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ABUNDANCE ESTIMATION OF THE SPAWNING LOFOTEN COD 1971

By

J. Blindheim and O. Nakken
Institute of Marine Research
Bergen, Norway

INTRODUCTION

Since 1935 the Lofoten area has regularly been echo surveyed during the spawning season of the Arctic cod (Sund 1935). The results after these surveys have, so far, been given as estimates of relative abundance of cod (Monstad et al.1969). No absolute values have been published since the estimates evidently would have been too low. The reason for this was presumed to be that an erroneous sampling volume of the echo sounder was used in the calculations and that the survey grid was insufficiently dense.

In March 1971 the Lofoten survey was carried out with the more efficient equipment onboard the new research vessel "G.O.Sars". The aim of the investigation was firstly to estimate the number of cod within the main spawning area (Fig. 1) and secondly to find out the density of survey grid to be applied in the area. In this paper some preliminary results of the 1971 survey is presented.

MATERIAL AND METHODS

The area was surveyed 6 times during the cruise (Table 1), and as demonstrated in Fig. 1 the survey tracks were laid very close, only 1 nautical mile apart. The positions were determined very accurately by bearings (radar or visually) and further supported by excellent decca coverage.

The material was collected with 3 echo integrators which integrated the squared voltages from a 38 kHz echo sounder. A 120 kHz echo sounder was also used to obtain better resolution. With the settings used the main characteristics of the two sounders were:

	38 kHz	120 kHz	
Source level	136	124	db//1 μ Bar ref 1 m
Voltage response	+ 7.8	- 0.6	db//1 volt per u Bar
Pulse length	0.6	0.3	milliseconds
Beamwidth	5.0° and 5.5°	4.5° circular	between 3 db points
TVG	20 log R+2 x R	40 log R+2 x R	

The gain settings were choosen so that the minimum recordable signal corresponded to a target strength of -52 db.
The echo sounders and integrators were connected on-line to a computer onboard the ship. This permitted accuarate and reliable reading of the integrators, and sampling of echo sounder data provided possibility for determining the sampling volume or area of the echo sounders (Midttun and Nakken 1971). The 3 echo integrators sampled voltages from 6 depth slices. The 6 channels were read by the computer which gave an outprint each nautical mile as shown in table 2. As the voltage is squared before integration the values in table 2 are proportional to echo intensity, and a TVG of 20 log R+2 x R make the output of the integrator proportional to number of fish per unit area (Midttun and Nakken 1971, Bodholt 1969).

The integrators have a bottom stop system. However, when passing a steeply sloping bottom, the bottom echo is weak and will be integrated. As the bottom topography in the area is irregular, this occured rather often. This erroe was corrected during the daily scrutiny of the echo records and the corresponding integrams. During this scrutiny it was also decided what kind of fish that contributed to the integrated echo intensity, and contributions from false echoes (interferences, noice) were deleted.

The values of integrated echo intensity, M, were converted to number of fish per unit area, ρ, using the formula (Midttun and Nakken 1971):

$$\rho = C \cdot M \qquad \text{(I)}$$

Writing
$$C = \frac{\rho}{M} = \frac{N}{M \cdot A} \qquad \text{(II)}$$

where N is number of fish and A is the surface area within which the fishes are distributed. C can be calculated when associated values of N, M and A are observed.

N was found by counting fish traces on the recording paper when only single fishes were recorded. The corresponding sampling area, A, was calculated from the formula:

$$A = \frac{1}{1852} \cdot R \cdot tg\,\varphi_{max} \qquad \text{(III)}$$

where R is the mean depth of the depth slice and φ_{max} is the athwardships width of the beam. Frequency distributions of the detection sector angle, φ, were obtained (Midttun and Nakken 1971) and φ_{max} found by the formula:

$$\varphi_{max} = \frac{4}{\pi} \cdot \overline{\varphi} \qquad \text{(IV)}$$

The further management of the acoustic data was to plot the sums in table 2 into charts (Fig. 1). Two methods have been applied for obtaining the total number of fish within the area. Firstly isolines were drawn through points of equal integrator deflection and these values multiplied by the appropriate areas. Secondly the area covered was divided into subareas of 4 square nautical miles. All observations within each subarea were averaged and the averages were accumulated to give the total. An attempt to determine the neccessary closeness of course lines was made by using observations from every second and every third track as basis for the estimates of the totals.

RESULTS

Fig. 1 shows relative density distributions of cod within the area during survey no. II and no.V. A comparison of the two surveys illustrates clearly that the most dense consentrations are found at different localities. However, Fig. 1 illustrates the two surveys with the most different pictures with regard to locations of maximum fish consentrations. The values of total echo abundance according to survey are given in Table 1 and Fig. 2 for the 3 different survey grids and the two methods of calculation.

A frequency distribution of, φ, observed with the 120 kHz echosounder is given in table 3, and the value of φ max was 5,3^{o} when equation IV was applied. Equation III gives then a sampling area, A, per nautical mile steamed in the depth slice 55-100 m of A= 0,73 $\cdot$ 10^{-2} square nautical mile.

The results of a series of paper counts of individual fish on the 120 kHz echosounder and corresponding values of integrator deflections in the depthslice 55-100 m are given in Table 4. The mean value, $\frac{N}{M}$ = 0.24 fish/unit deflection, applied in equation II gives

$$C = \frac{N}{M \cdot A} = \frac{0,24}{0,73} \cdot 10^2 \approx 33 \text{ fish/unit deflection} \cdot (\text{nautical mile})^2$$

The total number of fish within the area is now found from Table 1 when multiplying the figures of total echo abundance by 33, giving $6.8 \cdot 10^6$ fish and $13.5 \cdot 10^6$ fish as the lower and upper limits respectively. These numers are based on the "isoline" method and 1 nutical mile between the survey tracks.

DISCUSSION

Calculation of the sampling area, A, from equation (III) requires full overlap by the beam from ping to ping. With the actual speed, beamangle and pulse rate used, however, the error introduced is insignificant.

Even the highest of the present estimates is evidently only a fraction of the total spawning stock (Anon 1970, Hylen and Dragesund 1970). In spite of this the results are likely to be reasonable. It must be considered that even though the main spawning grounds were surveyed, this is only a part of the total area where spawning occurred. It is well known that considerable concentrations of cod migrated to the north-eastern part of Lofoten. This area was not surveyed because many skerries and shallows make the waters too difficult to survey with the relatively big reseach vessel. It is also of importance that a spawning cod do not stay in the area during the whole spawning season. Concequently it is very unlikely that the whole spawning stock was present in Lofoten at the time of the surveys.

As already mentioned integration of bottom echo occurred rather often. Although the utmost care was taken to correct for this it influenced the results. However, exactly the same survey tracks were followed on each survey and the corrections were undertaken in the same way every time. This error should therefore effect the results of all the surveys in the same manner. The variation from survey to survey is, therefore caused by other factors, such as fish movements to and from the area. As seen in fig. 1 there was considerable fish movement also within the area between surveys, a matter which was supported by the fishermens opinion.

A comparison of the two methods ("Isoline" and"Square") for obtaining the total number of fish does not indicate any clear difference. As a mean for the 6 surveys the numbers derived by the "square" method are 3% below the "isoline" method.

A first glance at Fig. 2 gives the impression that there is no considerable difference between the results of the three grid densities. From Table 1, however, it can be seen that deviations reaching 38% are observed when a grid with 2 nautical miles between the survey tracks is applied. The results obtained by the isoline method and the most dense grid is then taken as 100%. The same comparison when only every third track is used, gives deviations up to 54 %. A consequence of this must be that a very dence survey grid is needed if a reliable number shall be achieved.

SUMMARY

This paper presents some preliminary results of acoustic surveys in Lofoten during the spawning season of the Arctic cod in 1971. The aim of the surveys was to estimat the number of cod within the main spawning area.

The area was surveyed 6 times and a very dence survey grid were applied, the survey tracks being only 1 nautical mile apart.

The surveys resulted in numbers varying between 6.8 and 13.5 millions of cod within the survey area. The reason for the great fluctuation of the numbers is likely to be fish movements in and out of the area. Bottom echoes influenced on the results to some degree, but this was not different from survey to survey.

Estimates were also worked out applying only every second and every third survey track. This resulted in greater fluctuations and accordingly indicated that a dense survey grid is nessecary.

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Table 1. Total echo abundance x 10^{-3} in the investigated area during the 6 surveys. Values are worked out by two different methods and with three grid densities.

DIST. BETWEEN COURSE LINES		SURVEY NUMBER AND DATE											
		I 20 MARCH		II 21 MARCH		III 22 MARCH		IV 24 MARCH		V 25 MARCH		VI 30 MARCH	
NAUT. MILES	METHOD	ABUN-DANCE	%	ABUN-DANCE	%	ABUN-DANCE	%	ABUN-DANCE	%	ABUN-DANCE	%	ABUN-DANCE	%
1	ISOLINE	205	100	320	100	409	100	212	100	333	100	366	100
	SQUARE	185	90	250	78	348	85	238	112	389	117	370	101
2	ISOLINE	200	98	278	87	296	72	189	89	404	121	354	97
	SQUARE	190	93	258	81	254	62	180	85	336	101	324	89
3	ISOLINE	171	83	244	76	264	65	212	100	324	97	499	136
	SQUARE	209	102	226	71	189	46	196	92	388	117	410	112

Table 2. Print out of echo abundance in 6 echo integrator channels, total for all channels (right) and log readings (left). Depth interval for each channel is indicated.

CHANNEL	1	2	3	4	5	6	
	DEPTH INTERVALS, METRES.						
LOG	10-55	55-100	100-145	145-190	190-235	235-280	TOTAL
863	15	54	98	156	2170	3451	5944
864	15	98	137	73	4942	3759	9023
865	15	132	112	68	59	29	415
866	15	244	225	406	5704	6281	12875
867	15	152	1403	2454	3866	2508	10397
868	15	39	49	34	1031	3950	5118
869	15	29	29	39	44	1051	1207
870	15	34	15	68	15	20	166
871	20	15	20	54	10	59	176

Table 3. Frequency distribution of the detection sector angle, observed with the 120 kHz echosounder.

Degrees	1	2	3	4	5	6	7	8	9	10	11
Number	16	53	31	17	17	20	25	9	3	4	1

$\overline{\varphi} = 4,15°$

Table 4. Ratios between numbers of fish on the paper record, N, of the 120 kHz echosounder and units of deflection, M, of the integrator for 7 different nautical miles in the depth slies 55-100 m.

$\frac{N}{M}$: 0,23 0,20 0,19 0,22 0,23 0,31 0,30 Mean 0,24

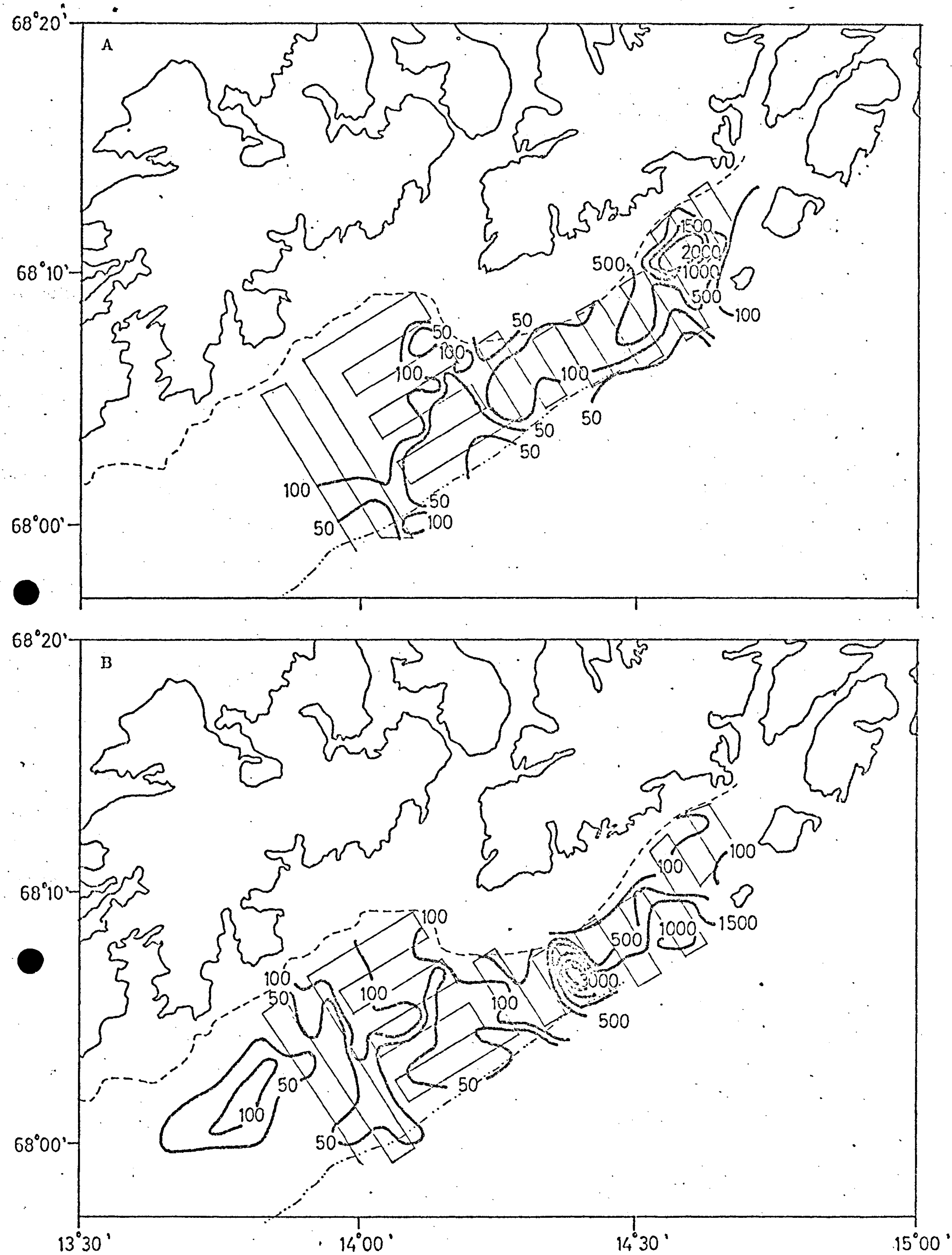

Figure 1. Distribution of integrated echo intensity, $M \cdot 10^{-1}$,
A) Survey II B) Survey V

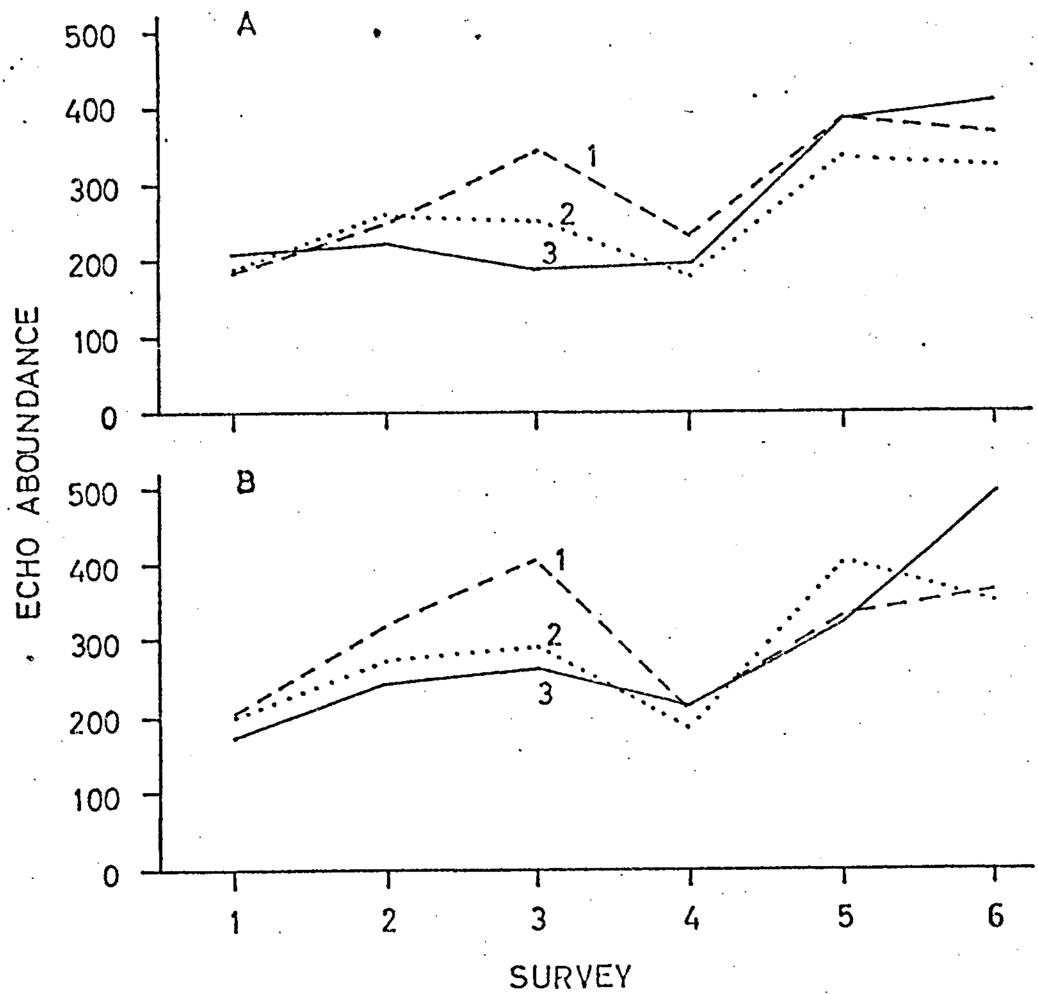

Figure 2. Total echo abundance for the different surveys in thousands of units.
A) The "Square" method B) The "Isoline" method