Fish Capture Committee **ICES CM 1997/B:5**

REPORT OF THE

WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY (FAST)

Hamburg, Germany
18–19 April 1997

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International Council for the Exploration of the Sea

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Table of Contents

1. TERMS OF REFERENCE

In accordance with C. Res. 1996/2:16 the Working Group on Fisheries Acoustics Science and Technology (Chairman: Dr. F. Gerlotto, France) met in Hamburg, Germany, 17-19 April 1997 to:

a) review the progress of the Study Group on Echo Trace Classification;
b) assess the impact of acoustic scattering from plankton on acoustic survey methods for fish stocks;
c) describe and assess methods for separating the acoustic scattering from plankton and fish;
d) discuss problems and uncertainties in vertical echo-sounder performance, taking account of information to be collated by Dr. D. Demer (USA) prior to the meeting.

2. MEETING AGENDA AND APPOINTMENT OF RAPPORTEUR

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

1. Session on uncertainties in vertical echosounding;

2. Session on plankton and acoustics;

3. Session discussing the report from the echo trace classification study group;

4. Session on general topics and poster presentations;

5. Recommendations.

3. SESSION ON UNCERTAINTIES IN VERTICAL ECHOSOUNDING

3.1 Scalabrin, C. Shoal acoustic signal simulation

The so-called random walk model describes a scattered field as a coherent summation of individual contributions from discrete point scatterers; this model is useful to describe the reverberation response of targets inside a fish shoal. When the phases are uniformly distributed and the number of scatterers is large and fixed, the probability distribution of the signal envelope amplitude can be well approximated by a Rayleigh distribution and the intensity distribution can be approximated by an exponential distribution. This gaussian process is an essential requirement for the validity of the echo integration technique used in biomass assessment. However, examination of experimental data of fish shoal signals showed that the underlying assumptions of the gaussian model do not reflect the reality of the physical process forming the fish school echoes.

A simulation model of fish shoal backscattered signals was developed in order to explore which parameters could be responsible for this departure from normality. A major cause of echo fluctuations is expected to be the ships movement. This phenomenon is modelled by a single parameter, the minimal geometrical interception rate MGIR (coefficient between 0 and 1), which is the ratio of the intercepted shoal width to beam width. The intensity distributions were then characterised according to a 38 kHz signal, 1 ms pulse length and 8° beam width. The fish were modelled as clupeiods from 12 to 24 cm.

The results indicate that the Rayleigh distribution is not sufficient for describing the fish shoal echo statistics. A good alternative might be the K or gamma distribution; this is explained by fluctuating the number of individual point targets at a given time and also by the fluctuating character of the individual TS. The dependence of signal statistics upon purely geometrical features of shoal shape and beam intersection leads to reservations about the potential for fish species identification using standard monobeam echosounders.

3.2 Diner, N. Shoal acoustic image simulation.

This presentation described software developed to simulate vertical echosounder images in order to explain the variability in the results of automatic classification of echo traces using shoal descriptors extracted by MOVIES-B software. The simulation software allows all the parameters for image construction to be defined: species specific TS and length weight; vertical echosounder settings; display settings; bottom characteristics; and up to 10 different shoals with various shoal descriptors. When the parameters are defined it is possible to obtain and image of the real configuration, a file of shoal descriptors and a simulated image of the shoal and bottom echoes which takes into account the directivity of the echosounder. It is therefore possible to compare, for the same descriptors the numerical difference between the real shoals and the corresponding acoustic shoal images obtained after the deforming filter which is the echosounder.

The software is still under development , but is nevertheless a useful tool in interpreting echo trace images and the accuracy of the descriptors which can be extracted for classification purposes. The display threshold seems an important parameter which has a direct effect on the actual detection angle. When the required accuracy for shoal descriptors is very high, it is better to use a threshold not too different form the reverberation index of the shoal. In this case the accuracy will be increased for shoal geometric descriptors and shoal reverberation index, but the accuracy of the shoal total reverberation energy will be decreased. When working on biomass assessment, more useful information is obtained when applying a low display threshold where the total reverberation energy can be recovered at the expense of other shoal descriptors. One should therefore consider setting a threshold according to the objective.

Also mentioned in this presentation was the problem of false bottom echoes formed from multiple bottom echoes from ping at time t recorded during the t+1 ping sequence. These can be similar to a plankton layer, or in certain bottom conditions to a fish school. It occurs when the bottom reverberation index is high and the display threshold low, particularly at high ping rates in moderately deep water.

3.3 Goss, C., Brierley, A. and Watkins, J. L. Calibration of hull mounted transducers.

The calibration of hull mounted transducers at the British Antarctic Survey (BAS) has a history of instability. An experiment was set up to examine the fluctuations in calibration results of three frequencies of echosounder, 38, 120 and 200 kHz. This was carried out throughout the night during a cruise in South Georgia in January of this year. The temperature and salinity of the water was measured with CTD casts. Variations in the 200 kHz calibration could not be solely attributed to changes in salinity, temperature or sound speed, but were associated with an apparent change in range. The apparent range recorded by the 120 kHz sounder was smaller and much more consistent than that of the 200 kHz sounder.

The changes in gain settings required to calibrate the 200 kHz sounder correctly were erratic and progressive throughout the observation period. No explanation is evident for the fluctuations observed, however, it is thought that a change of temperature in the transducer space may have an effect. The transducer is usually exposed to cold moving water whilst the ship is underway, but once stopped there is potential for warming under the influence of the ships engines. This will be investigated by inserting a temperature probe in the transducer space.

Discussion: Pall Reynisson (Iceland) has had similar experiences with his 200 kHz transducer; fluctuations in gain have been of the order of 2 dB. The question of suspension media for sphere calibration was raised: nylon line tends to absorb water and therefore may have a different length to its dry state; and the use of "Sea Dacron" is recommended for the main lines as it is less elastic than fishing line, although fishing line should be used for the final metre as it is less reflective.

3.4 Maclennan, D. and Simmonds, E. J. Fish detection near the seabed.

We consider the problem of discriminating echoes from fish against the strong reflection from the seabed. A tower frame has been designed to hold a cage containing an aggregation of fish in a defined position relative to the seabed. The tower is 10 m high and 5 m across the base with the transducer (38 kHz) attached to the top and the fish cage (2 m x 1 m high) at the bottom so that the lower netting panel is aligned with the base of the tower. The geometry of the tower is aligned so that the lower metalwork is in the second null of the transducer beam pattern, to give minimal interfering echoes. Experiments using the tower frame have been conducted from a raft at the Loch Duich field station on the West coast of Scotland. The tower was placed on the seabed with 1-2 m slack wire so that the tide slowly raised and lowered the assembly in the near-bottom zone. The measured acoustic properties of the tower were found to be in general agreement with the theoretical predictions. The echo-integral of the bottom ring of the tower was less than one third that of the empty fish cage and about 4% that from 1 kg of gadoid fish in the cage.

A Simrad EK500 scientific echosounder was used to collect data on the raft. Signal telegrams from the echosounder are transmitted to a Sun workstation and recorded on DAT magnetic tape cassettes for subsequent processing. The transmitted data include the echo intensity and the phase angles in two planes detected by the split-beam transducer, at 0.1 m range intervals. Six experiments have been conducted with different densities, species and size compositions of fish, however all the fish were gadoids which have similar acoustic properties (cod, haddock, whiting and saithe). In each case the experiment continued over at least two tidal cycles while the cage moved from the seabed to a height of 2-3 m and back again.

Preliminary results are presented on the possible use of split-beam phase measurements to improve the discrimination of fish targets close to the seabed. It is suggested that the ping-to-ping variance of the phase angle is substantially less for the seabed signal compared to fish echoes.

Discussion: The relative changes in the bottom and fish school echoes may reflect angular change as the cage is lifted from the sloped bottom. A point was made about the conservative nature of the EK500 bottom definition algorithm - typically it works with a 0.5 to 1 m safety margin of its actual evaluation.

3.5 Knudsen, H. Long term stability of echosounder performances

This paper summarised the calibration exercises carried out by the Institute of Marine Research since 1989. The principal factors leading to a successful calibration were identified as: the sill of personnel; a calm site; good weather; sufficient water depth; proper equipment; and measurement of the temperature, salinity and sound speed profile on site. The transducers have shown an acceptable long term stability, with the exception of the 120 kHz which has varied by up to 1 dB. Generally the results are more influenced by wind, and this can be reduced by increasing the transducer depth (e.g. in a dropped keel). The incorporation of meteorological data into calibration reports is considered essential to the understanding of system performance.

3.6 Reynisson, P. Monitoring of equivalent beam angles of hull mounted transducers in the period 1983-1995.

A method for measuring the directivity of hull-mounted transducers has been in use at the Marine Research Institute for over a decade. In this paper the results from measurements of the equivalent beam angle (ψ) on 18 individual transducers carried out in the period 1983-1995 are summarised and compared to values supplied by the manufacturer. Important to the method is the need for detailed knowledge of the geometrical arrangement of the suspension of the sphere. The repeatability of the method was very good (average of 6% observed difference between individual measurements). Repeated measurements of a particular transducer over a time period of several years indicate that the performance of the transducers is inherently stable with time (to within 0.2 dB). Values of ψ obtained from measurements after hull mounting have generally been lower than the values supplied by the manufacturer (up to 86 %) and in some instances significant differences in performance of transducers of the same type have been observed. However, the most recent line of transducers manufactured by Simrad are a notable exception where the difference in ψ measured before and after hull mounting is in all cases, except one, less than 5 %.

3.7 Demer, D. Report on problems and uncertainties in vertical echo sounding

This presentation was a compilation of submissions based on a request by the WGFAST to collate known problems and uncertainties in vertical echosounder performance. These problems were divided into four groups according to the calculation of fish density in the equation:

$$\hat{\rho} = \frac{C.E}{\psi.\sigma}$$

where:

$\hat{\rho}$ = Fish density

C = Calibration constant. This may be affected by:

- Temperature
- Temperature stability
- Pulse length
- Standard sphere
- TVG

E = Echo energy. This may be affected by:

- Species delineation
- Noise
- Non linearity
- Bubble attenuation
- Non stationarity
- TVG

ψ = Equivalent beam angle. This may be affected by:

- Ship motion
- Transducer mounting
- Threshold
- Sound speed

σ = Backscattering strength. This may be affected by:

- Fish size
- Fish orientation
- Morphology
- Frequency dependence

The problems may be manifested through physical limitations of the techniques themselves, deployment considerations, or through software and hardware bugs. A summary of the main contributions is given in Table 1. Details of each problem are best obtained from the report available from D. Demer, from the references given in Table 1, or via direct communication with contributors (see Appendix II for contact information).

3.8 Discussion

The group acknowledged that the current self-evaluation of acoustic techniques was a good thing and should be continued. The exact forum for the dissemination of information was a point of debate. It was concluded that rather than continue with a mass collection of observations, a questionnaire be distributed to ascertain what are the most important problems so that these can be focused on and then go some way to being solved. This questionnaire will be compiled by John Simmonds, Aberdeen, and will include an evaluation of the magnitude of the problem (either quantitative or qualitative), its direction (i.e. whether it leads to over or underestimates) and some indication as to the feasibility of a solution. The categorisation put forward by D. Demer was accepted as a reasonable framework for the definition of problems; the questionnaire will follow a similar breakdown. The questionnaire will be distributed to all members and the results will be presented at the next WGFAST. The point was made that most of the problems outlined to date tend to imply that acoustic surveys should actually underestimate stock size (avoidance, TS aspect, signal loss,

Table 1a. Contributions to known problems and uncertainties in vertical echo-sounder performance (summarised from D. Demers report). Sol^{n}: solution to problem is available (🗐); or as yet unknown (🖮); or not indicated (?). See references or report for details.

Contributor(s)	Brief description of the problem	Sol^{n}	References
N. Diner, IFREMER, France	Uncertainty in fish school classification • Beam pattern introduces ambiguities in aggregation dimensions, volume backscattering strength and school size and shape measurements.	🗐	Scalabrin & Masse (1993)
	• Side lobes can detect bottom echoes difficult to discern from fish layers	🖮	
	• Bottom echoes may result in ghost schools / layers	🗐	
	Cavitation of Simrad ES120-7 transducer • At normal power (1 kW) a 120 kHz transducer signal suffered cavitation - remedied by slight reduction in emitted power (<10%)	🗐	
	Variance of TS measurements versus pulse length and off-axis angle • At 120 kHz changes in pulse length from 0.3 to 1 ms decreased measured TS from -36.0 to -39.0 dB	🖮	
P.Fernandes & J.Simmonds, Marine Lab, UK	Receiver delay and TVG start time delay • Receiver delay not incorporated in EK500 prior to version 5.2. Causes underestimate of range to target. Depending on distance calibrated to distance detected causes up to 3% biomass underestimate.	🗐	Fernandes & Simmonds (1996)
	• TVG start time delay also not included prior to version 5.22. Depending on distance calibrated to distance detected can cause up to an additional 11% underestimate of biomass.	🗐	
	• Both now incorporated in new EK500 software (5.22). Correction equations are given in reference.		
C. Goss, J. Watkins, A. Murray, A. Brierley & D. Socha BAS, UK	Summary of software bugs in EK500 • Averaging layer bug. At slow ping rates S_A values for data collected by transceivers 2 and 3 may only be 20 % of the true values, due to a miscalculation of the average layer thickness. This can be corrected for and has been eliminated from EK500 version 5.0.	🗐	
	• Ethernet bug. When multiple sublayers are set then output data logged through ethernet put are wrongly forced to fit the number of sublayers in the final main layer. Fixed as of EK500 version 4.0	🗐	
	• Serial output bug. S_A data are only saved with an accuracy of one significant figure - important for low TS targets such as zooplankton and krill. Fixed as of EK500 version 5.0	🗐	

Table 1b. Contributions to known problems and uncertainties in vertical echo-sounder performance (summarised from D. Demers report). Sol^n: solution to problem is available (🗐); or as yet unknown (🖮); or not indicated (?). See references or report for details.

Contributor(s)	Brief description of the problem	Sol^n	References
BAS, UK	Summary of software bugs in EK500 (continued) • Low signal strength on 38 kHz. Possibly caused by air bubbles under ships hull. Proposed solution to use towed bodies.	🗐	
	• Changes in calibration settings. Calibration values for 38 and 120 kHz have varied by up to 5 dB.	🖮	
R. Kloser, CSIRO, Australia	Deep water echo sounding • Vessel mounted transducer significantly underestimates the volume reverberation of deep water fish - significant improvement obtained by using a deep towed body	🗐	Kloser (1996)
	• Apparent target strength of copper sphere decreased with increasing depth	🖮	
P. Reynisson, Marine Research Institute, Iceland	Extra sample in the Simrad EK500 • Extra sample pulse was identified during calibration over depths from 15 to 85 m which effects the S_A values at equi-distant range intervals. The problem is most evident on the BI500, probably because the data are pixel based.	🖮	
	• TVG function also affected by extra sample, remedied to large extent by incorporation of TVG start time delay in EK500 version 5.22 (see above).	🗐	
N. Williamson, J. Traynor, D, Twohig, & C.Wilson, Alaska Fisheries Science Center, USA	Summary of software and hardware bugs in EK500 • Speed telegram from Northstar 941 navigational device locks setting vessel speed to zero and stopping echo-integration. On rare occasions vessel speeds of 199 kts were observed)	🖮	
	• Single sheet printing quality supported by version 5.20 is very poor.	🖮	
	• TS bar chart in TS detection menu does not always agree with histogram values printed on the echogram.	🖮	
	• 120 kHz operating range restricted due to noise, limited use for euphausiid studies	🖮	
	• 120 kHz calibration very unstable. 2.1 dB difference over 2 years	🖮	

Table 1c. Contributions to known problems and uncertainties in vertical echo-sounder performance (summarised from D. Demers report). Sol^n: solution to problem is available (🗐); or as yet unknown (🖮); or not indicated (?). See references or report for details.

Contributor(s)	Brief description of the problem	Sol^n	References
D.Demer (USA) & M. Soule (South Africa)	Calibration at 120 kHz • Controlled tank calibrations using 3 spheres measuring TS, vector admittance vs water temperature. • Estimate TS calibration accurate to ±0.2 dB; integrated intensities accurate to ±0.1 dB		
J. Kirsch, Prince William Sound Science Center, USA	Summary of software bugs in Biosonics ESP Dual-beam Acquisition Software • Software crashes if CPU is overloaded (e.g. with deep ranges, low thresholds and auto bottom)	?	
	• Real time TS plots and exported voltages not compensated	?	
	Summary of software bugs in Biosonics ESP Echo-Square Integration Acquisition Software • Real time density plots and exported voltages not compensated	?	
	• NMEA 0183B is the only GPS format that can be read	?	
	ESP ESP_View Conversion Software • During conversion the first significant decimal digit is dropped if it is zero	🗐	
	171 Tape Recorder Interface and Recorder • Sync gain and signal gain are combined, so establishing correct signal gain forces the sync below trigger threshold or the bottom above trigger threshold	?	
	• Mechanical parts accumulate sooty "crud" leading to failure in tape recognition	?	
	DT Acquisition software • No Sync In - so no multiplexing with another system	🖮	
	• Output sync is less than 4 volts - prevents other hardware slaving	🖮	
	DT Analysis software • Slow: processing rate is only about twice as fast as collection rate	🖮	

TVG start time delay, non-linearity), whereas assessment scientists generally believe that acoustic surveys overestimate stock size. The group should also bare in mind the fact that improvements often bring about discontinuity in time series datasets such that assessment scientists should be consulted on this matter.

A few specific points were made. One regarded the use of high frequencies which seem to be the subject of many calibration problems: although unacceptable, the current sphere calibration technique may be as precise as is possible such that another method may be more appropriate. This may be confounded by the influence of temperature which despite D. Demer's contribution remains a contentious issue - particularly with regard to transducer temperature changes over time.

4. SESSION ON PLANKTON AND ACOUSTICS

4.1 A. Lebourges and Marchal, E. Use of mean volume backscattering strength to survey the spatial variation of the micronekton biomass in the equatorial current of the Atlantic Ocean.

In the frame of a programme called PICOLO (Production Induite en zone de Convergence par des Ondes Longues Oceaniques = Production Induced by Oceanic Long Waves in a Convergence Area), the survey of the micronekton is a major component, as it is the main part of the tuna diet in the area under study. During a replicate meridian transect crossing the main equatorial current system in the Atlantic Ocean (along 15° W, from 1° S to 4° N) we observed spatial and temporal variations of the Mean Volume Backscattering Strength in the 500 meters upper layer. An attempt is made to relate those variations to the behaviour of the Micronekton biomass.

Acoustical measurements are made jointly with environmental observations (currents, nutrients, primary production), zooplankton sampling, and trawlings on micronekton. Physically, the area can be divided in three areas : divergence area (1° S - 1° N), convergence area (1° N - 3° N), typical tropical situation (3° N - 4° N). Zooplankton and micronekton biomasses appear to decrease from 1° S to 4° N, with a rather high step between South and North of 1° N. *Vinciguerria nimbaria*, main prey of the small tunas, are found with high densities in the area 1° N - 3° N, where they show an 'aberrant' behaviour already observed during previous surveys : forming dense small schools during the day, they stay at the same depths than during the night, when they reorganise to form layers with dense 'swarms'.

Southerly (South of Equator) we find also *Vinciguerria*, but 'normal' ones, migrating from 400 - 500 m depth during the day to close to the surface during the night. We can guess that in the divergence area, the lack of an homogeneous mixed-layer and of a strong thermocline, precludes the concentration of living material at certain levels is not suitable for fish in schools seeking for food. The situation is the contrary in the convergence area.

Discussion: A comment was made regarding similar observations in the Pacific where micronektonic aggregations seem to influence on tuna distributions.

4.2 L. Gordon. FISHMASS: ADCP technology adapted to split beam echo sounding provides significant new capabilities

This is a progress report about the first phase of an NSF-funded research project that includes participants from the US (Steve Brandt), Canada (Len Zedel) and Norway (Ken Foote). The objective is to adapt elements of ADCP technology into split-beam echo sounding. Opportunities for improvement come from wide bandwidths (50% bandwidth at 300 kHz), incorporation of velocity (Doppler) data and addition of autonomous operation (battery and recording capacity to allow operation for up to a year).

Because wide bandwidth signals hold more information than narrowband signals, wide bandwidth can reduce the uncertainty of single-target echoes from 3-6 dB down to a fraction of a dB. For the same reason, wide bandwidth enables better differentiation of single-target and multiple-target echoes, both when targets are separated radially and when they are at the same range but at different angles. We can also process echoes to obtain the echo spectrum (we are planning to extract spectra with about 8 frequency bands). Wide bandwidth will make a significant contribution to target discrimination and perhaps even fish species classification.

Within a split beam we can process velocity several ways. We obtain the radial velocity using normal Doppler processing. This can apply to fish-free echoes, discrete targets and schools of fish. We can obtain transverse velocity of discrete targets, although we fear the uncertainties will be too large to make this result worth much. Both of the first two methods apply to single-ping observations, but we can also use ping-to-ping tracking to obtain single-target velocities. A single Doppler beam can be trained to recognise both discrete targets and schools of fish, although it is less able to differentiate single and multiple fish; it has the same ability to measure radial velocity but is unable to obtain radial velocities.

Velocity data adds the ability to observe fish behaviour. Mean velocities allow observation of migration and flux. Statistical products such as velocity standard deviation enable observation of feeding or predator-avoidance behaviour. Correlations of velocity with, for example, TS may further aid species classification.

Self contained operation puts stress on signal processing within the instrument as well as on data recording. Limited recording capacity means the system cannot record raw data for long deployments but instead must compute and record intermediate or final data products. Data recording must adapt to recording single-target events in addition to the routine, predictable data organised into bins and ensembles - we must develop some strategy to prevent recording from being overwhelmed during short intervals of plentiful fish.

Discussion: There was some debate over the theoretical ability of the instrument to echo integrate due to pulse compression but from observations to date the speaker believed that this should not be a problem. Reservations were also expressed about the calibration of the equipment.

4.3 A. Brierley, Ward, P., Watkins, J. L. & Goss, C. Acoustic discrimination of Southern Ocean zooplankton

Acoustic surveys in the vicinity of the sub-Antarctic island of South Georgia revealed the existence of a number of horizontally extensive yet vertically discrete scattering layers in the upper 250 m of the water column. These layers were fished with a Longhurst-Hardy plankton recorder (LHPR) and a multiple-opening 8 m^2 rectangular mid-water trawl (RMT8).

Analysis of catches suggested that each scattering layer was composed predominantly of a single species of either the euphausiids *Euphausia frigida* or *Thysanoessa macrura*, the hyperiid amphipod *Themisto gaudichaudii*, or the eucalaniid copepod *Rhincalanus gigas*.

Instrumentation on the nets allowed their trajectories to be reconstructed precisely, and thus catch data to be related directly to the corresponding acoustic signals. Discriminant function analysis of differences between mean volume backscattering strength at 38, 120 and 200 kHz separated echoes originating from each of the dominant scattering layers, and other signals identified as originating from Antarctic krill *Euphausia superba*, with an overall correct classification rate of 77%. We therefore demonstrate that with the use of echo intensity data alone, gathered using hardware commonly employed for fishery acoustics, it is possible to discriminate in situ between several zooplanktonic taxa, taxa which in some instances exhibit similar gross morphological characteristics and have overlapping length-frequency distributions. Acoustic signals from the mysid *Antarctomysis maxima* could additionally be discriminated once information on target distribution was considered, highlighting the value of incorporating multiple descriptors of echo characteristics into signal identification procedures. The ability to discriminate acoustically between zooplankton taxa could usefully be applied to provide improved acoustic estimates of species abundance, and to enhance field studies of zooplankton ecology, distribution and species interactions.

4.4 Discussion

The presentation by A. Brierley was highlighted as an example of what can be done to assist in the discrimination of fish and plankton, and it was pointed out that the work was based on a two frequency model used to separate zooplankton, from euphausiids and fish. Other work in this field is done by D. Sameoto in Canada and some work is carried out in Norway on krill. The group was reminded however, that simply working on multifrequency is usually not good enough as this is based purely on size discrimination. It would be advantageous to combine the technique with some analysis of echo statistics. The prospect of adding velocity information from Doppler measurements was also considered.

5. REPORT FROM THE STUDY GROUP ON ECHO TRACE CLASSIFICATION (EVERSON, I. AND REID, D.G.)

The Study Group met on 15-17 April, 1997. It was chaired by D. Reid and the report prepared by I. Everson. This complete report is published separately. We publish here the background presented in the report.

5.1. *The terms of reference of SGETC were agreed at the meeting of the Fisheries Acoustic Science and Technology WG (WGFAST) in Woods Hole, USA in April 1996 and subsequently approved at the ICES Annual Science Conference in Reykjavik, Iceland in September 1996. These are set out in paragraph 2.19 of the report the 1996 ICES Science Conference. They are to:*

address and document aspects of fish aggregation, distribution and classification including:

i. methods for classifying echo traces,

ii. comparison of the performance of these methods, *iii. the effect of fish behaviour on the precision of classification,*

iv. the scope for integrating existing research programmes.

The Study Group will report to the April 1997 meeting of the WGFAST, and to the Fish Capture Committee at the 1997 Annual Science Conference.

5.2. For many years acoustics has been recognised as a valuable tool for standing stock estimation of a wide variety of harvested fish. The analytical process of estimating standing stock involves, for each survey and species, the condensation of megabytes of data into a single value with an associated variance. Recognising that there was a vast amount of additional information available in the data that could provide valuable insights into the aggregative behaviour, distribution, spatial structure and temporal variability of the target species, several groups have been working on ways of analysing the data and presenting the results in order to provide insights into how the aggregative behaviour and the distributions of the target species are influenced by exploitation, the environment, predators (including fishing boats) and prey. SGETC was set up to address these issues and take the subject of fisheries acoustics to new and exciting areas beyond the initial task of abundance estimation, and to provide managers with more detailed advice on the impact of different stock situations on the surveying, management and exploitation of commercially fishable species.

5.3. Following the discussions within the group it was agreed to recommend that the study group should prepare an ICES Co-Operative Research Report for publication by ICES and a target date for completion of a first draft was set as April 1998.

6. GENERAL TOPICS

6.1 P. Stewart New ICES structures.

The existing administrative structure of ICES is to be modified subject to the recommendations of a consultative committee review carried out in 1995. As of 1 November 1997, the 12 science committees will be reduced to 7 consisting of: oceanography, marine habitat, fisheries resources; resource management; fishing technology; mariculture; Baltic. These new committees will require new members so the group was reminded to confirm their nominations with the ICES delegate.

The format of the Annual Science Conference will change (starting with this years meeting): the conference will run from Tuesday to Saturday, with a committee day on Tuesday and then a mini-symposium of theme sessions from Wednesday to Saturday. Only papers submitted under the topic of the theme sessions will be accepted as ICES papers; others papers may be submitted but only as posters. ACFM and ACME are currently under review to examine how they operate and suggest improvements.

6.2 Ptak, J. and Appenzeller, A. Inter and intra-specific hydroacoustical classification of fish shoals in Lake Constance (Poster).

Descriptional Parameters of fish shoals have been extracted from hydroacoustical data sampled in Lake Constance, Germany, during the years 1994 to 1996 by means of image analysis techniques. The extracted parameters have been used to discriminate a) between shoals of whitefish (*Coregonus lavaretus*) and perch (*Perca fluviatilis*) sampled during the month January to April and b) between shoals of whitefish sampled during the first half of the year (months January and February) and shoals of whitefish sampled during the second half of the year (months July to November) by using linear discriminant analysis. Success rates for interspecific discrimination (whitefish/perch) ranged from 75.2% to 84.7%, while success rates for intraspecific discrimination (whitefish 1st half of the year/whitefish 2nd half of the year) ranged from 80.2% to 95.8%. The higher success rates achieved for intraspecific discrimination may be related to a depth dependent change of the used descriptional parameters.

6.3 Appenzeller, A. Acoustic estimates of fish stock in prealpine lakes; implications for fish management.

Lakes undergoing reoligotrophication after human pollution in earlier decades are prone to major changes in fish stock abundance, fish growth and species diversity. Such tendencies may lead to fish management problems when gill-net mesh sizes have to be altered. Since fish growth is influenced by many factors, such as fishing pressure, fish density and biomass, as well as nutrients, decisions on how to perform adapted fish management are difficult. For such reasons and others, no significant relationship between total phosphorous (TP) and fish standing stock or catch, as proposed by other empirical studies, does exist when time series of lakes are compared that undergo dramatic changes in their trophic status.

In this study acoustic estimates of fish biomass in prealpine lakes in southern Germany were compared with their total phosphorous concentrations and their history of trophic change. As reference for these comparisons, I chose the empirical relationship of phosphorous and fish biomass published by Hanson and Leggett (1982) from a comparison of various lake data from the literature.

It turned out that Lake Constance had relatively low fish biomass in 1993, and that the fish stock increased during the following years, despite decreasing TP. In contrary, Lake Ammersee with very low phosphorous content showed an overabundance of fish and total fish biomass. In this lake serious problems in regard to fisheries had occurred, with a dramatic slow-down in fish growth and consequently low fishing pressure. Two other lakes did not deviate much from the general TP - fish biomass relationship of Hanson and Leggett.

In conclusion, this study shows that fish management in lakes undergoing changes in trophic status should be accompanied by regular acoustic monitoring of the total fish biomass and fish densities, in order to improve the data base on which to found reasonable decisions for a flexible fish management, and in order to avoid over - or under-exploitation of stocks.

6.4 Diner, N. New Thalassa: acoustic equipment and performance.

The new IFREMER research vessel Thalassa carried out her first cruise in July 1996. She is 74.5 m long, 14.9 m wide with a 5.8 m draft and a displacement of 2300 to 2900 tonnes. She is specifically designed for fisheries research although she is also equipped for oceanographic studies (e.g. 8000 m of cable on a CTD winch). She can take up to 25 scientists on board and has space for 5 containerised labs (3 if fishing operations are required). The acoustic equipment consists of three scientific echosounders: an Ossian 1500 at 38 and 200 kHz; an 11 kW Ossian 2500 at 38 kHz; and a Simrad EK500 at 38 and 120 kHz. There is also an Ossian 500 49 kHz netsonde, a Simrad SR240 omnidirectional 24 kHz sonar and a Scanmar net monitoring system.

One of the principal features of the vessel is the multipurpose computer network and multimedia broadcasting real time system. This incorporates a number of systems which carry out data acquisition, broadcasting and archival across shared devices and resources: CINNA is the system for integrated navigation; CITE is for technical data such as ship movements, CTD winch information, Scanmar trawl positioning; TERMES, for scientific data such as weather information, biological data from trawls, depth for sounders; ARCHIV for storage of all data to optical disk; MOVIES, echointegration software; VIDOP, cruise mapping and multifunctional display; SDIV, video broadcast facility for vessel statistics, mapping, weather or trawl information; and CASINO records relevant cruise parameters in an Excel spreadsheet. E-mail facilities are also available.

Vessel noise is considerably lower than that of the old Thalassa and within the range of current modern research vessels, although it is a little higher than specified; this is being addressed by filtering engine noise. Acoustic intercalibration exercises with the old Thalassa have been carried out and although backscattering profiles were not the same, mean values were quite similar. Fishing comparisons will also be carried out.

6.5 Duncan, A. Report on the Shallow Water Fisheries Sonar Meeting.

The Shallow Water Fisheries Sonar Meeting took place at the Royal Holloway College in London over three days from 16-18 September 1996. 53 participants attended from 15 different countries, mostly from the freshwater fisheries management community. A book of abstracts was produced and later a 17 paper special volume of Fisheries Research will be published. The programme was divided into 4 sessions: hydroacoustic monitoring of fish behaviour and migration (mostly salmon, fixed location studies in rivers); fisheries sonar in shallow tropical water bodies, lowland rivers and shallow lakes; complementary application of horizontal and vertical beaming in deep water; and hydroacoustic technology and methodology in relation to horizontal applications (invited lectures by Ken Foote on physical limitations and Dick Thorne on shallow water experiences).

The presentations were mostly derived from work carried out at very shallow depths (< 4m) and consequently the mode of surveying was predominantly horizontal. Sampling strategies were mostly of a fixed nature although mobile surveys were considered as a powerful, yet relatively recent development. A number of working frequencies are used although most utilise 120, 200 or 420 kHz.

One of the principal conclusions was the identification of future needs such as training and access to the expertise in the marine community.

6.6 J.Kubecka. Recent developments in horizontal echosounding.

Relatively high frequency systems are usually considered in horizontal applications because of the low cost, small size and small near field area. Further requirements are a narrow angle, concentricity of both beams and low side lobes (30 dB down compared with on-axis sensitivity).

Most of the work takes place occurs in large rivers which are consistently close to 3 m in depth. Even when lakes are considered, most of the fish are contained in the epilimnion (upper layers). Consequently, an important parameter is the maximum usable range (MUR) defined as the distance from the transducer where the acoustic beam fills all the water column between the bottom and the surface. Any area beyond MUR needs to be eliminated by manual bottom tracking as surface and bottom reverberation are the main sources of noise. For fish abundance surveys by echo counting using a mobile Biosonics 420 kHz dual beam sonar, the first level of analysis separates fish targets from noise by applying a signal to noise ratio of 3:1 or better for setting stratified thresholds. The second level of data filtering utilises a beam pattern factor to define the position of every target in relation to the acoustic axis of the beam. Targets can then be accepted within a sampling volume as defined by an off-axis distance. If similar attention to thresholding is applied in echo integration a reasonable relationship between fish densities from the two methods should be achievable.

A reasonable relationship for target strength versus fish aspect has been described in Kubecka (1994). A $\cos^3$ model gave the best fit of data for three freshwater fish species. This model can be used for : estimation of the most probable aspect in the horizontal plane; estimation of the mean all-aspect target strength of fish; and calculation of probability of recording of a fish of given size when a noise threshold is applied.

Discussion: There was some debate over the possibility of multipath echoes. The specific design of transducers, which have very small side lobes, and the rejection of targets beyond MUR reduces the likelihood of recording these echoes.

6.7 Duncan, A. and Kubecka, J. Patchiness of longitudinal fish distributions in a river as revealed by a continuous hydroacoustic survey (poster).

The longitudinal distributions of fish communities along 34 km of the upper River Thames and 32 km of the Yorkshire River Ouse (24 km in non-tidal and 8 km in the tidal regions) were obtained by mobile acoustic surveys, conducted at night (dusk to dawn) and using a dual-beam echosounder at 429 0 kHz and a transducer beaming horizontally and recording at four horizontal strata delimited by different noise thresholds. Although acoustic ranges were small (10-20 m), the total sampled volume was large (5-10 million cubic metres). Continuous records of fish densities active in the water column at night were obtained by echointegration at between 20 m to 57 m EI report intervals along the river.

The fish communities of both rivers were similar in species composition (roach, bleak, perch, chub, dace, gudgeon) as was the range of fish densities (1-7 fish) per 100 cubic metre (mean values from all EI reports in files from different parts of the river) and the range of mean lengths (80-180 mm) from fixed location echocounting of the predominantly present single targets. A significant relationship between single target and quantitatively seined densities in the River Thames showed that single targets formed about 62% of the netted fish (Kubecka et al., 1992). In the River Thames, a feature of the continuous longitudinal distribution of the EI report densities was the visual evidence of different scales of patchiness. The larger patches were associated with river features (sewage outfalls - 33 fish/100 cubic metre) or particular events (mass emergence of insects at dawn - 22 fish/cubic metre). For other detectable patches, there were no obvious causes but they were persistent in replicated runs during one night or occupied the same locality in July and September. A preliminary look at the variance between densities of EI reports and of the four strata in the horizontal sound beam suggest that, at night, fish are randomly or uniformly distributed within the water column. This will be subject to further analysis.

6.8 Kubecka, J. and Duncan, A. (poster). Acoustic size versus real size relationships for common species of riverine fish.

Target strengths of brown trout, rainbow trout, roach, perch, dace and chub, crucian and common carp, bleak and bream were determined for two ultrasonic frequencies of 200 kHz and 420 kHz using dual-beam sonar directed horizontally at individual stunned fish of known size whilst being rotated through 360 degrees by means of a carousel structure. This provided a data base for each fish of real size in length or weight for side body aspect, head/tail and mean all-aspect. The latter was the average acoustic size of an individual fish rotated through 360 degrees. In all, 182 fish were insonified in this way with more than 800 sonar runs (= replicated rotations).

In all individuals, the largest target strength was for side-aspect, the lowest for head/tail aspect and the mean all-aspect was intermediate. Significant linear regressions (TS=m.LogL + b equation ; 6.3 MacLennan and Simmonds 1992) were fitted to the data for individual species with an adequate number of measured individuals for each frequency. The regression slopes (m) of side-aspect TS ranged from 20 to 35 and intercepts (b) from -76 to -114 dB. Pooling the data permitted calculation of family regressions for salmonids (n=41) and cyprinids plus perch (n=114). These differed significantly either in regression slope, or where slopes were parallel, in regression elevation. The salmonid regression usually lay lower than the cyprinid plus perch regression. By assuming a slope (m) value of 20, the intercept b equivalent value was -76.6 dB for fresh water cyprinids in side-aspect at 200 kHz and -77.3 dB and 420 kHz frequencies ; the m value for salmonids at 420 kHz came to -81.6 dB. Comparable m values for marine physostomes and physoclists at 38 kHz and in dorsal aspect are -71.9 dB and -67.4 dB, respectively. That is, intercepts for a slope of 20 lie 5-10 dB lower in freshwater side-aspect regressions than in marine dorsal-aspect regressions.

Side-aspect TS vs real size regressions are directly applicable to fish target strength measured by fixed location studies as frequency analysis of tracked slopes shows most fish in the river at night were oriented erpendicularly to the beam and presenting their side-aspect to the transducer - (in press - Fisheries Research).

6.9 Petitgas, P. Report on the Working Group on the effect of time variability in acoustic surveys (see annex).

A workshop on the effect of time variability in acoustic surveys took place at ORSTOM, Montpellier, in November 1996. The rationale for the meeting was to attempt to consider the importance of what is in effect a third dimension of variability to consider, that beyond spatial variability.

Discussion: The group agreed that the subject of time variability was an important issue, but as yet knowledge in the area is limited. Computer simulation studies were thought of as good approaches to understanding the problems involved.

6.10 Discussion

The general discussion prior to the close of the meeting centred around the issue of uncertainty. It was extended to include the effects due to the whole integration process, by addition of behavioural aspects and time variability. As such a new categorisation was proposed breaking down the whole subject of uncertainty according to:

- Acoustic signal
- Sampling strategy
- Fish discrimination
- Fish behaviour

The questionnaire (see section 3.8) will be expanded to address this framework. It will be prepared by J. Simmonds by the end of August and members should submit replies by Christmas. A recommendation to this effect was drafted (see below).

With regard to the issue of the separation of plankton and fish the group concluded that the following methods should be considered as the main components of any process:

- Multifrequency discrimination
- Echo statistics
- Thresholding
- Doppler
- Morphometrics

On the issue of shallow water acoustics it was recognised that this is a complicated area lacking in theoretical information. There is however, a large community outside of ICES which is enthusiastic and keen to develop. It was agreed that there was enough common interest to merit the communication and exchange of information between the two groups. This was accepted as a reasonable recommendation to the group (see below).

The group discussed the issue of fish behaviour and consideration was given to the invitation of an invited speaker specialising in the discipline. A few names were proposed: Tony Pitcher; Neil Huntingford; J. Parrish; A. Magurran; and G. Turner. There was no general consensus on this and it was left to the chairman to decide in time for the statutory meeting as to how to proceed.

7. Working Group Recommendations

The Working Group made the following recommendations:

1. The WGFAST should meet in La Coruna, Spain on Thursday 23 - Saturday 25 April 1998 to:

   a) review the progress of the Study Group on Echo Trace Classification;

   b) review the results of the questionnaire on sources of uncertainty in acoustic surveys, with the aims of discussing the problems which are perceived as important, and assessing to what extent these can be resolved by further research;

Justification:

a) The Study Group noted that considerable progress had been made at the first meeting and consequently plans for a great deal of work had been realised. Arising from this it was considered important to hold two further meetings, with the principal justification for the next meeting to review the results of the comparative image analysis exercise. This exercise involves many members of the group and by its nature will undoubtedly result in a great deal of subjective analysis which is best explained at a meeting. It is recommended that the SGETC continue to work by correspondence and meet just prior to the WGFAST to review work in progress and to prepare a draft report for presentation to the WGFAST.

b) At the 1997 WGFAST meeting a review was given on the uncertainty in vertical echosounder performance and a number of other presentations also addressed the same issue. The variety and scope of the problems encountered was extensive and the group now has an appreciation of the extent of the problems as defined in D. Demer's presentation. However, it was not clear exactly how critical the problems are, how they affect the estimation process, and importantly, to what extent they can be resolved or eliminated by further research. The questionnaire aims to obtain an consensus of opinion of the magnitude, direction and tractability of these defined uncertainties. Once priority areas in causes of uncertainty are known, more concentrated efforts can be made in an attempt to resolve the problems. This will contribute to an improvement in the precision and accuracy of acoustic surveys.

2. The FTFB and WGFAST should have a joint session (chairman to be arranged) on Wednesday 22 April 1998 to consider the trawl sampling for acoustic stock estimation and pelagic trawl sampling design.

   Justification: The fish sampling by pelagic trawl during acoustic surveys is used for allocating the measured biomass to each species and each age class. Any bias or error on these results will affect the final result. It is therefore important to consider how to improve the gears used in acoustics surveys to obtain biological samples and, further, how to improve the procedures applied to incorporate these sampling data in the estimation of biomass.

3. The WGFAST recommends that a questionnaire be prepared by E. J. Simmonds (Aberdeen, UK) and be circulated to members of the working group to compile a synthesis of opinion on sources of uncertainty in acoustic surveys. The questionnaire should be structured to provide information under the following categories of uncertainty:

   - Acoustic signal
   - Sampling strategy
   - Fish discrimination
   - Fish behaviour

The questionnaire will ask for a qualitative, or where possible, quantitative evaluation of sources of error and their direction (leading to under- or over-estimation), as well as some indication of the feasibility of reducing or eliminating errors. The questionnaire will be prepared by August for distribution and members should submit completed versions by Christmas.

Justification: At the 1997 WGFAST meeting a review was given on the uncertainty in vertical echosounder performance and a number of other presentations also addressed the same issue. The variety and scope of the problems encountered was extensive and the group now has an appreciation of the extent of the problems as defined in D. Demer's presentation. However, it was not clear exactly how critical the problems are, how they affect the estimation process, and importantly, to what extent they can be resolved or eliminated by further research. The questionnaire aims to obtain an consensus of opinion of the magnitude, direction and tractability of these defined uncertainties. Once priority areas in causes of uncertainty are known, more concentrated efforts can be made in an attempt to resolve the problems. This will contribute to an improvement in the precision and accuracy of acoustic surveys.

4. The WGFAST recommends that special attention be paid to the problems associated with horizontal echosounding in shallow waters such as: short distance echo interpretation (nearfield effects); different fish aspect angles; and phase boundaries in small spaces. The exchange of information and communication between members of the WGFAST and groups working in the field of shallow water acoustics should be encouraged.

   Justification: Although not yet relevant to the ICES community the problems of shallow water acoustics are mostly related to horizontal echo sounding. The use of horizontal echosounding may be of value to fisheries scientists in ocean studies as is evident in the AVITIS program where a 90° beam is orientated at 45° to the course of the vessel and will therefore encounter problems of a horizontal nature. This project has the potential of increasing the survey sampling volume by up to 800 %. The techniques could also be used to extend surveying to areas where navigational hazards prevent large research vessels from going, such as close to shore and between islands. It would therefore be worthwhile to keep an eye on developments in this field.

5. The WGFAST recommends that an e-mail bulletin board be set up to provide a forum for discussion and the exchange of information. This will be investigated by Bo Lundgren (Hirtshals, Denmark) and may be modelled on that of the FTFB WG which is based at ICES in Copenhagen.

   Justification: Most, if not all, members of the WGFAST now have e-mail facilities. The establishment of an e-mail bulletin board is becoming common practice for large groups separated by long distances to voice opinion and more importantly to allow for a wide dissemination of questions and problems, which can be addressed by all members. A bulletin board is now available for the WGFTFB and it is partly from their favourable experiences that the WGFAST recommends a similar system be set up.

8. CLOSURE

The chairman thanked the staff of the Institute for Fishery Technique, Hamburg, for their hospitality, and members of the Working Group and Study Groups for their efforts and contributions.

9. NATIONAL PROGRESS REPORTS

Appendix A

10. PARTICIPANT LIST

Appendix B

11. REFERENCES

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APPENDIX A: National progress reports

A. DENMARK

1. Three standard acoustical surveys were performed by the institute:
   a. A survey for herring in the Skagerrak and Kattegat and the nearby North Sea by the end of July with the R/V DANA.This survey is part of the International Herring Survey in the North Sea coordinated by ICES.
   b. Three cruises during February-April and two cruises during October - November in the Sound between Denmark and Sweden to monitor the R• gen herring stock with the 20 tonnes research cutter Havfisken. The project is launched to check possible influences on the stock and its migration due to the works in connection with building of a bridge across the Sound.
   c. Two cruises with the R/V DANA, one in the winter and one in the autumn to investigate the conditions for the recruitement of cod in the Baltic were supplemented by acoustical surveing. This survey is part of the FAIR Baltic CORE project.
2. Special field investigations:
   a. A cruise to measure swimming activity and swimming speed of individual saithe by tracking them with the split-beam echosounder took place in August in the Northern North Sea with R/V DANA The diurnal swimming activity and speed is calculated by use of a newly developed programme. The swimming speed of the individual fish tracked is corrected for the water current velocity obtained during the survey by ADCP.
   b. Two surveys in May and September with the R/V DANA to investigate the sandeel stock in the North Sea were complemented with acoustical surveying for identification and Roxann recording to complement bottom sampling.
3. Laboratory investigation.
   An experiment to measure the target strength of 0-group cod (5-10 cm) was carried out in the large 2000 m3 tank in Hirtshals using an 120 kHz EY500 split beam echosounder. The experiment was complemented by video recording to check the size and approximate tilt angle of the fish.
4. New equipment:
   The institute has aquired one 38 kHz and one 120 kHz EY500 echosounder supplemented with EP500 software.
5. Other activities:
   New methods to stratify survey data with regard to depth contours are tried out. Evaluation of previous surveys to optimize the allocation of trawl hauls in relation to the distribution of age and size classes in the survey area are done. Work has been done to describe the distribution of the positions of single fish in layers using point process methods.

B. ESTONIA

In 1996 any experimental investigations by fisheries acoustics science and technology were not provided in Estonia. However, Estonia got full hydroacoustic equipment from Sweden and two scientists from Estonian Marine Institute passed special training course in Sweden (ACOUSTIC ASSESSMENT OF FISH STOCKS, SIDA - ÖST PROJECT BAL 0571). In 1997 the testing of the equipment and the study of the acoustic assessment of fish stocks is planned.

C. FRANCE

Progress report : ORSTOM
(contact : gerlotto@mpl.orstom.fr marchal@orstom.fr lebourge@orstom.fr petitgas@orstom.fr)

ORSTOM is developing several acoustic programs in the world. During the year 1996-1997 the main activities were the following :

- Program PICOLO (Equatorial Atlantic) : research on the trophic relationships between tunas and scattering layers (2 surveys).
- Program VARGET (Compared variability of Sardinella spatial behaviour) : surveys in Venezuela (April 96) and Senegal (March 96 and 97).
- Program ECOTAP : relationships between tuna and "pelagic habitat" in the Pacific (4 surveys).
- Program TECHO (EU FAIR) : this program is finished and the final report was delivered in the beginning of 1997.
- A survey was realised in Cuba for observing the impact of anthropic changes on environment in shallow waters lagoons (May 1996).

The research vessels employed for the surveys are :

- ANTEA, new 35 m long catamaran, Atlantic based.
- ALIS, 29 m classical stern trawler, Pacific based.

They are operated with the following acoustic tools :

EK-500 (ALIS) 38 kHz.
OSSIAN (ANTEA) 38 and 120 kHz.
Biosonics dual beam (both vessels) 38 and 120 kHz.
EY-500 (shallow water) 120 kHz.
RESON Seabat multibeam sonar 455 kHz.
SIMRAD SR240 multibeam sonar (ANTEA).
A Biosonics DT5000 dual beam portable sounder (120 kHz) has been purchased recently.

Two projects were submitted to EU/FAIR, and accepted.

- CLUSTER : study of spatial distribution of fish shoals.
- AVITIS : application of multibeam sonar technology to fisheries acoustics.

These two programs began on January 1st of 1997.

Several working groups were organised.

- Time variability (November 96) within ECHOSPACE framework, Montpellier.

- Caribbean Acoustic Network, March 96, Venezuela.

Progress report : IFREMER
(contacts jmasse@ifremer.fr ndiner@ifremer.fr scalabri@ifremer.fr bliorzou@ifremer.fr)

1 - Technical developments :

In this field, the efforts have been concentrated on the new FRV THALASSA. She is operational since July 96 and is equiped by all kinds of acoustic detection equipments. A special effort has been done in the field of noise reduction and a special device is under development for a continuous and automatic noise control. A prototype for synchronising the acoustic equipments is installed on board so as to be able to operate many active equipments with minimum interferences between them.
A computer network allows the processing of the information from all equipments and sensors. Special software have been designed for integrated displaying and recording of the data available.

In December, an intercalibration survey has been done, in the southern part of Bay of Biscay, between old and new THALASSA focusing on the compared performances in pelagic fish detection.

2 - At sea experiments

In July the first cruise of new THALASSA was conducted in Northern Ireland for evaluation of very deep resources. This was mainly realised by the analysis of systematic pelagic and demersal hauls (maximum depth : 2000 m) but exploratory acoustic detection of these resources was also intented.

Pelagic resources assessment and ecology was realised by routine surveys in the french Mediterranean sea.

3 - Modelling

In the field of acoustic shoal classification, a special effort has been done in order to take into account the biological and physical aspects of shoal detection by vertical single beam echo-sounders. Two models were developped, the first one for image simulation and the second one for shoal backscattering signals simulation.

4 - Acoustic processing software

A new software is being developed to process signals from every kind of digital echo-sounder (OSSIAN, SIMRAD, BioSonics etc...). This new software will support the *.HAC file format. It takes into account the framework of the last version of MOVIES-B, but allows a more flexible approach and analysis.

D. GERMANY

Bundesforschungsanstalt für Fischerei
Institut für Fischereitechnik, Hamburg
(Federal Research Centre for Fisheries
Institute for Fisheries Techniques, Hamburg)

1. International surveys

R/V „Walther Herwig" 173, : June-July 1996

Joint international survey on oceanic redfish (S. mentella) in the Irminger Sea and adjacent waters, Participants : Germany, Greenland, Iceland, Russia R/V „Solea" 379 ; July 1996 ICES co-ordinated Herring Survey in the North Sea R/V „Solea" covered the eastern part of Div. IVb between the Dogger-bank and the Danish coast.

R/V „Solea" 397 ; October 1996

ICES co-ordinated survey on herring and sprat stocks in the Baltic The working area of R/V „Solea" was the Western Baltic. In the Bornholm Sea an intercalibration of the R/V's Argos (Sweden), Baltika (Poland) and „Solea" was celebrated.

2. Special investigations

R/V „Walther Herwig" 170 ; March 1996

Acoustic measurements on mackerel and horse mackerel in Div. VII and VIII. The investigations were aimed to compare the acoustic measurements with the catch of bottom trawls.

3. Acoustic equipment

On both research vessels acoustic data were collected using the EK500 echo-sounder on 38 kHz. The datasets were stored and analysed by the Bergen-Integrator BI500. For normal conditions R/V „Walther Herwig" used a hull-mounted transducer ES38 but in bad weather situations and looking in a greater depth also a towed body VD500 is available. Especially in the redfish survey this towed transducer was used.

The measurements onboard R/V „Solea" were only performed with a transducer 38-26 installed in a towed body to avoid fish reactions to vessel noise. The lateral distance of 30 m from the ship kept the transducer free from bubbled keelwater. The towed body permitted a working speed up to 8 knots depending on weather conditions and wave interactions.

4. Technical developments

For the „Solea" towed body a diving depth control was developed. The aim was to get a more stable course and better forecasts of the diving depths for different lengths of towing cables. With this body first investigations of the avoidance reactions of fish were started.

The signal and image processing software system „Khoros" running on a SUN workstation was used to examine the echostructure.

E. ICELAND

Marine Research Institute, Reykjavik

Acoustic activities in 1996

A survey of the oceanic-type redfish (Sebastes mentella) in the Irminger Sea and adjacent waters was carried out in June-July in coordination with Germany and Russia. About 250,000 nm2 were covered.

A survey on the Atlanto-Scandian herring was conducted in May-June in coordination with Norway, the Faroes and Russia in the Norwegian Sea.

The yearly investigations of the Icelandic capelin were undertaken in autumn and winter. In August the juvenile stock in the Iceland-Greenland-Jan Mayen area was surveyed as a part of the traditional 0-group survey. In October/November a two-ship survey of the adult and juvenile components was carried out in the same area.

A survey on the Icelandic summer spawning herring was carried out in November and December. The survey area covers the known distribution of this herring stock in the Icelandic fjords and shelf area. An effort was made to cover both the juvenile and adult components of the stock.

The acoustic data are collected using the Simrad EK500 and recorded using the BI500. The Principal frequency is 38 kHz, but 18, 120 and 200 kHz have been recorded on an irregular basis. Split-beam data at 18, 38 and 120 kHz are recorded using the BI500.

Data collected in 1995, during a survey specially aimed at investigating the diel variation of the acoustic intensity and target strength of oceanic redfish, were analysed. The analysis revealed, not surprisingly, that these two parameters were closely correlated.

Measurements of the beam pattern of the hull-mounted survey transducers have been carried out using a technique which depends on a details knowledge of the geometrical arrangement of suspension of the calibration sphere. Compilation of results obtained in the period 1983-1995 is well under way. The transducers measured, total 18, are all manufactured by Simrad. The transducers cover frequencies from 12 to 200 kHz and the equivalent beam angles range from -14 to -25 decibels. Significant differences have been observed with data supplied by the manufacturer. An important exception is the contemporary line of transducers made by Simrad.

F. UNITED KINGDOM

SOAEFD Marine Laboratory, Aberdeen

Surveys

Surveys of herring were carried out in July 1996 in the following ICES areas: VIa north; IVa (eastern section in the Shetland, Orkney areas); VIa south and VIIb. The latter survey was carried out on contract to the Irish government. The surveys encompass a large area in collaboration with the Norwegian, Danish and Dutch fisheries research laboratories co-ordinated by the Marine Laboratory. Survey data were collected using the Simrad EK500 and recorded using the BI500 at frequencies of 38, 120 and 200 kHz. Environmental data was collected during the survey.

Results from a survey of spawning herring in the Celtic Sea in November 1996 were analysed under contract to the Irish Marine Institute. Data were collected using an EK500 at 38 kHz and recorded using the EP500 software. Significantly larger quantities of herring were observed in even when compared to last years very high estimate. This indicates that the Celtic Sea herring stock is in reasonably good health.

The lab has purchased a Reson Seabat 6012 multibeam sonar to work on the AVITIS project. Experience with the use of the system was through a kind invitation from ORSTOM in Senegal. Two cruises in Scotland have been planned for 1997.

Acoustic data were also collected during the International Young fish Surveys in the North Sea and off the west coast of Scotland. These were collected using an EK500 at 38 and 200 kHz, and recorded on the BI500. The survey mainly targets demersal fish, but it is hoped that the analysis of acoustic data might help to improve swept-area estimates in some way.

An acoustic survey for mackerel was conducted in December 1996 in the Viking Bank area between Shetland and Norway as part of the SEFOS project.

The geostatistics project continues and a routine for the calculation of estimation variance in herring surveys has been established through the use of a log-backtransform. High resolution data is being looked at to provide a ping based variogram and the issue of fish movement is being investigated.

(Contact persons: John Simmonds, David Reid and Paul Fernandes)

British Antarctic Survey, Cambridge.

Acoustic studies were carried out in the South Atlantic from RRS *James Clark Ross* during a one-month cruise in December 1996 and January 1997. We used a Simrad EK500 sounder with hull-mounted 120 kHz and 38 kHz split-beam and 200 kHz single-beam transducers. Integrated and ping by ping data were logged over a LAN to a Sun workstation. A PC was additionally used to send set-up files of sounder settings. Integrated data were processed on the ship to obtain a krill biomass estimate. The sounder was calibrated on three occasions at South Georgia using the standard sphere method. Detailed studies were made of the variability in the 200kHz calibration with time.

Studies began and ended with large scale acoustic and oceanographic transects between Stanley, Falkland Islands, and the South Georgia shelf. These provided information on the current location of the Antarctic Polar Frontal Zone (APFZ). To the north of South Georgia two rectangular boxes were surveyed using acoustics and nets, and accompanying oceanographic measurements were taken using CTD, ADCP and undulator. During the majority of the transects, quantitativeobservations were made of the birds and seals encountered. These box surveys were the second in a series that will be repeated each year for at least five years, in order to study inter-annual variation in krill and other zooplankton in relation to oceanography.

In addition to the above surveys that were carried out at pre-selected locations, time was allocated for fishing on targets found during acoustic transects. This targeted fishing, using a RMT8 net, was in support of our continuing investigations into the identification and classification of acoustic targets of the region.

G. USA

USA FAST Progress Report

APRIL 1997

The **Alaska Fisheries Science Center** continues work on stock assessment of pollock and whiting in the North Pacific. Research projects include in situ target strength measurement (including the development of a lowered transducer system), variance estimation using geostatics, and the use of an acoustic buoy for examination of vessel and trawl avoidance. Contact : Jim Taylor, jimt@afsc.noaa.gov.

The **Antarctic Ecosystems Research Group at the Southwest Fisheries Science Center** continues work on stock assessment of krill off the Antarctic peninsula, in the Sea of Cortez, and off the coast of Southern California. Research projects include predator-prey interactions, uncertainty in echo-integration techniques, in situ target strength measurements, multi-frequency methods for taxa identification and delineation, and velocity measurement of fish and zooplankton aggregations with acoustic Doppler techniques. Contact : David Demer, ddemer@ucsd.edu.

The Georges bank Predation Study (funded by the **NOAA Coastal Ocean Program and the Northeast Fisheries Science Center**) continues its examination of the impact of predation on larval and early demersal juvenile Atlantic cod and haddock. This study will conduct hydroacoustic, midwater trawling, and plankton sampling operations on Georges Bank during April 1997 in coordination with the US GLOBEC field studies. Operations will be conducted from the NOAA R/V Delaware II which was recently equipped with new acoustical instrumentation (eg, EK500, trawl monitoring systems, sonar). Contact : William Michaels, William _Michaels@noaa.gov.

The **Great lakes Center** at Buffalo State College continues work on acoustic stock assessment of pelagic fishes in east coast estuaries (Chesapeake Bay, Hudson River and Delaware Bay) and the Great Lakes of North America (Lakes Erie and Ontario). Acoustic data are also linked directly with spatially-explicit ecological models and Geographic Information Systems to assess predator-prey relationships and fish production. A buoy-mounted, split-beam echo sounder is being used to measure fish densities over extended time periods. Recent research also is evaluating the potential for multi frequency acoustics and scattering models to identify fish targets. Contact : Stephen B Brandt, brandt@glc.snybuf.edu.

The **Naval Research Laboratory, Stennis Space Cente**r, is conducting investigations on the low
frequency backscattering characteristics of schools of swimbladder bearing fish. These studies include biological modelling of fish distributions, theoretical modelling of school-scattering, simulations, and measurements. An experiment si planned for October-November 1997 during which theoretical scattering models for large schools of fish will be tested on schools of semi-tropical herrings and sardines in the northern Gulf of Mexico.

The **Southeast Fisheries Science Center** is continuing hydroacoustic stock assessment activities on sharks, small pelagics, and reeffish. Activation testing of hull mounted 38, 120 and 200 kHz transducers aborad the NOAA Ship OREGON II currently underway. Zooplankton work with 120 and 200 kHz planned this year. Contact : Walt Gandy, Walt_Gandy@noaa.gov.

Tracor's current programs in bioacoustics currently involve projects in three areas : 1) the use of multiple frequency acoustical sensors to study vertical structure's in zooplankton with sub-meter dimensions ; 2) improvements and extensions of inverse theory and applications related to transformation of volume scattering strength data to estimates of biomass and size spectra for zooplankton ; and 3) the application of high resolution acoustical methods in problems in benthic ecology. We continue to work with Richard Pieper at USC and a number of other scientists in processing, interpreting and publishing data from the BITS mooring off Southern California and deployments of our TAPS technology in the Arabian Sea (on a SEASOAR), on Georges Bank (on a SEASOAR), in the Bering Sea (on a CTD), in estuaries and fjords (bottom mounted, upward looking) and elsewhere with various modes of deployment.

Additional information on our activities, as well as some data and information relevant to technology of interest to FAST WG members are now available on the World Wide Web at « http ://www.aard.tracor.com » in the section on Ecosystems Research.

Contact : D V Holliday, holliday@gaileo.tracor.com.

Woods Hole Oceanographic Institution Scientists continue their work on acoustic surveys of zooplankton. Research projects include theoretical development of acoustic scattering models, laboratory measurements of zooplankton target strengths, and acoustic surveys of zooplankton over the George Bank. Contacts : Tim Stanton, tstanton@whoi.edu and Peter Wiebe, pwiebe@whoi.edu.

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APPENDIX C : Report of the workshop on time variability and space-time interaction in fisheries acoustic surveys

by
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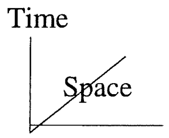
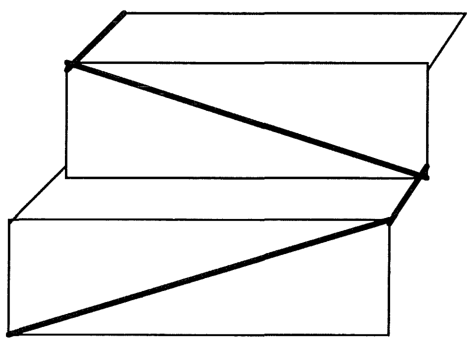
This workshop was an initiative of Orstom proposed to the group Echospace. It was held at Orstom-Montpellier, on November 18-20, 1996, and convened by the authors. Orstom has in the past stressed the importance of time variability being confronted to this reality in tropical areas. Afsc had in winter 1996 performed extensive space-time sampling of Alaskan Pollock in a Bay in the Shumagin Islands area to test for spatial structure and its geostatistical modeling.

The rationale for the workshop was the following. Acoustic survey data have space-time variability and interaction in them. Geostatistics has up to now been used to model the structure in the data as if it were only spatial. How could time be accounted for in the geostatistical analysis ? How important is the time effect in our surveys?

At a given location in space, density values will change in time because of fish (school) movements but also because of the endless dynamical reorganisation of aggregative structures (schools). During a survey, while sampling space, time is passing, thus the survey design and the boat speed define a space-time interaction in the data. A survey made of parallele equidistant transects looks in the 3D space-time like going up an inclined stare case. The geostatistical model accounts for the space-time structure of the survey data and not exactly of the fish population. The space-time structure of the survey data depends on the space-time interaction defined by the survey design and the boat speed. Can we measure how important is the space-time interaction for a survey ? If we have to consider time variability in the data, how could we take it into account ?

A survey in 3D Space-Time : a survey made of regularly spaced parallele transects looks like going up an inclined starecase.





First each participant explained one's perception of how time affected one's data. A table was built where the different time effects were listed (Table 1). The list was ordered considering the relation between space and time, from a discontinuous to a very continuous relation. Short and long range scales of variability were defined relatively to the survey area and survey duration. Time variations occur at many spatial scales and a biological cause acts at different scales.

1. Effect of time variability on the biomass estimation

Situations where the space-time interaction in the data may introduce bias in the zone mean estimate are when avoidance or availability changes, when cyclical and oriented changes occur and when these situations are not controlled for.

In situtations when density values change in time during the survey because of avoidance, availability, Ts, biological behaviour and cyclical time changes, some participants were of the opinion that sampling along the time axis in different areas is a realistic survey strategy because it provides a good sampling of the time variability of the density in each area.

Also, considering time as a third dimension, one may think of different estimation configuration in the 3D space-time cube. We may estimate the 3D space-time mean in the cube or a 2D space-time mean in the vertical planes of transects. We shall see in the section on space-time models that considering time as a third dimension may not be a realistic approach.

2. Effect of time variability on the variogram

2.1. Effect on the nugget

2D Nugget

At the shortest scale, time and space seem unseparable. The nugget can be as much spatial than temporal. In the 2D latitude-longitude plane, the nugget is most determined by the passage from the outside to the inside of schools. This discontinuity is as much spatial (eg the vessel sails rapidly over schools) than temporal (schools move and pass under the drifting vessel).

1D Nugget

For surveys made of regularly spaced parallele transects, it has been proposed to sum all ESDU values and compute simply the estimation variance with the correlation model of the one dimensional data set made of the biomass per line. Examples were shown where estimation variance computed in 1D and 2D gave similar results. A senegalese example was shown where the difference between adjacent transects was very important and thus the nugget value in 1D was uncertain (Example 1, Fig.1.1 and 1.2). The nugget value in 1D physically quantifies how much a single transect varies when sampling it again. The nugget in 1D was proposed as a simple measure of time variability at transect scale. It was argued that the nugget in 1D is also as much spatial than temporal. The time variability being allready in the data, it cannot correspond to an additional component that is simply added. 1D and 2D variograms should be compatible and model the same amount of variability.

2.2 Day/night effect

Day/night changes in spatial structure have been evidenced on tropical data by Orstom since a long time. The Day/night change in spatial structure is in general a consequence of the fact that schools at night are less structured if not dispersed. Similar changes were present in the data set of Alaskan pollock (Example 2, Fig. 2.2a and 2.2b). In general, night time variograms are characterized by a low sill, long range, and low nugget. Day time variograms display a higher sill, smaller range, and higher nugget.

In the Alaskan pollock example (Example 2, Fig. 2.2a and 2.2b), two types of variograms were observed during day time. One showing the night range with an additional day small range, the other showing just a day small range.

Before pooling day and night survey data to examine spatial structure, a check for diurnal differences should be conducted. It is recommanded to seperate day from night data when structuring is different. Aggregative dynamics during a local breakdown will affect the variogram in a similar way than the Day/night change.

2.3. Effect of random non oriented fish movements

We considered the situation where fish schools move but the internal school structure stays constant, the number of schools stays constant and the zone biomass also. Assume the movements of schools are isotropic, independent from each other without memory of previous displacement. In this situation, the effect of time on the spatial covariance is a convolution by a diffusion (Rivoirard). At time to, consider a certain spatial distribution of the schools with its corresponding spatial covariance r(h). At time to+t, the space-time covariance r(h,t) differs from r(h) : it has a higher nugget and a smoother correlation for long distances. The variogram is thus affected in all distance ranges. This is so because the probability of finding, at to+t, the same school in the vincinity of its position at to, decreases with time t. And the probability of finding the same school at a greater distance increases with distance and time. Consider the school movements as a brownian motion. The trajectory swam by a school during a time lag Δt is a gaussian variable with mean zero and variance proportional to Δt, say $b\Delta t$. In the isotropic case, the spatio-temporal covariance is:

$$\rho(h,t) = \int \rho(h-u)\, \frac{1}{\sqrt{2\pi b \Delta t}}\, e^{-u^2/2b\Delta t}\, du \quad (u \text{ and } h \text{ are distances in } R^2).$$

We see that time is not here a third dimension. This example states that the separation of the variability into the sum of a temporal and a spatial component is not a realistic approach.

2.4. Effect of anisotropy of survey design

For surveys made of regularly spaced transects, the variogram computed along the transects is more spatial than temporal where as the variogram computed accross the transects is more temporal than spatial. Let d be the inter-transect distance. Two points d apart along a transect have a smaller time lag between them than two points d apart belonging to two different transects. Thus the variogram in the direction perpendicular to the transects is determined by the survey space-time interaction and will seldom serve to analyse anisotropy in the fish spatial distribution. For this purpose, we need to perform a transect in the direction perpendicular ot the transects (Example 2, Fig. 2.3).

3. Density Map in presence of time variability

Usually, the variogram is computed as if the space-time variability of the data was only spatial. The density map derived from the data and this variogram relates to the survey data but not necessarely to the map of the fish at a given moment. The difference between these maps depends on the amount of time variability and on the type of space-time interaction.

It was argued that in the density field sampled, some patterns are more variable in time than others. For example, high densities may vary in their value and location. The location of specific areas may stay constant at a seasonal time scale. Therefore, the space-time interaction was thought to be different for different parts of the density histogram. The probability map for trespassing a medium density value may therefore be closer to the map of the fish than the actual density map of the survey.

4. Space-time variogram models and simulations

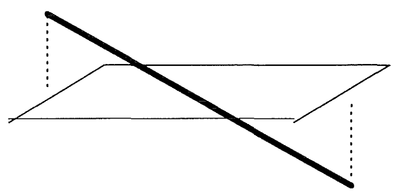
At present, the space-time variability being modeled as spatial only, the geostatistical formula of the estimation variance tells that if we had an infinite number of transects in space the estimation variance would be zero. This is not thought to be correct because of time variability. For this reason there should be an incrompressible mininal non zero variance. Space-time structural models are thus thought to be needed.

Two types of space-time models were presented. They may not be the only possible ones. One considered time as a third dimension. The other considered the effect of time as an autoconvolution of space.

4.1. Time as a third dimension

In this model, variability in space and time are seperable and additive. We have a zonal anisotropic model for the variogram: $\gamma(h,t)=\gamma(\sqrt{h^2+t^2})=\gamma_1(h)+\gamma_2(t)$. This model has problems. First, seperation in the field of time and space is impossible and its inference will be problematic. Second, it leads to problematically very high estimation variances as a time component is added. The estimation configuration for a transect is for instance :

estimation of the middle planar rectangle by the oblique transect.



4.2. Autoconvolution of space in time

This approach was thought very interesting. It does not separate the space-time variability into two components. The effect of diffusive movements (all other parameters staying constant) on the variogram has shown that all ranges of spatial scales are affected by time in different ways (see paragraph 2.2).

This approach leads to performing simulations to test for space-time interactions. In particular, movements where not thought sufficient to account for time variability. Dynamical changes in aggregative behaviour were thought to be as important as movements.

5. Measuring space-time interaction in survey data

5.1. Simulations

It was thought that simulations were a good approach to envisage measuring the importance of time effects in survey data. Classes of space-time models with the « convulion approach » could be deduced from these experiments. Presently the procedure requires making hypothesis on temporal changes, performing simulations in space and computing space-time variograms.

The « convolution approach » also states that separation between space and time requires a deconvolution procedure.

5.2. Comparing variograms in different space-time directions

When transects have been performed in different directions, then it is possible to compute variograms in the same spatial direction but with different space-time interaction (see paragraph 2.4). Comparison of these variograms will indicate how much space-time interaction there is in the data set.

Assume the transects are oriented N-S and that in the E-W direction (perpendicular to the transcets) we have peformed a transect. In direction E-W we have two variograms with two different space-time interactions: one computed along the E-W transect and one computed accross the N-S transects. Comparison of the two may serve as a simple test to analyse how much time variability there is in the data.

5.3. Experiments at sea

We listed the different experiments that are commonly undertaken (Table 2). All experiments consider replicating measurements in space, at a fixed location, a varying one, or repeating part of the survey. All experiments produce data where space and time interact. No experiment can provide a separation between spatial and temporal sampling. One experiment alone will not address the space-time interaction completely. Measurements in the field of space-time variability was thought very important to perform.

Results of some experiements in different seas were presented. Presently, no general rule sumarises them. In particular, the dynamical endless reorganisation of schooling has three variables, the zone biomass, the number of schools and the biomass per school. But we don't know which is the first variable guiding the others and the guiding variable may be different depending on the ecological situation.

It was stressed that some of the variability observed is attributable to sampling error. For instance, sailing through a cluster of schools repeatedly, will provide different school counts. The variance of such count is not only due to time changes but is also dependent on the volume sampled. The use of sonar will enable to lower the part of variance due to sampled volume.

6. Consequences on Survey design

Whenever possible, survey design should control for all identifiable variability - e.g. availability issues including migration and cyclical (day/night) changes.

Coming back to allready surveyed areas depends on the objective of the survey. The main problem is to define the time lag before coming back.

It may be important to sample in time over a given area when it is known that density values in this area have a high variability in time. But time spent in an area will affect the space-time interaction at the scale of the entire area to survey.

No recommandations was thought possible to make at this stage, considering the present state of the art on space-time structural models. It was stressed that new acoustic technology, particularly school tracking, insitu TS and lateral multibeam sonar will help acquire field information on space-time variability.

Conclusion :

Temporal changes occur at many space and time scales. It is not thought realistic to simply seperate space from time in an additive model. Rather, convolution of space in time was agreed to be an adequate approach. Simulations of simple space-time changes were thought interesting to perform to evaluate the potential of the problem for survey design. Performing transects in the direction perpendicular to the transects was thought to provide simple field information on the space-time interaction in the survey data.

Example 1 : 1988 acoustic survey in Senegal south of Dakar.

Fig. 1.1. Proportional representation of Echointegration values. ESDU=1Nm. Transects containing high biomass are very different from their adjacent transects.

2D Variogram : The variogram accross the transects (black disks) reaches the sill at its first lag (inter-transect distance). The relative estimation error is : 16.8% (square root of estimation variance over simple data average).

Fig. 1.2. 1D Covariogram : The nugget value is not well known. The modeling without nugget effect leads to a relative estimation error of 15.4% which is compatible with the one computed in 2D. The addition of a nugget raises the relative error to 30.7%.

Example 2 : 1996 acoustic survey on Walleye Pollock in Stepovak bay, Shumagin Islands, Alaska.

Fig. 2.1a Tracklines of survey. A first grid of transects covers the whole bay. Three regions are evidenced, A a low density area and B and C high density areas. Then small mesh grids cover areas B and C. Let us call Bay grid the one coevring the whole bay and B and C grids the fine mesh ones covering specifically these areas. All grids were replicated.

Fig. 2.1b Tracklines of survey. In addition to the previous grids, transects in two directions were replicated in areas A, B and C.

Fig. 2.2a Proportional representation of values in area B allowing comparison between day and night variograms. Grid used are Bay grid pass 2 and 3, and B grid pass 4 and 7.

Fig. 2.2b Difference between night and day variograms observed in area B, on Bay and B grids.

Fig. 2.3. Difference between along and across transect variograms in the same E-W spatial direction, in area C. Along transect structure exists and is consistent in time as is observed for Bay grid pass 1

and some time later on the replicated transect. Accross transect structure is pure nugget as observed on the C grid pass 5. Comparison was made for night values.

Table 1 : List of temporal changes and how they affect the data

Type	Relation between space and time	Causes	Effects on Survey data	Expected statistical effects
A : Local breakdown at scale of survey reorganisation on spot	Discontinuity in time	Gales, meteo Fishery Technical problems	Discontinuity Schooling and aggregative dynamics Reorganisation delay	Mixed structure Bias
B : Erratic and non oriented movements reorganisation on spot	more or less continuous	Meteo Feeding, Predation, Spawning Avoidance Sampling error Multispecies interaction Residuals	TS Schooling and aggregative dynamics Availability	Nugget Small structure
C : Cyclical changes reorganisation on spot	deterministic relation	Day/Night Tides In/off shore migration Feeding	TS Schooling and aggregative dynamics Availability Bias	Mixed structure Biais
D : Oriented changes reorganisation at scale of survey	strong continuity	Migration Development, growth	Trend in the density structure	Trend Bias related to direction of survey

Table 2 : Measuring time variability at sea

Type of experiment	Variability analysed	Biological results
Fixed station (Eulerian)	Correlation in time	aggregation dynamics several points needed
Replicated transect	Correlation in time Correlation in space along transect	Cyclical changes Temporal effect between point and survey aggregation dynamics
Intercalibration transect	small scale space/time variability measurement error	
Transect perpendicular to the other transects	anisotropy of fish density distribution	test of time effect by comparison of variograms computed across transects and along the perpendicular transect
Replicated surveys over the entire area or a subzone	Spatial covariation of time change design based estimator variance	cyclical changes (Day/Night) test oriented movements dynamics of aggregative structures
Replicated square tracks (Eulerian)	Correlation in time	cyclical change aggregative dynamics
Replicated square tracks (Lagrangian)	Correlation in time averaged in space	cyclical change aggregative dynamics
Fish school tracking	movements, speed and dynamical structure of schools	test for oriented / non oriented movements aggregative dynamics
Different boat speed	Correlation in space-time with different space-time interactions	space-time interactions related to changes in avoidance

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