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IN SITU TARGET STRENGTH OBSERVATIONS ON HADDOCK

by

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ABSTRACT

In situ target strength measurements of ideally resolved haddock have been made using the ES-400 split-beam echo sounder. The measurements are compared with the mean target strength obtained simultaneously by counting/integration. Within the estimated confidence limits of the observation volume in the counting method the two estimates of mean target strength agreed, both being about 4 dB above the currently applied mean target strength of gadoids.

INTRODUCTION

Knowledge of the scattering properties of fish is needed to obtain absolute acoustic abundance estimates. Earlier, such information was obtained through experimental single fish measurements, counting, cage calibration and statistical beam pattern correction of amplitude data. A general review of the results from these methods has been made by MIDTTUN (1984).

The most realistic estimates of mean target strength are made *in situ* using dual- or split-beam systems. In these, the beam pattern corrections are made directly on each echo on the basis of its measured position (EHRENBERG 1974, 1979).

The currently applied target strength relation on gadoids used in stock assessment in Norway is derived both from experimental work on single fish and from count-calibrations (DALEN and NAKKEN 1983). These are significantly lower than the values obtained with the split-beam system (FOOTE et al. 1985). In this report the split-beam measurements are compared with simultaneous count calibrations on ideally resolved haddock.

MATERIAL AND METHODS

The measurements were made in Varanger, a large fjord in north Norway, on April 26, 1986. A large pelagic layer of haddock, extending from the fjord-shelf at about 100 m depth, covered most of the central parts of the fjord over a bottom depth of more than 300 m. The pelagic channel of the SIMRAD ES-400 split-beam echo sounder was opened over the main body of the layer, 75-150 m, and the target strength window was operated in both upper -44/-14 dB and lower -56/-26 dB modes during the measurements.

Estimates of mean target strength are made on the basis of the target strength distributions produced directly by the echo sounder itself over distances of 0.5 nautical miles. From an on-axis sphere calibration and corrections for non-ideal beam compensation according to MACLENNAN and SVELLINGEN (1986) on this specific transducer, the overall accuracy of mean target strength is correct to within ±1.0 dB.

Target strength from counting/integration

During the target strength measurements, the integrator was connected to the EK-400, working on the summed signal output from the ES-400 reciever. Parallel recordings with EK-400/120 kHz on 40 logR TVG were also made to determine the counting observation volume.

Using the integrator output, the area density of fish can be estimated as:

$$\rho_A = \frac{1}{\langle\sigma\rangle} C_I \cdot M$$

where $\langle\sigma\rangle$ = average back scattering cross section of the observed fish

C_I = instrument constant specifying equipment performance (FOOTE et al. 1986)

When the instrument constant is included in the integrator output, the area density is

$$\rho_A = M_a / \langle\sigma\rangle \quad .$$

Within a specific depth layer, area density can also be estimated by counting (MIDTTUN & NAKKEN 1971):

$$\rho_A = N_c / A_c \quad ,$$

where N_c is the number of echo traces and A_c is the mean observed area in the counted depth layer.

Combining the two methods gives

$$\frac{M_a}{\langle\sigma\rangle} = \frac{N_c}{A_c} \quad ,$$

or

$$\langle TS\rangle = 10 \log \left[\frac{M_a \cdot A_c}{N_c \cdot 4\Pi}\right] .$$

Thus, when the instrument performance can be isolated, direct estimates of mean target strength can be made by the counting method. The parameter containing most of the uncertainty in this equation is the area sampled by counting, A_c. However, if this is estimated from the monitor of the ES-400, or from its colour echograms, the area is determined by the exact cutoff angle of the echosounder, 5 degrees.

During this investigation, the colour printer was not available, and the sampled area is determined using trace length and threshold considerations. From the maximum trace length recordings in the for and aft direction, the observation angle was determined to be $7^{o}\pm0.5^{o}$. Assuming circular directivity of the transducer, the observation volume used in the calculations is given in Table 1.

Using the instrument performance and applied threshold on the integrator, Table 1, the observation volume can be estimated from the directivity diagrams of the transducer. According to AGLEN (1982), the threshold position of a fish with given target strength can be calculated on the basis of the instrument parameters from

$$20\log b(\theta)=20\log R-(SL+VR)-G+20\log R(u)+2\alpha R(u)-TS+20\log U_{rms}$$

where symbols are defined in Table 1.

Using the calibration results and instrument performance from Table 1 , it is seen that a typical large target with target strength of -30 dB will be detected as far as 25 dB off the acoustic axis at 100 meters depth. A target corresponding to TS = -55 dB is then detected only on the acoustic axis at this depth. Using the specific directivity pattern for this transducer, the detection angle of the observed haddock is estimated to be $7.3^{o} \pm 0.2^{o}$. At the applied receiver gain settings, the larger targets were actually weakly detected at the latter part of the trace, down into the first side lobe of the beam, at approximately -28 dB. This is because the transducer is fitted approximately 1.5^{o} in the fore direction to avoid turbulence on the transducer surface.

Sampling

Two pelagic trawl hauls with the 16x16 fathoms capelin trawl gave a pure catch of haddock with a mean length of 43.8 ±4.2 cm.

RESULTS

A typical example of the haddock registrations is shown in Fig. 1, with the corresponding target strength distribution measured by the ES-400 in the depth layer 50-150 m in Fig. 2. As the alternative target strength window, covering the range from -44 to -14 dB showed that less than 0.1% of the targets were recorded in the cell -26.0 to -24.5 dB, only observations obtained using the lower scale, covering the range indicated in Fig. 2, were used in the calculations of mean target strength. A clear grouping around the target strength -32 dB is seen, with no significant threshold in the lower part of the distribution.

As the echo sounder was operated in log mode, the actual number of targets in each distribution is not known. From trace counting, and the number of echoes in each trace, the number in each of the 12 used distributions is estimated to be 2000-3000. The number of echoes measured in the pooled distribuiton, Fig. 3, is then between 24000 and 36000.

The results from the comparison between split-beam target strength and target strength estimated by counting/integration is summarized in Table 2. Over a distance of 15 nautical miles, the mean target strength estimated by the split-beam echo sounder varied from -33.5 dB to -36.1 dB, with a pooled mean value of -35.1 dB. The mean target strength estimated from counting/integration over the same distance varied from -32.6 dB to -37.3 dB, with a mean value for all observations of -34.9 dB. The difference between the two estimates is well within the estimated confidence limits in both methods.

DISCUSSION

The split-beam measurements on ideally resolved haddock fully agrees with methods earlier used to establish the conversion factors from integrated echo intensity to fish density. During these measurements, the conditions for both target strength measurements and counting were nearly ideal. The significant part of the target strength distribution fitted well the dynamic range of the lower mode of the split-beam system, and no threshold or cutoff effects of any importance were observed. These effects may otherwise be a limiting factor for target strength measurements, especially on small fish (ONA and RØTTINGEN 1986).

In estimating the accuracy of the split-beam measurements, it is necessary to consider both the on-axis calibration accuracy and the non-ideal beam compensation of the echoes (MACLENNAN and SVELLINGEN 1986). On R/V "ELDJARN" the on-axis calibration is performed during the general calibration of the integrator system, and the sphere target strength is adjusted to the nearest 1.5 dB cell on the ES-400 monitor. As the copper sphere has a target strength of -33.7 dB at 38 kHz, a calibration accuracy well within ±0.5 dB is obtained by adjusting the sphere echo to a level where a small portion of the echoes appears in the -33.5/-32.0 cell, while the larger part of the echoes still is within the cell below (I. SVELLINGEN, pers. comm.). A higher accuracy can be obtained if the serial line of the echo sounder is logged by a computer. This was not available during this investigation.

The overall effect of non-ideal beam compensation is measured to be less than 0.5 dB on the transducer mounted on R/V "ELDJARN". Total accuracy of the target strength measurements using this system is therefore estimated to be better than ±1.0 dB.

The overall confidence limits of the counting methods must be wider because of the difficulties in exact determination of the sampling volume. The signal-to-noise ratio is high enough for the fish to be detected over the significant part of the beam, and the actual observation volume is therefore relatively insensitive towards target strength variations. The assumed observation angle of $7.0^{\circ}\pm0.5^{\circ}$ is a mean value obtained using trace length measurements on 38 kHz/20 log R, and 120 kHz/40 log R, combined with the threshold estimates described earlier. In order not to exaggerate the precision of the estimates of target strength in this method, a ±2 dB confidence limit is felt to be appropriate (Fig. 4). Use of the colour echograms under similar conditions will increase the precision of this method.

Using the obtained mean length of the haddock, and adjusting the mean target strengths to the commonly used 20 log L dependence, gives a target strength relation of

$$TS = 20 \log L - 67.9$$

for the split-beam measurements, and 0.2 dB higher for the count calibration. This is 4.0 dB higher than the currently applied target strength for this size of gadoids in Norway, but in full agreement with other split-beam measurements on gadoids (FOOTE et al. 1985).

In this report, the split-beam measurements are also checked against the method originally used to obtain the gadoid target strength relation, and found to be in full agreement with this.

The only difference is that the instrument constant can now be isolated with a higher degree of accuracy than earlier, when hydrophone calibrations were commonly used to measure the instrument performance (FORBES and NAKKEN 1972). Differences in threshold between the integrator systems may also acount for some of the observed discrepancy. One factor which may be an extremely important one, especially for gadoids, is the representativity of the catch. Using trawls as sampling devices, there is always a chance of having a biased mean length and species composition compared to what is observed with the echo sounder (ONA and CHRUICKSHANK 1986). This may be the source introducing most of the variability in target strength measurements in the future.

CONCLUSIONS

Comparable <u>in situ</u> target strength observations are obtained with split-beam echo sounder and counting/integration.

The findings support new split-beam measurements on gadoids.

The difference between the currently used target strength on gadoids in Norway and the observed values is 4.0 dB.

Increased precision in the counting method can be achieved by more exact determination of the counted sampling volume, for instance by the use of echograms from the ES-400 echo sounder.

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Table 1. Symbols, equipment settings and performance used in the text.

Symbol	explanation, setting and performance
$b(\theta)$	directivety pattern function of the beam
G	attenuator setting (-10 dB)
SL+VR	sum of source level and voltage respons (136.0 dB)
R(u)	range where the TVG correction is expired (580 m)
U_{rms}	applied treshold on the integrator (20 mV)
A_c	mean observation area within a depth layer in the counting method ($7.0^\circ \pm 0.5^\circ$). [Mean depth of the layer is corrected for the mean vertical fish distribution in the layer]

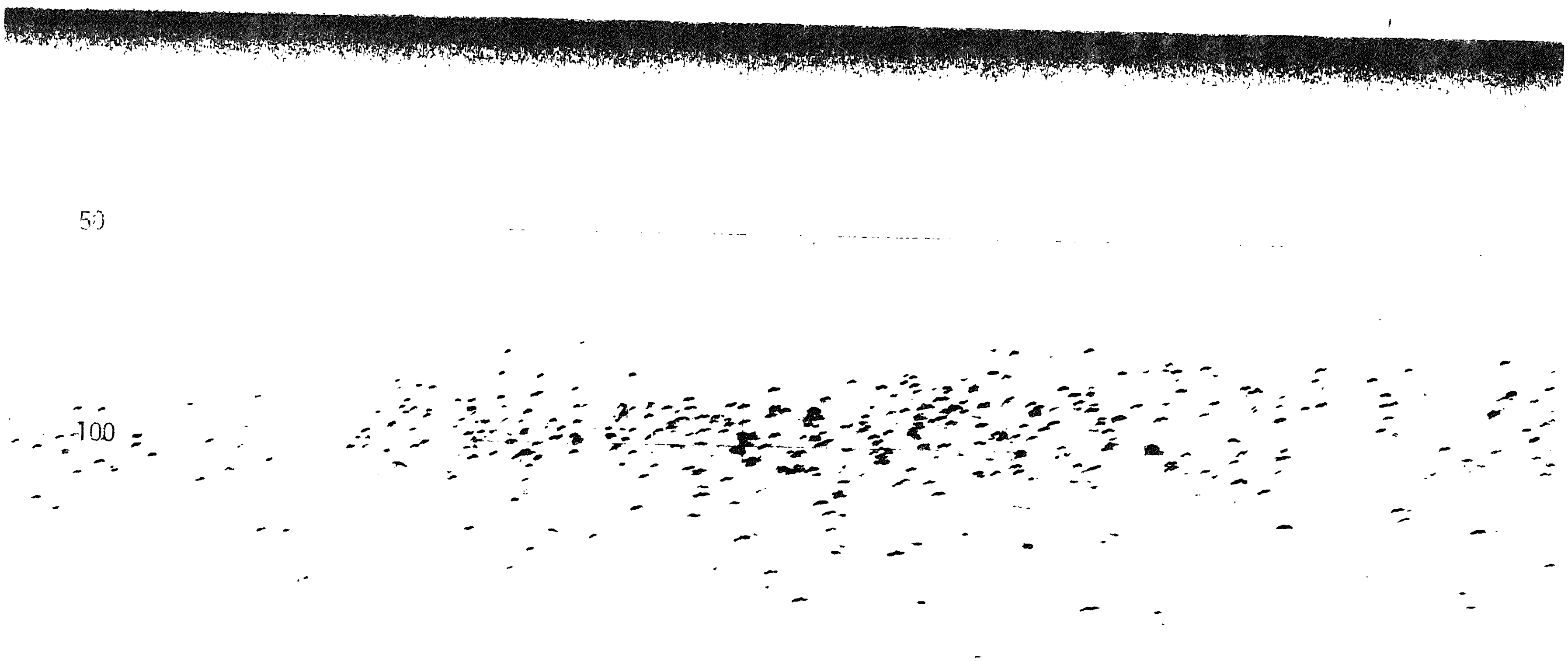

Fig.1. A typical example of the registrations used in the analysis. Clean, dispersed haddock.
Bottom depth, 350 m.

Table 2. Results from split-beam and counting measurements.

log no.	speed [knots]	$\langle TS \rangle$ ES400 [dB]	COUNTING METHOD CHANNEL I M_A	N_c	$\langle TS_c \rangle$	CHANNEL II M_A	N_c	$\langle TS_c \rangle$
136.0-137.0	3.0	-33.5	51	138	-35.3	299	666	-32.3
137.5-138-0	3.0	-35.7	28	62	-34.5	73	180	-32.7
144.0-144.5	3.0	-33.4/-33.8	90	208	-34.7	59	166	-33.3
149.5-150.0	3.5	-36.0	29	110	-36.8	22	124	-36.3
150.0-150.5	3.5	-36.1	27	125	-37.3	34	163	-35.6
152.0-153.0	4.0	-36.0/-36.1	- NC					
153.0-154.0	9.0	-35.6/-35.8	- NC					
154.0-155.0	9.0	-35.5/-34.8	- NC					
		* -35.1	** Mean M_A/N_C = 0.357, SE = 0.021; Mean TS_C = - 34.9					

* Mean value over 24000-36000 individiual TS measurementh from ES-400

** Mean value from 4503 counted traces

NC -not counted, sligtly too high density for counting

CHANNEL I 50-100m, CHANNEL II 100-150 m

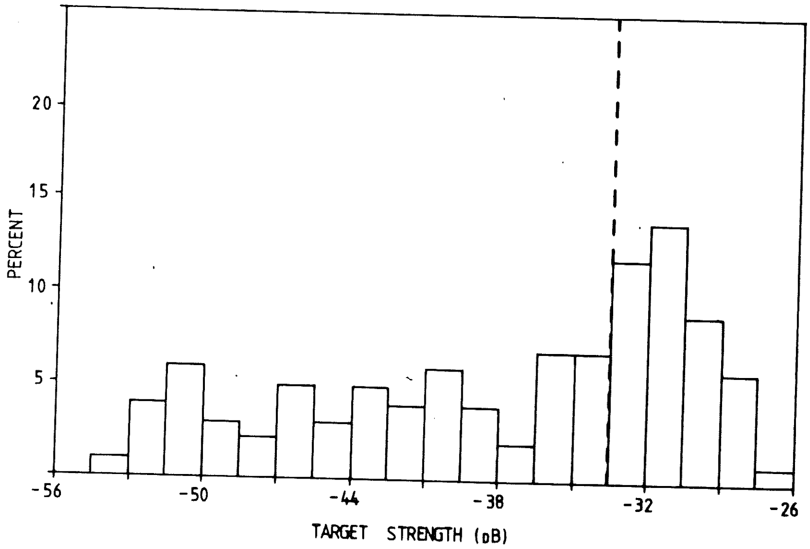

Fig.2. Example of a target strength distribution containing about 2000 - 3000 echoes. Average target strength is indicated by the stipled line.

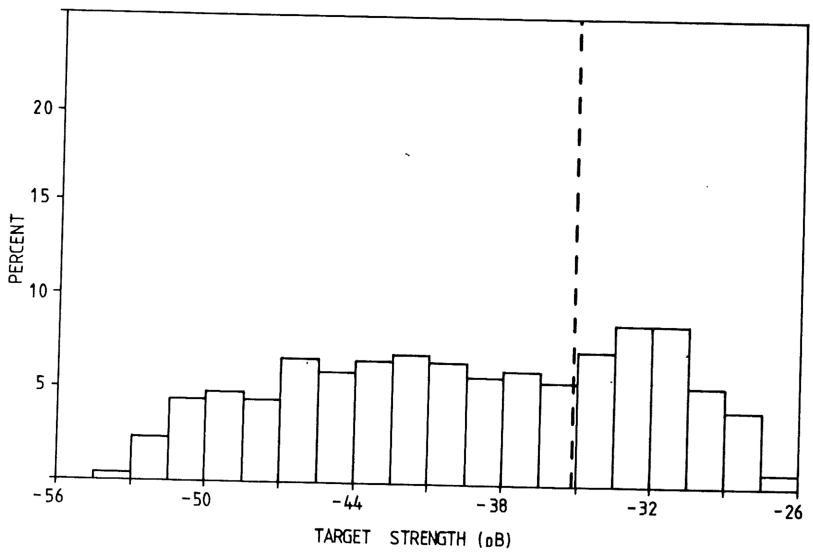

Fig.3. Target strength distribution of all observations using the lower TS window of the ES-400, containing 24000 - 36000 echoes.

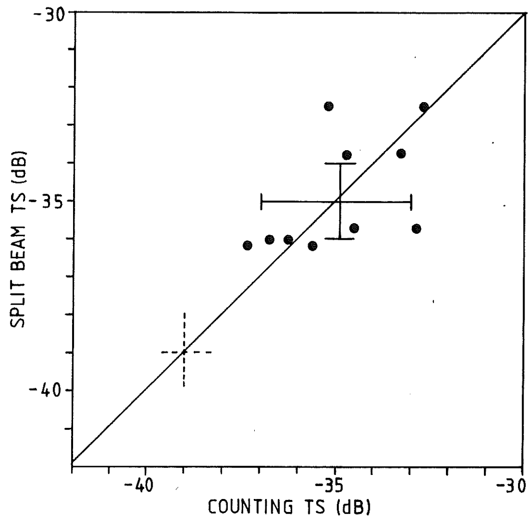

Fig.4. Comparison of split-beam target strength and simultaneous observations of counted target strength. Confidence limits for the two methods, and currently applied target strength of haddock of this length (stipled) is shown.