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SONAR MODELLING IN FISH ABUNDANCE MEASUREMENT

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INTRODUCTION

For some years estimates of fish abundance have been made using the output of an echo-sounder system. By considering the integrated energy of the echo of a shoal and with knowledge of the sonar parameters and the target strength of the species of fish involved, a crude estimate of the biomass can be made. Some years ago one of the present authors published some work in which a computer model of a typical sonar system was used to try to evaluate the accuracy with which the number of targets could be estimated from the integrated energy [1]. However the model used was fairly simple and did not take into account some important effects such as the directivity of the target strength of the fish which may have a significant effect on the estimates. The present work is an attempt to modify the computer model by considering these factors and to try to approach more nearly the practical situation.

BRIEF DESCRIPTION OF MODEL

In reference [1] it is shown that the output of a simple echo-sounder can be represented by the convolution of two functions.

$$v(R) = \Sigma\ h(R)*Ti(Ri)$$

where h(R) is the transmitted pulse shape, Ri is the range of the ith target and Ti is its amplitude taking into account a number of factors which include propagation losses, the target strength of the fish, the sensitivity of the receiver and the position of the target in the beam etc. It should be noted that the output waveform of the echo-sounder receiver is expressed as a function of range rather than time, since the signal is normally displayed using range (depth) as the variable in an echo-sounder.

Ti will not in general be constant from pulse to pulse because of the variability of the many factors which contribute to its magnitude. One of the major factors will be due to the movement of the fish itself. Many published papers have shown that the target strength of a fish depends strongly on the orientation of the fish as well as on its size and on the frequency of the acoustic signal. In the earlier modelling work referred to it was assumed that the target strength of the fish varied according to an arbitrary probability distribution and for simplicity the Gaussian distribution was chosen. This paper takes a closer look at this choice.

The orientation of the fish will include tilt, roll and pitch, but when the fish is viewed in the dorsal aspect it has been shown that the significant factor is the tilt angle [2[. In reference [3[it is shown that the shape of this curve varies considerably with species but as might be expected there is a strong inverse correlation between the width of this function and the length of the fish. In fact the curves are not unlike those that might be expected from a crude approximation of a fish as a reflector of an appropriate length.

To make an estimate of the effect of the dependence of target strength on angle on the probability distribution of target strength, it is necessary also to know or to assume the probability distribution that represents the way in which the tilt angle will vary in practice. In reference [4] measurements are reported on different species and it is shown that this distribution is close to normal. Using these two functions it is then possible to predict the probability distribution for the variation of the target strength and hence to calculate the effect of this probability distribution on the estimation of biomass.

RESULTS AND DISCUSSION

In our model we have assumed, again for simplicity, either a uniform or a normal distribution for the probability distribution of tilt angle and one of the two functions shown in Fig. 1 for the variation of target strength with tilt angle. These curves are not unlike the measured curves and represent two different fish lengths. It is fairly clear from the nature of the problem that the distribution of target strength of the fish derived from these curves will not be symmetrical and indeed we see in Fig. 2 that this is so. This shows a set of distributions calculated using simulation for each of the four conditions discussed above and for four different angles of tilt in each case. When the mean angle of tilt of the fish is not zero then the possibility of a double moded distribution arises and this can be seen clearly in the figures.

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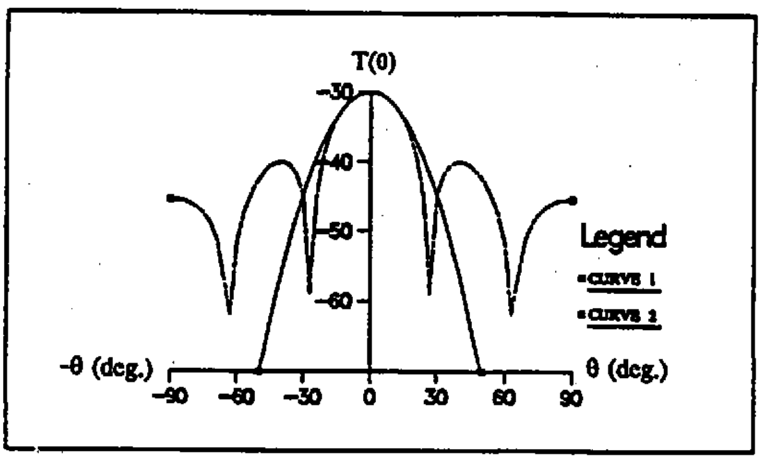

FIG. 1. Distributions of target strength versus angle assumed in model.

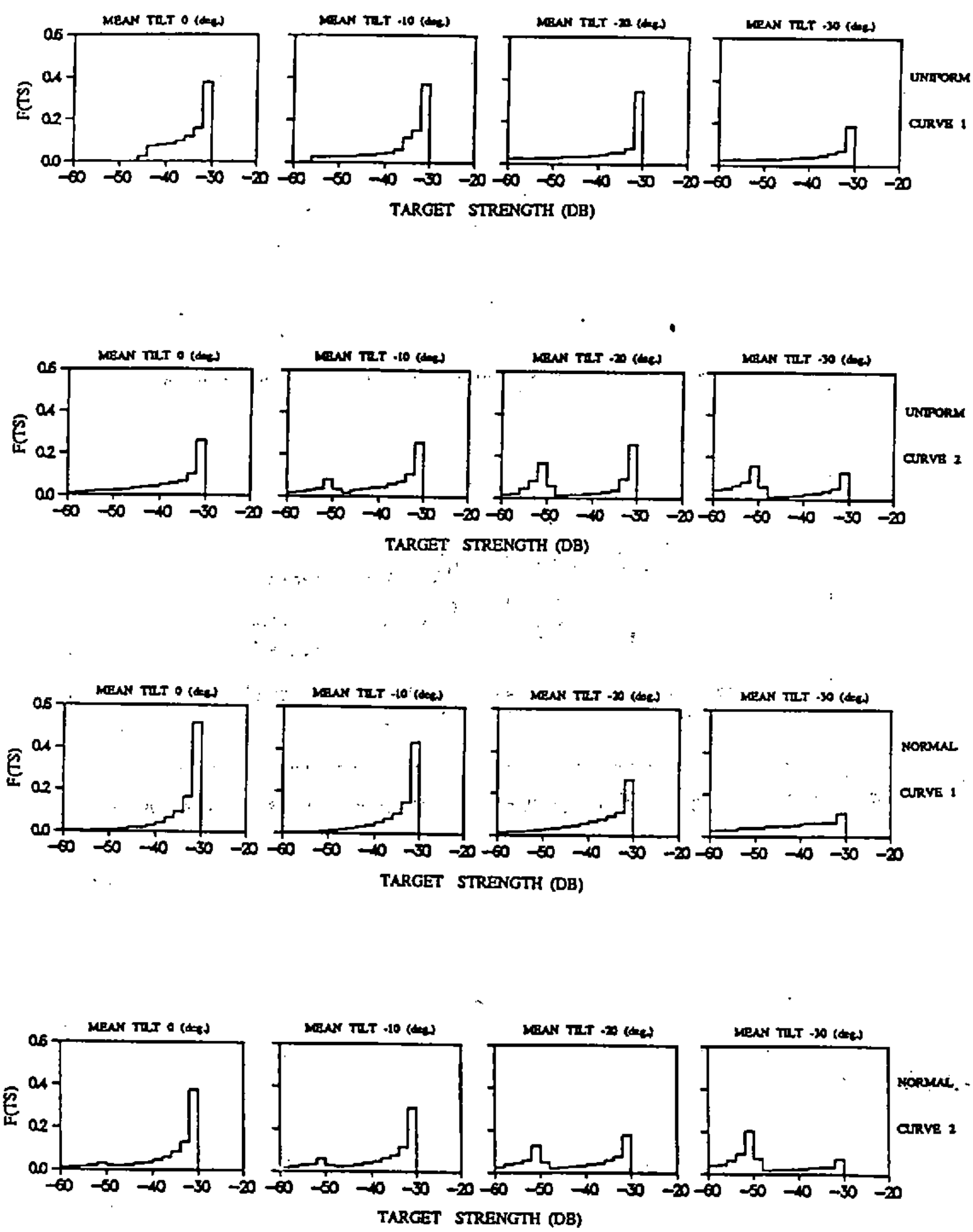

FIG. 2. Probability distributions for the target strength of the fish obtained from the model with various assumptions.