G. Bib. Bibl.

This paper not to be cited without prior reference to the authors.

International Council for the Exploration of the sea

C.M. 1979/G: 51
Dermersal fish (N) Committee
Ref. Fishing Technology Committee.

ACOUSTIC METHOD FOR ESTIMATING ABSOLUTE ABUNDANCE OF YOUNG COD AND HADDOCK IN THE BARENTS SEA

by

John Dalen and Odd M. Smedstad

Institute of Marine Research, Bergen

C.M. 79 / G 51

ACOUSTIC METHOD FOR ESTIMATING ABSOLUTE ABUNDANCE OF YOUNG COD AND HADDOCK IN THE BARENTS SEA

by

John Dalen and Odd M. Smedstad
Institute of Marine Research, Bergen

ERRATA

where	printed	should read
p.1., 1.10 from below	-method to assess absolute-	-method to estimate absolute-
p.3, l. 1	- dB// • 1 μPa at 1 m ,	- dB// 1μPa at 1 m ,
" l. 5	4 τ/e where	4 τ/3 where
p 5, l. 3	$C = [I_o v_p^2 \frac{C\tau e}{2} <\sigma>]^{-1}$	$C = [I_o v_p^2 \frac{c\tau e}{2} <\sigma>]^{-1}$
" " l. 4	in the density	is the density
" " l. 8	$\rho_a = \zeta M - \rho_o$	$\rho_a = CM - \rho_o$
p.7, l. 8	For the [jth] category	For the j^{th} category
p.8, eg.19	$\frac{k_1}{k_2} = \frac{C_1 M_1}{C_3 M_e}$	$\frac{k_1}{k_3} = \frac{C_1 M_1}{C_3 M_3}$
p.9, l. 7	235 dB 11.1 μPa ref. lm,	235 dB//1μPa ref. lm,
" " 1.10	bandwidth:	band width:
" " 1.13	having siz depth	having six depth
References p.4, 1.13	for censuser and	for censuses and
Fig.1.	any mixing of rations? Yes / no	any age obser-vations? Yes / no
"	on the process of echo integra-tion on assessing	of the acoustic method of estimating absolute
Fig.2.	of the instruments and sampling equipment.	of the echo integration process.

ACOUSTIC METHOD FOR ESTIMATING ABSOLUTE ABUNDANCE OF YOUNG COD AND HADDOCK IN THE BARENTS SEA.

1. Introduction.

Acoustic equipment has been used for observing and monitoring fish stocks for several decades. When trying to estimate abundances of fish stocks, echo counting and echo integrating have been the most employed methods (BLINDHEIM & NAKKEN 1971, BUZETA & NAKKEN 1975, CRAIG & FORBES 1969, CUSHING 1968, EHRENBERG 1974, JOHANNESON & LOSSE 1977, MIDTTUN & NAKKEN 1977, NAKKEN & DOMMASNES 1975, THORNE 1977, THORNE, REEVES AND MILLIKAN 1971, THORNE & WOODEY 1970). Out of these two methods echo integration techniques have shown up to be the most applicable one.

The project on acoustic abundance observation of demersal fish in the Barents Sea started in 1970. Initially we concentrated on finding the most suitable time of the year for abundance estimation both from biological and surveying prospects. From 1974 we gradually put increasing effort into assessing absolute abundances of recruits of north-east Atlantic cod and haddock. Since 1976 the surveys have followed a detailed and well-defined schedule and working plan which we consider yields and acceptably high quality of collected information.

2. Methods.

2.1. Fundamentals of the method.

The acoustic method to ~~assess~~ estimate absolute abundances of fish we define as containing the following processes:

1 - observing and recording integrated echo intensities by means of calibrated echo sounders and echo integrators,

2 - identifying your recordings on species by means of echograms, integrator readings, and biological samples,

3 - determining the size distribution of recorded fish by means of biological samples, and to some extent by echo strength classification,

4 - applying mathematical models to estimate fish density, amounts of fish and distributions of length, weight and age.

Notice that we define the acoustic methods as consisting of more activities of equal significance than just using acoustic instruments or making acoustic observations. The quality of each of the processes and their effects on the abundance estimates have been discussed by several investigators (BODHOLT 1977, CUSHING 1968, DOUBLEDAY 1976, EHRENBERG & LYTLE 1977, FOOTE 1979, NAKKEN 1975, SHOTTON & DOWD 1975). This together with experience from own investigations is summarized in DALEN 1979.

2.2. Echo integration.

The intensity of an underwater acoustic signal scattered back from a collection of scatterers is proportional to the density of the scatterers. This holds for a wide density range (FOOTE 1978, RØTTINGEN 1976) and is the basic philosophy for applying echo integration when assessing abundances of fish stocks. The process is illustrated by a block diagram in Fig. 1.

We now consider an ensonified volume, V_s, from which we may receive echoes simultaneously. This volume may contain:

1 - randomly, homogeniously distributed fishes, i.e. the location of each fish is independent of the location of the others, with a density ρ_V per cubic meter, and

2 - planktonic organisms, bubbles and other small particles.

Assuming that the phases of the echoes of the individual fish are randomly distributed we can express the back scattered intensity as:

$$E\ [I(r)] = I_o v_r^2 \circ \frac{c\tau_e}{2} \cdot \frac{e^{-2\beta r}}{r^2} \cdot G^2(r) \int_\Omega E[s_V] b^2(\theta,\phi)\ d\Omega \qquad (1)$$

where

I_o - source level [dB// \ 1 μPa at 1 m],

v_r - the pressure to voltage conversion factor of the transducer and fixed system gain,

τ_e - effective pulse length, which is found to be approximately 4 τ/3 where τ is transmitted pulse length (MITSON 1976),

β - attenuation coefficient [dB/ m],

r - distance from transducer to considered volume,

G(r)-time varying gain function,

s_v - volume back scattering coefficient,

b (θ,ϕ) - beam pattern directivity factor for fish at angular coordinates θ and ϕ,

Ω - solid angle determining the angular coordinates of the volume.

We have put the directivity beam pattern functions during transmitting and receiving as being equal. This is true only when having stabilized transducers which we used here. We define the volume back scattering coefficient as:

$$s_v = \frac{\sigma}{4\pi} \cdot \rho_v + s_v' \tag{2}$$

where σ is the backscattering cross section of a fish.

The first term of eq. 2 is the fraction of the back scattering in respons to the targets of interest and the second term is in response to what we may denote as "noise" (i.e. caused by plankton, bubbles, other particles and ambient noise).

If we apply a time varying gain function $G(r) = re^{\beta r}$, eq. 1 now becomes:

$$E\,[I(r)] = I_o v_r^2 \frac{c\tau_e}{2} \left[\int_\Omega \rho_v \frac{E[\sigma]}{4\pi} b^2(\theta,\phi)d\Omega + \int_\Omega E[s_v']b^2(\theta,\phi)d\Omega\right] \tag{3}$$

The two integrals of eq. 3 can be estimated when the following terms are known:

1 - the directivity function of the transducer,

2 - the backscattering cross section as a function of species, size and tilt angle, and

3 - the behaviour pattern (distribution of the tilt angle) of the species.

We define the effective backscattering cross section as:

$$<\sigma> = \int_{\Omega} \overline{\sigma} \ b^2(\theta,\phi)d\Omega \qquad (4)$$

where $\overline{\sigma}$ is the orientation distribution-averaged value of $\sigma/4\pi$ [FOOTE 1979], and the effective "noise" volume back-scattering coefficient as:

$$<s_v'> = \int_{\Omega} E[s_v'] \ b^2(\theta,\phi)d\Omega \qquad (5)$$

This yields for eq. 3.

$$E\ [I(r)] = I_o v_r^2 \cdot \frac{c\tau_e}{2} \cdot [\rho_v <\sigma> + <s_v'>] \qquad (6)$$

The number of fish within a depth interval r_1 to r_2 can be expressed as:

$$\int_{r_1}^{r_2} \rho_v \ dr = [I_o \frac{c\tau_e}{2} \ v_r^2 <\sigma>]^{-1} \int_{r_1}^{r_2} E[I(r)]dr - \int_{r_1}^{r_2} \frac{s_v'}{<\sigma>} \ dr \qquad (7)$$

We define the echo abundance, M, as the sum of intensities from each transmission over the depth interval r_1 to r_2 per unit distance, l.

$$M = \frac{1}{l} \sum^{p} \int_{r_1}^{r_2} E[I(r)]dr \qquad (8)$$

where p = Pl/s is the number of transmissions over l, P is the rate of transmission (pulse repetition frequency), and s is the vessel speed.

$$\rho_a = \frac{1}{P}\sum^{P} \int_{r_1}^{r_2} \rho_v \, dr \qquad (9)$$

is the area fish density per unit distance.

$$C = [I_o v_p^2 \frac{c\tau_e}{2} \langle\sigma\rangle]^{-1} \qquad (10)$$

in the density coefficient.

$$\rho_o = \frac{1}{P}\sum^{P} \int_{r_1}^{r_2} \frac{\langle s'_v \rangle}{\langle\sigma\rangle} \, dr \qquad (11)$$

can be regarded as a threshold density.

This yields:

$$\rho_a = CM - \rho_o \qquad (12)$$

For the echo abundance, M, to be a consistent, general term we have to compensate for the rate of transmissions, P, and the vessel speed, s. In most integrators this is done automatically by presetting the value of P and sensing a signal proportional to the speed, s.

ρ_o determines mathematically the lower limit of the echo abundance, M, for which eq. 12 can be applied. On the other hand the magnitude and hence the effect of ρ_o can be controlled by a threshold generator within the integrator.

Active use of the threshold control can to some extent be useful in supressing noise signals and signals from smaller organisms. A particular effect of this threshold should be stressed because it makes the integrator system generally discriminating against small targets as discussed by EHRENBERG & WEIMER 1974 and WEIMER & EHRENBERG 1975.

The density coefficient, C, is besides being a function of the instrument characteristics such as source level, receiving sensitivity, system gain and effective pulse length, a function of the effective back scattering cross section of the fish under observation. This latter parameter is a multivariable function which takes care of species, length or weight dependences, modes of behaviour, spatial distribution of the fish, and beam pattern function of the transducer. Just recently a satisfactory analytical treatment has been done on the effective backscattering cross section - first to some extent by LOVE 1977 and thereafter to a higher level by FOOTE 1979.

2.3. Estimation model for calculating absolute abundances.

This model is to convert echo intensity into fish density on the basis of the information from the biological sampling. The echo abundance produced by a population of fish is generally a function of the total abundance of the fish, the distribution of species and sizes of the different species. We define the term "category" as consisting of a certain length group from a certain species.

Echo intensities, M_i, from "n" categories contribute simultaneously to the total value of M (FORBES & NAKKEN 1972), and these yields:

$$M = \sum_i^n M_i \qquad (13)$$

The fish density and the integrated echo intensity form a linear relation for each category "i", conf. eq. 12.

$$\rho_{ai} = C_i M_i - \rho_{oi} \qquad (14)$$

Applying a proper threshold setting together with being aware of any effect from noise sources, the influence of ρ_o is removed through the preprocessing of the acoustic data.

This yield for eq. 14:

$$\rho_{ai} = C_i M_i \tag{15}$$

Having assigned a particular echo abundance M_s to a species "s" or a group of species through the scrutinizing processes, we have to distribute M_s to the specified categories. The necessary information for this is drawn from the frequent trawl sampling by assuming that the samples yield true density ratios by number between the different categories of the actual species which are observed. For the jth category we have:

k_j = (number of fish of category "j" in the catch)/(total number of fish in the catch which have contributed to the assigned echo abundance, M_s)

i.e.

$$k_j = \frac{m_j}{\sum^n m_i} \tag{16}$$

From the assumption about true sampling which implies that the number of fish of category "j" in the catch is proportional to the areal density of the fish of the same category, we may write:

$$k_j = \frac{\rho_{aj}}{\sum^n \rho_{ai}} \tag{17}$$

For all values of "i" we may write:

$$\frac{k_1}{k_2} = \frac{\rho_{a1}}{\rho_{a2}} \tag{18}$$

$$\frac{k_1}{k_3} = \frac{\rho_{a1}}{\rho_{a3}}$$

$$\vdots$$

$$\frac{k_1}{k_j} = \frac{\rho_{a1}}{\rho_{aj}}$$

Eq. 18 together with eq. 14 yields:

$$\frac{k_1}{k_2} = \frac{C_1 M_1}{C_2 M_2} \qquad (19)$$

$$\frac{k_1}{k_3} = \frac{C_1 M_1}{C_3 M_3}$$

$$\vdots$$

$$\frac{k_1}{k_j} = \frac{C_1 M_1}{C_j M_j}$$

By inserting eq. 19 into eq. 13, M_i can be expressed by i, C_i and M_s.

$$M_1 = \frac{k_1}{C_1} \cdot \frac{M_s}{\sum^{n} k_i/C_i} \qquad (20)$$

$$M_2 = \frac{k_2}{C_2} \cdot \frac{M_s}{\sum^{n} k_i/C_i}$$

$$M_j = \frac{k_j}{C_j} \cdot \frac{M_s}{\sum^{n} k_i/C_i}$$

We obtain our desired functions by eq. 20 and eq. 14 which express the absolute fish density, ρ_{ai}, from k_i, C_i and M_s.

$$\rho_{a1} = \frac{M_s\ k_1}{\sum^{n} k_i/C_i}$$

$$\rho_{a2} = \frac{M_s\ k_2}{\sum^{n} k_i/C_i}$$

$$\rho_{aj} = \frac{M_s \, k_j}{\sum^{n} k_i/C_i}$$

2.4. Instruments and sampling equipment.

The vessel we have used, R.V "G.O. Sars" is equipped with SIMRAD scientific echo sounders - both with hull-mounted transducers and with towed ones. The particular sounder used for abundance estimation has the following main characteristics:

Source level:	235 dB // 1 μPa ref. 1 m,
transmitting frequency:	38 kHz,
pulse length:	0,6 ms,
bandwidth:	3 kHz and
beam width, half power level:	5.5^{o} approx. circular.

The sounder is connected to an analogue echo integrator system having six depth channels. The schematics of the sampling and processing of data are shown by a block diagram in fig. 2.

When observing demersal species special attention has to be paid to the depth column close to the bottom. There are limitations of near bottom fish detection which practically are determined by:

1 - the beam angle of the transducer,
2 - effective pulse length,
3 - size of the fish targets,
4 - roughness of the bottom, and
5 - slope of the bottom.

These problems are discussed in detail by MITSON 1976 and DALEN 1979. The conclusion is that an echo sounder should fulfil requirements of having a narrow beam transducer and working with short pulses when estimating near bottom fish populations.

It is necessary to have an integrator with a proper bottom stop function and also a bottom lock function. To extract as much information as possible about fish standing close to the bottom, the channels having the two bottom mode functions are run parallel. The gained information comes from comparison of the integrator readings from the two channels or the difference between them. These values are also especially useful in processing echo intensities when having a rough or uneven bottom.

As important as acoustical data are the biological data when assessing absolute abundance of the actual species. Requisite biological data from ground fish we collect both from bottom trawls and pealgic trawls with fine-meshed net in the cod end.

2.5. Survey design.

An over all objective is to try to minimize the effect of the known sources of error in assessment methods and to optimize with respect to all important parameters which influence the accuracy of an abundance estimate. Some significant points will be discussed.

2.5.1. Biological basis.

While developing the survey design (through the years from 1970) we have been looking for any favourable biological situations from the acoustic point of view for estimating young cod and haddock. In this context we require:

1 - to survey the species when it has the most advantageous spatial location or spread within its area of residence,

2 - that the greater number of the fish have to stay off the bottom to be observed acoustically,

3 - a minimum of migrating movements of the fish within the surveyed area to minimize certain biases in the estimates, and

4 - not too strong interference of other species among those being assessed.

For young cod and haddock in the Barents Sea we have found that the period January to the middle of March is favourable for applying acoustic methods.

2.5.2. Survey net and distribution of trawl stations.

We try to design the survey pattern and to distribute the trawl sampling to obtain the most presice abundance estimate for a given survey period. This is on the basis of:

1 - the expected extension area of cod and haddock,

2 - the probable distribution of the species in the area,

3 - the probable size distribution of the species, and

4 - the large-scale behaviour patterns of the species.

We also require sufficient total sampling effort both acoustically and biologically to obtain representative coverage of the different strata when the whole surveyed area is divided into smaller units.

Considering the large-scale biological sampling, this always takes place whenever the pattern of the echo recordings of demersal species changes or when biological data is needed in response to distribution and coverage. Standard towing distance is three nautical miles to give an approximately equally effective swept volume both for demersal and pelagic trawl stations.

The survey pattern may generally be described as a zigzag path, crossing zigzag path, parallel lines or unsystematic lines to reach a point/small area at random. The statistical effects of the variance of an estimate when choosing different patterns, have been examined by several investigators (HANSEN, HURWITZ & MADOW 1953, NICHERSON & DOWD 1977, SHOTTON & DOWD 1975, YATES 1965). For a related discussion see DALEN 1979.

Our approach has developed into a parallel line pattern. It gives well defined transects through the subareas, and at average the lines are equidistant, but slightly denser in areas with higher fish concentrations. The total survey area is divided into subareas which we denote as statistical squares. The dimensions of the squares are 30 nautical miles in the north-south direction and $60 \cdot \cos \alpha$ nautical miles - where α is degree latitude, in the east-west direction. This particular size is determined from the distribution of:

1 - the species composition,

2 - the size (length/age) of the specimen, and

3 - the density of the fish, i.e. the values of the echo abundance.

Within each square these functions are found to contain minor and acceptable variations (DALEN, HYLEN & SMEDSTAD 1977 a,b, DALEN,+SMEDSTAD 1979).

We transect between 70 and 100% of the subareas depending on the extension and density of the fish distribution. Some of the basic ideas behind this pre-planned, well defined survey pattern, are to establish a repeatable program from year to year. This yields clearly comparable information about yearly changes of fish density, distribution and size composition.

26. Scrutinizing and preprocessing of data.

The main objective of the preprocessing is to attach the right echo abundance to all observed species or groups of species and to remove unwanted effects on the echo abundances from non-biological sources.

A daily scientific staff meeting is held to utilize the running information from:

1 - the echo abundance observation - by echo sounder and integrator,

2 - the biological sampling - by trawls,

3 - the oceanographic sampling - by CTD-sonde and thermograph, and

4 - any influence from the weather on the acoustic data acquisition, i.e. wind and wave induced air bubbles in the surface layer which will cause additional absorbtion of the transceived echo energy (LØVIK & DALEN 1979).

The acoustic data are scrutinized and preprocessed both for mapping purposes and for the computer aided estimation of all relevant biological quantities.

3. Some results.

The period of investigation for the different years are:

1976: 1 February to 20 February
1977: 10 January to 4 February
1978: 30 January to 15 March
1979: 2 February to 20 March.

In 1976 we had relatively short time for the investigations, but the weather was good. In 1977 the eastern part of the Barents Sea was badly investigated because of bad weather. In 1978 the weather was excellent and the whole area was well investigated. In 1979 there was again trouble with the weather so that the eastern part of the area was not investigated. However, this did not matter this year because of the extreme cooling of the water masses in the eastern area.

The geographical distribution of the different age groups were very similar from year to year. The results from 1978 can be used as examples (Figs 3-9). For cod it seems that 2-3 years old fish are most numerous in the eastern part of the Barents Sea (Figs 5 and 6), while the older cod have a more westerly distribution. However, in 1979 the picture was quite different. This winter the tounge of warm water which usually is situated from the Skolpen Bank to the Goose Bank and Novaya Zemlja disappeared. East of about 36^{O}E all temperature observations were below 0^{O}C from the surface to the bottom. This cooling forced the fish consentrations to move westwards. Most of the young cod were in February 1979 found between 30°E and 35°E.

The haddock prefer warmer water than the cod and are therefore found more westerly than the cod (Figs 8 and 9).

Table 1 gives the estimated abundances of the year classes of cod in the different years. It shows that the I-group always are greatly underestimated and to some extent also the II-group. Fish older than 6 years are also underestimated because they are mostly distributed west of the investigated area. It is thus the abundances of 3 to 5 years old cod that are best estimated by this method in the Barents Sea. However, in 1977 the estimates of the three to four youngest year classes was not good because of the bad investigation of the eastern area.

The abundances of the different year classes found by the acoustic method are in good agreement with the 0-group indexes (Anon 1979). Both 1976 and 1974 are found to be weak year classes, while 1975 is strong. The 1973 year class is, however, found to be somewhat weaker than indicated by the 0-group index.

Comparing the estimates from the acoustic method with the estimates from the VPA made by the Arctic Fisheries Working Group (ANON 1979), we find that the acoustic estimates are between 35% and 70% of the VPA estimates except for the 1975 year class. For this year class the acoustic estimates are much higher than the VPA. Normally the acoustic method will underestimate the year class strength. This indicates that there are some errors in the input data of the VPA.

Table 2 gives the estimates of the abundances of the haddock year classes. Haddock older than 5 years are mainly distributed west of the investigated area and therefore almost lacking in our material.

Comparing the acoustic estimates with the VPA we find greater variances than for cod and also higher percentages. However, also for haddock the 1975 year class seems to be estimated too low in the VPA.

REFERENCES

ANON 1979. Report on the Arctic Fisheries Working Group, Charlottenlund, 26 May - 1 June. Coun. Meet. int. Coun. Explor. Sea, 1979 (G:): 1-35 [Mimeo].

BLINDHEIM, J. and NAKKEN, O. 1971. Abundance estimation of the spawning Lofoten cod 1971. Int. Coun. Explor. Sea, Coun. Meet. 1971 (B15): 1-9 [Mimeo].

BODHOLT, H. 1977. Variance error in echo integrator output. In Hydro-Acoustics in Fisheries Research, ed. A.R. Margetts (Rapp. P.-V. Réun. Cons. int. Explor. Mer 170, 1977), 196-204.

CRAIG, R.E. and FORBES, S. 1969. A sonar for fish counting. FiskDir. Skr. Ser. HavUnders. 15: 210-219.

CUSHING, D.H. 1968. Direct estimation of a fish population acoustically. J. Fish. Res. Bd. Canada, 25(11): 2349-2364.

DALEN, J. 1979. Acoustic methods for assessing abundances of demersal fish stocks with special attention to cod and haddock in the Barents Sea. FiskDir. Skr. Ser. HavUnders. [In prep.]

DALEN, J., HYLEN, A. og SMEDSTAD, O.M. 1977a. Akustisk mengdemåling av torsk og hyse i Barentshavet i Februar 1976. Acoustic abundance estimation of cod and haddock in the Barents Sea in February 1976. . Fisken Hav. 1977(2): 3-15.

—— 1977b. Investigations on demersal fish in the Barents Sea in winter 1977. Coun. Meet. int. Coun. Explor. Sea, 1977 (F:23) 1-19 [Mimeo].

DALEN, J. og SMEDSTAD, O.M. 1979. Akustisk mengdemåling av torsk og hyse i Barentshavet vinteren 1978. Acoustic abundance estimation of cod and haddock in the Barents Sea in winter 1978. . Fisken Hav., 1979 [In print].

DOUBLEDAY, W.G. 1976. A pilot study of a survey design for a combined acoustic and other-trawl groundfish survey. Coun. Meet. int. Coun. Explor. Sea, 1976(B:30): 1-15, [Mimeo].

EHRENBERG, J.E. 1974. Two Applications for a Dual-Beam Transducer in Hydroacoustic Fish Assessment Systems. OCEAN'74. Proceeding of OCEAN'74 IEEE International Conference on Engineering in the Ocean Environment, 1974.

EHRENBERG, J.E. and LYTLE, D.W. 1977. Some signal processing techniques for reducing the variance in acoustic stock abundance estimates. In Hydro-Acoustics in Fisheries Research, ed. A.R. Margetts (Rapp. P.-v. Réun. Cons. int. Explor. 170, 1977), 205-213.

EHRENBERG, J.E. and WEIMER, R.T. 1974. Effects of thresholds on the estimated fish scattering cross section obtained with a dual-beam transducer system. Appl. Phys. Lab., Univ. of Wash. Report No. 7421.

FOOTE, K.G. 1970. Analysis of empirical observations on the scattering of sound by encaged aggregations of fish. FiskDir. Skr. Ser. HavUnders., 16: 423-456.

——— 1979a. Averaging of fish target strength functions. J. Acoust. Soc. Am. [In press].

——— 1979b. On representing the Length Dependence of Acoustic Target Strengths of Fish. J. Fish. Res. Bd. Canada, [In press].

HANSEN, M.H., HURWITZ, W.N. and MADOW, W.G. 1953. Sample survey methods and theory. Vol.1, Wiley & Sons, Inc. New York 1953, 638 p.

JOHANNESON, K.A. and LOSSE, G.F. 1977. Methodology of acoustic estimations of fish abundance in some UNDP/FAO resource survey projects. In Hydro-Acoustics in Fisheries Research, ed. A.R. Margetts (Tapp. P.-V. Rêun. Cons. int. Explor. 170, 1977), 296-318.

LOVE, R.H. 1977. Target strength of an individual fish at any aspect. J. Acoust. Soc. Am. 62: 1397-1403.

LØVIK, A. and DALEN, J. 1979. On the influence of wind induced bubbles on echo integration surveys. [In prep.].

MIDTTUN L. and NAKKEN, O. 1977. Some results of abundance estimation. Studies with echo integrators. In Hydro-Acoustic in Fisheries Research, ed. A.R. Margetts (Rapp. P.-V. Rêun. cons. int. Explor. 170. 1977). 253-258.

NAKKEN, O. and DOMMASNESS, A. 1975. The application of an echo integration system in investigations on the stock strength of the Barents Sea capelin (Maelotus villosus, Müller) 1971-1974. Int. Coun. Explor. Sea. Coun. Meet. 1975(B:25): 1-9, [Mimeo.].

NICHERSON, T.B. and DOWD, R.G. 1977. Design and operation of survey patterns for demersal fishes using the computerized echo counting system. Rapp. P.-v. Rêun. Cons. int. Explor. Mer., 170: 232-236.

RØTTINGEN, I. 1976. On the relation between echo intensity and fish density. FiskDir. Skr. Ser. HavUnders., 16: 301-314.

SHOTTON, R. and DOWD, R.G. 1975. Current Research in Acoustic Fish Stock Assessment at the Marine Ecology Laboratory. Serial No. 3468. ICNAF Res. Doc. 75/16.

THORNE, R.E. 1977. A New Digital Hydro-acoustic Data Processor and Some Observations in Herring in Alaska. J. Fish. Res. Bd. Canada 34: 2288-2294.

THORNE, R.E., REEVES, J.E. and MILLIKAN, A.E. 1971. Estimation of the hake population in Port Susan, Washington, using an echo integrator. J. Fish. Res. Bd. Canada. 28(9): 1275-1284.

THORNE, R.E. and WOODEY, J.C. 1970. Stock assessment by echo integration and its application to juvenile sockeye salmon in Lake Washington. Univ. of Wash. Coll. Fish. Circular no. 70-2, 1970.

WEIMER, R.T. and EHRENBERG, J.E. 1975. Analysis of Threshold-Induse Bias Inherent in Acoustic Scattering Cross-Section Estimates of individual Fish. J. Fish. Res. Bd. Canada. 32(12): 2547-2551.

YATES, F. 1965. Sampling methods for censuser and surveys. Griffin 1965, 440 p.

Table 1. Estimates on year class abundances of cod (thousands), and the relative abundance compared with the VPA (ANON 1979).

Year	1978 N	1978 % of VPA	1977 N	1977 % of VPA	1976 N	1976 % of VPA	1975 N	1975 % of VPA	1974 N	1974 % of VPA	1973 N	1973 % of VPA	1972 N	1972 % of VPA	1971 N	1971 % of VPA	1970 N	1970 % of VPA
1976							1002		58		309	45	212	42	83	34	110	34
1977					44		975		101	36	288	60	124	39	45	36	41	
1978			9		62		1029	216	116	60	176	72	32	24	9		3	
1979	7		13		105	34	480	150	69	58	38	31	12		6		1	

Table 2. Estimates on year class abundances of haddock (thousands), and the relative abundance compared with the VPA (ANON 1979).

Year	1978 N	1978 % of VPA	1977 N	1977 % of VPA	1976 N	1976 % of VPA	1975 N	1975 % of VPA	1974 N	1974 % of VPA	1973 N	1973 % of VPA	1972 N	1972 % of VPA	1971 N	1971 % of VPA
1976							3165		69		54	96	30	107	12	75
1977					250		762		192	165	56	170	8	73	8	114
1978			74		213		791	410	46	102	1	14				
1979	7		10		167	98	261	227	9	45						

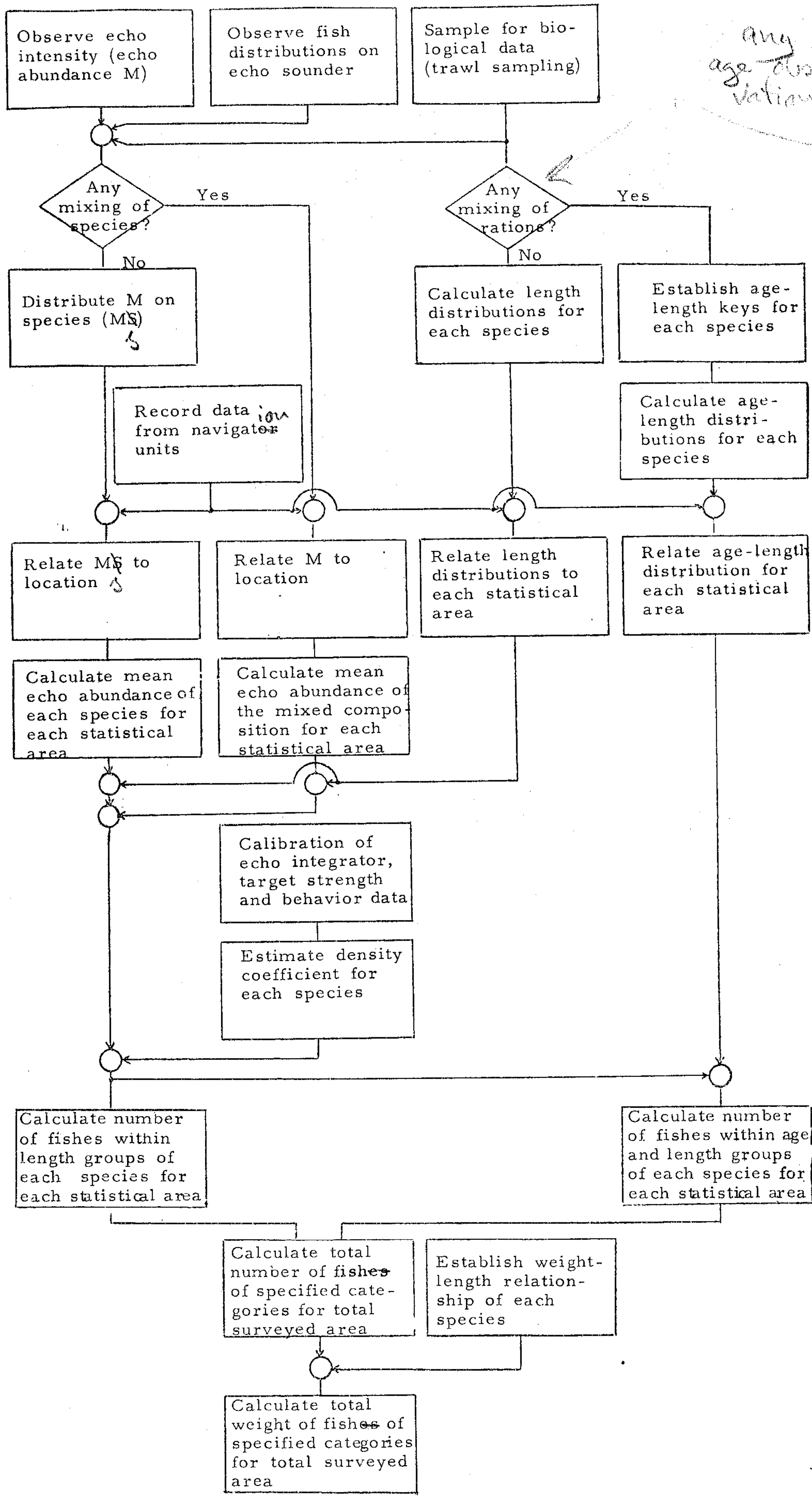

Fig. 2. Block diagram on the prosess of echo integration on assessing abundances of fish stocks.

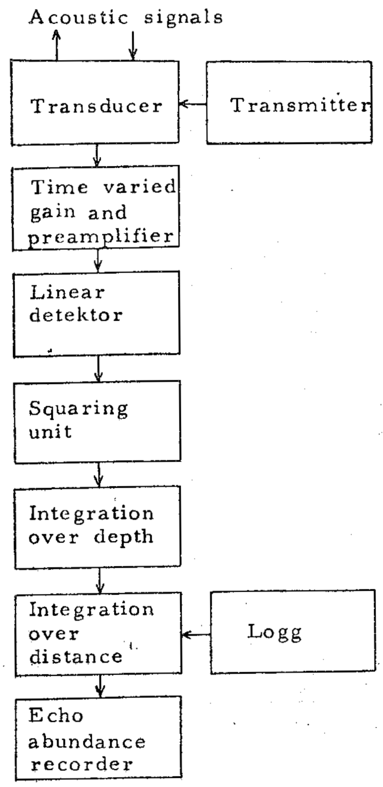

Fig. 2. Block diagram of the instruments and sampling equipment.

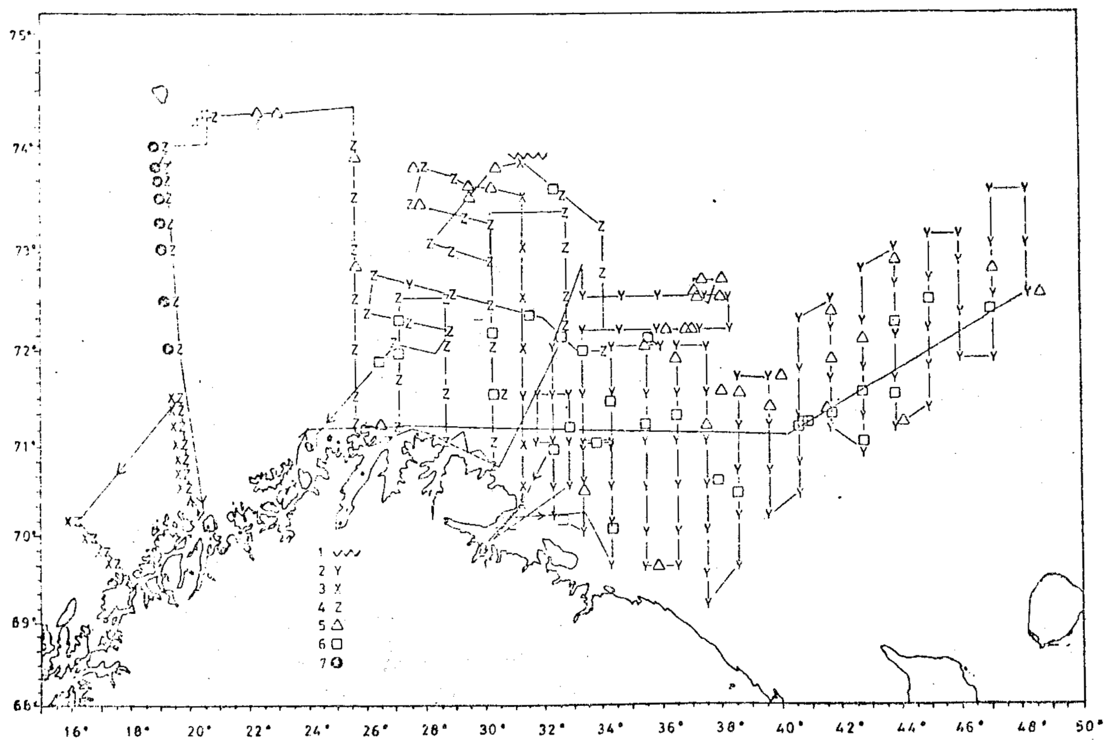

Fig. 3. Survey routes, hydrographical stations, and trawl stations in February - March 1978. 1) Ice boarder, 2) Bathytermograph, 3) Nansen bottles, 4) CTD-sonde, 5) pelagic trawl, 6) bottom trawl, 7) Juday-net.

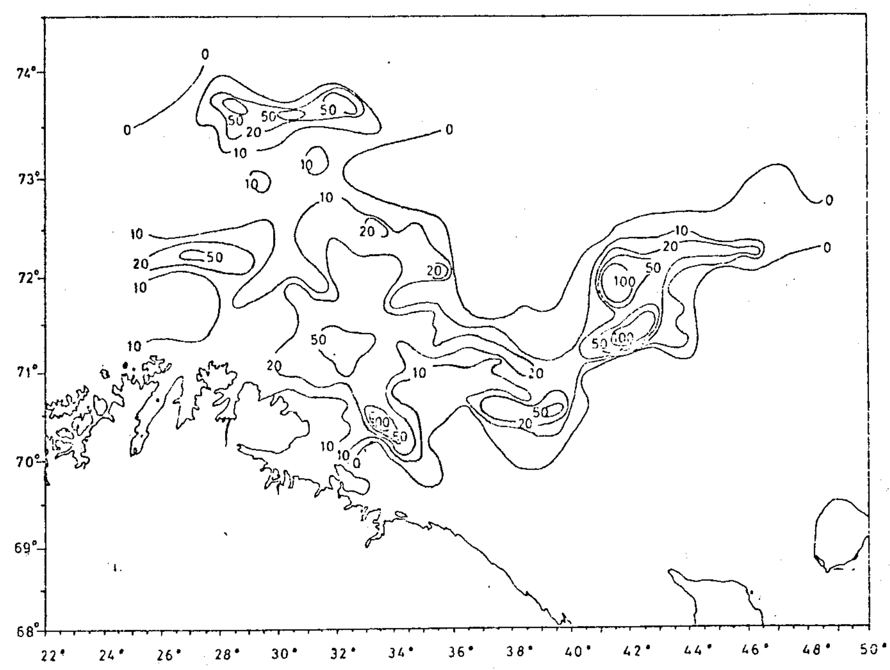

Fig. 4. Echo abundance of cod and haddock in 1978.

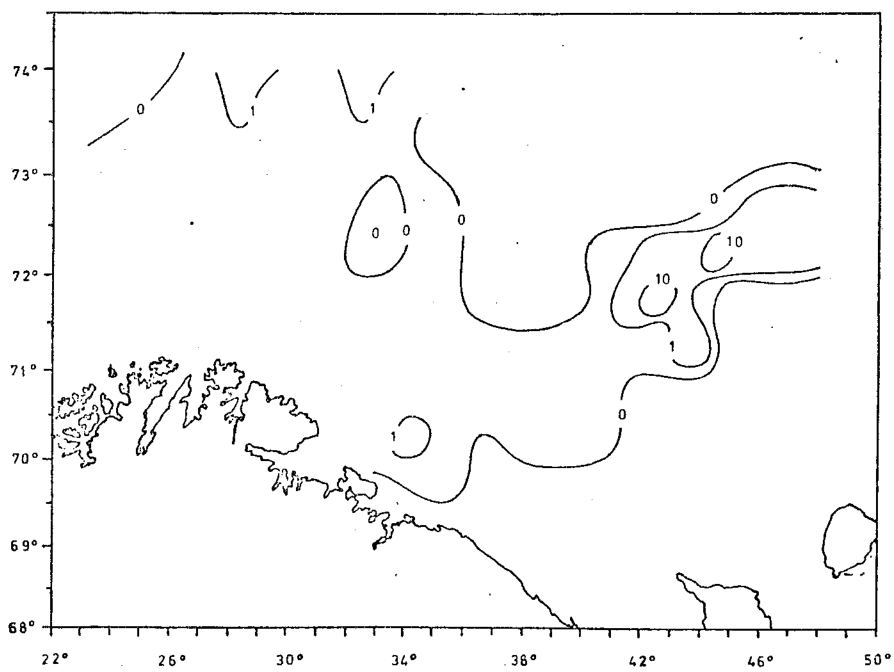

Fig. 5. Distribution of 2 years old cod in 1000 per (nautical mile)^2 in 1978.

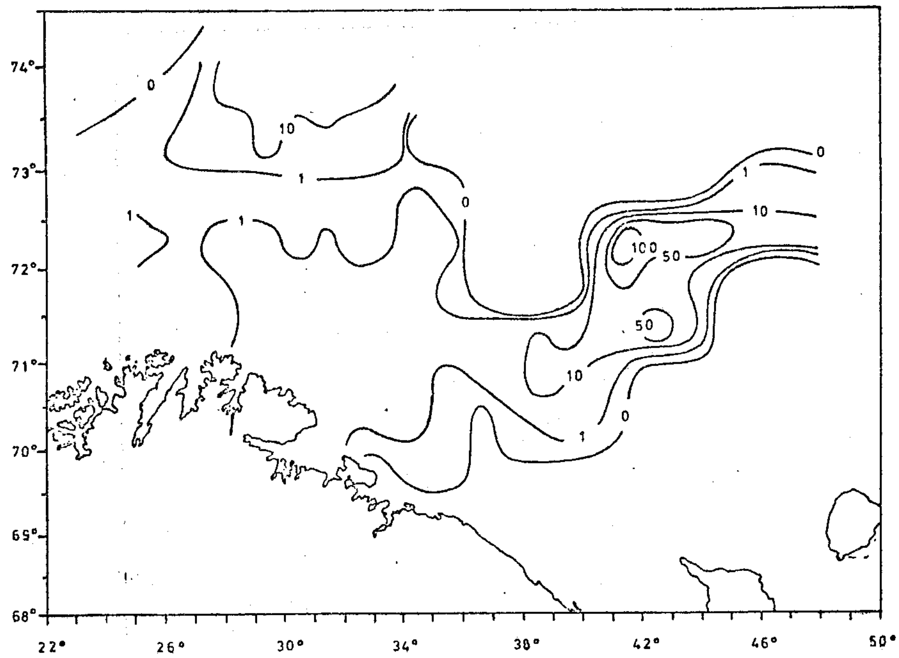

Fig. 6. Distribution of 3 years old cod in 1000 per (nautical mile)^2 in 1978.

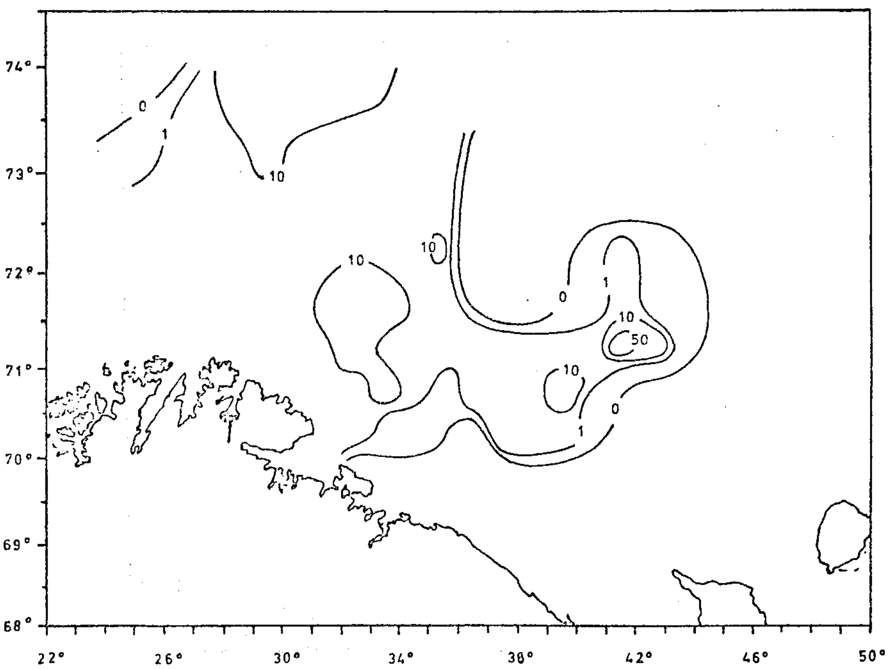

Fig. 7. Distribution of 4 years and older cod in 1000 per (nautical mile)^2 in 1978.

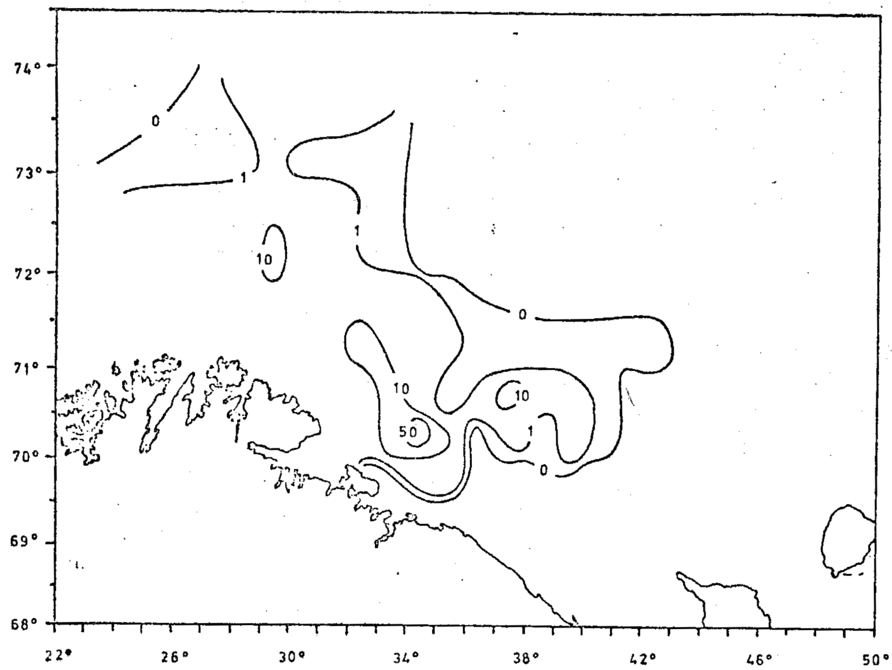

Fig. 8. Distribution of 2 years old haddock in 1000 per (nautical mile)^2 in 1978.

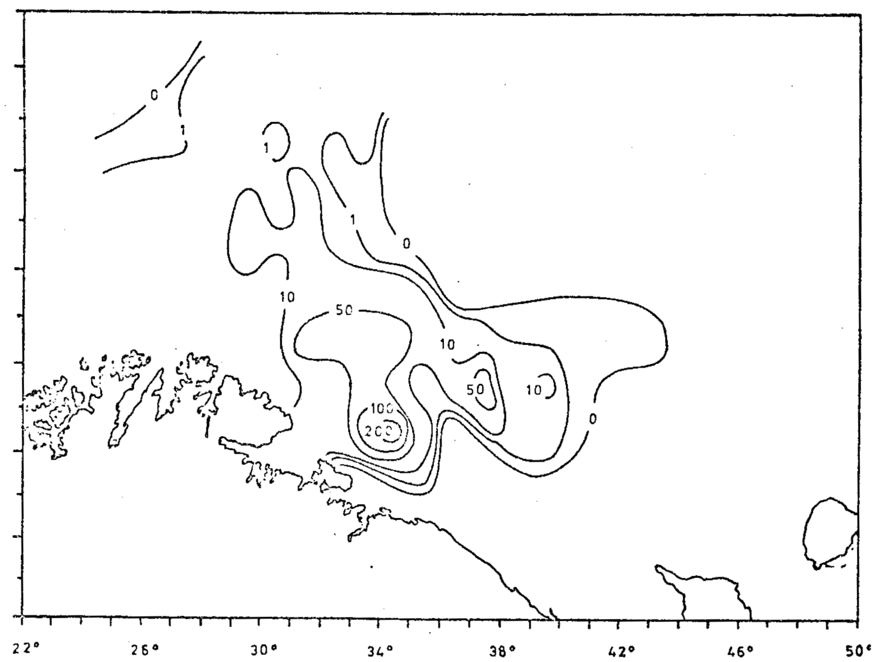

Fig. 9. Distribution of 3 years and older haddock in 1000 per (nautical mile)^2 in 1978.