method, assigned an average of all trawls in nine connected squares to the central square. It was found that both techniques produced similar results except in areas where new recruitment was occurring. Split by species was also affected, mainly in low abundance areas. It was concluded that the study should be extended over more years, there was a requirement to study trawl allocation, and location, and that more sampling effort should be assigned to high density areas.

6.15 Diner, N. Remote control closure of trawl cod-end.

A new technique was described to allow subsampling in the trawl during fishing operations. The cod-end was provided with a series of compartments which could be closed sequentially, allowing the capture of separate schools. Closure was achieved using acoustically released drogues. The system allows the collection of discrete uncontaminated samples. It is currently about to be marketed.

6.16 Holliday, V. Observing small zooplankton from moorings.

Presented as a poster.

6.17 Thorne, R. Digital transducer technology.

This paper presented a review of the philosophy of digital transducer technology development at Datasonics.

6.18 Svellingen, I. TAPF. A unit for testing the receiver of a 38 kHz split beam sounder.

This paper describes a new unit to test the following parameters on 38 kHz split beam sounders:

1. Target strength
2. Phase measurement
3. TVG function 40 logR
4. TVG function 20 logR
5. Integrated echo energy S_A
6. Linearity of the receiver system

7. Working Group Recommendations

The Working Group made the following recommendations:

1. The FAST WG should meet in Aberdeen on Saturday 17 June 1995 following the ICES Fisheries and Plankton Acoustics Symposium to:

   a) consider the implications of work presented at the ICES Symposium on Fisheries and Plankton Acoustics and to identify the most important and productive areas for research.
   b) consider the report of the workshop on hydroacoustic instrumentation (Cambridge 3-5 May 1994).

2. The report of the study group on the essential noise requirements of research vessel should be published as a cooperative research report

3. The report of the study group on In Situ Target Strength Measurement Methodology should be published as a cooperative research report

8. Closure

The chairman thanked the host institute for their hospitality and thanked the members of the Working Group and study groups for their efforts and contributions.

9. National Progress Reports

Appendix A.

10. Participant and Address List

Appendix C.

APPENDIX A: NATIONAL PROGRESS REPORTS

A.1 AUSTRALIA

CSIRO Division of Fisheries

Development

In January the first phase of a portable acoustic system project was completed with the construction of an instrument container and the successful testing of a constant tension winch. The second phase, involves the redesign of our towed body to include two frequencies, is scheduled for completion by May 1995. The portable system is designed to be suitable for conducting deep water acoustic biomass and *in situ* target strength surveys from 600-1,000 m on commercial fishing vessels 30 m in length.

The first phase of a software development project (collaboration with Antarctic Division) to analyse multi frequency acoustic fish and benthic surveys is nearing completion. The software developed on a SUN IPX using C++, Open Look and Oracle data base has an open design which will initially accept Simrad EK500 data but will readily work with other digitised formats. The software is being tested initially using single frequency algorithms. Multi-frequency algorithms and easy-to-use interfaces will be built in 1994-95.

A new project to develop an acoustic receiver and algorithms for benthic habitat discrimination commenced in July 1993. The equipment and software developments are now under way. The equipment development centres around building an acoustics receiver (230 dB dynamic range) that can be interfaced to standard fishing vessel sounders. The software development will be based on our existing acoustic software but will extend to specific algorithms for benthic habitat monitoring.

Surveys

In July 1993 the fourth annual acoustic survey was conducted of spawning orange roughy off the east coast of Tasmania using both hull mounted and towed transducers. The towed transducer survey was performed by towing the towed body to a depth of 600 m. The data were processed in October 1993 showing consistently higher biomass for the towed body surveys when compared to the hull mounted surveys.

In February 1993 the second survey was undertaken of a 600-1,300 m mixed species ground that consisted of 35 hills off the south coast of Tasmania. The acoustic data were obtained by towing the towed body at depths of 500 to 900 m at speeds of 5 to 7 knots virtually continuously for 14 days. *In situ* TS data were collected on various species down to 1,200 m.

Acoustic data were also collected from mixed species assemblages in shallow water in southeast and northern Australia. The data set produced will be analysed with multi-frequency algorithms.

Contact: Mr Rudy Kloser

A.2 CANADA

Bedford Institute of Oceanography and St Andrews Biological Station (DFO Scotia-Fundy)

Acoustic information continued to be collected during groundfish trawl surveys on the Scotian Shelf and during special inshore trawl surveys covering traditionally unfished hard bottoms. Strong correlations have been found between trawl catches and the acoustic measurements that suggests the possibility of usefully applying the technology to groundfish.

An examination of the feasibility of applying acoustic techniques to aid in groundfish stock assessment has been undertaken at St Andrews Biological Station. A 50 kHz single beam transducer has been deployed during trawl sets on two surveys to determine the degree of correlation that exists between trawl catch and acoustic area scattering. Trawl catch for this comparison has excluded benthic species such as sculpins, skates and flatfish as well as dogfish that have very low reflectivity due to their lack of a swim-bladder. The correlations achieved between catch and areas scattering from these surveys has been quite high (r-0.83 and 0.94). This indicates that the acoustic system is effective at detecting fish near the bottom. Determination of the proportion of acoustic area scattering attributable to individual species would need to be based on trawl catches, since species recognition is not feasible from the acoustic information alone. Based on these results, we intend to use our 120 kHz dual beam acoustic system to investigate the representativeness of trawl stations for the George's bank survey. This will be based on a comparison of acoustic results from trawl stations with those from a more geographically inclusive data set collected while steaming between stations. The acoustic system is also being used in an investigation of diel variation in distribution of cod within a spawning assemblage on George's Bank.

A bottom-mounted upward looking sonar of long-term quantitative zooplankton monitoring was successfully deployed for a 50 day period on the Scotian Shelf. The acoustic system was able to monitor populations of euphausiids and juvenile silver hake in the 150 m of water using a 150 kHz RDI Acoustic Doppler Current Profiler. Over the period of time, both short-term diel migration and longer-term migrations of the biological populations were observed. Some of the observations could be related to the movements of water masses in the area.

Maurice-Lamontagne Institute, Mont-Joli, Quebec

An acoustic mission dedicated to the development of an abundance index for mackerel was conducted in Cabot Strait in June, during the seasonal migration to the Gulf of St Lawrence. It used an EK500 (120 kHz) coupled to an HDPS. This system was also used for an estimation survey of herring in eastern Gulf of St Lawrence in November.

Acoustic data were gathered with a Biosonics 102 (38 and 120 kHz) in eastern Hudson Bay in September, during an oceanographic mission. Tests of research ships of opportunity as platforms to automatically acquire echointegration data were also performed.

Roxann data for bottom classification were collected during scallops and Stimpson surf clam surveys in the Gulf of St Lawrence in July and September.

Freshwater Institute, Winnipeg, Manitoba

A feasibility study to evaluate the potential of using hydroacoustics to study the spawning migration of broad whitefish (*Coregonus nasus*) was carried out on the Arctic Red River, Northwest Territories in November 1993. A Simrad EY500 split-beam hydroacoustic system was deployed through the ice in early November 1993. An elliptical beam transducer was aimed horizontally from each shore towards the centre of the river. Through careful site selection, about 80% of the cross-sectional area of the river was ensonified. The ice surface made a stable platform from which to deploy the transducers and calibration sphere. Dual axis rotators allowed precise aiming and calibration of each transducer. The deployment of the system under the ice presented few hydroacoustic problems. Environmental noise levels were relatively low (-108 dB) when compared to open water conditions and calibration was greatly simplified because the ice provides a stable work surface. However, a significant proportion of the broad whitefish had passed the study site by the time the hydroacoustic system was operational. Nonetheless, enough data was recorded to evaluate the future potential of the technique for this type of assessment. Analysis of the data will continue through 1994.

NW Atlantic Fisheries Centre, St John's, Newfoundland

Enclosure experiments on target strength/length relationships for herring continued in 1993. One survey was conducted to estimate herring abundance of one stock complex. This 120 kHz survey includes *in situ* target strength measurements.

One large survey was conducted for capelin (49 kHz) covering 8,850 nm of survey track in NAFO Division 2J3KL. The trend in biomass, declining from 1991, continued in 1993.

A survey of cod stocks employed two vessels for a 20 day period. Work focused on *in situ* target strength measurement and species identification research. Multiple frequencies (38/49/120 kHz) were employed and inter-vessel calibration was performed.

Acoustics was used in an experiment to examine the effect of trawling on the distribution of spawning cod.

The conversion of the Atlantic Champion from a commercial trawler to a research vessel is proceeding. Trials are scheduled to commence in the fall.

A.3 DENMARK

Danish Institute for Fisheries and Marine Research

Research and Development

Projects concerning classification of species entities by image processing of acoustic scattering layers and the estimation of bivalve (*Mytilus*) populations by acoustics have continued. The bivalve project will be finalised in 1994 while the classification project will be published in 1995.

Surveys

The disturbances caused by the construction work on a bridge connecting Denmark and Sweden across the Øresund are a cause for concern in relation to the important migrations of spring spawning Western Baltic herring through the sound. The regular monitoring programmes of the herring migrations through the sound, implementing acoustic techniques and gill net sampling, has been initiated. Baseline data are collected before construction works start and the monitoring programme is expected to last for the duration of the bridge construction.

Acoustic methods have been employed in surveys of pelagic 0-group cod in the North Sea and in the Baltic. These attempts have met major problems in distinguishing 0-groups in dense plankton layers (North Sea) and in extremely low stock sizes (Baltic).

The Danish Institute for Fisheries and Marine Research has participated in international acoustic surveys concerning herring in the North Sea and Skagerrak and in the Western Baltic.

A.4 ICELAND

Contact: Gudni Thorsteinsson

Experiments with netting with 135 mm mesh opening in the overhang of a Nephrops trawl, otherwise made of 80 mm mesh opening, resulted in significant reduction of undersized haddock. After the experiment many boats used the bigger mesh size in the overhang voluntarily in addition to the obligatory 135 mm square mesh window in the upper belly. The combined reduction of undersized haddock by using a square mesh window in addition to the bigger mesh size in the overhang is more than 50%. In 1994 experiments with no overhang in the Nephrops trawl are planned to check on the relative bycatch of undersized and marketable fish by species. These experiments are carried out on a twin-trawler.

Experiments with square mesh windows in bottom trawls indicated that the bycatch rates of small haddock can be reduced greatly and the catches of small cod to some extent. The results are much depending on depth, fishing grounds and other factors. The influence of the day-time and year-time has not been investigated yet. Square mesh windows are however not used in the trawl fishery. Seiners permitted to use 120 mm netting when catching lemon sole must on the other hand use square mesh windows in the upper part of the cod-ends.

Iceland has participated in a Scandinavian project on the selectivity of shrimp trawls. A TV film has been made on the problems of the shrimp fisheries in the North Atlantic in cooperation with a filming company.

Private companies have developed two kinds of dredges for catching sea urchin (*Strongylocentrotus droebachiensis*). Both designs were successful and are widely used in commercial fishing. Underwater TV observations showed the catchabilities of both versions to be good and the influence on bottom organisms to be rather low.

An experimental fishing for the common whelk (*Buccinum undatum*) has been started with different kinds of traps. An experimental fishing on ocean quahog (*Arctica islandica*) has been started recently.

As a part of a Scandinavian research project on the hidden mortality of fishing gears an experiment on the survival rates of small fish and shrimp (*Pandalus borealis*) escaping through diamond and square mesh cod-ends and a metal grid has been planned. The survival rate of caught shrimp, released at the surface, will also be dealt with.

A.5 IRELAND

Fisheries Research Centre

The Fisheries Research Centre (FRC) has undertaken acoustic surveys to estimate the spawning stock biomass of herring in the Celtic Sea (ICES Divisions VIIg and j) since 1987. Two surveys are carried out each year, one in autumn and one shortly afterwards in winter. The results of the acoustic surveys are submitted to the ICES Herring Working Group.

Although FRC personnel (J Molloy *et al.*) have always participated in these surveys, the acoustic equipment and expertise has been contracted from specialists outside Ireland. Liverpool University's Port Erin Marine Laboratory undertook the first surveys in 1987/88, and the Scottish Office Agriculture and Fisheries Department (SOAFD) have undertaken them since 1989/90. However, under the EC funded STRIDE programme, FRC have acquired the necessary equipment and personnel in an attempt to establish an independent fisheries acoustics programme.

This programme began in 1993, with the acquisition of the Simrad EK500 echosounder and a 38 kHz split-beam transducer, and the appointment of Mr J Milne, who attended the ICES FAST WG in Gothenburg last year. The equipment list is currently more comprehensive, with a PC running Simrad's EP500 post processing software, a towed body and appropriate standard target calibration apparatus.

Dr P Fernandes took up the position of acoustic scientist in January 1994. His experience in the field is as follows: use of a Simrad EY200P and integration software to study biological distributions across the western Irish Sea front (1988-1991); participation in the autumn Celtic Sea herring survey (1989); acting as adviser to an EC funded project in South America with ambitions to conduct acoustic surveys (1992); and attendance of the fisheries acoustics courses run by Simrad (1993).

P Fernandes took part in the January survey of the Celtic Sea carried out by SOAFD, and in the data analysis at the Marine Laboratory Aberdeen. He recently undertook field trials of a new calibration set-up and the deployment of the FRC towed body from the RV *Lough Beltra*. He is currently preparing for forthcoming cruises and reviewing data analysis procedures.

An acoustic survey has been planned for 11-30 July, to assess the herring biomass off the west coast of Ireland. This is to be carried out independently by FRC, but will be coordinated with the other IES surveys which will cover most of the continental shelf in the North Sea and west of Scotland. The FRC survey will commence at 56°N, proceeding

south to 52°N, extending out as far as the 200 m contour. Local fishermen have been consulted to determine a survey design which takes into account the suspected herring distributions for that time. The RV *Lough Foyle* has once again been chartered for the survey.

FRC have again planned surveys for the Celtic Sea in autumn (31 October-12 November) and winter (14-27 January 1995). It is also interested in the prospect of using acoustic techniques to assess stocks of lesser exploited deep water species on the continental slope. FRC is particularly concerned with securing acceptance and support for fisheries acoustics from the Irish fishing community. In addition to informal discussions, a seminar/ workshop with fishing organisations has been planned for later this year.

A.6 FRANCE

Acoustique Sous-Marine Appliquee a la Peche

Les travaux en acoustique sous-marine appliquée à la pêche sont menès en partie par l'IFREMER et en partie par l'ORSTOM, les deux organismes restant en contact étroit en particulier en ce qui concerne les aspects mèthodologiques.

1. Travaux menés à l'IFREMER

1.1 Echo-intégration et classification des bancs

Le travail de classification des bancs à partir des paramètres géométriques et énergétiques des bancs déterminés grâce au logiciel MOVES B se poursuit dans le cadre du projet BIOMASS (programme FAR). Les descripteurs classiques se révélant insuffisants pour assurer l'identification de bancs, une analyse spectrale de l'amplitude des échos dans un banc a été entamée.

Par ailleurs nos partenaires dans le projet BIOMASS que travaillent sur l'identification des échos obtenus en sondage large bande (Insitut de chimie et de physique industrelle de Lyon, France; Marine Laboratory d'Aberdeen, Scotland) sont arrivés à des résultats prometteurs (détermination de la signature acoustique de groupes de poissons, reconnaissance de la signature spectrale entre gadidés, chinchards et maqueraux, sur des poissons observés en cage).

1.2 Essais du sondeur large bande

Pour pouvoir réaliser des essais due transducteur large bande à la mer sans être gêné par les bruits du navire, nous avons réalisé un corps remorqué support de transducteur dont les performances hydrodynamiques sont très satisfaisantes. L'engin est parfaitement stable en remorquage entre 4 et 11 noeuds.

1.3 Traitement des données sonar

La possibilité d'un traitement numériquen en temps réel des images d'un sonar de pêche multifaisceau a été prouvée (trajectographie de bancs); ce travail devrait se poursuivre en exploitant mieux les possibilités de reconnaissance automatisée des détections de bancs de poissons.

1.4 Evolution des sondeurs OSSIAN

Un accord avec la Société MICREL a permis d'intégrer au sondeur OSSIAN (dans sa version scientifique) les modules d'écho-intégration par tranches d'eau et par bancs de poissons contenus dans le logiciel IFREMER "MOVIES B", et de reconnaissance automatisée de la nature du fond.

D'autre part les travaux de mise au point du transducteur du sondeur OSSIAN 2000 se poursuivent pour obtenir un sondeur grand fond à haute définition. Les premiers essais d'une maquette du sondeur seront faits en Méditerranée, à bord du N/O EUROPE dès le début de 1994.

2. Travaux menés par l'ORSTOM

Suite à la mise en évidence par acoustique de structures biologiques liées à la présence de thons dans une zone de l'Atlantique Equatorial pendant une partie de l'année, et à leur identification comme poissons méso-pélagiques, des études en particulier sur la croissance de cette espèce sont en cours, et des campagnes complémentaires, à des saisons non encore explorées, sont en cours ou prévues (E Marchal, J Panfili).

Le réseau Caraïbes poursuit ses travaux, entre autres de détections sur les petits fonds. Les participants se sont réunis en février 94 à La Havane; réunion qui se prologeait par un Congrès des Sciences de la Mer (F Gerlotto).

Au Sénégal, outre les travaux en petits fonds qui vont être renforcés par l'affectation d'un chercheur de l'INRA, ont commencé des études sur le mode de structuration de la population, et ses conséquences sur l'évaluation, par l'affectation d'un géostatisticien de l'ORSTOM (P. Petitgas, J.J. Levenez, J. Guillard). Le développement de Dakar comme site de méthodologie acoustique est en projet, afin d'approfondir nos recherches sur les TS *in situ* et l'apport des systèmes large bande dans la variabilité des mesures et la caractérisation de cibles (B Samb, A Lebourges).

Le groupe de travail francophone sur l'"Occupation de l'espace par les organismes aquatiques", s'est tenu pour la troisième fois en mai 93 à Evian; il se réunira de nouveau à Montpellier à la faveur du FAST, en avril 94.

En Indonésie, l'étude du comportement des poissons au voisinage des dipositifs de concentration de poissons se poursuit dans la Mer da Java (D Petit).

Pendant l'été 93 a eu lieu une première campagne en Polynésie visant à étudier l'efficacité des dispositifs de concentration de thons. Les mesures ont été faites avec un dual-beam BIOSONICES à 120 kHz et un intégrateur INES-MOVES. Le comportement des thons a été suivi par marquage acoustique (E Josse).

Le programme AIR mené en collaboration avec l'Instituto de Ciencias del Mar (Barcelone, Espagne) et l'Instituto Ricerca Pesca Maritime (Ancona, Italie), se poursuit, avec non seulement l'écho-intégration mais aussi l'emploi d'un sonar haut fréquence pour l'étude de la structure des bans (P Freon, F Gerlotto).

Une collaboration avec le laboratorie d'acoustique des pèches du VNIRO (Moscou) débute, afin de mettre au point un prototype de sonar paramétique pour les travaux en petits fonds et large bande (A Lebourges).

Travaux menés par acoustique à la Direction des Ressources Vivantes de l'IFREMER

Atlantique

Dans le cadre des programmes du laboratoire d'Ecologie Halieutique (ECOHAL), la campagne ERAG 93 a été effectuée à bord de la THALASSA sur les concentrations d'anchois du sud du golfe de Gascogne en juin 1993. L'acoustique est considérée, pour ce programme, comme un outil privilégié permettant de caractériser la distribution et l'abondance relative de cette espèce dans son contexte multispécifique. Au cours de cette campagne, l'effort a été porté d'une part sur la collecte des paramètres d'environnement associés et d'autre part sur l'étude des variabilitées spatio-temporelles de la distribution des adultes à différentes échelles d'observation.

Méditerranée

Dans le cadre d'un programme financé en partie par la CEE (FAR), avec la collaboration de l'Espagne (IEO et CSIC) et de l'Italie (ICRAM), une compagne d'écho-intégration a été effectuée en Méditerranée en 1993 sur les aires de ponte de l'anchois à bord du N/O THALASSA. La prospection acoustique s'est déroulée du 01/07/93 au 01/08/93 entre le folfe de Valence (Espagne) et le sud de l'île d'Elbe. Simultanément, le GARCIA DEL CID (N/O du CSIC) a effectué une estimation de la biomasse des géniteurs par la méthode de la production journalière d'oeufs.

L'EUROPE, nouveau navire de recherche haliqutique, catamaran de 30 m, a été mis à l'eau en 1993. Il sera opérationel sur la façade méditerranéenne en 1994. Une attention particulière a été portée sur la conception de ce navire pour répondre aux exigences des campagnes acoustiques en particulier en ce qui concerne les quipements et le bruit rayonné.

Travaux menés par l'INRA

Les travaux d'acoustique subaquatique du laboratoire d'Hydrobiologie Lacustre de Thonon-les-Bains sont menés suivant deux axes de recherche principaux:

- l'utilisation des techniques acoustiques pour le suivi des stocks de poissons dans les différents lacs alpins, et de barrage (barrage Aube) afin d'appréhender les fluctuations annuelles des biomasses totales des poissons en relation avec les dynamiques de populations, les statistiques de pêches et la climatologie. L'occupation spatio-temporelle des populations de poissons en fonction des paramètres environnementaux (physico-chimiques, biologiques), est étudié en complémentarité avec les méthodes traditionnelles d'échantillonnage, tel que les filets maillants et le chalutage. En zone de petits fonds (inférieure à 10 m) la faisabilité et la complémentarité des techniques acoustiques ont été abordées (rivière Seine), et poursuivies par des expérimentations en collaboration avec l'ORSTOM (dans le cadre d'ECHOSPACE) dans la zone côtière du Sénégal et dans l'estuaire du Sine-Saloum.

Simonstown and has been used extensively in the field on a wide range of targets, from horse mackerel and squid to anchovy recruits. Further significant developments are at an advanced stage and will be tank tested in 1994.

- The development, through local consultants, of a multi-beam, high resolution system (code named ABACUS) capable of counting individual fish at densities higher than typical upper limits for *in situ* target strength determination.

Other acoustic interests of the institute are the development of acoustic survey design and data analysis techniques, including the use of spatial statistics to characterise distribution on various scales.

A.8 SPAIN

During 1993 different acoustic activities were carried out, all of them using an EK500 echosounder.

IEO - Palma de Mallorca
Contact: Joan Miquel, Magdalena Iglesias

Development of Acoustic Techniques

A new research program, DETAC, for developing acoustic techniques was started last year. The main objectives are to develop and to check a new tool for control/capture data from EK500 echosounder, studies about fish behaviour and TS measurements and survey planning studies. Two surveys were performed in Mallorca island on board RV *Odón de Buen* in February and June.

During these surveys the control/capture program, *Bravo* was checked; this program briefly consists in a qbasic program that controls the main settings of EK500 (scales, printers, GPS output, etc) and captures the integration table telegram each mile via RS232 serial port.

The survey track consisted in a parallel grid design with 2.5 nm between transepts. For pelagic fish present in the studied area, there were not significant differences among CVs considering all the transepts, removing one (5 nm between transepts) or two (7.5 nm between transects).

IEO - A Coruña
Contact: Pablo Carrera

Acoustics Survey for Assessment

Atlantic and Cantabrian waters

Two surveys were carried out, *Pelacus 0493* during April and *Ecocádiz 0693* in June.

The main goal for *Pelacus 0493* was the abundance estimation of sardine and blue whiting present in cantabrian and galician waters, but it was not possible to do *in situ* TS measurements for both species.

IEO - Cádiz
Contact: Milagros Millán

Ecocádiz 0693 was the first acoustic survey for the assessment of pelagic fish done during spring in the Gulf of Cádiz. A total of 517 nm were surveyed covering an area of 2,865 nm^2; small boar fish (*Capros aper*) was the most abundant species found, with 217,579 mt, corresponding to 20,784 million fish. This species, with small trumpet fish (*Macrorhanphosus scolopax*), which were distributed within 500 to 100 m isobath, have restricted the distribution area of sardine and anchovy to shallower waters (less than 100 m). For sardine and anchovy, the total biomass assessed were 90,974 and 6,569 mt respectively corresponding to 2,485 and 462 million fish.

IEO - Malaga
Contact: Rogelio Abad

Mediterranean Sea

Ecomed 93 was the fourth fall survey carried out in the Spanish Mediterranean Sea. These surveys usually covered the area between the Gulf of Lion to Punta Europa, Gibraltar. Unfortunately in 1993 a failure in our EK500 echosounder, reduced the survey area to Cataluña and Alborán Sea (Malaga to Punta Europa).

In 1992, an important population of boar fish (*Capros aper*) had been found in Alborán Sea (as in the Gulf of Cádiz in 1993), but during *Ecomed 93* this population had disappeared. Fishermen from both Gulf of Cádiz and Alborán Sea (also from Portugal) have reported about the presence of important amounts of boar fish or trumpet fish for periods more-or-less shorter that cause great problems to the normal fishing activity.

A.9 UNITED KINGDOM

Marine Laboratory, Aberdeen, Scotland

Surveys of herring were carried out 1) in the ICES area VIa North and 2) in the Orkney, Shetland and Buchan areas, in July 1993. These surveys were in conjunction with the Norwegian, Danish and Dutch fisheries research laboratories. Survey data were collected using the Simrad EK500 and recorded on a Sun computer using the BI500 software at frequencies of 38, 120 and 200 kHz. Data on temperature, salinity and seabed type (ROXANN) are collected during the survey. The relationships between stock and water depth, temperature, salinity, and seabed are being investigated from this data. Some significant correlations have been found between fish density and depth, temperature and substrate. Acoustic surveys of migrating mackerel have been carried out in January 1994.

Work on wide-band acoustics has been continued with the development of an improved transducer, and a new computer controlled receiver and transmitter. Initial trials of wide-band beams from a flat transducer have been completed. Studies on reflectivity continue with measurements on cod, saithe, haddock, horse mackerel and mackerel. The data are being analysed for recognition rates using neural net and discriminant analysis. This work is supported under the EC FAR program and is being carried out in cooperation with ICPI Lyon, IFREMER Brest and IMB Crete.

- l'utilisation d'un sonar large bande, en phase d'expérimentation, aborde les problèmes de la reconnaissance spécifique de cibles individuelles et de bancs de poissons.

ECHOSPACE

Marine and fresh water organisms are not randomly distributed, but present organised structures at any scale, from 1 m up to several hundreds of kilometres. Such a deterministic occupation of space depends on physiological and behavioural reactions, as well as on spatio-temporal structures of the environmental characteristics. The aquatic space is three-dimensional, with strong vertical gradients; thus the shape that the spatial organisation may present is complex. Failure to take this spatial structure into account risks neglecting fundamental characteristics of the biology of the species, and serious errors in the population analysis. Although these spatial structures are fundamental characteristics of the populations in the ecosystems.

It is only the introduction of acoustic methods (echosounders, sonar) that has overcome the limitations of the traditional sampling methods and allowed the direct observation of the three-dimensional structures of the populations as well as their reactions to hydrological characteristics, hence an understanding of the relationship between the population distribution and the environment. As a matter of fact these methods are the only ones that allow a remote, continuous and synoptic observation of the individuals in their own space.

Taking advantage of these possibilities, the Working Group ECHOSPACE (Etude du Comportement, de l'Hétérogénétié et de l'Organisation Spatilale des Populations Aquatiques Considérées par Echo-prospection, on the Spatial Organisation of Aquatic Populations as recorded using acoustic methods) was created in 1991. This group is open to every scientist of any country who is concerned with its objectives, ie the understanding of the mechanisms producing the spatial structures of aquatic organisms, and the evaluation of their consequences on the study of these populations. Annual meetings are organised and the main oral communication language is French.

ECHOSPACE has explored different ways of using the information that can be extracted from the acoustic data. They concern the study of the mechanisms that are responsible for the spatial organisation, as well as the spatial geometry of the structures, the behavioural mechanisms of the populations (and particularly gregariousness), the biological mechanisms induced by the hydrological conditions, and the impact of the structures on the results of acoustic biomass estimates. An issue of *Aquatic Living Resources* (Vol. 6, No 3, 1993) is devoted to the recent work of the scientists belonging to ECHOSPACE (11 papers).

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A.7 REPUBLIC OF SOUTH AFRICA

Sea Fisheries Research Institute, Cape Town

The institute conducts acoustic surveys from two research vessels RS *Africana* and RS *Algoa*, both of which are equipped with Simrad EK400 and ES400 38 kHz split-beam sounders interfaced to a locally-developed, PC-based, integration and data logging system. *Africana* is also equipped with an EK500 sounder at 38 kHz and 120 kHz, and *Algoa* is to be fitted with a 38 kHz EK500 this year. *In situ* target strength analysis is done on both vessels through locally-developed single-target recognition and beam-compensation software, using data from the ES400 parallel data port.

Random stratified surveys of anchovy *Engraulis capensis* and pilchard *Sardinops ocellatus* spawning stock on the South African continental shelf have been done annually in November since 1984. The anchovy spawning stock is determined contemporaneously by an egg production survey from the same vessel. After adjustment for the most recent *in situ* target strength figures, the acoustic time series agrees well with that from the egg production estimates. Acoustic surveys of anchovy and pilchard recruitment on the west coast have been done in mid-year every year since 1985. Management of both species is heavily reliant on the results from both the spawner biomass and recruitment surveys, with the latter carrying most weight for anchovy, and the former for pilchard. Round herring *Etrumeus whiteheadi* biomass has also been estimated acoustically during the November surveys. The results show this species to be under-exploited at present. In conjunction with routine bottom-trawl surveys, Cape Horse mackerel *Trachurus capensis* have been assessed acoustically on the Agulhas Bank at night when they are clear of the bottom. In the course of these surveys evidence has been obtained of major changes in target strength in response to the midwater trawl. Attempts have also been made to assess the commercially important chokka squid *Loligo reynaudi* on its summer spawning grounds inshore on the Cape South Coast. It has been found that the biomass of spawning aggregations can be estimated acoustically, and ways of combining these estimates with mark-recapture information on migration, and trawl estimates of the non-aggregated part of the population are being sought. Finally, the institute conducts occasional acoustic surveys on Antarctic krill *Euphausia superba* as part of the nation's commitment to CCAMLR. Study areas have been Prydz Bay, South Orkneys, the Antarctic Peninsula and most recently (1994), S Georgia.

In addition to the surveys, acoustic work has been done on behaviour and distribution, primarily on the species mentioned above (with a strong emphasis on Antarctic krill), as well as on juvenile hake *Merluccius capensis*. A start has also been made in classifying fish and zooplankton targets acoustically through principal component and discriminant analysis of between and within aggregation variables.

Methodological work has centred on the following:

- The in-house design and production of a PC based integrator and data logger (code named AIDA), which accepts data from the EK400 and ES400 sounders, and is soon to be interfaced to the EK500.

- The development of single-target recognition and analysis software for *in situ* target strength determination. The current system has been tested on model targets in a 20 m test tank at the National Underwater Acoustic Centre in

Work on survey design methods has continued. The series of simulations to investigate the precision of estimates with different survey methods has been developed to include consideration of variance as well as abundance. The results are encouraging and indicate that systematic designs have distinct advantages in survey precision. Use of geostatistical estimators for variance allows examination of survey strategies. Automatic fitting procedures for variograms have been used to obtain better understanding of the precision of the variance estimates. The conclusions of this work are that the best abundance estimates are obtained with systematic surveys and variance can be calculated using geostatistics. The best variance estimates can be obtained using a transect design of two transects per strata. The final choice of strategy depend on the relative importance given to these two parameters. A project funded by the EC to examine the usefulness of Geostatistics will start in May and is in cooperation with IMR Bergen and Ecole de Mines Fontainbeau.

A second EC project investigating aspects of target strength and near seabed detection lead by IMR Bergen and in cooperation with IMB Crete has been awarded but a starting date has yet to be announced.

British Antarctic Survey

Acoustic studies were carried out on the RRS *James Clark Ross* in January, February and March 1994 using Simrad EK500 split beam 120 kHz and 38 kHz and single beam 200 kHz hull-mounted sounders, logging integrated data to a PC, and raw data over a LAN to a Sun work station. Surveys began with large scale transects between Stanley, Falkland Islands, S Georgia, and the South Shetland Islands and back to Stanley. In between these long transects, mesoscale surveys were undertaken close to the South Orkneys and S Georgia to investigate several components of the pelagic food web including krill. The sounder was calibrated at S Georgia. Krill were encountered in the South Orkney region, but were very infrequent elsewhere.

In February acoustics, net sampling and predator observations continued north of S Georgia (around 50°S), north of the Antarctic Polar Frontal Zone. The objective was to study a different part of the pelagic system where the grey headed albatrosses are the top predators and squid the main prey. The site was selected by tagging albatrosses and observing their foraging trips. Small numbers of squid were caught, but too few to attribute specific acoustic signatures to them.

The *James Clark Ross* returned to the S Georgia shelf just after the middle of February to begin a two ship survey of krill with the South African research vessel RS *Africana*. Shortly before the start of this work the *James Clark Ross* had to leave the area to go to the assistance of another vessel, but a mesoscale survey was completed by *Africana*. The findings were that numbers of krill were generally exceptionally low throughout the region.

The Falkland Islands' fisheries protection vessel *Cordella* was used in January for a bottom-trawl survey of fish on the S Georgia/Shag Rocks shelf. A Simrad EK400 sounder was installed for the survey and a chart record of the track covered during the survey was obtained at 38 kHz. This survey confirmed the dearth of krill recorded by the other ships.

A.10 USA

Fisheries Acoustic Science and Technology Issues

Alaska Fisheries Science Center
Contact: Jim Traynor, Neal Williamson

Alaska Fisheries Science Center (AFSC) in Seattle has continued research on pollock (*Theragra chalcogramma*) and whiting (*Merluccius productus*) in the northeast Pacific Ocean. During 1988 and 1989 and again in 1991-1994, acoustic survey of the spawning population of pollock have been carried out in January-March in the deep water portion (>1,000 m) of the Bering Sea, and, in 1989, 1991-1994 including shelf waters of the eastern Bering Sea. In 1993, in a multi-national effort, the survey area was expanded to include the western Bering Sea and the Aleutian Basin. Annual surveys of the Gulf of Alaska spawning stock in the Gulf of Alaska have continued through 1993. Target strength studies of fish using the split beam technique continue and standard sphere calibration is the primary calibration technique. Cooperative surveys of pollock in the Bering Sea with the Japanese Fisheries Agency have continued.

Southeast Fisheries Center
Contact: Chris Gledhill

The Southeast Fisheries Center continued assessment and experimental work using a 38 and 120 kHz dual beam system. Activity in 1993 included: 1) a survey of reef fish; and 2) a fall fisheries acoustic/trawl survey for small pelagics in the western and north-central Gulf of Mexico. Additionally, a pilot survey to estimate the abundance of spawning Atlantic menhaden was conducted off the southeastern coast of the United States in conjunction with an egg/larval survey in December 1993. The data from the menhaden cruise are not yet analysed.

Naval Research Laboratory
Contact: Redwood Nero, Richard Love

The Ocean Acoustics Branch of the Naval Research Laboratory is investigating ways to improve Navy predictions of scattering from dispersed and aggregated fish. A major emphasis is at swimbladder resonance, frequencies of 0.5 to 10 kHz. Routine measurements are made using a near-surface explosive sound source and a downwardly directional receiver. Ongoing studies are:

1. A model aimed at using satellite remote sensing and historical databases of fisheries information to predict the distribution and level of low frequency scattering from whiting, rockfish, and near surface pelagic species on the US west coast. The effort includes developing theoretical acoustic models of low frequency resonance scattering from fish schools. Tests are planned for summer 1995 in conjunction with the Alaska Fisheries Science Center.

2. A sea surface scattering study in the Gulf of Alaska in March 1992 using a horizontal line array also detected near surface salmon. Measurements gave their swimbladder resonance spectra and spatial distribution pattern over several km^2 of ocean surface. Analyses are underway.

3. An acoustic survey of mesopelagic fish in the Arabian Sea is planned for spring 1994.

Tracor Applied Sciences and University of Southern California

In December 1993, the BITS mooring, which uses high frequency acoustical sensors to measure zooplankton biomass, was retrieved from the shelf slope break south of Los Angeles, CA, where it has been operating since April 1993. This mooring uses VHF telemetry to report volume scattering strength measurements from seven discrete depths to a shore based computer, from which the data are accessed by several cooperating investigators at Tracor Applied Sciences (Holliday and Greenlaw) and the University of Southern California (Pieper and Dawson). Temperature and light measurements are reported on half hour intervals at each depth instrumented with acoustical sensors. Data from several weather sensors are also included from instruments located on the surface mooring. We were unable to detect any substantial impact on the acoustical data from the moderate fouling incurred during the deployment. It is anticipated that the BITS mooring will be deployed again in the same location in the late winter or early spring of 1994.

Funding has been approved for a second BITS mooring to be used during the GLOBEC field programme on Georges Bank. The initial deployment now scheduled for mid 1995. This system will include sensors for up to six or more discrete depths, each operating at as many as eight frequencies.

Plans are advancing rapidly for deployment of two eight frequency zooplankton sensors on a JGOFS mooring in the northern Indian Ocean. These sensors will be used to examine temporal variability in zooplankton biomass and size structure as modulated by monsoon related physical forcing. Initial deployment of these sensors is planned for October 1995. Two six month, back to back deployments are anticipated to achieve a full annual cycle. Research is also in progress at Tracor to develop and build a four frequency acoustical zooplankton sensor for use on a Seasoar to yo platform to be used during JGOFS cruises in the Indian Ocean. The most challenging part of this work is the design of transducers in the multiple megahertz operating range which will survey numerous pressure cycles to depths of 300-500 m or deeper, while maintaining their calibrations.

Southwest Fisheries Science Center
Contact: Roger P Hewitt, David A Demer

Acoustic technology is used in a study of predator/prey interactions in the Antarctic marine ecosystem. The predators are chinstrap penguins and southern fur seals breeding in the vicinity of Elephant Island, off the northern tip of the Antarctic Peninsula; their principal prey is Antarctic krill (*Euphausia superba*). Aspects of the foraging ecology and reproductive success of seals and penguins are studied at selected breeding sites. Complementary shipboard observations are used to describe within and between season variations in the distributions of krill, zooplankton, phytoplankton and water types. during the 1993 field season, a Simrad EK500 echosounder was used by the Antarctic Ecosystem Research Group at NMFS's Southwest Fisheries Science Center to map the distribution of krill and to estimate its abundance. A 120 kHz split-beam transducer and a 200 kHz single beam transducer were deployed on a dead-weight towed body from the RV *Surveyor*. The acoustic system was also used to collect target strength measurements on both individual and aggregated krill, as well as to direct simultaneous high-resolution

net sampling. Following the field work, a series of calibration experiments were conducted using the anechoic tanks at the Acoustics Laboratory, Naval Post-Graduate School in Monterey, California. In support of another field project that addressed winter foraging strategies of seabirds in the vicinity of S Georgia, a Simrad EK500 echosounder was used, with 38, 120 and 200 kHz transducers mounted in the hull of the RV *NB Palmer*, to map the distribution of prey. In early 1994, acoustic surveys for krill were again conducted in the vicinity of Elephant Island using 120 and 200 kHz transducers mounted in the hull of the RV *Surveyor* and a side-looking 120 kHz transducer mounted in a towed body. Additional experiments addressed fine-scale structure of backscattering across an oceanographic front, horizontal and vertical movements of krill aggregations, and acoustic classification of zooplankton taxa.

Cornell University
Contact: Chuck Greene

Overall research interests are centred on the application of acoustic techniques to fundamental problems in biological oceanography. In applying these techniques, an emphasis is placed on improving oceanographic instrumentation as well as the information technology necessary for managing, analysing, visualising and disseminating primary data and higher order data products. Recent research projects have included studies of trophic interactions involving krill in the Gulf of Maine and Southern Ocean, as well as studies of physical-biological interactions associated with abrupt topography in the oceanic Pacific.

Atlantic Oceanographic and Meterological Laboratory
Contact: Peter Ortner

A series of field tests of a modular high-frequency "search-light SONAR" were made in the northern Gulf of Mexico and off the Florida Keys. Acoustic backscatter returns were closely correlated with zooplankton abundance measured by the *in situ* camera system. The final design has incorporated two sets of three independent frequencies each. When software refinements are complete it will generate real-time size-frequency distributions of plankton populations. The system can be mounted on a MOCNESS or other traditional sampler to yield directly comparable data. Gulf of Mexico data generated by the system were used in a paper presented at the Estuarine Research Foundation meeting last fall.

The sonar was also deployed as part of an integrated biophysical sampler towed at 8 kts for a two day survey off the Florida Keys. It yielded real-time maps of all sensor information CTD, fluorometer, transmissometer and acoustic backscatter at six frequencies ranging from 256 kHz to 3.0 MHz. Surprisingly an extended body of low salinity water was found whose biological and physical characteristics confirmed that the source was the Mississippi River. The data are the basis of a paper about to be submitted to *Science* describing the observations and relating them to an unusual wind regime in the Northern Gulf, an extreme northern position of the Loop Current and unusually high summer discharge from the Mississippi in the wake of the widely-reported late spring flooding in the midwest. Later in the year it was used to sample larval fish predators and prey in the south Atlantic Bight as part of SABRE.

South Carolina Marine Resources Research Institute
Contact: Charlie Barans

A Tracor Acoustic Profiling System (TAPS) within a local estuarine inlet provided high resolution, size specific information on plankton distribution in real-time. The four frequency system is used to integrate plankton and physical data over long time periods to investigate ingress of larval shrimp and blue crab megalope. The TAPS unit is being deployed in collaboration with V Holliday and C Greenlaw of Tracor Sciences and Systems.

An old military side scan sonar system (1.5 MHz), with resolution of several centimetres, is being renovated by Deep Sea Systems International Inc and may be demonstrated in fisheries assessment applications during 1994. Meanwhile, offshore groundfish population assessment continues to be based on traps with attached still cameras, while developing an independent/inexpensive video "point count" system.

Woods Hole Oceanographic Institute
Contact: Peter Wiebe and Tim Stanton

Scientists at the Woods Hole Oceanographic Laboratory have been working on the frequency dependence of acoustic backscattering from zooplankton and micronekton and the development of appropriate scattering models. Laboratory measurements have been made of a decapod shrimp species, a copepod species and various machined objects using a laboratory sonar (50 kHz to 5 MHz) under development by Tim Stanton. The data are used to develop and test scattering models of finite length elongated bodies with realistic boundary conditions. The results show that the target strength of elongated zooplankton can be predicted very well using a bent cylinder model. Later this year, they plan to use the equipment to make measurements at sea of freshly captured specimens. Work continues on obtaining acoustic measurements with BIOSPAR (Bioacoustic Sensing Platform and Relay) and other high resolution sensors for use on towed systems such as MOCNESS.

Northeast Fisheries Science Center
Contact: Mark Berman or John Green

The Plankton Ecology Investigation Group of the Narragansett Laboratory has undertaken a study of the small scale patchiness of the zooplankton on Georges Bank in relation to water column structure. This work is designed to better assess the prey field of larval and juvenile fish, and is supported by NOAA's office of Climate and Global Change and CLOBEC. The plankton distribution is being measured by the Tracor Acoustic Profiling System (TAPS), which measures volume scattering strength at 256, 420, 1,100 and 3,000 kHz. Differences in volume backscattering at the four frequencies are used to infer the number and sizes plankters as small as 0.4 mm with a spatial resolution of about 1 m.

Preliminary results show that in a stratified area of Georges Bank in May 1993, plankton biomass was concentrated into patches having maximum concentrations of between 300 and 500 cc/m^3. These patches were usually no more than a metre or two thick, and located at the top of the thermocline. Their length ranged from less than 3 m to about 150 m. Plankton concentration between patches was very low (<100 cc/m^3). Pump

samples show that during this period *Psuedocalanus minutus* was the most common copepod in the sample area.

A.11 NORWAY

Institute of Marine Research

Surveys

The acoustic systems EK500 and BI500 have been used on six research vessels for about 1,500 vessel survey days in 1993.

Development Projects/Activities

Sonar Project
Contact Persons: O A Misund, A Aglen and J Dalen

The sonar Simrad SA950 was installed on *G O Sars* in July 1992 and has been tested on several surveys. Interface towards an HP720 for downloading graphical information, and some software for this have been developed. The same sonar is now mounted on the new research vessel *Dr Fridjof Nansen*. The sonars will be used in a project aiming for biomass estimation of fish schools, and to study their behaviour and migration pattern.

Deep Towed Body Project Phases 1 and 2
Contact Persons: J Dalen, IMR and H Bodholt, Simrad

Further development on the deep towed body concept continued in 1993, but was delayed by financial reasons. Most of the work in connection with bringing parts of the EK500 into a pressure resistant nose of the body is finished, as well as the communication part to the vessel over an optical/electrical cable. The main sea test of the full system will be made in April/May 1994.

BEI/BI500, The Bergen Echo Integrator
Contact Persons: R Korneliussen, Egil Ona, IMR and H Naes, Simrad

The mapping/charting module for BI500 is now being tested. A system for manual data input has been implemented, as well as a system for scrutinising multiple frequencies. The last year has also been used to ensure a high stability on the system, needed for the extensive survey work conducted by IMR. About 650 GB of scrutinised raw data was stored from the system in 1993.

Seismics and Fish

Several projects concerning seismic activity and fish were run in 1992, and have been reported in 1993. These are:

a) Two projects to determine the effect of air gun sounds on eggs and larvae, one experimental and one combined field and modelling project
Contact Person: J Dalen

b) One project to determine the effect of seismic investigations with air guns on catch rates success and fishing availability.
Contact Persons: A Engås, E Ona, A V Soldal and S Løkkeborg

c) One project to determine harmful effects on fish from explosives.
Contact Person: S Olsen

In Situ TS Measurements
Contact Persons: E Ona and I Huse, IMR

Measurements of target strength of herring have been conducted in 1993, with the goal to measure the average target strength inside the dense layers in the herring hibernating areas, where also the spawning stock survey is conducted. The measurements were made from a rig, holding split beam transducers, scanning sonar and stereo single frame camera. Supporting data from net penned herring and purse seining/acoustic comparisons are also collected in 1993. The project aim is also to establish routine procedures for *in situ* TS measurements in general.

Survey Design
Contact Person: K G Foote, IMR

Detailed mapping of the herring distribution during its hibernation phase in Ofotfjorden was repeated in 1993, using two research vessels. Geostatistics are used to compute stock coverage confidence intervals. Multiple frequencies 18, 38, 120 and 200 kHz have been analysed for the same surveys.

Protruding Transducers
Contact Person: E Ona and H P Knudsen, IMR

Three of our research vessels have been equipped with instrument keels, protruding to any length 2.5 to 4 metres below the vessel hull in order to improve the acoustic data in bad weather. Two to four transducers have been mounted in the keels and systematic trials have been made with respect to both vessel stability and transducer aeration.

APPENDIX B: OUTLINE OF REPORT FROM THE STUDY GROUP ON TARGET STRENGTH METHODOLOGY

1. Introduction

2. Definitions and terms

3. Single Beam echo sounders
   - 3.1 Principle
   - 3.2 Calibration
     - 3.2.1 On axis sensitivity
     - 3.2.2 Acoustic beam
   - 3.3 Removal of beam effect
   - 3.4 Effect of noise and thresholds involved
   - 3.5 Example in detail

4. Dual Beam echo sounders
   - 4.1 Principle
   - 4.2 Calibration
     - 4.2.1 On axis sensitivity
     - 4.2.2 Acoustic beam
   - 4.3 Removal of beam effect
   - 4.4 Effect of noise and thresholds involved
   - 4.5 Example in detail

5. Split Beam echo sounders
   - 5.1 Principle
   - 5.2 Calibration
     - 5.2.1 On axis sensitivity
     - 5.2.2 Acoustic beam
   - 5.3 Removal of beam effect
   - 5.4 Effect of noise and thresholds involved
   - 5.5 Example in detail

6. Biological sampling
   - 6.1 Recommended biological measurements
   - 6.2 Discussion of sampling errors

7. Brief summary of other methods, integration and catch controlled experiments and analytical methods

   Specialised measurements
   Tracking
   Multifrequency methods
   Deep water towed vehicles/transducers

8. Single fish recognition criteria.
   - 8.1 General principles
   - 8.2 Consequences of using the above.
   - 8.3 Problems of multiple fish echoes being identified as a single target.

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