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Target strength measurements and C-values determinations of live Skagerrak herring and cod

by

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Abstract

This paper presents measurements of the target strength per kilogram of live caged herring and cod. It describes the experimental method employed and measurements of a table tennis ball as a reference target. The target strength per kilogram for herring with a mean length of 23.7 cm was found to be -38.3 dB. The result is compared with other TS-values reported and the differences are discussed.

The divergence between actual hydrographic conditions in Swedish waters and the built in compensation for sound absorption and velocity in the Time Variated Gain Amplifier is reported. The need for frequent calibrations and adopted TVG amplifiers is stressed.

INTRODUCTION

To establish the conversion factor C in the equation

$$D = C \times M + b \qquad (1)$$

where

D = Fish density in weight per unit area

C = Conversion factor

M = Integrator output per nautical mile (NM)

b = correction factor

measurements on caged live herring and cod were performed. The experiments were initiated by the radical change in performance data of the equipment of the Swedish R/V "Argos" (Simrad 120 kHz echo sounder EK 120 S and Simrad QM MK II). The hull mounted transducer (ceramic, 120 kHz, 10°, ITC) was also replaced 1980-09-05. The change in important performance data is shown in table 1. Since no calibration was made in connection with the determinations of C in 1978 (Hagström et al, 1979; Håkansson et al, 1979) these values of C no longer have any significance.

The value of C is a function of fish target strength, calibration constants, settings of the equipment and hydrographic factors such as sound velocity and attenuation in water:

$$10\ \lg C = -\overline{TS}_{kg} - 10\ \lg\Psi - (SL + VR) + (20\ \lg R_o + 2\,\alpha\,R_o) - 10\ \lg\frac{C\tau}{2} + V_o - A \qquad (2)$$

where

$\overline{TS}_{kg}$ = mean target strength per kilogram of fish

$10\ \lg\Psi$ = correction term for the beam pattern of the transducer in use (Ψ = equivalent transducer beam width)

SL = Source level (dB// 1 µbar ref. 1 m)

VR = Recieving voltage response (dB// IV per µbar)

R_o = Maximum TVG-range (m)

α = Absorption coefficient (dB/m)

c = Sound velocity (m/s)

τ = Pulse duration (sec)

V_o = The average value of the input signals to the integrator that gives 1 mm integrator deflection at 0dB gain in a 1 m interval (dB//IV)

A = Echo integrator gain setting

Using the calibration data from 1980-09-05 the equation can be expressed as

$$10 \lg C = - \overline{TS}_{kg} - 48.8 - A$$

There are several methods of measuring target strength (Goddard and Welsby, 1977; Johannesson and Losse, 1977; Nakken and Olsen, 1977; Hagström et al, 1979). The method used in our experiments resembles those used by Johannesson and Losse (1977) and Edwards (1975) and has been adopted to the conditions on R/V "Argos".

MATERIALS AND METHODS

The live fish was placed in a cylindric cage of 3.0 m in diameter and 3.0 m of depth. The two frames were made of massive 13 mm ø steel and the netting of 21 mm mesh knotted 0.17 mm monofilament nylon (fig. 1).

The cage was placed at such a distance from the transducer that the frames and the netting should give minimum background values according to the transducer beam pattern, i.e. the upper frame of the cage was 4 m from the transducer. A diver helped to centrate the cage and made observations of the fish during the experiments. Under these circumstances the main lobe of the transducer was almost entirely within the cage (fig. 2).

In the first experiment 17 cods were placed in the cage. However, the cod refused to cooperate and gathered itself peripheral at the upper frame of the cage. In experiment No. 2, 15 cod was in the experimental cage (mean weight = 0.709 kg). During the first part of this experiment the cod seemed to distribute itself not uniformily, but during the last 7.5 hours the fish, as observed on the oscilloscope, appeared to have a more random vertical distribution. These latter values were used for target strength estimate. At the end of the experiment two cods had escaped from the cage so a mean of 14 cods was used for the calculations. All measurements on cod were performed with the cage included.

In experiment No. 3 one hundred herrings were placed in the cage. The herring had a mean length of 23.7 cm and a mean weight of 0.112 kg. The vertical distribution seemed to be random according to oscilloscope observations. At the end of the experiment 11 herrings had died so a mean of 95 herrings was used for the calculations for channel B, which covered an interval of 1 m within the cage and 100 herrings for channel A, which covered the whole cage. The herring was integrated over 4.5 hours. One experiment on herring failed due to bad weather. As reference and for calibration a table tennis ball (Stiga) was used. The ball was attached to 0.5 mm monofilament nylon cord by Araldite. The nylon cord was fixed in the middle of a 4 m long rod so that the table tennis ball was two meters over this rod. The table tennis ball was placed in the acoustic axis at 5.7 m distance from the transducer. The settings of the equipment during the fish experiments are shown in table 2 and of the table tennis ball calibrations in table 3.

RESULTS

At the setting 20 lgR+0dB 1/1 effect the target strength of the table tennis ball was determined to -42.2 dB, when SL + VR = 117.3 dB was assumed. The conditions were stable with less than 10 % variation in U_p (peak voltage) from ping to ping. Table 3 shows the sum (SL + VR) at various settings if one assume a target strength of -42 dB of the table tennis ball.

The background values of the empty cage when integrated completely were determined to 7.1 mm integrator deflection S.D. 1.1 on channel A and 8.2 mm, S.D. 1.1 on channel B, both values referred to the settings: 20 lgR + OdB, 1/10 effect, Integrator gain OdB x 10, thresh. = 0.

The experiments on cod gave a result of

Channel A: $\overline{TS}_{kg} = -36.9$ dB C = 2.24 tonnes/NM^2 and mm/NM

Channel B: $\overline{TS}_{kg} = -36.5$ dB C = 2.07 tonnes/NM^2 and mm/NM

The mean length of the cod was 41.25 cm. The variation in integrator deflection per NM for cod is shown in fig. 3.

The average of channel A and B gives

$\overline{TS}_{kg}$ = -10 log L - 20.6 dB and

C = 0.052 x L tonnes/NM^2 and mm/NM (L is fish length in cm) backscattering cross-section per unit weight is assumed to be inversely proportional to fish length.

In experiment No. 3 on herring, channel B integrated a one meter interval in the middle of the cage and channel A integrated an interval covering the whole cage. The contribution from the cage in channel B could be neglected. The variation in integrator deflection per NM is shown in Fig. 4. The experiment on herring gave a result of

Channel A: $\overline{TS}_{kg}$ = - 38.7 dB, C = 3.35 tonnes/NM^2 and mm/NM

Channel B: $\overline{TS}_{kg}$ = - 38.3 dB, C = 3.04 tonnes/NM^2 and mm/NM

The mean length of the herring was 23.7 cm.

The average of channel A and B gives

$\overline{TS}_{kg}$ = - 10 log L - 24.8 dB and

C = 0.135 x L tonnes/NM^2 and mm/NM

when the backscattering cross-section per unit weight is assumed to be inversely proportional to fish length.

DISCUSSION

Since the behaviour of the cod was not favourable for the measurements, the results will not be discussed until further experiments have been performed.

In the herring experiment the two integrator channels gave different results. However, we assume that channel B, which integrated an interval in the middle of the cage, is more accurate. This channel was less influenced by the cage and the integrated herring was swimming freely and no dying or dead herring on the bottom or at the roof of the cage was included. Consequently, we use the channel B values in the discussion and for further calculations.

Edwards (1980) reports that the target strength per kg of herring in the size group 21-25 cm is -31.5 dB. Our results differ a great deal from Edwards. The result could also be compared with the -34 dB commonly used in estimating herring abundance. It is not likely, that the difference in frequence (120 and 38 kHz) could explain the large discrepancy.

Nakken and Olsen (1977) have shown that small changes in the tilt angle cause large changes in the target strength. One possible explanation could therefore be the mean tilt angle differ in the two experiments. Our experiment was carried out in a comparatively short time period and if the herring had not time to acclimatize, another tilt angle could be established. On the other hand neither of the results could claim that they represent the "normal" situation along acoustic survey. As Olsen (1979) has pointed out herring react to ship passage by diving and the tilt angle could be quite different from that in a cage after acclimatization.

Unfortunately too little behaviour observations were made during the experiment. Therefore we do not know what kind of tilt angle distribution the observed results do represent. In fact we do not even know if the fish was randomly distributed horisontally. Therefore the determined $\overline{\overline{TS}}_{kg}$ is highly uncertain. However, the resulting C-value seems to be comparable to the C-values assumed at earlier surveys with R/V "Argos". When the determined $\overline{\overline{TS}}_{kg}$ is used to calculate C-values corresponding to earlier calibrations the results are

	Factor $\left(\frac{C}{C_{1980}}\right)$	C-value
1979-11-29	6.87 = 8.37 dB	20.9
1976-04-27	2.29 = 3.60 dB	7.0

There is 4.77 dB difference in the (SL + VR) between the calibrations in 1979 and 1976. To make a rough estimate of the C-values at earlier surveys, one can assume that the (SL + VR) has decreased with 0.111 dB/month during the 43 months between the two calibrations. The assumption will give the following values of (SL + VR) and recalculated values of C if the results of the present experiments on herring are used.

	Months from calibr. 1976	(SL + VR)	Δ (SL + VR) ref. 1980-09-05	C-value
June 1976	2	113.48	3.82	7.3
Sept 1976	5	113.14	4.16	7.9
Febr 1977	10	112.59	4.71	8.9
April 1978	24	111.04	6.26	12.8
Sept 1979	41	109.15	8.15	19.8
Aug 1980	52	107.93	9.37	26.3

In Hagström et al. 1979 and Anon. 1980 a C-value of 15 tonnes/NM^2 and mm/NM was used. According to the above assumptions this value might have been reasonable in the summer or autumn 1978 but rather low in September 1979 and August 1980.

An important problem in Swedish waters is the divergence between the actual hydrographic conditions and the built in compensation for sound absorption (α) and velocity (c) in the Simrad TVG amplifier. Simrad compensates for α = 0.045 dB/m and c = 1 500 m/s. The difference could, according to equation (2) be expressed as

$$H = 2\ R\ (\alpha - \alpha_a) - 10\ \lg \frac{C \times \tau}{2} - 10\ \lg \frac{Ca \times \tau}{2} \qquad (3)$$

where

H = Difference in dB between Simrad compensation and actual conditions

R = Distance between transducer and target (m)

α = Simrad compensation for sound absorption (dB/m)

α_a = Actual sound absorption in water (dB/m)

C = Simrad compensation for sound velocity (m/s)

C_a = Actual sound velocity in the water (m/s)

T = Pulse length (s)

If we assume that in Skagerrak and Kattegat

α_a = 0.032 dB/m and C_a = 1 487 m/s (salinity 30 ‰ temperature 10^0C)

and in the Baltic

α_a = 0.013 and C_a = 1 456 m/s (salinity 9 ‰ temperature 9^0C)

Depth (m)	H (Skagerrak and Kattegat) dB	Factor	H (Baltic) dB	Factor
20	0.48	1.12	1.15	1.30
40	1.00	1.26	2.43	1.75
60	1.52	1.42	3.71	2.35
80	2.04	1.60	4.99	3.15
100	2.56	1.80	6.27	4.23

The values of α_a and C_a are taken from Foote (in press) and Fisher & Simmons (1977).

This means that the TVG amplifier overcompensates and that the integrated values are higher than what they should have been when integrating in Swedish waters, especially in the Baltic proper.

The discussion above strongly stresses the need for frequent calibrations and TVG amplifiers adopted to the actual hydrographic conditions.

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SUMMARY

This paper presents measurements of the target strength per kilogram of live caged herring and cod. It describes the experimental method employed and measurements of a table tennis ball as a reference target. The target strength per kilogram for herring with a mean length of 23.7 cm was found to be -38.3 dB. The result is compared with other TS-values reported and the differences are discussed.

The divergence between actual hydrographic conditions in Swedish waters and the built in compensation for sound absorption and velocity in the Time Variated Gain Amplifier is reported. The need for frequent calibrations and adopted TVG amplifiers is stressed.

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Table 1. Calibration data

Date of calibration	SL dB// 1 µbar ref. (m) 1/1 eff.	1/10 eff.	VR dB// 1 volt per µbar 1/1 eff.	SL + VR (dB) 1/1 eff.	1/10 eff.
1976-04-27	116.9	107.7	-3.2	113.7	104.5
1979-11-29	116.7	107.1	-7.77	108.93	99.33
1980-09-05	122	113	-4.7	117.3	108.3

Table 2. Settings of equipment during fish experiments and empty cage measurements

Echosounder Simrad EK 120 S		
Output power	1/10	
Band width and pulse length	3 kHz, 0.6 ms	
TVG and gain	20 lgR + 0dB	
Discriminator	0	
Recorder gain	2	
Echo integrator QM MK II	Channel A	Channel B
Gain	0dB	0dB
Display setting	10	10
Threshold	0	0
Interval (cod experiment)	4-8 m	4-8 m
Interval (herring experiment)	4-8 m	5-6 m
Bottom stop	off	off

A speed of 12 knots was set on the ships log

Table 3. Calibrations with table tennis ball and settings of the equipment

$\overline{TS}_{ref}$ = -42 dB

R/V "Argos" Sept. 16 1980

Sounder: EK 120 S
ransducer: ITC 120 kHz, 10 cm diameter

Distance transducer - table tennis ball:

R = 5.7 m, 20 log R = 15.1 dB

Variations in U_p less than 10 % from ping to ping

	1/1 Power 20 log R 0dB	1/1 Power 20 log R -20 dB	1/1 Power 40 log R 0dB	1/1 Power 40 log R -20 dB	1/10 Power 20 log R 0dB	1/10 Power 40 log R 0dB
U_p (cal. output)	5.0 V	0.44 V	0.34 V	0.0335 V	1.9 B	0.13 V
SL + VR	117.1	117.0	118.6	119.5	108.7	110.3

Integral per N. Mile = 53 mm at 0dB x 10, threshold 0
1/1 Power, 20 log R 0dB, 12 knots

Sounding = 10.5 mm

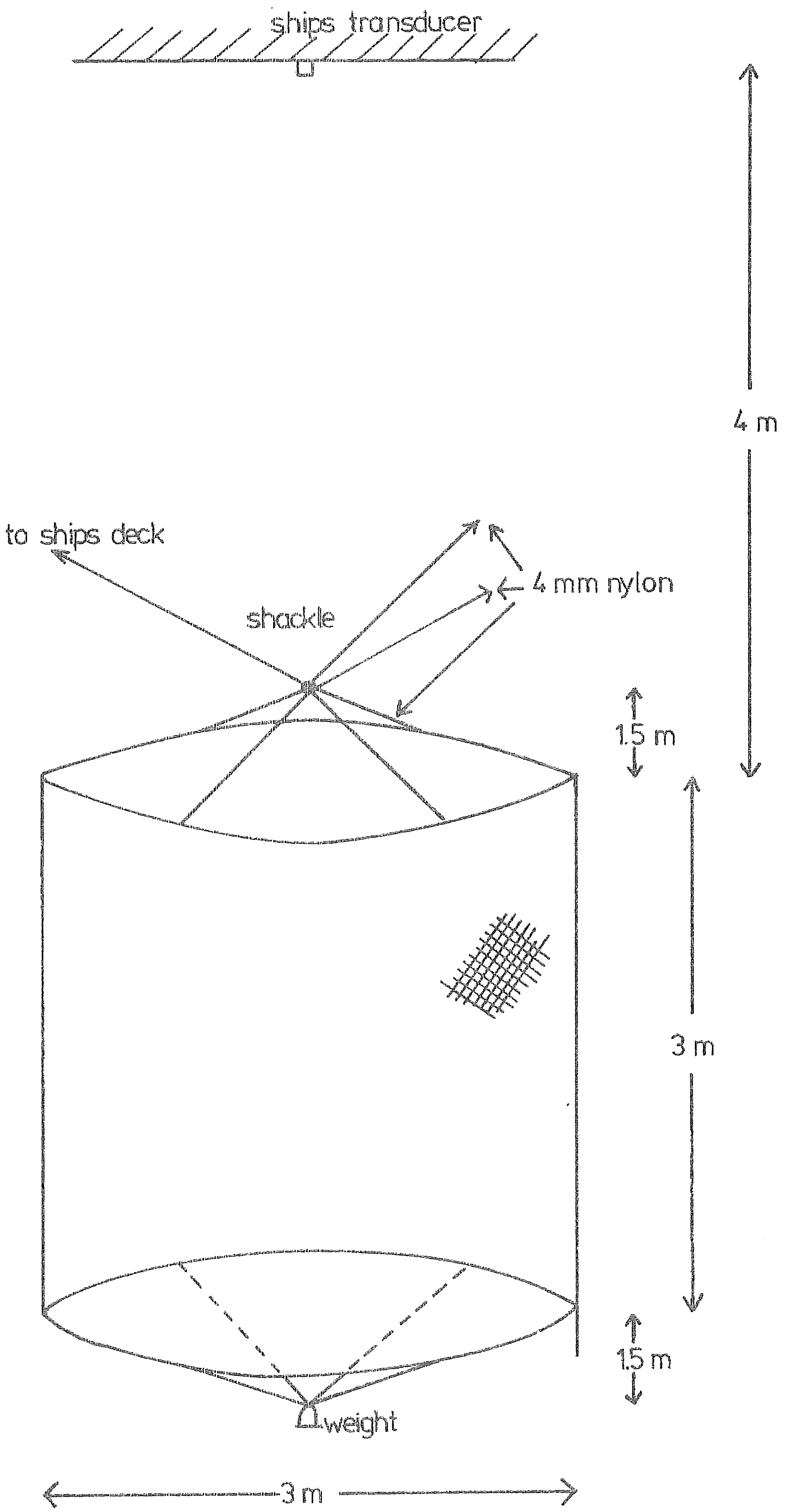


Fig. 1. Experimental cage.

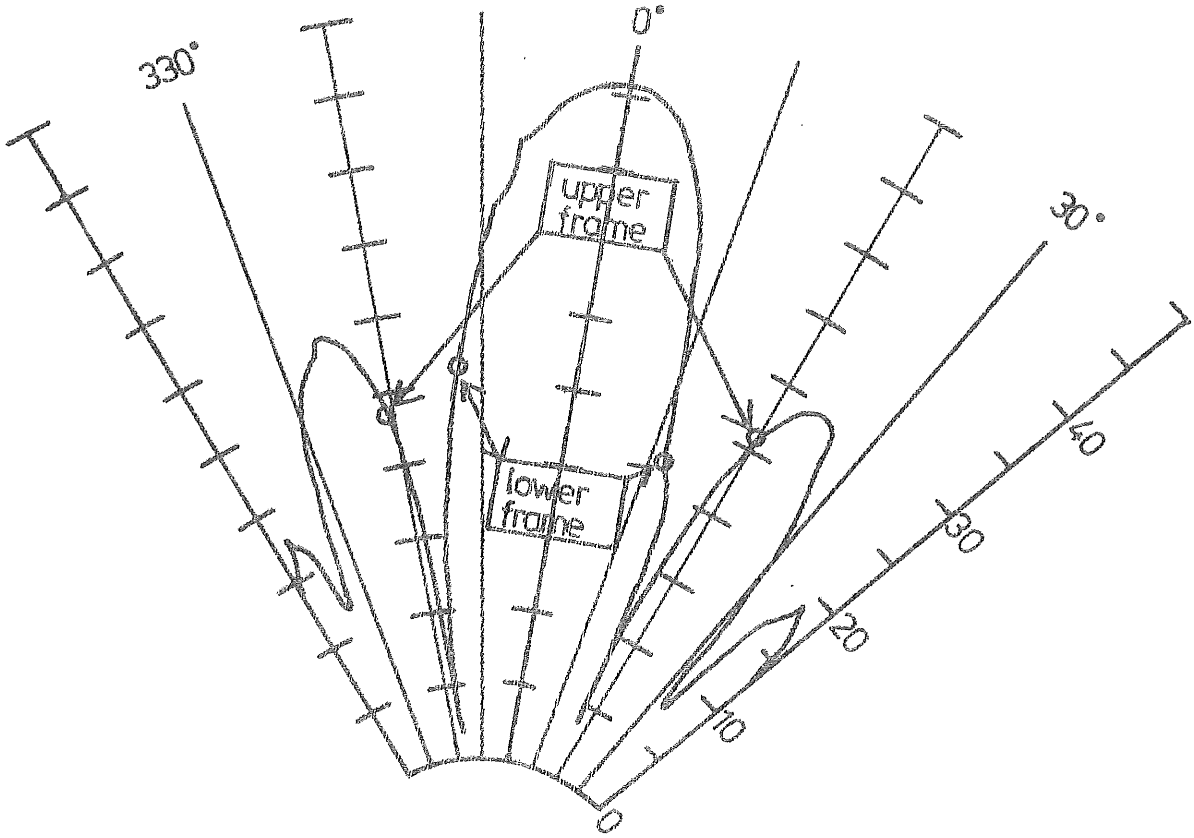
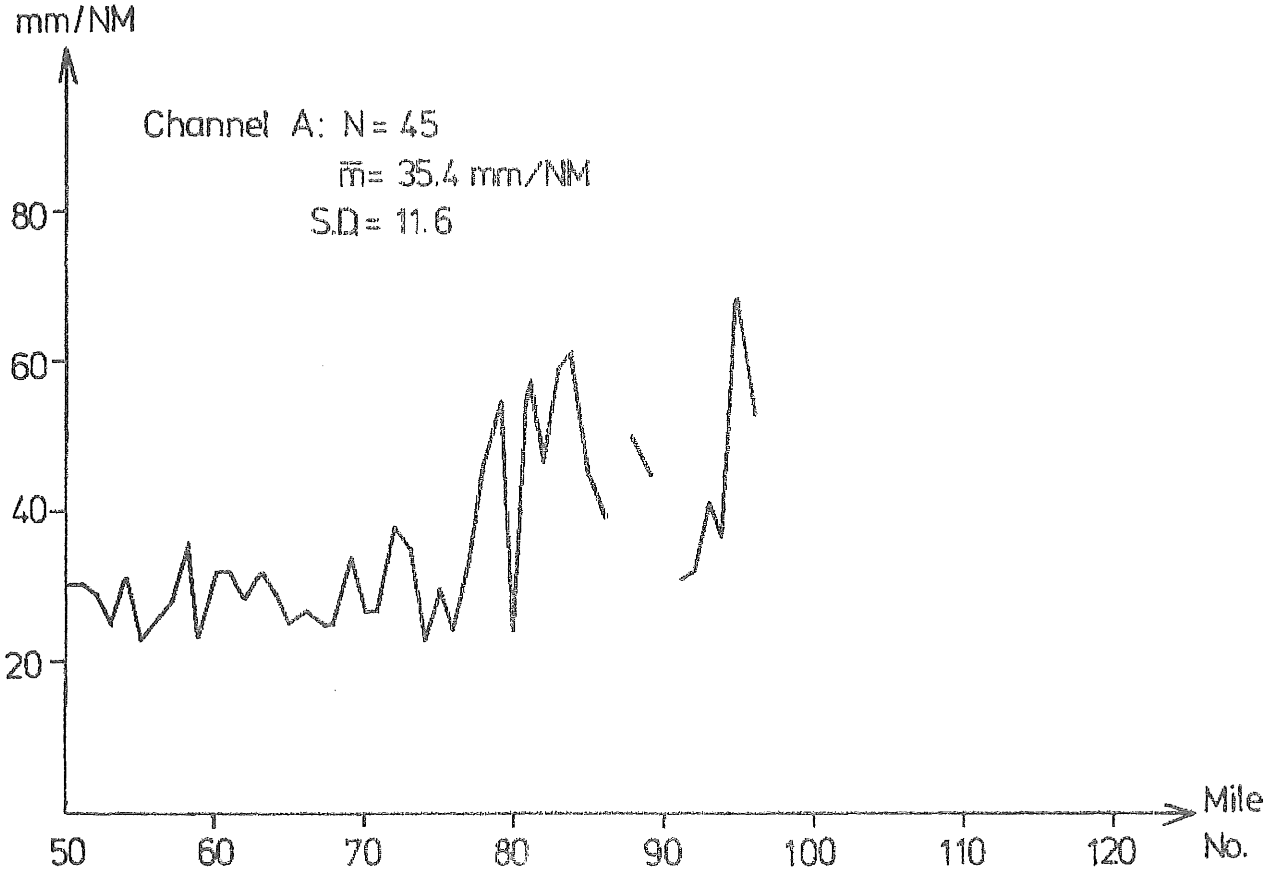


Fig. 2. Position of experimental cage in relation to the transducers directivity pattern



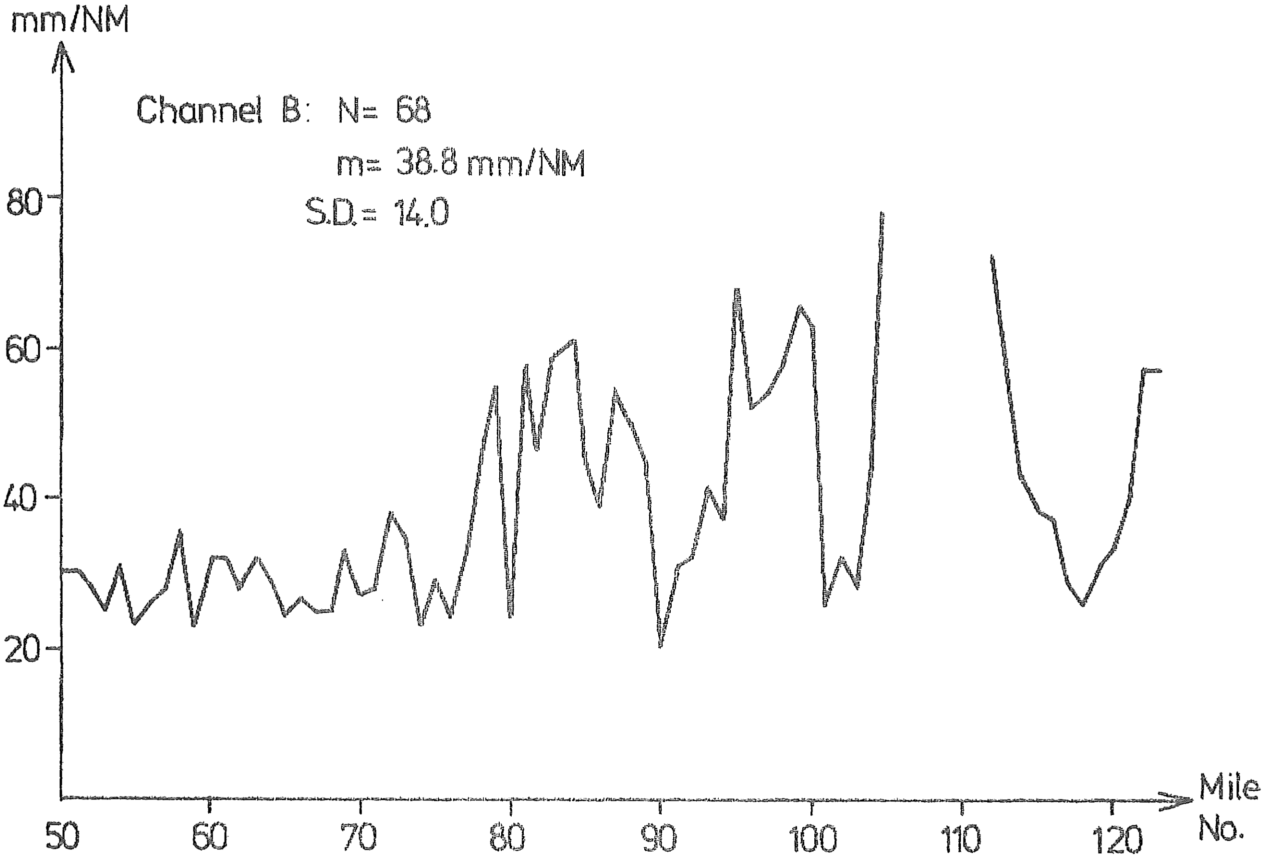


Fig. 3. Plot of integrator deflection during experiment No. 2 on cod.

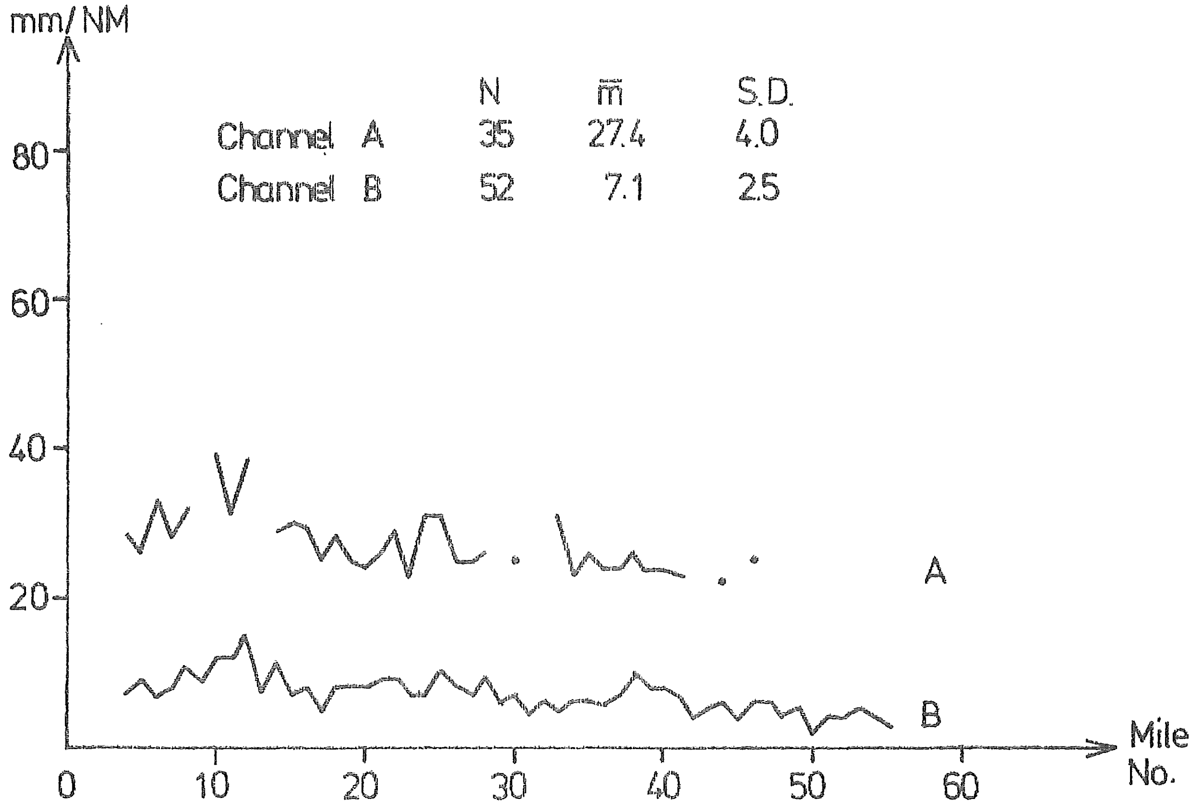


Fig. 4. Plot of integrator deflection during experiment No. 3 on herring.