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DETAILED IN SITU TARGET STRENGTH MEASUREMENTS OF 0-GROUP COD

by

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ABSTRACT

Target strength measurements *in situ* of cod fry have been made using 38 and 120 kHz split beam echo sounders. Two data sets are sampled in essentially pure, evenly sized, cod concentrations, one in a Ullsfjord, Northern Norway, and the other one in Parisvatnet, a closed 270.000 m^3 saltwater basin used for production of cod fry. The average length of the two cod populations were 5.1 and 3.1 cm, respectively. The target strengths measured are significantly lower than the values obtained if extrapolating the target strength to length relation used for larger cod towards small fish. The target strength measured at 120 kHz is lower than at 38 kHz. Details on measurement procedures, biology and analysis are reported.

INTRODUCTION

The annual 0-group surveys in the Barents Sea and adjacent waters provide information on distribution, abundance and biological parameters of several important fish species. Indices of abundance are computed using the catch per unit effort data from a more or less fixed grid of sampled stations covering the usual distribution area of 0-group fish, Anon (1992). The pelagic trawls used during the survey are described by Godø et al. (1993). Acoustic data are collected during the survey, and attempts have been made to compute the absolute abundance of some important species, like cod (Nakken et al. 1994), acoustically. The conversion of echo integrator data to fish density have provisionally been made by using the target strength obtained when extrapolation the target strength to length relation for larger cod:

$$TS = 20 \log L - 68 \qquad [dB]$$

to the lengths of the 0-group cod. This extrapolation is likely to be biased, and direct target strength data was needed to improve the acoustic abundance estimate.
On the standard 0-group survey, however, pure concentrations of one species seldom occur, and the sampling trawl used have been shown to be size selective (Godø et al. 1993). It has therefore often been difficult to obtain species-specific, reliable TS data on 0-group fish during the survey itself. In this paper, new target strength data on 0-group cod, collected under nearly ideal conditions for direct measurements, are presented.

MATERIAL AND METHODS

The measurements was conducted using Simrad EK-500 split beam echo sounders. The first data series was collected in June 1991, at Parisvatnet, a closed 270000 m^3 saltwater basin used by IMR, Bergen for production of cod fry (Blom et al. 1991). The echo sounder was connected to a 120 kHz stationary transducer on a fixed raft in the deepest part of the basin, 8 m, collecting target strength data between 2 and 7 meters as the fry passed the acoustic beam. The automatic feeders in the pond was stopped 4 hours prior to the measurements. A target tracking program, (Ona & Hansen 1991), run on a portable computer collected the target strength and angular data available on the serial output of the sounder. Individual length and weight of the fish was measured from a dipnet catch taken three days after the acoustic measurements. Total length of the fish was recorded.
The second data series was collected mainly at 38 Khz in Ullsfjord, (69°51' N, 19°54' E) from R/V "Michael Sars" in July 1992. The 0-group was sampled with the three level pelagic trawl (Godø & Valdemarsen, 1993). A total of 12 separate trawl hauls were taken at the same location, each covering a depth range of 15 meters, split vertically in three by the levelled trawl. Three successive hauls then covered the full depth distribution of cod larvae, 0- 45 meters. The standard length, SL, of the fish was measured in millimeters, and the total weight of each sample measured in grams. In one sample, both standard and total length of cod was recorded, and total length was later converted from the obtained relation:

$$SL(mm) = 0.941 x TL(mm) - 1.261 \quad (N=331, r^2 = 0.997)$$

The *in situ* TS measurements was made mainly with the EK-500 38 kHz echo sounder, but also included a comparative measurement at 120 kHz. The echo sounders at both locations were calibrated with respect both to sensitivity at acoustic axis and beam directivity using standard targets, CU 60 mm at 38 kHz and WC38.1 at 120 kHz, according to Ona (1990).
A lower threshold of -78 dB was used during the measurements, combined with a beam threshold of -6.0 degrees. During processing, a beam cutoff angle of 3.0 degrees was later applied to remove data in the outer part of the beam. The transmitted pulse length was 0.3 and 1.0 msec at 120 and 38 kHz respectively, and targets with a received pulse length, measured at the -6.0 dB level, to be within 80% and 130% of the nominal pulse length, was

accepted as single targets. The tracking program further accepted the target strength data if the target could be tracked over at least five successive transmissions. The average fish density was 0.02 fish per pulse volume in Ullsfjord and about 0.01 fish per pulse volume in Parisvatnet.

RESULTS

The conditions for direct target strength measurements in the two selected periods were nearly ideal with respect to density, size distribution and species mixture. Examples of echo recordings from the two series are shown in Fig. 1. In the closed basin, the fry was swimming through the acoustic beam at low speed, tracked to about 5 cm/sec. at depths between 2 and 7 meters. In the evening between June 9 and June 10, a total of 3396 accepted target strengths were collected and analyses. The average length of the fish in the pond was 5.1 cm, SD = 0.72 cm, Table 1. The weight to length relation of the fish is shown in Fig.3. Average target strength for the two data series collected within the pond at 120 kHz were -55.1 dB for the first series and -57.1 dB for the second series.
The main concentration of cod 0-group in Ullsfjord occurred between 15 and 25 m, Fig 1. The target strength data was sampled from the hull mounted transducers, with the vessel slowly moving or partly drifting over the distribution. The 0-group cod found in Ullsfjord was significantly smaller than the 0-group measured outside the coast at the same survey, and probably originates from a late local spawning stock within the fjord. The average length was 3.2 cm, SD=0.59 cm, Table 1. The length distribution of the 1139 0-group cod caught in the trawl is shown in Fig. 2. A total of 8697 target strength measurements were accepted as valid at 38 kHz from Ullsfjord, varying between measurements series from -58.2 dB to -60.4 dB, (Table 2). A small data material was collected simultaneously at 38 and 120 kHz in order to compare the target strength distributions. (Table 3.) A distinct target strength difference was found in this set between the two frequencies, the 0-group at 38 kHz giving on the average 2.7 dB higher target strength than at 120 kHz.

DISCUSSION

The target strength of 0-group fish seems in general to be lower than the values obtained when extrapolating the target strength to length relation used at 38 kHz for larger cod. The constant term in the target strength to length relation, b_{20} , assuming a 20 log L length dependency, varies at 38 kHz between 68.1 and 70.4, Table 2. If all measurements at 38 kHz are pooled and weighed with respect to the number of measurements in each series, the estimated constant, b_{20}= 69.9. As variations in the order of 1 dB occur between data series, a suggested working equation at 38 kHz for 0-group cod between 3 and 10 cm from this investigation is:

$$TS = 20\log L - 70 \quad [\mathrm{dB}]$$

The measurements at 120 kHz indicate a lower constant term than for 38 kHz, both in the basin data, and from Ullsfjord.

Intrinsic errors in the measurement methodology is judged to be well within the observed between series variability. When using a five parameter model to fit the measurements of the calibration sphere within the limits of the angle detectors, as suggested by Ona (1990), the residual error between measurements and model is smaller than when using the internal EK-500 beam compensation algorithm. The RMS of the residuals were 0.12 and 0.16 dB at 38 and 120 kHz respectively within the 3.0 degree cutoff angles of the transducers used.
Threshold errors may occur when trying to measure low target strengths at the border of the beam at long range. In Parisvatnet, the target strengths sampled at the border was not significantly different from target strengths sampled inside 1 degree off acoustic axis, while a slight threshold effect was observed outside 4 degrees in the Ullsfjord data. A beam threshold of 3.0 degrees was later applied to all data in order to minimize this effect.
Also a threshold problem, as seen in the target strength data from Ullsfjord, is to decide where the minimum target strength for the 0-group should be set. Since the directivity of the fish is low at 38 kHz, the weaker target strengths registered may originate from smaller organisms in the water column. Only at extreme tilt angles, head up or head down, target strengths of 0-group fish below -70 is expected. Modelling of 0-group swimbladder directivity may be used to better decide on where to cut the lower end of the target strength distribution. A strong indication of where this limit should be, is however apparent in the Parisvatnet data, where no targets below -70 dB was measured. The rared cod is mainly fed by pellets, but also on the naturally occurring plankton organisms in the pond. At this stage of the production the density of naturally occurring plankton is however low, due to the large number of cod fry in the pond, totally 318 000 some weeks later, when the pond was fished out. As the average target strength is computed in the linear domain, a removal of the data below -70 dB from the Ullfjorden data will only have a moderate effect on the average target strength, and the conclusion from this investigation remain.
More target strength data on fish of this size is needed if absolute acoustic abundance estimates of 0-group fish is regarded as a realistic research objective. If current target strengths at 38 kHz are used for computation of 0-group cod abundance in the Barents Sea and adjacent waters in 1992 and 1993, the abundance computed provisionally (Nakken et al. 1994) should be increased by a factor of 1.58, to $169 \cdot 10^9$ and $133 \cdot 10^9$ for the two years respectively.

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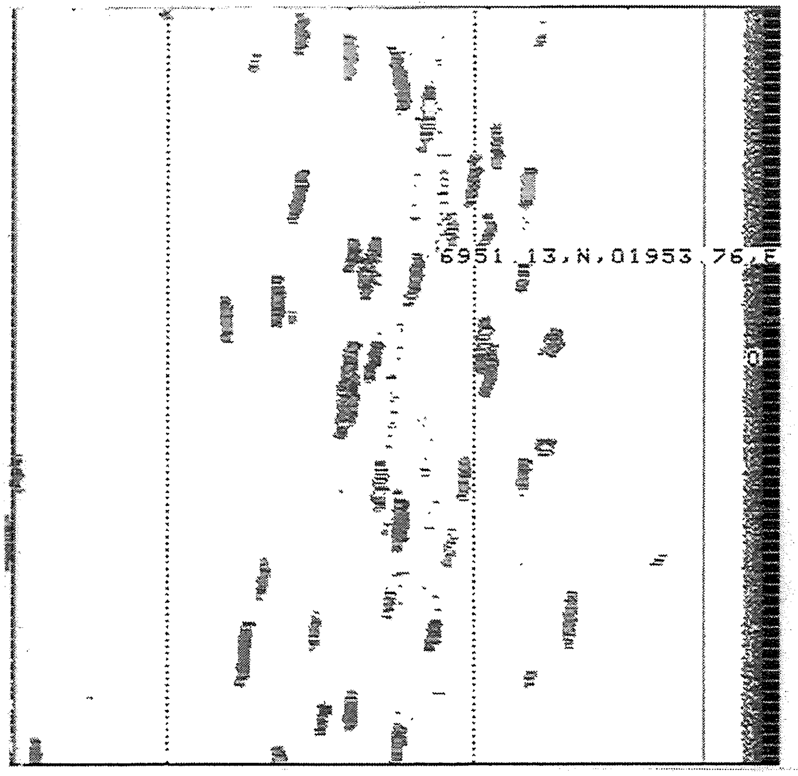
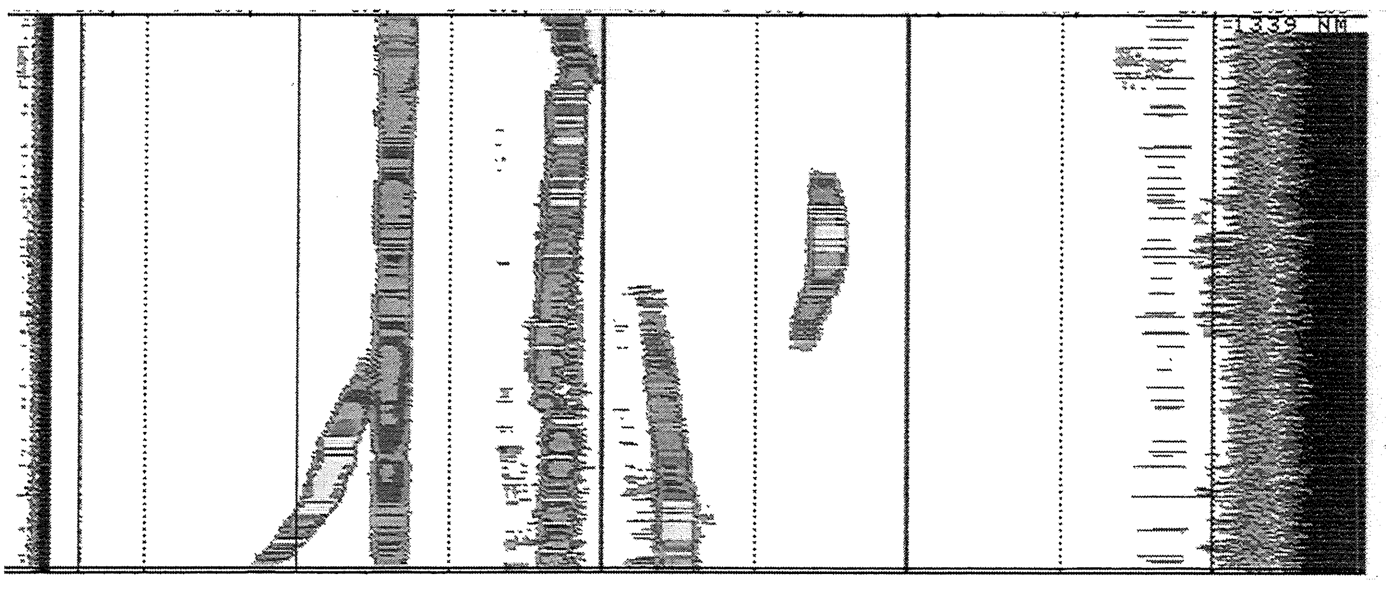
Table 1. Biological data, length measurements.

SAMPLE	N	Date	Mean length(cm)	SD(L)
Parisvatnet	329	130691	5.06	0.721
Ullfjord	1139	240792	3.14	0.587

*Parisvatnet: $w = 0.007\ L^{3.245}$





0 dB	TS-step = 1.5 dB			-75		-72		-69		-66		-63		-60		-57		-54		-51		-48		-45		-42		-39
2 Sur.	3.0	5.0	66	0	0	0	0	0	0	0	2	3	23	15	11	38	9	0	0	0	0	0	0	0	0	0	0	
3 Sur.	5.0	7.0	198	0	0	0	0	0	0	0	1	28	20	8	19	20	4	0	0	0	0	0	0	0	0	0	0	
4 Sur.	7.0	9.0	3	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	
10 Sur.	5.0	10.0	201	0	0	0	0	0	0	0	1	28	20	8	20	20	3	0	0	0	0	0	0	0	0	0	0	

10	Sur.	-80	9	Sur.	-80	8	Sur.	-80	7	Sur.	-80	6	Sur.	-80	5	Sur.	-80	4	Sur.	-80	3	Sur.	-80	2	Sur.	-80	1	Sur.	-80
	5.0	10.0		40.0	60.0		35.0	40.0		30.0	35.0		25.0	30.0		20.0	25.0		7.0	9.0		5.0	7.0		3.0	5.0		1.0	3.0
	147	2.9		0	0.0		0	0.0		0	0.0		0	0.0		0	0.0		1	0.4		146	2.0		55	2.0		167	2.0

Fig.1 Echo recordings from Ullfjord (left) and Parrisvatnet (right), showing 0-group cod swimming past a stationary transducer.
Vertical range : Ullfjord 0-50 m
Parrisvatnet 0-10 m

Table 2. Results of the target strength measurements. Ullsfjord 1-10, 38 kHz.

SAMPLE	N (tracks)	Date Time	< TS > (dB)	b_{20} (dB)
Parisvatnet 1 120 kHz	1620 (270)	090691 2000-2300	-55.1	-69.2
Parisvatnet 2 120 kHz	1776 (296)	090691 100691 2300-0200	-57.1	-71.2
Ullfjord1	1744	240792 0230-0300	-60.4	-70.4
Ullfjord 2	1374	0300-0330	-60.2	-70.1
Ullsfjord 3	973	0330-0400	-60.5	-70.4
Ullsfjord 4	1261	0400-0430	-59.8	-69.7
Ullsfjord 5	1180	0430-0500	-60.2	-70.1
Ullsfjord 6	734	0500-0530	-60.0	-69.9
Ullsfjord 7	368	0542-0550	-59.9	-69.8
Ullsfjord 8	291	0600-0612	-58.2	-68.1
Ullsfjord 9	463	0612-0618	-59.6	-69.5
Ullsfjord 10	309	0618-0624	-59.7	-69.6

Table 3. Target strength comparison at 38 and 120 kHz in Ullsfjord, collected simultanously.

Vessel log	N_{38}	$\langle TS_{38} \rangle$	N_{120}	$\langle TS_{120} \rangle$
6254	332	-60.2	290	-61.7
6255	329	-60.8	452	-62.9
6256	256	-60.1	454	-64.5
6257	253	-60.9	442	-64.1
6258	354	-59.9	449	-63.4

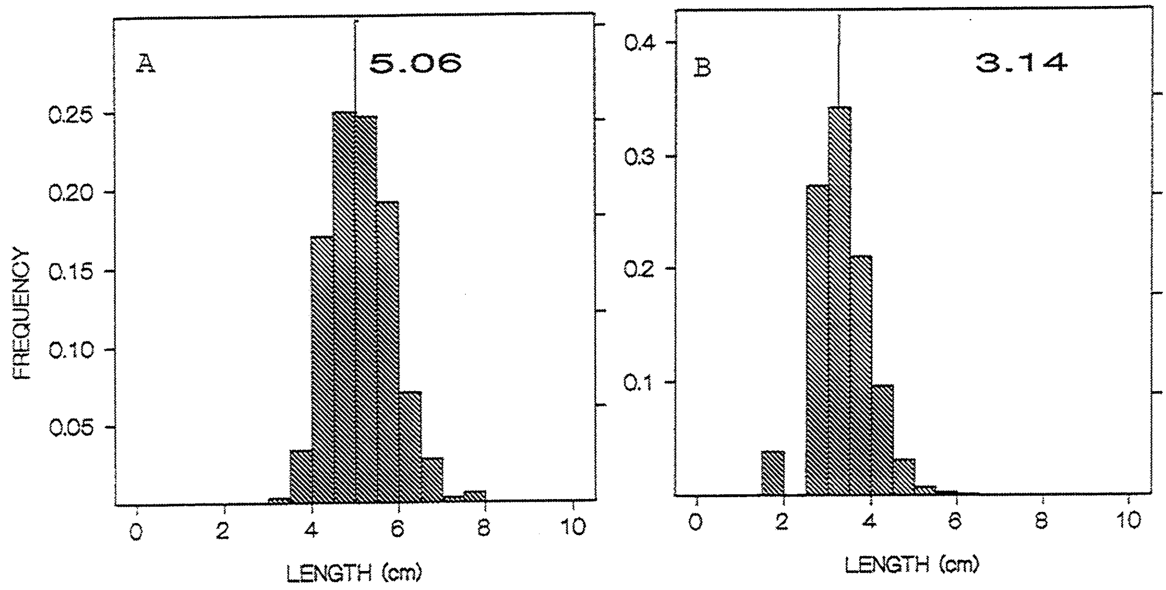


Fig. 2.
Length distribution of 0-group cod in Parrisvatnet (A) and in Ullsfjord (B).

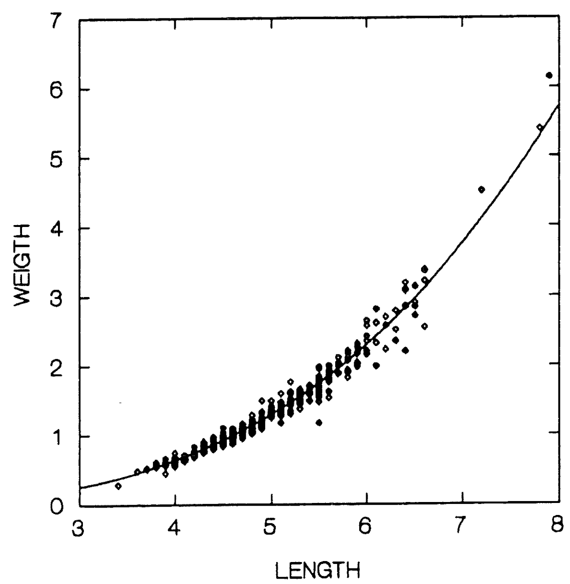


Fig. 3.
Length-to-weigth relation for 0-group cod in the Parrisvatnet basin. L-cm, w - gram.

$$W = 0.007\ L^{3.245}$$

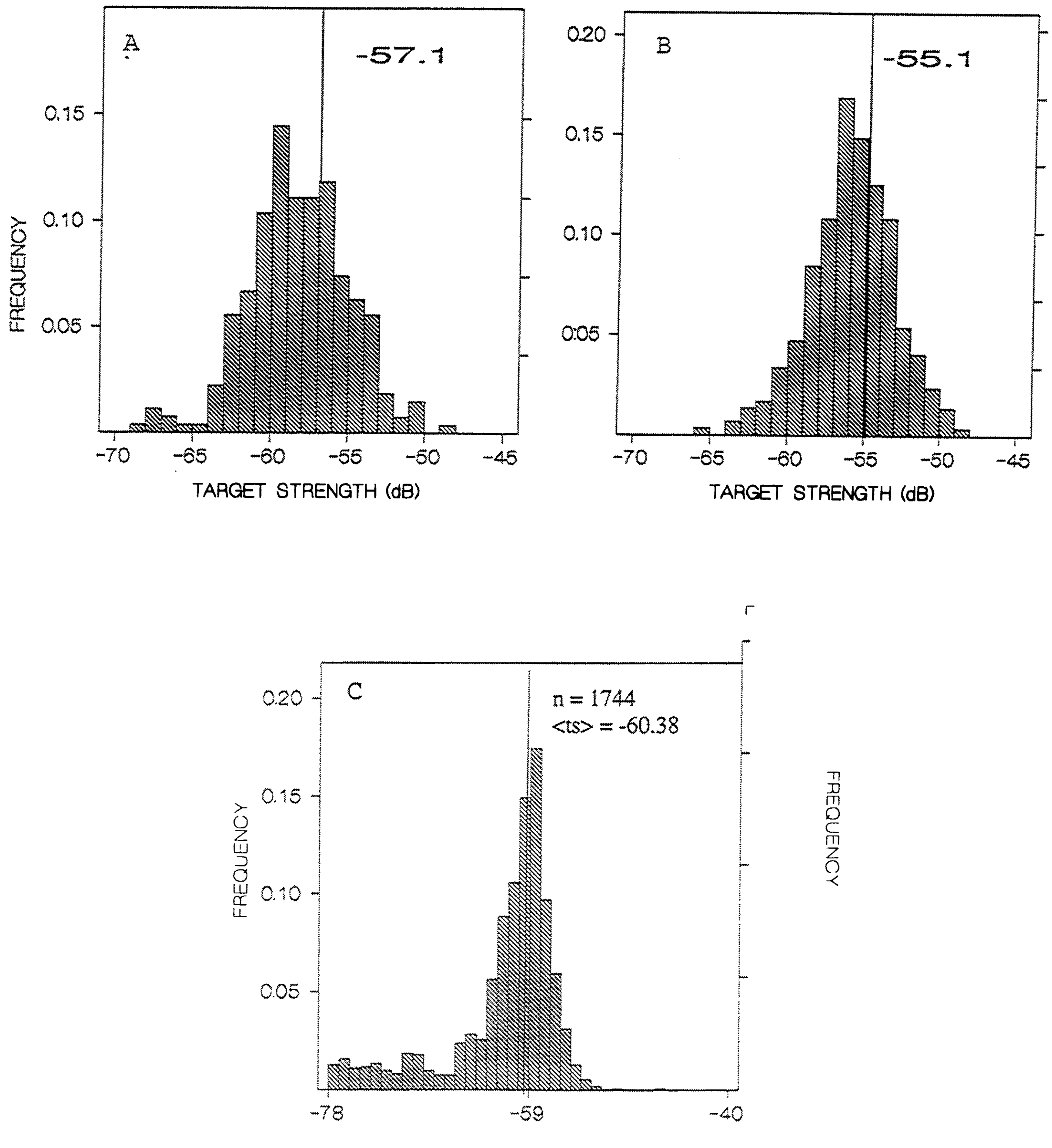


Fig. 4.
Target strength of 0-group cod from Parrisvatnet(A & B) and from Ullsfjord (C).