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COUNTING OF FISH WITH AN ECHO-INTEGRATOR

by

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1. Introduction.

The use of acoustic methods for abundance estimation have been introduced by several authors. Most often relative abundance have been found, but the method has also been used for absolute estimation of abundance. Attempts on that were made by Midttun and Sætersdal (1957) and by Richardsen et al. (1959) on cod. More recently Truskanov and Sherbino (1964) have used an acoustic method for estimating the abundance of Atlanto Scandian herring, and Cushing (1968) has used echo-sounding technique for estimating the abundance of hake off South Africa. His method is also described in Cushing (1964) and (1966).

Dragesund and Olsen (1965) have introduced an echo integrator for estimating echo-abundance, but the relation between echo-abundance and fish-abundance has not yet been fully established.

The present paper shows how the integrator can be used for the counting of single fish targets within a depth range. When the mean sampling area within this depth range is known, the number of fish per unit surface can be found.

2. Equipment and Calibration.

The integrator as described by Dragesund and Olsen (1965) has two channels, A and B. During the observations treated in this paper channel A was reset to zero between each transmission (Midttun 1966), while channel B was reset after one nautical mile or after full scale value. The integrator worked in conjunction with the 30 kHz Simrad Research Sounder, operating the broad beam transduser (24 cm by 10 cm). The sounder was calibrated and had a source level of 119,6 db, a sensitivity of -55,0 db and a puls length of 1,2 millisecond, The equipment includes a calibrated CRT display and as the receiver also was set on TVG (time varied gain) compensating two way geometric spreading, signal strength observed at angle Θ, $T' = T + 20 \log b_{\Theta}$, could be read directly from the CRT (Midttun 1966). (T' is below refered as signal strength, T is the target strength).

$$T' = -39,6 + U \text{ (db)}$$

The relation between the integrator value of channel A and the signal strength is

$$\log I = K(T' - T'_0) \qquad (1)$$

where I is the integrator value, T' is signal strength and T'_0 is the signal strength corresponding to an integrator value of I = 1 (cm).

Simultaneous readings of single fish targets on the CRT and on channel A gave:

$K = 0,06 \log$ cm/db and $T'_o = -29,6$ db

The relation between the two integrator channels was

$$M = 0,027 \sum I \qquad (2)$$

where M is the value in cm of channel B.

3. Method.

After a certain minimum number of single fishes are recorded, a linear relation between the number of fish, N, and the integrator value, M, can be established (Dragesund and Olsen 1965):

$$M = CN \qquad (3)$$

The constant C is the mean contribution of one single fish to M. This contribution can be expressed by:

$$C = \bar{n}\,\bar{v}\,\tau_e = \bar{n}\,\bar{I}\,0,027 \qquad (4)$$

where $\bar{n}$ is the mean number of echo, $\bar{v}$ is the mean voltage and τ_e is the echo puls length, all from one fish. $\bar{I}$ is the mean contribution on the channel A of a single fish in one transmission.

The echo puls length τ_e can be regarded as a constant as long as the dimension of the puls in water, $c\,\tau$ (c being the sound velocity), is large compared to the fish size.

Combination of equation (3) and (4) gives

$$N = \frac{M}{\bar{n} \cdot 0,027\,\bar{I}} \qquad (5)$$

This is a very convenient equation if channel A can be used for recording traces of single fish (Midttun 1966).

If however the CRT readings of T' are used, I must be found from equation (1), simply by using a calibration curve.

4. Trial results.

The method was tried with "G.O.Sars" in Lofoten last February on large cod mainly ranging from 70 to 100 cm. The integrator was operated on a layer between 50 m and 130 m. The sounder worked on the range 0 - 250 m (Fig. 1). The CRT were recorded on film and the distribution of signal strength T', integrator A values, I number of echo per fish, n, and depth of fish is given in Table 1, where also the mean values are indicated.

Table 1.

Observed distribution of n, T'and d together with computed values of I for fish recorded during the Lofoten trial February 1968.

n	%	T' db	I cm	%	d m	%
1	21	- 39,6	0,26	8	95	4
2	15	- 38,6	0,28	12	100	13
3	9	- 37,6	0,33	11	105	31
4	6	- 36,6	0,38	8	110	22
5	3	- 35,6	0,43	5	115	14
6	6	- 34,6	0,49	16	120	7
7	10	- 33,6	0,57	7	125	8
8	3	- 32,6	0,66	6		
9	7	- 31,6	0,76	6		
10	7	- 30,6	0,87	3		
11	3	- 29,6	1,00	5		
12	2	- 28,6	1,15	4		
13	2	- 27,6	1,32	4		
14	3	- 26,6	1,50	2		
15	1	- 25,6	1,73	1		
		- 24,6	2,00	1		
		- 23,6	2,31	1		

$\overline{n}$ = 5,4 echoes per fish
$\overline{I}$ = 0,626 cm
$\overline{d}$ = 109 m

The total number of fish, N, recorded by the integrator during the trial run along a distance of 1,2 n. miles can now be found by reading the value M of channel B over that distange (Fig. 2), viz.: <u>M = 6,8 cm</u>

Equation (5) gives:

$$N = \frac{6,8}{5,4 \cdot 0,027 \cdot 0,626} = \underline{75 \text{ fish}}$$

The result is certainly in excellent accordance with the number of fish visible on the recording paper of Fig. 1 between log values 186,1 and 187,3.

5. The sampling area.

The sampling area is regarded as the distance sailed times the sampling cross section of the echo sounder refered to a certain depth. This depth could be the mean depth of the integrated layer provided the layer thickness is small enough. In our case we shall use the mean depth of the fish recorded during the trial run (Tab. 1), viz.: <u>109 m.</u> The sampling cross section at 109 m is

$$Q = 2\,d\,\mathrm{tg}\,\Theta = 218\,\mathrm{tg}\,\Theta \qquad (6)$$

where Θ is the maximum angle at which a target is recorded.

Θ can be found from the following equation

$$MRS = T + S + 20 \log b_{\Theta} - 96 \qquad (7)$$

where MRS is the minimum recordable signal, T is target strength, S is source level, b_{Θ} is the coefficient of directivity and - 96 db is the time varying gain compensation for two way transmission loss down to 250 m.

The minimum recordable signed MRS was during our trial run set to a sound level corresponding to a CRT reading of zero (db). The MRS can be found from

$$MRS = RS - F_e - F_s + U$$

where RS is the receiving sensitivity or the sound level required to give an oscilloscope reading of zero at maximum amplification of echo sounder and scope, F_e and F_s are ampflication settings of sounder and scope, and U is the CRT reading. During the operation here described, RS was by calibration found to be : - 55,0 db. The settings were:

$F_e = -9$ db and $F_s = -30$ db

giving $MRS = -55 + 9 + 30 + 0 = -16$ db

The target strength T could be found from Tab. 1 of T' if it could be belived that, say 10 % of the stronger echoes have been recorded close to the acoustic axis where $b = 1$ and therefore

$$T' = T + 20 \log b = T$$

This gives an approximate value of - 26 db as a mean target strength of the recorded fish.

The source level S was found by calibration to be : 119,6 db.

The drop in sound level both during transmitting and receiving caused by the transducer directivity, $20 \log b_{\Theta}$, can be found as a function of angle Θ. The coeffisient of directivity is

$$b = \frac{\sin^2 \beta}{\beta^2}$$

where $$\beta = \frac{\pi a}{\lambda} \sin \Theta$$

here a is the width of the transducer, λ the wavelength and Θ the angle from the acoustic axis. Table 2 gives values of Θ and $20 \log b$ for a 30 kHz sounder with a 24 cm transducer.

Table 2.

Two way directivity loss, $20 \log b_{\Theta}$, at different angles $\Theta°$ from axis . 30 kHz echosounder. Transducer width : 24 cm.

$\Theta°$	$20 \log b$ (db)
0	0
1	-0,2
2	-0,8
3	-1,8
4	-3,3
5	-5,3
6	-7,9
7	-11,2
8	-15,3
9	-20,9
10	-28,7
11	-41,6
12°	$-\infty$

From the equation (7)

$$20 \log b_{\Theta} = -16 + 26 - 119{,}6 + 96 = \underline{-13{,}6 \text{ db}}$$

The value corresponds to an angle of $\Theta = 7{,}5°$ (Tab. 2).

The sampling cross section can now be found from (6) giving $Q = 218 \text{ tg } 7{,}5° = \underline{28 \text{ m}}$. The distance sailed was 1,2 n.m. and the sampling area therefore $\underline{62{,}2 \cdot 10^3 m^2}$.

The number of fish per unit surface within the layer 50 to 130 m :

$$\underline{1{,}2 \text{ fish per } 10^3 m^2.}$$

6. Discussion.

It was seen that the sampling cross section was dependent on knowledge of mean target strength. For comparison it is seen that a target strength of - 20 db would give a cross section of 32 m while - 30 db would give 23 m. The maximum target strength of a Lofoten cod is probably around - 20 db. The maximum angle Θ at which a - 20 db target could be observed is about 8°. At an angle of about 5,5° half number of - 20 db targets would be outside this angle. We observed a 50 % value of T' around - 35 db and since $20 \log b_{5,5°}$ is -6 db this gives T = - 29 and cross section of 25 m. Target strength of fish is however varying not only with size but also with orientation (Midttun and Hoff 1962). It is therefore believed that the fish are detected much closer to the axis. This view is supported by the size composition of the traces (number of echoes per fish); they are much shorter than should be expected for spherical targets. The observed size composition can be explained by adopting a certain directivity in the target reflection. In fact we have observed even shorter traces when coalfish are recorded. According to Midttun and Hoff (1962) coalfish shows higher directivity than cod. The size composition of traces can however as well be explained as caused by ship rolling, therefore this observation have to be veryfied by means of a stabelized transducer.

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Fig 1

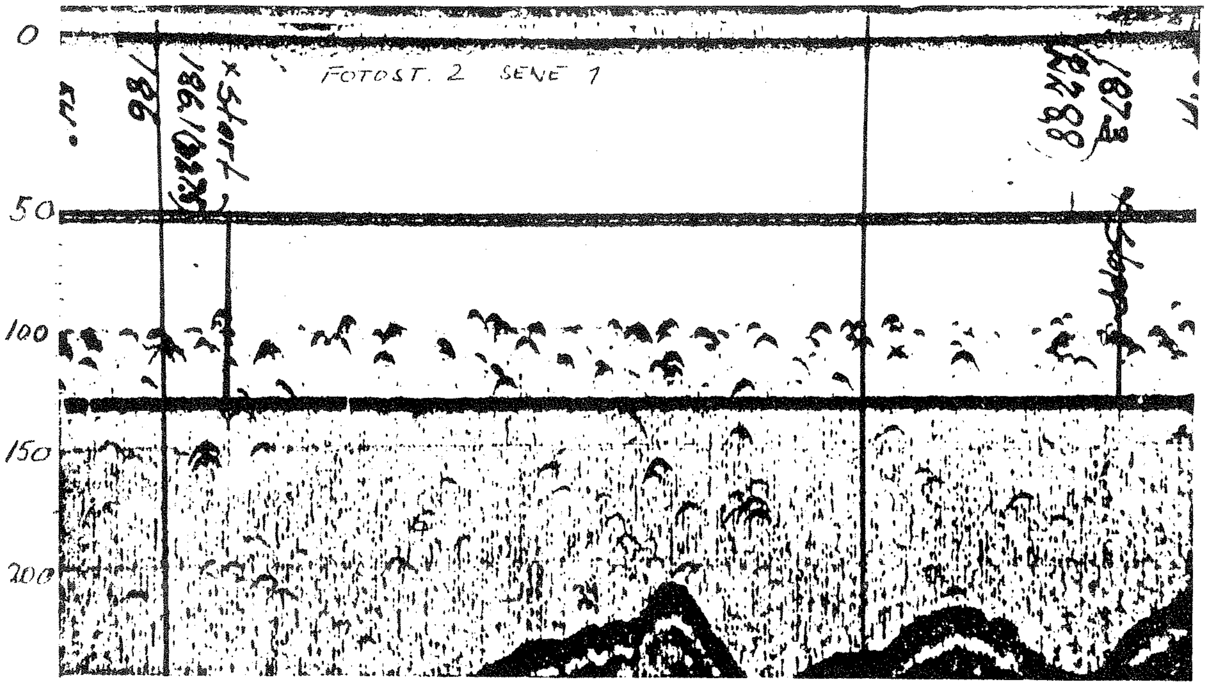

Fig. 1. Ekkorecording from "G.O.Sars", Lofoten, February 1968. Ship speed 5 knots.Horizontal lines indicate the integrated layer.

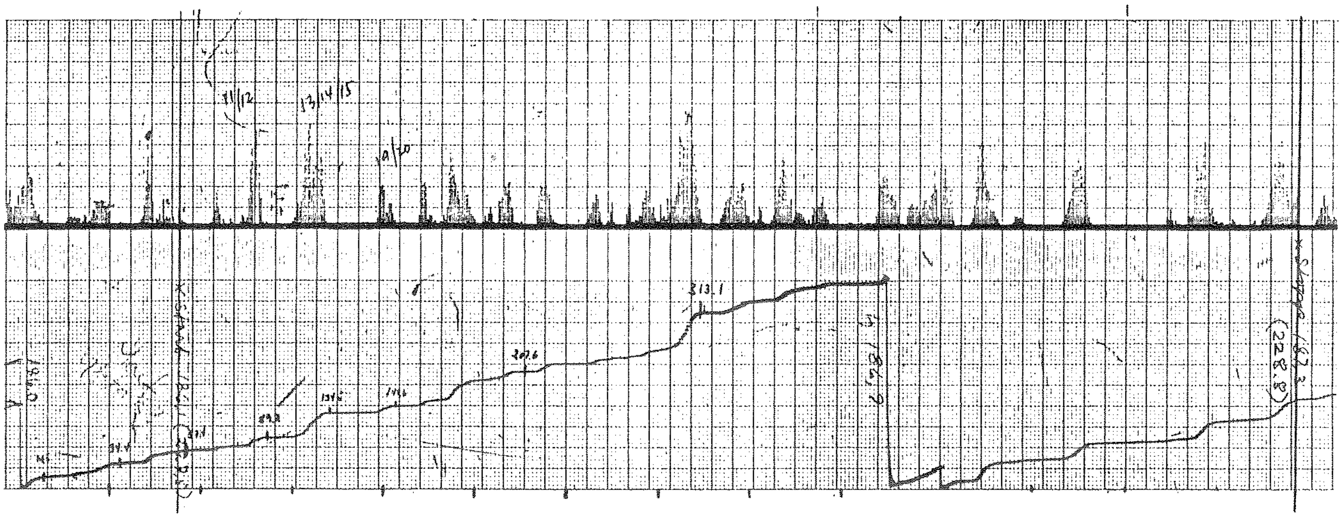

Fig. 2. Integrator recordings corresponding to the registration of Fig. 1. Above:Channel A, below:Channel B.