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Experimental Trawl-acoustic Survey in NAFO Subarea 3 from March to July 1987

by

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ABSTRACT

The methods and results of experimental trawl-acoustic survey carried out on board the RV "Persey-III" in NAFO Divs. 3KLMNO from 10 March to 4 July 1987 are set forth in the paper. The estimation of the pelagic component of hydrobiont concentrations by the acoustic method and the bottom one by valid hauls with the known trawl fishing efficiency, and further averaging of the results by geographic strata are the basis of the present survey.

The assessments of biomass and abundance obtained by the method of the trawl-acoustic survey are given for cod, haddock, redfish, capelin, young capelin, sand eel in comparison with the results of standard acoustic surveys for capelin and trawl survey for bottom fish species carried out simultaneously. The general ways of improving the survey methods are noted.

The data on the target strength *in situ* at a frequency of 38 kHz for the major hydrobionts of the North Atlantic obtained by summarizing the known data and results of PINRO TS *in situ* measurements for 1983-87 are given in the paper.

INTRODUCTION

The trawl surveys aimed at assessing the main commercial bottom fishes in NAFO Divs.3KLMNO have been carried out by the Soviet investigators since 1971 (Bulatova and Chumakov, 1986).

In recent years the acoustic methods are widely used for the stock estimation of such objects as capelin and redfish. Each of the methods has its own faults associated, in the first turn, with the fact that the trawl and acoustic surveys do not allow to cover the fish distribution in pelagial and in a shadow zone of echo sounder near the bottom respectively. That is why the concurrent use of the trawl and acoustic methods during the survey supplements each other to a certain degree and allows to obtain more unbiased data on the distribution, abundance and biomass of both pelagic and bottom fishes. Such methods are used in PINRO beginning in 1985 when conducting the trawl-acoustic surveys for redfish, cod and haddock in the Barents Sea.

With a view to improve the procedure of simultaneous use of acoustic and trawl methods for more complete assessment of the main commercial fish stock in NAFO Divs.3KLMNO the experimental multispecies trawl-acoustic survey was conducted on the RV "Persey-III" in March to July 1987.

MATERIALS

The trawl-acoustic survey and regular trawl survey for bottom fishes (Chumakov and Borovkov, 1988) were carried out by R/V "Persey-III" from 10 March to 13 April in Divs. 3NO, from 23 April to 11 May in Div. 3L, from 11 to 13 May and from 26 May to 6 June in Div. 3K, from 21 June to 4 July in Div. 3M. A chart of cruise tracks is given in Fig.1. Besides, during the acoustic survey for capelin from 15 to 26 May and from 13 to 20 June in Divs. 3LNO (Bakanev and Mamylov, 1988) the sampling and processing of acoustic and biological data on other hydrobionts were performed according to methods of the given multispecies trawl-acoustic survey.

In all 570 bottom and 31 pelagic hauls were made by R/V "Persey-III" during the trawl-acoustic survey. In addition, the information of 10 pelagic hauls was used reported from R/V "Obva" which with R/V "Persey-III" conducted the survey in Divs. 3NO in March.

The total area of the trawl-acoustic survey was 147 000 sq. miles with the total track length covered during the acoustic survey of about 13 800 miles.

The EK-S-38 echo sounder (SIMRAD, Norway) and two SIORS digital integrators (USSR) were used as echo integrating systems. The QD-200 integrator (SIMRAD, Norway) connected constantly to echo sounder allowed to measure the target strength <u>in situ</u> for different hydrobionts by the acoustic method.

METHODS, RESULTS, DISCUSSION

During the trawl-acoustic survey the echo intensities were measured by 10 depth channels of SIORS integrators one or two of which operated as the 2- or 4-metre bottom channel. The integrators ceased integrating of reflected pulses on the average 0.75 m to the bottom which determined the minimum shadow zone of echo integrating system. It is natural that with the increasing depth and at rough bottom the actual shadow zone of echo sounder increased.

In contrast to a traditional echo survey when the integrator readings are taken at equal intervals of covered by vessel distance, during the trawl-acoustic survey the readings were taken when crossing the boundaries of geographic strata, changing the vessel speed, with a sharp variation in density or pattern of fish distribution and, besides, separately - during the trawlings (i.e. within the time interval between fixing the warps and their loosing). The integrating interval corresponding to the given reading was registered by the vessel log NL (SIMRAD, Norway). The integrator readings with regard for the instrument constant of echo integrating system and after correction for the difference between the echo sounder TVG and 20 lg R + 2α R function were recalculated thereupon to standard units of echo intensity M determined as:

$$M = 4\pi \cdot 1852^2 \cdot 10^{0.1\bar{S}_s} \quad , m^2/mile^2 \qquad (1),$$

where $\bar{S}_s$ - mean surface backscattering strength of the layer per integrating interval, dB.

The M values in each integrating interval ($\mathfrak{D}$) were further classified by hydrobiont species on the basis of an accurate analysis of echograms and results of test hauls separately for pelagic (M_P) and bottom (M_B) channels of the integrator. In so doing **M** was calculated separately for 10 species: 1) cod, 2) haddock, 3) young redfish ($L \leq 15$ cm), 4) redfish ($L > 15$ cm), 5) capelin ($L > 7$ cm), 6) juvenile capelin ($L \leq 7$ cm), 7) sand eel, 8) SSL (medusa, krill etc.), 9) myctophids, 10) other bottom and pelagic fishes (polar cod, white hake, argentine, hake, barracudina, grenadier etc.).

The division of M values by species using the results of pelagic and bottom hauls was made by the ratio:

$$M_1 : M_2 : M_3 : \ldots = \frac{P_1 \cdot \bar{\sigma}_{kg1}}{K_{R1}} : \frac{P_2 \cdot \bar{\sigma}_{kg2}}{K_{R2}} : \frac{P_3 \cdot \bar{\sigma}_{kg3}}{K_{R3}} : \ldots \quad (2),$$

where P_i – catch size of hydrobiont species i including the fish enmeshed in the trawl, kg;

$\bar{\sigma}_{kg_i} = 4\pi 10^{0.1\overline{TS}_{kg_i}}$ – mean scattering cross section per 1 kg of weight, m^2/kg;

K_{Ri} – relative fishing efficiency of the trawl for species i.

Following the experience of using the trawls with the fine-meshed net on R/V "Persey-III" $K_{Ri} = 1$ for hydrobionts with $L > 10$ cm, $K_{Ri} \approx 0.3$ for $L = 5$–10 cm, $K_{Ri} \approx 0.1$ for $L = 3$–5 cm. Approximated data on the target strength $\overline{TS}_{kg}$ in situ for different hydrobionts depending on their length at a frequency of 38 kHz are listed in Table 1. The data were obtained by summarizing the results of the known and used during echo surveys in the Northeast Atlantic target strength $TS(L)$ in situ measurements of the main commercial fishes (IMR, Bergen, Norway) and results of $\overline{TS}$ in situ measurements taken in 1982-87 (PINRO, Murmansk, USSR) with regard for pooled length-weight characteristics of different fishes.

The measurements of $\overline{TS}$ in situ at a frequency of 38 kHz were made by the Polar Institute following two methods, first, with the use of QD-200 integrator realizing the Craig and Forbes algorithm (Solli et al., 1982) and, second, with the use of the known method of echo counting combined with echo integrating. The point of the latter consists in measuring the mean target strength of single fish $\overline{TS}_{\Omega}$ in scattered concentration within the known effective beam angle of echo sounder (Ω) with regard for transducer directivity and further reducing the obtained data to equivalent beam angle (Ψ) and standard target strength ($\overline{TS}$) by the formulae:

$$\overline{TS} = \overline{TS}_{\Omega} + 10 \lg \frac{\Omega}{\Psi} \qquad (3)$$

$$\Psi = \int_{0}^{\Omega} b^{2}(\Omega)\, d\Omega \qquad (4),$$

where $b^{2}(\Omega)$- directivity pattern of transducer.

The QD-200 integrator made the identification of echo recordings easier during the trawl-acoustic survey. As the operating experience during the surveys carried out in 1984-87 by PINRO vessels showed the device gave rather realistic data on the real distribution of TS <u>in situ</u> for different hydrobionts if the following requirements were satisfied:

- the number of treated in QD-200 echoes from single fish in each run of measurements should be not less than 1000-2000 and their resolving power relative to total echo energy - not less than 20-30%;

- correction for the difference between the actual echo sounder TVG function and required one 40 lg R + 2αR in TS scale at QD-200 output by depths.

The use of QD-200 integrator for the length-species identification of echo recordings in practice is shown in Fig.2 for which the data for defining the scale $\overline{TS}(L)$ <u>in situ</u> for different hydrobionts were taken from the same sources as for determining the values $\overline{TS}_{kg}(L)$ in Table 1.

The calibration of QD-200 integrator and echo integrating system during the acoustic surveys and TS <u>in situ</u> measurements was made by a standard copper sphere with the target strength of 33.6 dB.

It is convenient to have similar formats for basic acoustic and trawl data and algorithms of their processing which makes easier the comparison and interpretation of the results of the trawl and acoustic surveys. That is why the bottom trawl catches from each haul were recalculated to equivalent echo intensity for each species i of hydrobionts ($M_{TR\,i}$) by the formula:

$$M_{TR\,i} = \frac{1852 \cdot P_i \cdot \bar{\sigma}_{kg\,i}}{D_{TR} \cdot L_{TR} \cdot R} \qquad (5),$$

where D_{TR} - trawling distance, mile;

L_{TR} - distance between the bottom trawl wings equal to 14.3 m;

R - fishing efficiency of the trawl relative to L_{TR}.

In accordance with methods of the trawl survey for bottom fishes R = 1 (Bulatova and Chumakov, 1986). During the trawl-acoustic survey the opening height of the bottom trawl was about 1.5-2.0 m which in most cases exceeded, as a matter of fact, the real shadow zone of echo integrating system in the near-bottom layer. Therefore, to determine the actual density of bottom fishes the results of the trawl (M_{TR}) and acoustic ($M=M_P+M_B$) surveys were summarized.

To verify the potential usage of acoustic methods for determining the fish density in the near-bottom layer the echo intensity values in the bottom channel of echo integrator per a haul (M_B) were compared with the trawling data (M_{TR}) and the regression equation was formulated as

$$M_{TR} = a\, M_B + b \qquad (6).$$

The further treatment of the survey results consisted in averaging the M and M_{TR} values by strata with regard for integrating interval (D). In case of M_{TR} averaging by strata the results of all hauls in the given stratum and not only those used during the trawl survey were taken into account. The hauls made near the boundaries of neighbouring strata with similar depths were counted twice - for each of above strata. It is accounted for by the fact that a random choosing of the bottom trawl stations adopted for standard trawl survey, in practice is not always optimum (in particular, due to "patch" distribution of fish by area). In such cases the extra test hauls are necessary - for instance, when the echo recordings change abruptly in the near-bottom layer along the tracks.

As a result, the mean acoustic($\bar{M}$) and trawl ($\bar{M}_{TR}$) echo intensities were obtained for bottom fish by strata.

When determining the density of pelagic fish (capelin, sand eel) the value $M = M_P + M_B$ was taken for an actual density where M_B was corrected with regard for M_{TR} according to methods of the trawl-acoustic survey used during the echo survey for capelin in Divs. 3KLNO (Bakanev and Mamylov, 1988).

When treating the results of both acoustic and trawl surveys the total abundance and biomass of hydrobiont species were evaluated by the short-cut method - with the use of average length-weight characteristics of fish and $\bar{\sigma}_{kg}$ values by strata or groups of strata limited with similar isobaths:

$$W = \sum_K W_K = \sum_K \frac{\bar{M}_K \cdot S_K}{\bar{\sigma}_{kg\,K}} \qquad (7)$$

$$N = \sum_K \frac{W_K}{\bar{w}_K} \qquad (8),$$

where K - stratum index;

S_K - stratum area, mile^2;

$\bar{w}_K$ - mean weight of a specimen, kg;

N - abundance, spec.;

W - biomass, kg.

The mean density of the main commercial fish species by strata is given in Figs. 3-11 in echo intensity units of $\bar{M}$ and $\bar{M}_{TR}$ according to results of the trawl-acoustic survey. The mean density of cod, haddock and redfish by strata is given in the form of a fraction the numerator of which involves acoustic data ($\bar{M}$) and denominator - the data estimated from the bottom trawl catches ($\bar{M}_{TR}$). Such a form is convenient for comparison of pelagic and bottom components of fish density in different periods of survey. The results of the abundance and biomass assessment in these periods of the trawl-acoustic survey are given in Table 2. The term "experimental trawl survey" means the treatment and averaging of trawling data by the short-cut method mentioned above and used also for evaluation of pelagic component by the acoustic method. For comparison Table 2 lists also the results of the trawl survey carried out by the standard method (Chumakov and Borovkov, 1988).

As is seen from Table 2 the results of the fish abundance and biomass assessment obtained by two methods for the near-bottom layer turned to be similar (spread in N and W values did not exceed on the average 15-20%). To make the results of the trawl-acoustic survey more accurate in future, the abundance and biomass estimation by strata should be done by length groups according, for instance, to standard methods of acoustic capelin survey (Bakanev et al., 1986) rather than by average length-weight characteristics of fish.

The averaging of acoustic and trawl data by geographic strata requires an even sampling of M and M_{TR} values by area within each stratum - the tracks of the multispecies trawl-acoustic survey were plotted on this basis. When conducting the echo survey for some hydrobiont species the tracks are plotted based on the pattern of fish distribution by area with the further stratification of the area surveyed with regard for an even distribution of tracks and fish density within each of chosen strata (Bakanev et al., 1986).

Thus, for example, according to the results of standard acoustic survey the capelin biomass in Divs.3KLO was estimated in May at 2.2 mill.t and in Divs.3NO in June - at 315 thou.t (Bakanev and Mamylov, 1988). The estimation of the results of above surveys by the trawl-acoustic method yielded 2.3 mill.t and 540 thou.t respectively (Table 2). The difference in estimates obtained in June survey is accounted for by the non-optimum choosing of tracks within geographic strata in Div.3N from the standpoint of using the trawl-acoustic method - the considerable uneveness of tracks and density of capelin distribution within these strata requires an extra, more detailed, stratification of the area surveyed as it was done in Divs.3NO when treating the results by the acoustic method.

The rough abundance estimate of capelin of the 1986 year class (smaller than 7 cm) by the trawl-acoustic method (not less than 25 bill.spec.) was obtained due to the fact that the cruise tracks did not cover the whole area of young capelin distribution on the Grand Bank in May-June. Nevertheless, the comparison of these results and those of analogous abundance estimates of capelin yearlings during the acoustic survey in Divs.3LNO in May-June 1983 and 1984 (the 1982 year class numbered 110 bill. spec. in 1983 and abundant 1983 year class - 360 bill.spec. in 1984) does not allow to regard the 1986 year class as a rich one.

The results of the three trawl-acoustic surveys for cod in Divs.3LNO in March-June (Figs.4-6 and Table 2) show the variation in cod density on the Grand Bank during this time, the per cent of the pelagic component of cod abundance in relation to the bottom one being increased in May-June compared to March-April.

During the June echo survey for spawning capelin in Divs.3NO there was obtained a rough estimate of cod biomass by the trawl-acoustic method, the bottom component being determined by the following way: as a result of nine bottom trawlings the regression equation was set up

$$M_{TR} = a\,M + b \qquad (9),$$

where $a = 0.79$, $b = -1.59$ at the correlation coefficient $r = 0.997$.

$\bar{M}_{TR}$ and later the cod biomass in the near-bottom layer by strata were assessed thereupon by the known acoustic data ($\bar{M}$ by strata) with the use of equation (9). The total cod biomass in Divs.3NO in June (pelagic and bottom components) was roughly estimated by this method at 130 thou.t. A more accurate estimate was obtained by means of the detailed stratification by area (analogous one used during the June echo survey for capelin in Divs.3NO) and it was about 100 thou.t.

The acoustic surveys for redfish in NAFO Divs.3LMNO have been carried out by PINRO vessels since 1983. During these surveys as well as during the trawl-acoustic survey the M values were averaged by standard geographic strata. The results of the pelagic component assessment of redfish abundance and biomass obtained during these surveys are listed in Table 3. In most cases the data are approximate, in the first place, due to insufficient number of pelagic test hauls during the surveys. Therefore, they do not have an important bearing on the accuracy of the results of subjective factor when reading echograms and identifying redfish through the other hydrobiont echo recordings. None the less, the analysis of regular acoustic estimates on redfish by years and year classes, and their comparison with the results of the bottom trawl surveys for redfish carried out in the same periods give, as a matter of principle, an opportunity to obtain more reliable data on redfish stocks (juveniles, in particular) and to determine the error of the trawl-acoustic method.

The division of fish density into pelagic and bottom components with the use of above trawl-acoustic method is, to a certain degree, conventional. It is accounted for by the uncertainty of notions "effective opening height" and "fishing efficiency" of the bottom trawl depending on the length-species composition of trawlable hydrobionts and their behaviour in the trawling zone, and also by the uncertainty in the value of actual shadow zone of echo integrating system. From this point of view one of the ways for improving the trawl-acoustic method is the correction of echo integrating results, obtained during the survey for the near-bottom layer, according to the results of bottom trawlings with the use of regression relation between the trawling (M_{TR}) and acoustic (M_{B}) data obtained in the course of trawlings (equation (6)). It may be shown that in a case of reliable correlation between M_{TR} and M_{B} the regression coefficients a and b allow, as a matter of principle, to estimate the shadow zone and fishing efficiency of the trawl relative to the near-bottom layer determined by the bottom channel width of integrator.

The preliminary regression analysis of the results of about 300 bottom trawlings carried out in March-July 1987 during the trawl-acoustic survey showed that the reliable correlation coefficient ($r > 0.8$) between M_{TR} and M_{B} is possible just in separate particular cases, namely, when the fish are distributed evenly enough within the bottom channel rather than in a dense strip close to the bottom. Such situations were observed, for example, for concentrations of cod in Div.3K (late May) and 3N (June), young cod in the central part of Div.3M (late June), redfish in Divs.3KLMO during the darkness (late April-June). The prospects of improving the trawl-acoustic method on the given line are borne out by these results. In particular, the experience of the trawl-acoustic surveys conducted in the Barents Sea shows that the correlation between M_{TR} and M_{B} increases, for instance, when the bottom trawl opening height is increased (to 6-8 m).

CONCLUSIONS

On the whole, the results of experimental multispecies trawl-acoustic survey carried out in NAFO Subarea 3 showed its obvious advantages in comparison with traditional separate trawl or acoustic surveys. The concurrent use of acoustic and trawl methods supplementing each other allowed to obtain more comprehensive information on distribution, abundance and biomass of redfish, cod, haddock, capelin and sand eel in the area surveyed.

On the basis of the results of multispecies survey, with regard for the experience of analogous surveys in other areas of the North Atlantic, the general ways of improving the trawl-acoustic method and increasing the accuracy of its results can be formulated:

1. Increasing the number of test hauls (primarily, pelagic) for the length-species identification of hydrobionts and shortening the terms of the trawl-acoustic survey for the purpose of decreasing the influence of fish migrations during the survey.

2. Need for occupying the test bottom sets, by analogy with the acoustic method, at an abrupt change of the fish distribution pattern (echo recording pattern) in the near-bottom layer along the tracks and not only in random coordinates according to the methods of standard trawl survey.

3. Processing and averaging of acoustic and trawl data by geographic strata with additional stratification of them in a case of different density of tracks and considerable difference in fish density within each stratum.

4. Further experiments on the possible and limited use of acoustic method for the fish density estimation in the near-bottom layer.

5. Studying of the ship avoidance effect on the density and pattern of fish distribution during the survey.

6. Revising the data on the target strength <u>in situ</u> for different hydrobionts.

7. Need for optimizing the track and trawl set positions, and also the terms of multispecies survey, standardization of processing the survey results with regard for solvable problems and number of vessels participating in the trawl-acoustic survey.

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Table 1. Recommended $\overline{TS}_{kg}$ values for acoustic surveys (echo sounder frequency - 38 kHz).

Species	Length, cm	Mean weight, g	$-\overline{TS}_{kg}$, dB/kg	Used data on TS (L) in situ
Capelin	5-8	I-2	29.2-30.0	1) TS(L)=19.11gL-74.4 and correction for L≤12cm* 2) TS measurements in situ**
	8-I2	2-8	30.0-32.8	
	I2-I6	8-2I	32.8-34.7	
	I6-20	2I-40	34.7-35.2	
Polar cod	3-5	0.5-I.5	25.0-27.4	1) TS(L)=21.81gL-72.7 and correction for L≤10cm* 2) TS measurements in situ**
	5-6	I.5-4	27.4-28.6	
	8-I2	4-II	28.6-29.7	
	I2-I6	II -28	29.7-3I.0	
	I6-20	28- 55	3I.0-3I.8	
Cod	8-I2	I0-27	32.5-33.3	TS(L)=21.81gL-72.7 and correction for L≤ 10cm*
	I2-20	27-80	33.3-33.4	
	20-30	80-255	33.4-34.6	
	30-50	255-II40	34.6-36.2	
	50-70	II40-2900	36.2-37.I	
	70-I00	2900-8900	37.I-38.6	
	I00-I30	8900-23000	38.6-40.2	
Haddock	8-I2	I4-30	34.0-34.4	TS(L)=16.91gL-67.9 and correction for L ≤10cm*
	I2-I6	30-53	34.4-34.7	
	I6-20	53-95	34.7-35.7	
	20-30	95-240	35.7-36.7	
	30-50	240-I240	36.7-40.I	
	50-70	I240-3440	40.I-42.0	
	70-90	3440-6260	42.0-42.8	
Redfish	5- 8	I.5- 6	29.7-34.0	TS measurements in situ for different length distribution of redfish**
	8-I2	6 - 2I	34.0-36.5	
	I2-I6	2I - 57	36.5-37.8	
	I6-20	57 - II3	37.8-38.3	
	20-50	II3 -I430	38,3	
Blue whiting	I2-I6	I3-25	30.4-30.5	1) TS(L)=21.81gL-72.7 2) TS measurements in situ**
	I6-20	25-46	30.5-3I.0	
	20-25	46-I00	3I.0-32.2	
	25-30	I00-I60	32.2-32.5	
	30-35	I60-230	32.5-32.7	
	35-40	230-350	32.7-33.2	
Herring	8-I2	3-I0	28.3-3I.5	1) TS(L)=21.71gL-75.5 and correction for L≤12cm* 2) TS measurements in situ**
	I2-I6	I0-23	3I,5-33.2	
	I6-20	23-50	33.2-34.2	
	20-25	50-I20	34.2-35.8	
	25-30	I20-220	35.8-36.7	
Shrimp and Krill	2-3	0,05-0,I	28.0-29.2	1) TS measurements in situ** 2) Pooled data which known about TS of Krill in situ
	3-5	0.I -I	29.2-33.2	
	5-8	I -5	33.2-36.2	
	8-I2	5 -I0	36.2	
Sand eel	I6-23	I0-30	34.0±I.0	1) TS measurements in situ** 2) $\overline{TS(L)}$=201gL-78.3 (calculated relationship based on known data on TS)**

Table 1 continued.

Species	Length, cm	Mean weight, g	$-\overline{TS}_{kg}$, dB/kg	Used data on TS(L) *in situ*
Lantern-fish	4-7	I.5-4	3I.0+I.0	TS(L)=25.2lgL--75.0 (TS measurements *in situ* for different length distribution)**
Jellyfish	I0-30	200-700	48.5±I.5	TS measurements *in situ***
Squid (active)***	30-40	500-I500	44.8±I.5	TS measurements *in situ***
Squid (passive)***	-"-	-"-	42.2±I.5	
Saithe	36-62 62-79	460-2040 2040-5000	35.4-37.2 37.2-38.4	TS(L)=21.8lgL--72.7
Argentine	24-44	II0-700	34.0±I.0	1) TS(L)=21.8lgL--72.7 2) TS measurements *in situ***
Barracudina	20-30	I5-50	32.2±I.0	TS measurements *in situ***
Grenadier	20 30 40-70	30 I20 300-2200	39.0±I.5 43.0±I.5 45.0±I.0	1) The most probable TS values based on the morphology of this fish** 2) TS measurements *in situ***
Mackerel	30-40	350-720	5I.0±I.0	Appoximative value based on known mackerel TS data**
White hake	I6-25 25-40 40-55 55-70 70-85 85-I00	37-II4 II4-500 500-I300 I300-2760 2760-4980 4980-94I0	32.0-32.8 32.8-34.7 34.7-35.8 35.8-36.9 36.9-37.6 37.6-38.8	TS(L)=21.8lgL--72.7

* For fish with the length equal to echo length the $\overline{TS}$ values are higher than those calculated by major equations of the form TS=a lg L+b due to a weaker effect of fish distribution on beam angle in comparison with the larger fish.

** Results of the surveys carried out by the Polar Institute in 1983-87.

*** Squid (pass.) - mainly horizontal distribution in space. Squid (act.) - random distribution (such a situation is observed, for example, during the intensive fishery for squid with the vertical lines).

Table 2. Results of the trawl-acoustic surveys in Divs.3KLMNO in March-July 1987.

Area surveyed	Survey period	Acoustic survey: abundance, 10^6 spec.	Acoustic survey: biomass, 10^3t	Experimental trawl survey: abundance, 10^6 spec.	Experimental trawl survey: biomass 10^3t	Trawl survey: abundance, 10^6 spec.	Trawl survey: biomass, 10^3t
		Capelin L ≥ 7 cm					
3KLNO (south of 50°N)	I0.03-I3.05	80000	I700	-	-	-	-
3KLO	I5.05-06.06	I20000	2300	-	-	-	-
3NO	I3 -20.06	I7000	540	-	-	-	-
		Capelin L ≤ 7 cm					
3LNO	I0.03-II.05	I0000	I0	-	-	-	-
3LO	I5 -26.05	25000	25	-	-	-	-
3NO	I3 -20.06	I3000	I3	-	-	-	-
		Sand eel					
3LNO	I0.03-II.05	2700	54	-	-	-	-
3LO	I5 -26.05	2000	40	-	-	-	-
3NO	I3 -20.06	540	II	-	-	-	-
		Cod					
3LNO	I0.03-II.05	39	85	II9	370	I28	422
3LO	I5 -26.05	32	70	-	-	-	-
3K	II -I3.05 26.05-06.06	I36	I35	II6	II5	I33	I30
3NO	I3 -20.06	56	75	42	56	-	-
3M	2I.06-04.07	40	9	28	8	37	I2
		Haddock					
3NO	I0.03-I3.04	29	20	36	24	40	27
		Redfish					
3LNO	I0.03-II.05	745	I9I	329	89	282	80
3K	II -I3.05 26.05-06.06	I89	85	I4I	64	I55	69
3M	2I.06-04.07	>I4000	>350	503	I05	463	I06

Table 3. Results of the acoustic surveys for redfish in Divs.3KLMNO in 1983-87.

Area surveyed	Survey period	Length, cm	Mean weight, g	Abundance, 10^8 spec.	Biomass, 10^3 t
		I 9 8 3			
3 LN (outside CFZ)	3I.05-26.06	I0-40	275	5.8	I60
3 M	28.05-I7.06	7-I0	8	230*)	I80*)
	-"-	I2-20	50	44*)	220*)
		I 9 8 4			
3 LN (north of 45°30'N)	I9.04-07.05	I0-40	265	2.8	75
3 NO	23.04-I6.05	II-2I	7I	4.I	29
(south of 45°30'N)	-"-	22-50	272	3.6	98
3 M	28.03-08.04	7-2I	5I	92*)	470*)
	-"-	22-52	443	5.9*)	260*)
3 M	08-I9.04	7-9	8	I4	II
	-"-	I0-2I	64	45	290
	-"-	22-52	443	4.5	I98
		I 9 8 5			
3 M	I6.04-04.05	I0-25	95	6.4	60
	-"-	26-50	458	3.0	I39
		I 9 8 7			
3 NO	I0.03-I3.04	I0-50	229	6.2	I44
3 L	23.04-II.05	I0-50	392	I.2	47
3 K	II-I3.05	I0-50	447	I.9	85
3 M	26.05-06.06 2I.06-04.07	7-I5	I2	>I30*)	>I40*)
	-"-	I6-52	263	>8*)	>2I0*)

*) Approximated estimate to less than 50% accuracy.

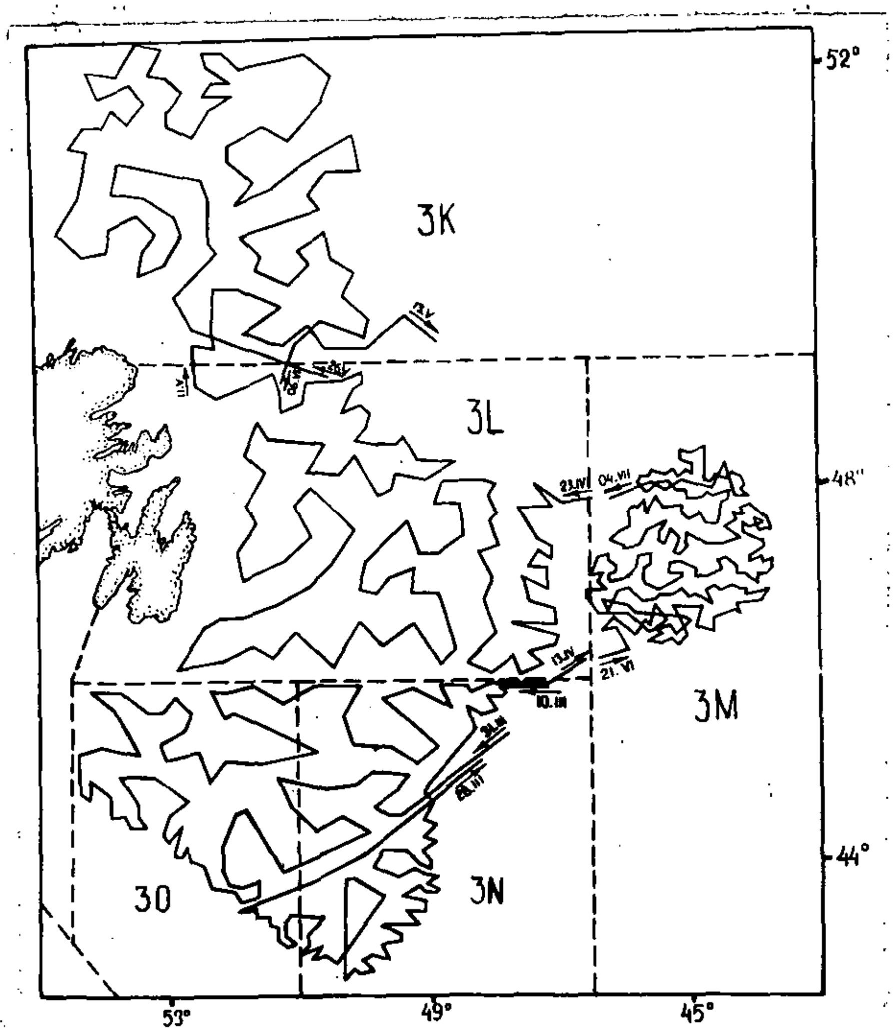

Fig.1 A chart of cruise tracks of RV "Persey-III" during the trawl-acoustic survey in March-July 1987.

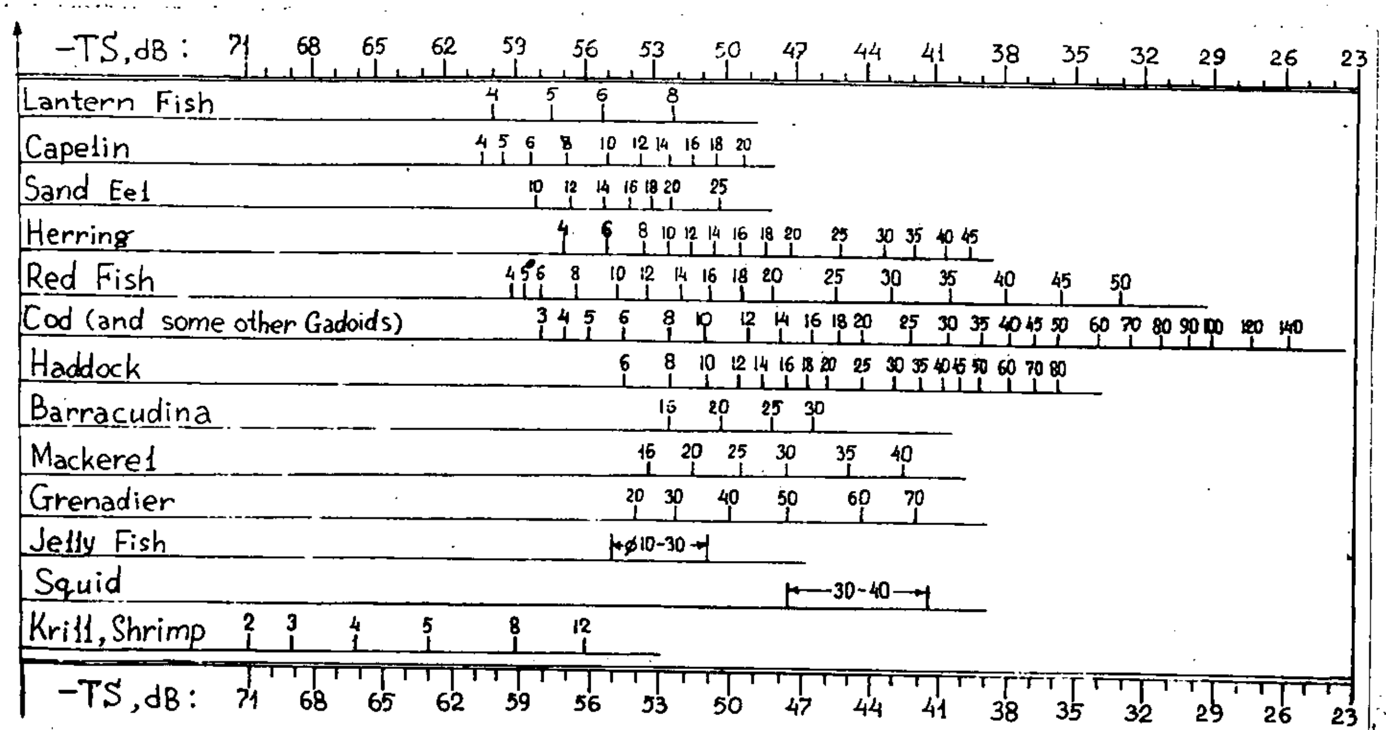

Fig.2 Relation between $\overline{TS}$ in situ for some hydrobiont species and their length (cm) at a frequency of 38 KHz.

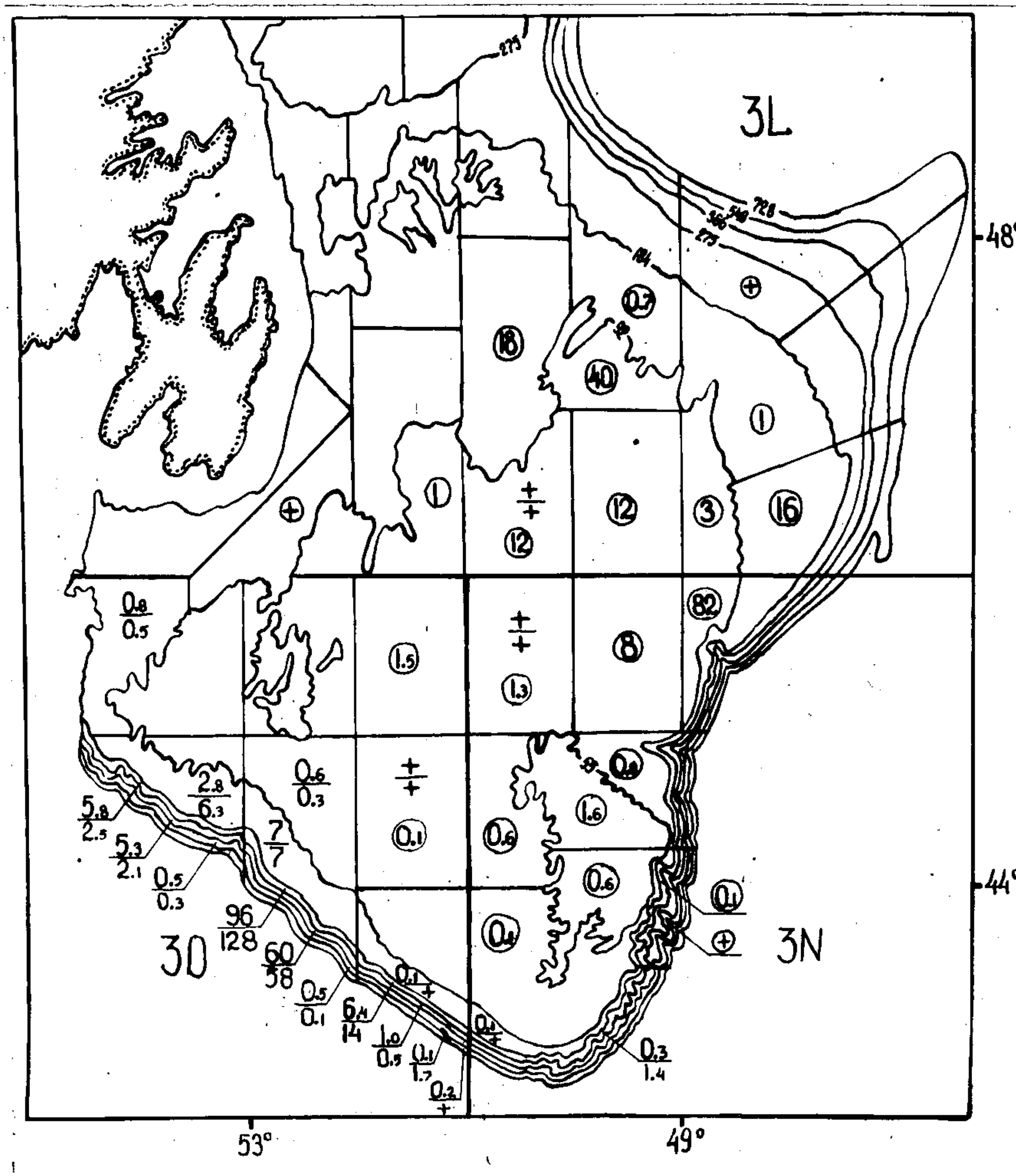

Fig.3 Distribution of sand eel ($\bar{M}$ values are encircled) and haddock in Divs.3LNO during the trawl-acoustic survey from 10 March to 11 May 1987.

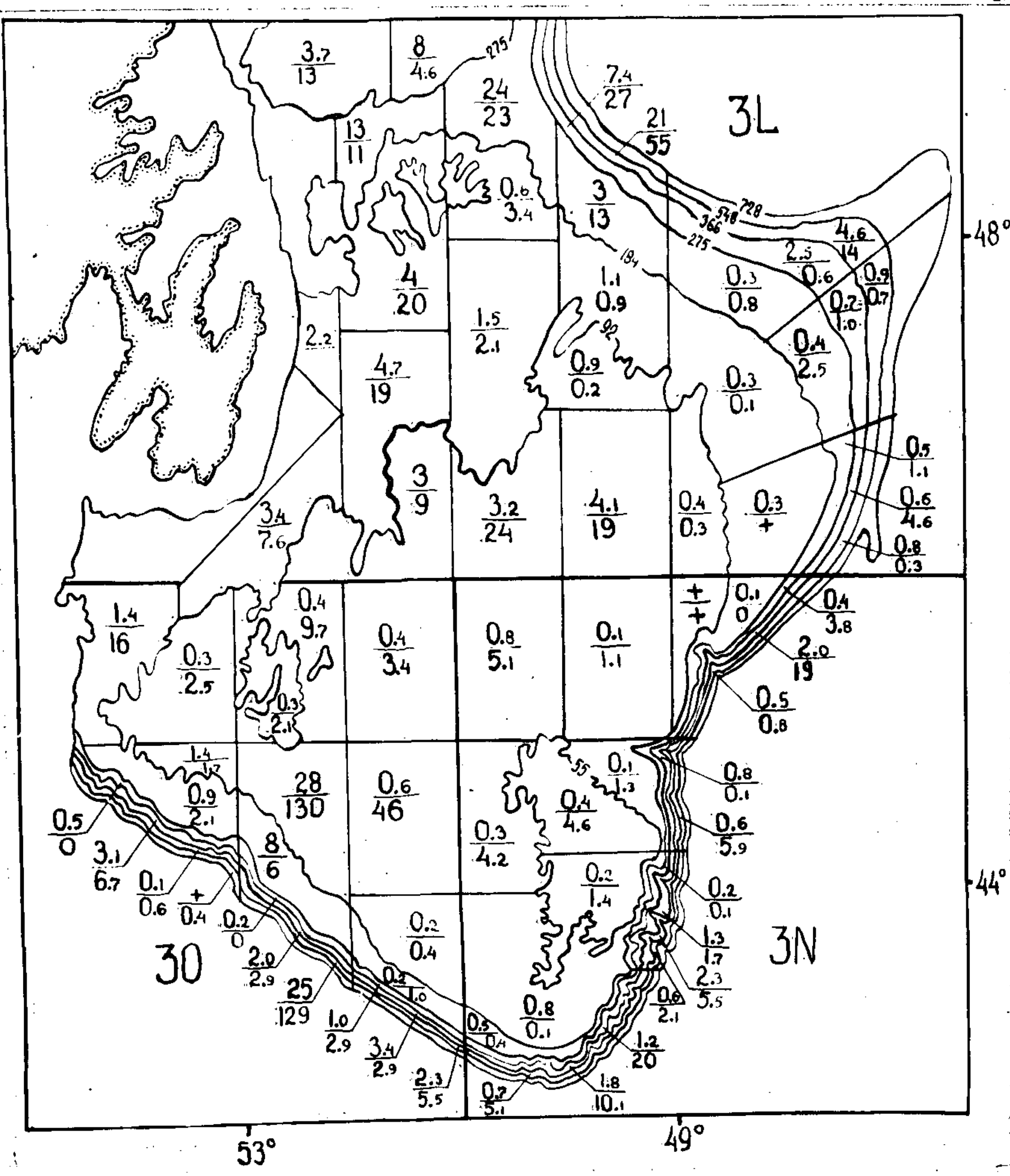

Fig.4 Cod distribution in Divs.3LNO during the trawl-acoustic survey from 10 March to 11 May 1987.

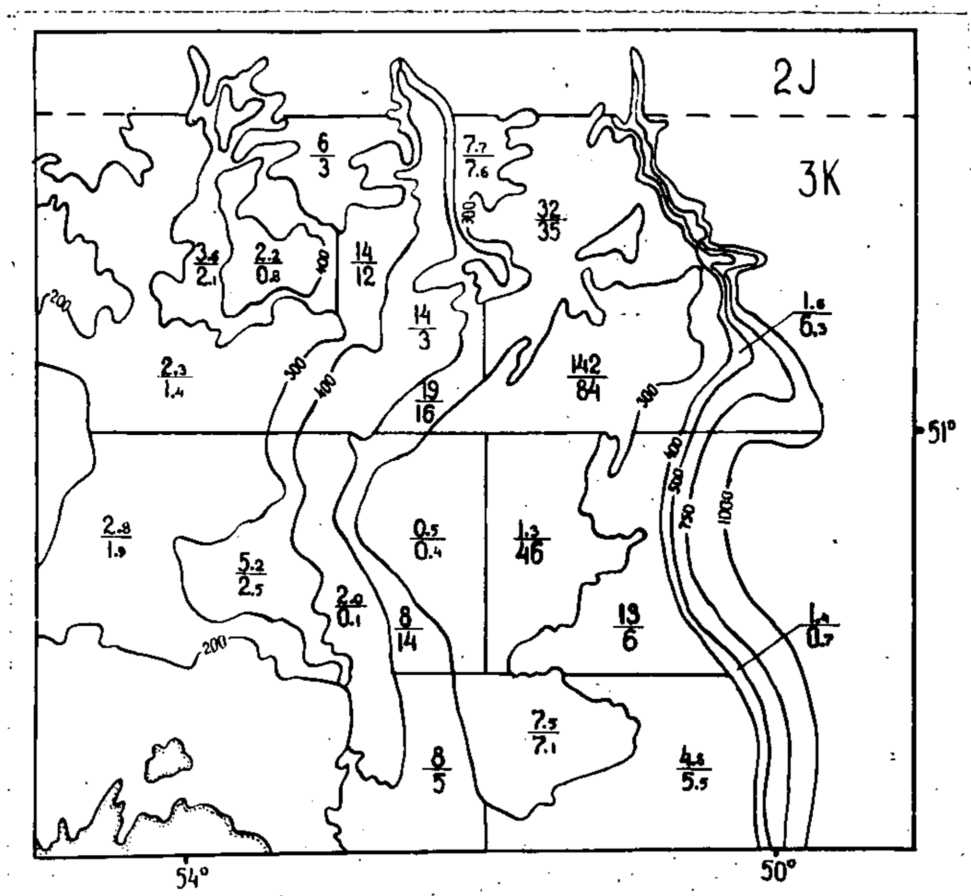

Fig.5 Cod distribution in Div.3K during the trawl-acoustic survey from 11 to 13 May and from 26 May to 6 June 1987.

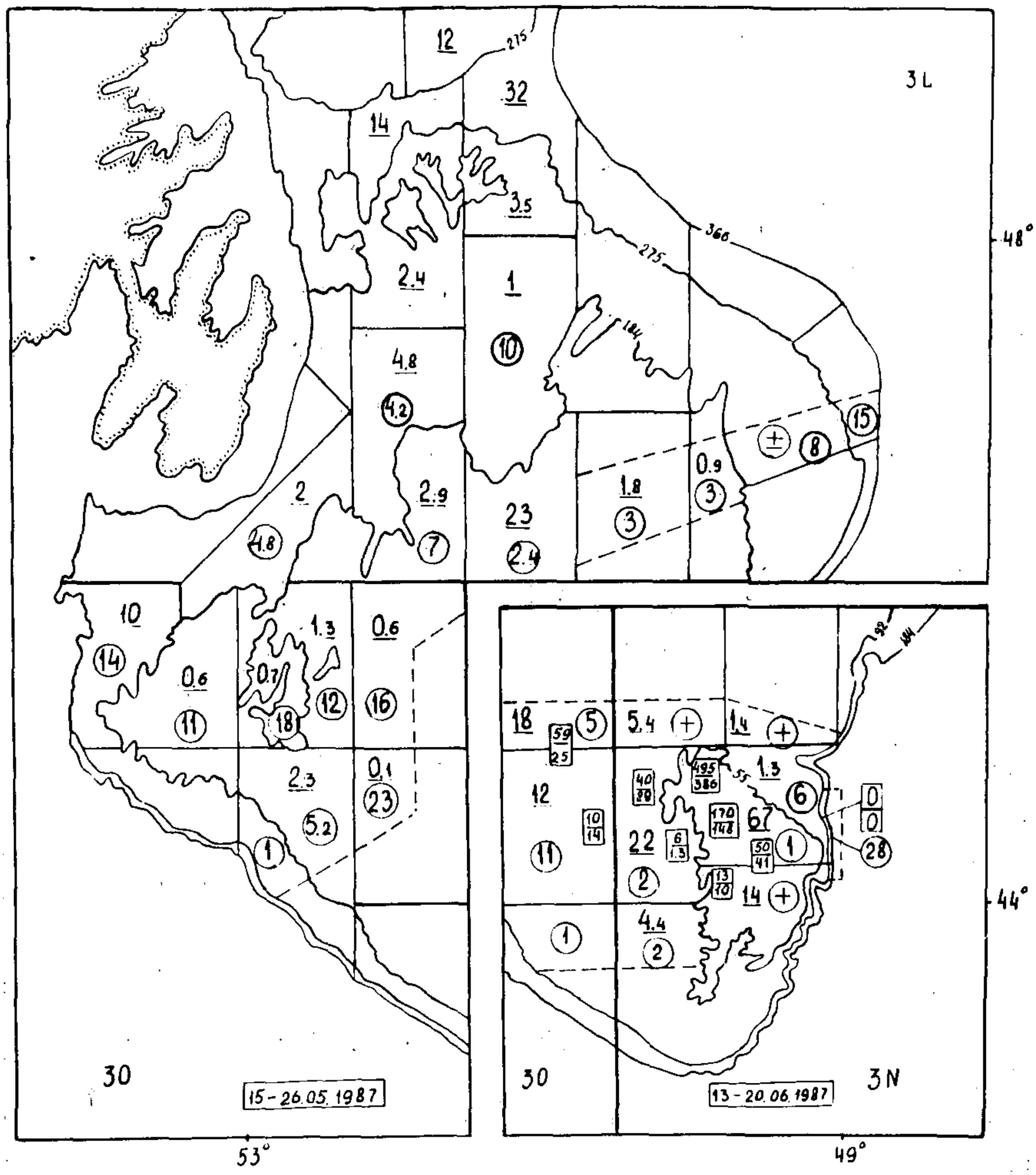

Fig.6 Distribution of sand eel ($\overline{M}$ values are encircled) and cod in Divs.3LNO during the echo survey for capelin from 15 to 26 May and from 13 to 20 June 1987. (Rectangles denote positions of bottom trawl stations with M and M_{TR} values for cod during the hauls).

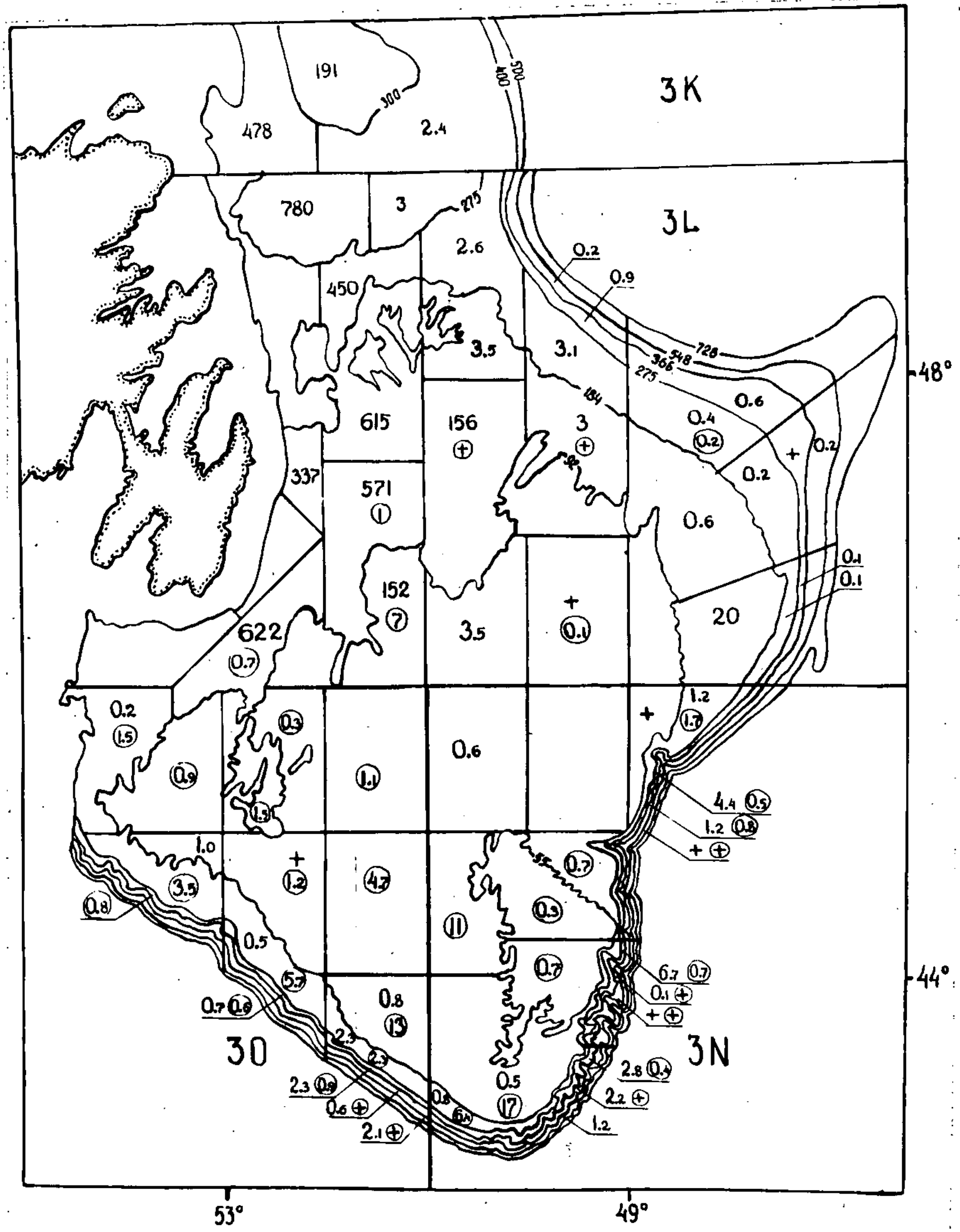

Fig.7 Capelin distribution in Divs.3KLNO during the trawl-acoustic survey from 10 March to 13 May 1987 ($\bar{M}$ values for young capelin smaller than 7 cm are encircled).

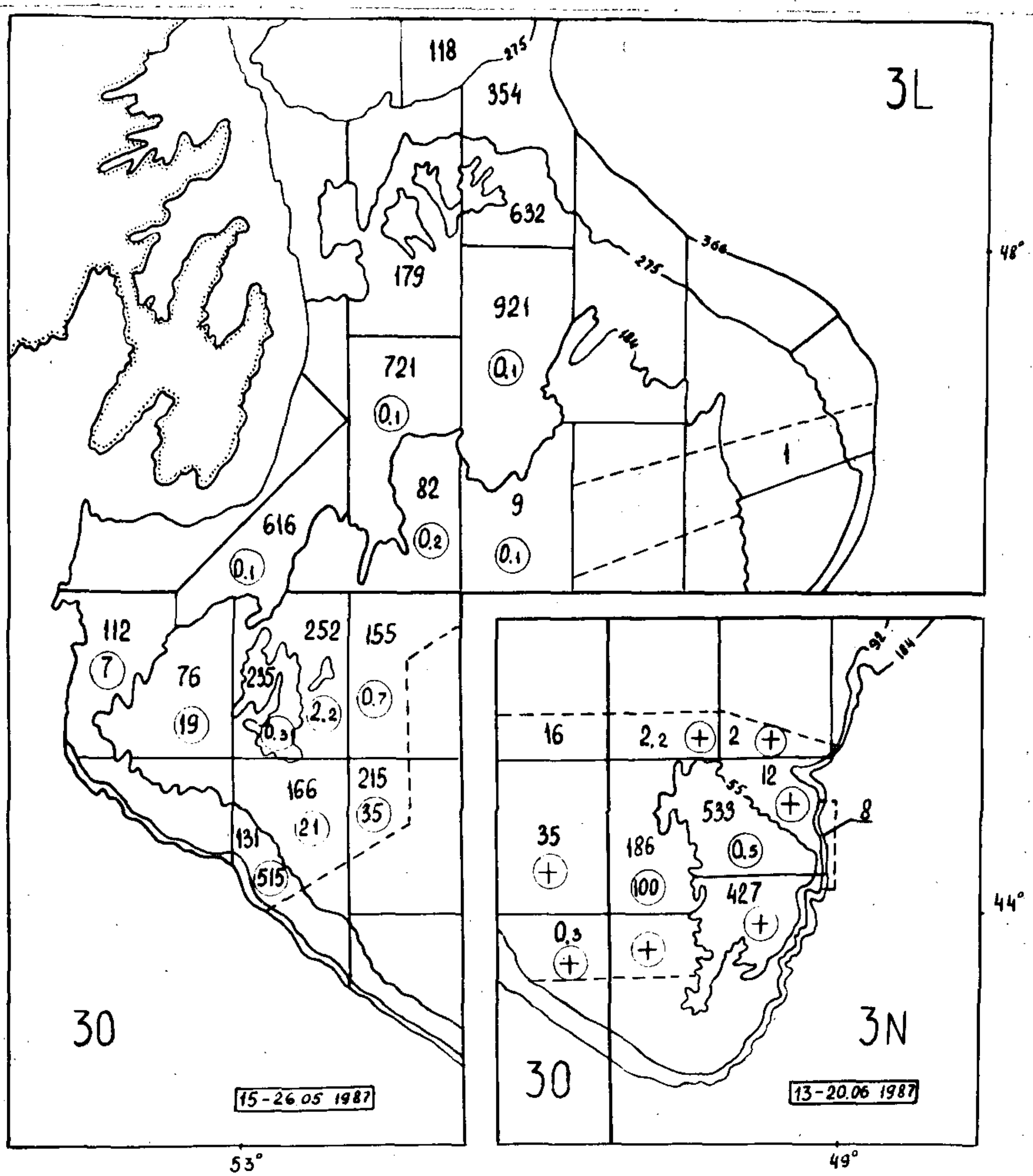

Fig.8 Capelin distribution in Divs.3LNO during the echo survey from 15 to 26 May and from 13 to 20 June 1987 ($\bar{M}$ values for young capelin smaller than 7 cm are encircled).

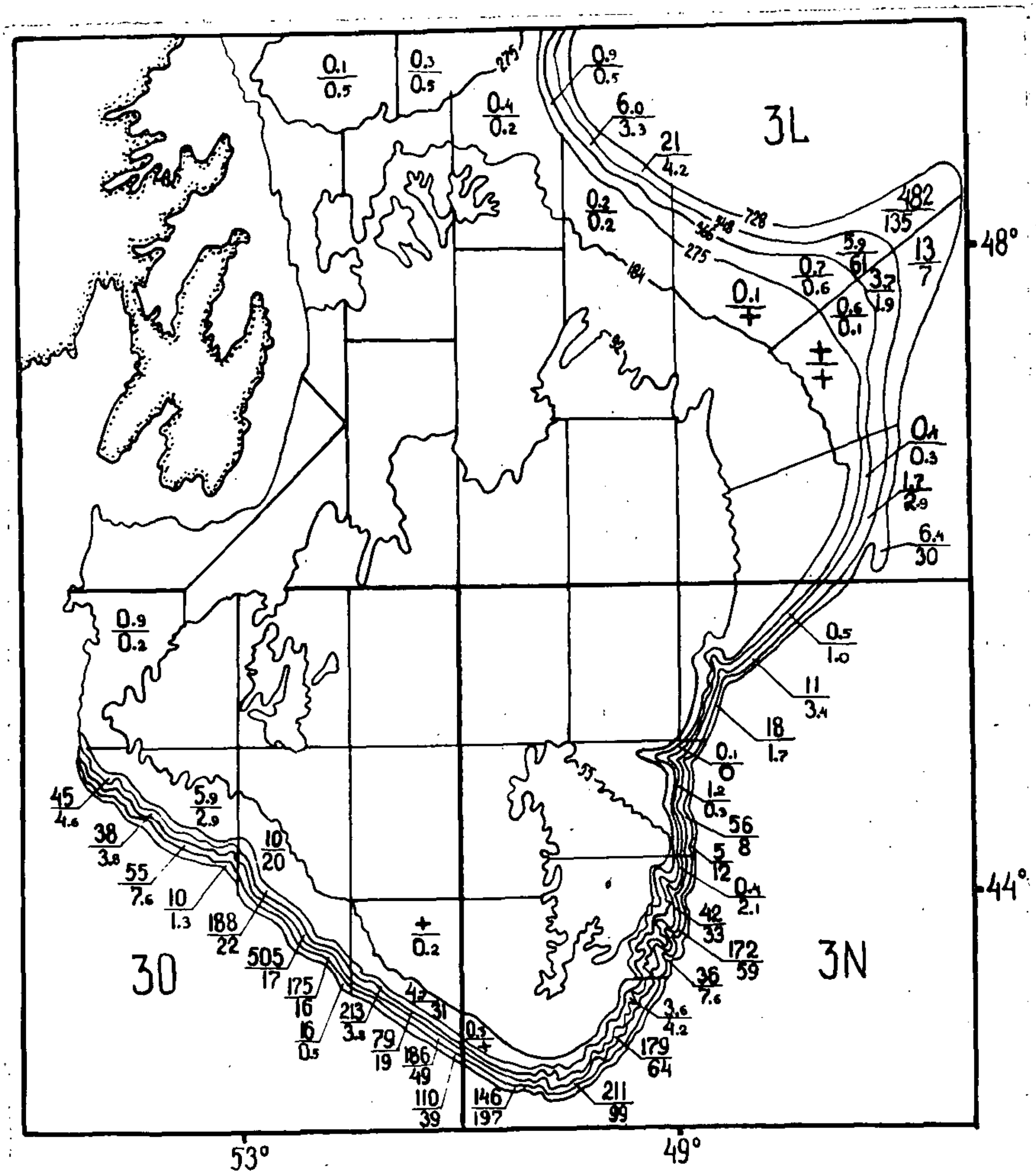

Fig.9 Redfish distribution in Divs.3LNO during the trawl-acoustic survey from 10 March to 11 May 1987.

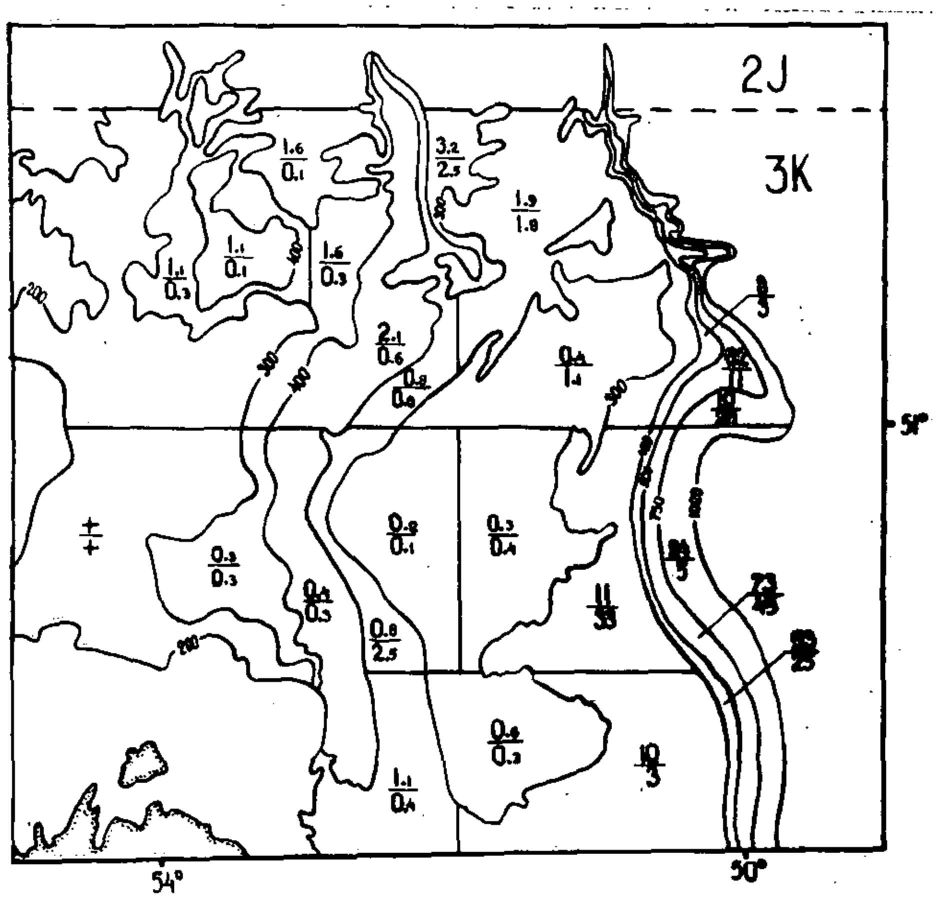

Fig.10 Redfish distribution in Div.3K during the trawl-acoustic survey from 11 to 13 May and from 26 May to 6 June 1987.

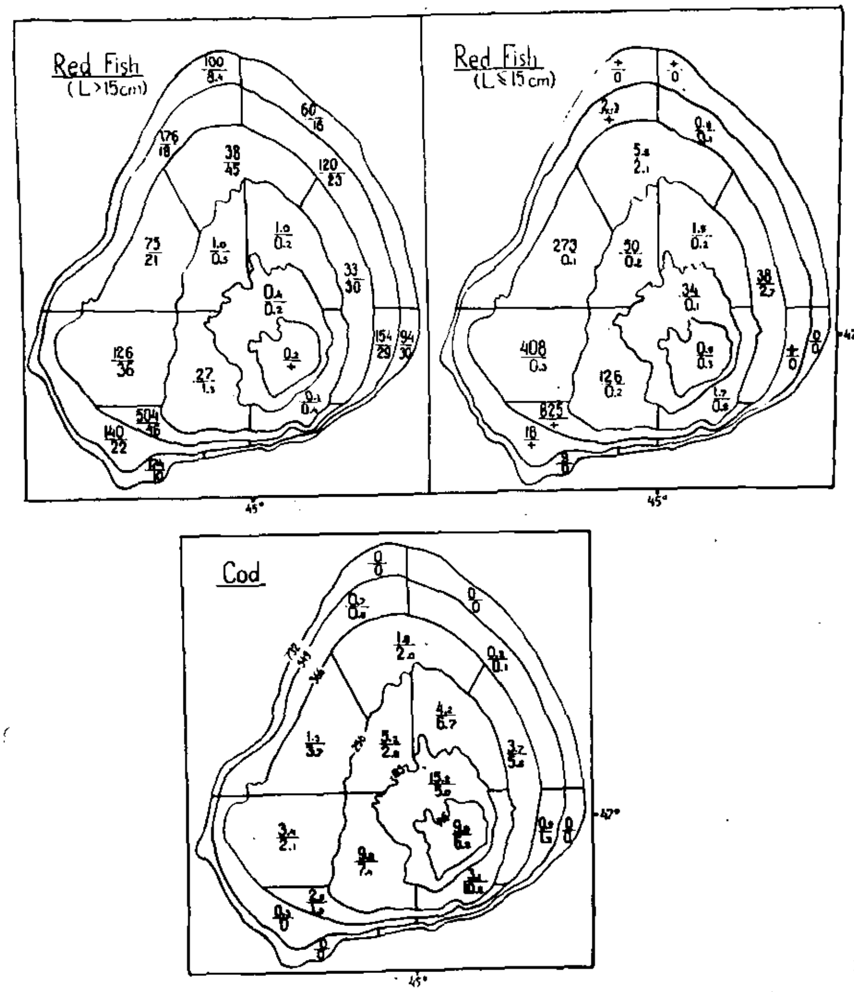

Fig.11 Cod and redfish distribution in Div.3M during the trawl-acoustic survey from 21 June to 4 July 1987.