

## Session 9: Rapporteur's Review. Introduction and edited discussion

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### Introduction

Acoustic classification of fish must be one of the few notions in our business that appeals to the popular imagination, both among laymen and non-fisheries scientists. Who among us has not regretted the casual mention of "fisheries" and "acoustics", worse if yoked together, and the inevitable denial of being able to distinguish fish species from the echo waveform? Just estimating fish density by acoustics has been a major challenge. Acoustic classification has indeed been a dream.

Now, work is presented which offers the distinct expectation of fulfilling this dream. The work is in a very preliminary state of development. We may hope that this development continues. Through the papers in this session we may learn what has been done and, if we will, plan its furtherance.

The several contributions are categorized according to *bandwidth* if the aim is measurement, or *technique* if the aim is classification. Under the category "wideband measurement" six papers are noted: those by Kjærgaard *et al.*, Simmonds and Armstrong, Zakharia ("Variations in fish target strength induced by movement: a wideband-impulse experiment"), Bondarenko and Novikov, Zakharia ("A prototype wideband sonar for fisheries in lakes and rivers"), and Bondarenko *et al.* These are further distinguished by the measurement conditions: the first four are controlled and the last two, field. Under "narrowband measurement" there is a single work: that by Kudryavtsev *et al.*

Classificatory techniques based on use of linear or quadratic discriminant functions are described by Vray *et al.* and Rose and Leggett, respectively. A mainstay of all current uses of acoustics, and in fact of all anticipated uses of acoustics in fisheries research, is catching, that is, classification by biological sampling. This theme, together with presentation of alternative or supplementary non-acoustic techniques, is vigorously taken up by Thorne.

### Edited discussion

*Paper by Kjærgaard et al.*, presented by Kjærgaard

[P. A. Skvorc] How is target strength defined over a long bandwidth?

A [= Author] This is defined by a set of normalized values which span the frequency range. The individual narrowband target strength is determined from the corresponding backscattering cross-section. This is the quotient of echo energy due to the fish and echo energy due to a reference target of known backscattering cross-section, when multiplied by the backscattering cross-section of the reference target.

[T. K. Stanton] The conversion efficiency of the parametric antenna used in the measurements is low. How useful is the parametric antenna in the field?

A For lack of practical experience I cannot answer this question. However, I would call attention to the work of Bondarenko *et al.*, who are beginning to use the system in practical applications. This work is described in the Symposium contribution: Bondarenko, V. M., Gavrilov, E. N., and Tarasov, S. P. "Use of parametric transducers for wideband measurements of fish target strength".

[P. N. Denbigh] Other systems can generate wideband signals. Why not use these?

A This was my feeling too when I began my work, but I encountered practical difficulties which convinced me of the superiority of the parametric antenna, at least for tank measurements.

[K. G. Foote] Will you or others in Denmark be continuing this work?

A No.

*Paper by Rose and Leggett*, presented by Rose

[P. Degnbol] This is a magnificent study. In your target-strength histograms in Figure 3 could there be a problem in the truncation of data below -56 dB?

A I cannot answer this. Frankly, I have little confidence in narrowband target-strength data.

- [T. Steig] How do you measure the mean distance between voltage peaks (PP) and like quantities?
- A I digitize the echo signals, put these on a spread sheet, and run a program to calculate those measures used in the quadratic discriminant functions.

*Paper by Simmonds and Armstrong, presented by Simmonds*

- [M. E. Zakharia] What are the classifying parameters? How is the standard deviation used in Figure 6 defined?

A The classifying parameters are the relative target-strength values in the eight frequency channels. Each of these is computed from the arithmetic mean of the corresponding power spectral value of 1000 transmissions or samples gathered over a six-minute interval. The standard deviation is that derived from the variance of many 1000-sample means.

- [P. A. Skvorc] The usual criterion for testing pattern recognition algorithms is that the testing data must be independent of the learning data. This seems to be violated in your study.

A In the present case it is felt that eight-point spectra based on 100 or 1000 samples, due to data gathered over 30-second or 6-minute intervals, respectively, are for testing purposes essentially independent of the reference spectrum. This is because the reference spectrum is formed from data collected over eight days.

- [A. Dyka] Is it not advantageous to use a parametric antenna or a short-pulse signal to generate a wideband spectrum?

A The general difficulty with the parametric antenna is the efficiency of parametric conversion, which is quite low. The problem with short pulses is their low energy level. In my opinion, the swept-frequency pulse is the superior method for getting wideband acoustic energy into the water.

- [R. Kieser] What is the likelihood of there being correlations in the data?

A Insofar as the engaged fish constitute ensembles of randomly moving targets, the data in adjacent frequency channels or in the same channels from ping to ping are not correlated.

- [P. N. Denbigh] Are the observed spectra caused by interference of echoes from multiple fish or are they due to individual fish?

A I do not doubt that the spectra are characteristic of the individual fish. I cannot believe that the spectra are due to school structure, because the same results are obtained for different densities of fish in the cage.

- [S. B. Brandt] The swimming behaviour of the fish must have been influenced by the cage. Do you believe that the present results can be applied to fish in the wild?

A Such an application would, of course, be premature. This work was designed as a preliminary investiga-

tion, to determine whether fish could, under any circumstance, be distinguished according to the frequency dependence of their target strength. If I may quote from the Conclusions in our paper: "The repeatability between experiments and over such long time periods with quite substantial changes in back-scattering strength indicates a high probability that fish in the wild will also exhibit distinct and repeatable spectra. These may not however correspond exactly to the spectra shown here."

*Paper by Skvorc, presented by the author*

- [A. Dyka] What was the time-bandwidth product? Did you implement a matched filter?

A The pulse duration was 1 ms, the bandwidth was 100 kHz, thus the time-bandwidth product was 100. Neither filter nor time-varied-gain was used.

- [K. G. Foote] What were the circumstances of fish measurement? Were measurements made on the same fish in different aspects?

A The fish were measured in a cylindrical tank of 1.7-m diameter and 7-m height. They were tethered singly, hence measured one at a time. Measurements were made at different aspects, but the whole measurement process was nightmarish. The reason is that small tugs on the fish harness or even bumps on the tank wall would cause profound changes in the echo signal.

- [R. S. Mitchell] How did the sampling frequency compare with the Nyquist rate?

A It was well beyond, being about 20 times greater.

*Paper by Thorne, presented by the author*  
There were no comments or questions.

*Paper by Vray et al., presented by M. E. Zakharia*

- [A. Dyka] In the described application to fish in Lake Annecy how do the authors know whether the echoes are due to coregonid or char?

A [= Zakharia] We must assume that the biologists were correct in their judgements.

- [G. A. Rose] Homogeneity of variance is an important condition for the present kind of analysis. Do you know whether this was tested?

A No.

- [K. G. Foote] Will this work be continuing?

A Yes, but also with the use of wideband or multiple frequencies.

- [S. C. Venema] Are the authors in contact with Azzali?

A Yes, they are. I note their citation of Azzali's work in their reference list.

*Paper by Zakharia ("Variations in fish target strength induced by movement: a wideband-impulse experiment"), presented by the author*

- [A. Dyka] In the case of narrowband signals, the limitation in discriminatory power is very definitely due

to the transducer. I also believe in some cases that the propagation part of the sonar equation cannot be known. What kind of signal did you use?

A [= Author] A rectangular pulse of 5  $\mu$ s duration.

[P. N. Denbigh] Dolphins can make decisions on the basis of a very small number of echoes, so they are probably not making use of statistical properties of echo signals.

A If you are referring to the NUSC work in Hawaii, then it should be noted that the subject dolphins are constrained and use 10–20 signals in a quite complicated sequence to identify objects. This is partly due to the dolphin's inability to move about, so as to observe the target from different aspects, and also to the requirement to classify stationary objects, which are usually uninteresting to dolphins.

[R. Kieser] Can you recommend a good reference on animal sonar signals?

A The NATO conference proceedings are the best source of such information. The proceedings from

the last conference, in Elsinore (Helsingør), Denmark, in September 1986, is to be published by Plenum Press.

*Paper by Zakharia* ("A prototype wideband sonar for fisheries in lakes and rivers"), presented by the author [A. Dyka] Is the processing output the envelope of the signal?

A No, it is the real signal. This is illustrated in Figure 2.

[A. Dyka] What is the attenuation in water as a function of frequency?

A I do not know.

[T. Sasakura] How much is the dynamic range limited by the CCD?

A Forty decibels in each direction. This is limited by the time-varied-gain. It should be noted that the dynamic range at the input is 120 dB, which is large.

[T. Sasakura] Who is the manufacturer of the CCD?

A EEG.