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PRELIMINARY REPORT OF THE NORWEGIAN INVESTIGATIONS ON YOUNG COD AND HADDOCK IN THE BARENTS SEA

by

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ABSTRACT

An acoustic survey and a bottom trawl survey for cod and haddock were carried out in the Barents Sea during the winter 1986. As a result of strong improvement in the recruitment for both species, most of the echo abundance is presently from the youngest age groups and the proportion of the biomass found pelagically has been rapidly growing during the last three years. Sampling with midwater trawl has therefore been increased. While the calculations previously were made by pooling all the data from midwater and bottom trawl, the calculations of numbers at age for 1985 and 1986 have been made using midwater trawl samples for the pelagic echo abundance and bottom trawl samples for the echo abundance in the bottom layer. The main effect of this change of method is to shift the estimated age distribution from 1 and 2 year old fish to 3-4 year old fish.

The results of the acoustic survey confirm the previous findings for cod that the 1983 year class is strong, and that the average recruitment for the period 1982-1985 is substantially higher than the long-term average. For haddock the estimates are much higher than those used in the stock assessment in 1985.

INTRODUCTION

Each year since 1975 a Norwegian acoustic survey has been carried out during the winter in the Barents Sea, and since 1977 the results have been used in the stock assessments of North-East Arctic cod and haddock. The aim of the survey is to estimate the number of cod and haddock by age group in the survey area.

Since 1981 a stratified random bottom trawl survey has been carried out in the same area and at the same time as the acoustic survey. Preliminary results from both surveys are reported by Dalen et al. (1982, 1983, 1984) and Hylen et al. (1985). The present paper reports on the results of the survey in the winter 1986.

MATERIAL AND METHODS

The surveys in 1986 were carried out in the period 23 January to 3 March using the two research vessels "G.O.Sars" and "Michael Sars" and the hired commercial trawler "Raiti". The three vessels were equally equipped for bottom trawling, using a 1600 mesh shrimp trawl with rubber gear. Only the research vessels were equipped with midwater trawls.

Stations included in the bottom trawl survey were taken by all vessels. These stations were also used in the final calculations of the acoustic survey together with additional trawl hauls taken by the two research vessels.

The total number of trawl stations was 356, of which 76 were taken with midwater trawl. The commercial trawler took 136 of the 280 bottom trawl stations. A total of 214 hydrographical stations were taken by the research vessels. Figs 1 and 2 show the survey tracks, hydrographical stations and trawl stations worked by "G.O.Sars" and "Michael Sars".

T1 Acoustic Survey

The acoustic survey was carried out as in previous years, except that there were two research vessels instead of one and the acoustic coverage of the area was therefore much improved. The method is described by Dalen et al. (1982). The acoustic equipment used was:

"G.O.Sars": Simrad EK 400, 38kHz hull mounted and towed echosounder.

"Michael Sars": Simrad EK-S, 38kHz hull mounted echosounder.

Both ships used a digital echo integrator system developed at the Institute of Marine Research, run on NORD 10 computers.

All the echo integrator systems produce output in units of reflecting surface per square nautical mile (m^2/nm^2). The factor used to convert this to number of cod and haddock per square nautical mile is set to $C = 2.49 \times 10^6 \times L^{2\ 18}$. This factor equals a target strength $TS = 10 \log (\sigma/4\pi) = 21.8 \log L - 74.9$ where L is the length of the fish and σ is the back scattering surface of a single fish of that length.

The Bottom Trawl Survey

Fig. 3 shows the survey area with the strata used in the bottom trawl survey, and also the division into the four sub-areas for which the bottom trawl indices are given. The distribution of the 193 bottom trawl stations included in the calculations are shown in Fig. 4. This is 107 less than in 1985 and the reason for this reduction was the need to increase the number of midwater trawl stations in the acoustic survey. Following the survey design described by Dalen et al. (1982) the number of stations were redused to the minimum required for keeping the accuracy at an acceptable level. The method used to calculate the abundance indices is based on the stratified swept-area considerations described by Dalen et al. (1983) using 25.0 m as the sweeping-width of the trawl. Table 1 gives the number of stations in each stratum.

RESULTS AND DISCUSSION

Hydrography

Fig. 5 shows the temperature distributions in the winter 1986 at the surface, at 100 m depth, and at the bottom. In 1986 the temperatures were lower than in 1984 and 1985 when the values in most of the Barents Sea were close to the 30-years mean (Hylen et al. 1985). The difference was about 0.5^{0}C in the western and central parts of the area and somewhat smaller offshore in the east. In the nearshore areas off the Murman coast only minor differences from the relatively low values of 1984 and 1985 were found. However, in coastal areas local meteorological conditions during the winter will influence the sea temperatures.

Distribution of Cod and Haddock

Fig. 6 shows the distribution of the total echo abundance of cod and haddock combined in 1986. In the two preceeding years (Dalen et al. 1984, Hylen et al. 1985) high concentrations of fish, mostly of the 1983 year class, were found east of 37^{0}E in the northeastern part of the survey area. In 1986 the concentrations in the same area were small and contained mostly fish of the year classes 1984 and 1985. As in 1985, the highest echo abundance was found between 30^{0}E and 36^{0}E. However, from 1985 to 1986 the area of main distribution had been split into two components, one between 70^{0}N and 72^{0}N and one from about 72^{0}30'N and northwards beyond 74^{0}N. The northern limit of this distribution was not found during the survey, but it was probably extending northwards along the west side of the Central Bank where a fleet of U.S.S.R. trawlers were fishing.

Fig. 7 shows the echo abundance in the 10 m layer above the bottom. The highest values were generally found in the areas with highest total echo abundance.

Table 2 shows the echo abundance of cod/haddock 1981-1986, total and in the bottom layer. From 1983 to 1986, the total echo abundance increased by a factor of 9.4. During the same period,

t echo abundance in the 10 m layer above the bottom also increased, but only by a factor of 4.4. The proportion of the echo abundance found in the bottom layer accordingly decreased, from 28% in 1983 to 13% in 1986. Thus, 89% of the increase in total echo abundance of cod/haddock has come from pelagic concentrations.

Acoustic Abundance Estimates

The increase in the pelagic recordings (Table 2) and the observation that there usually is a difference in both species and size composition between catches from bottom trawl and midwater trawl, made it necessary to increase sampling with midwater trawl substantially during the acoustic survey. Before 1985 the acoustic estimates were made on the basis of the total echo abundance of cod/haddock and samples from bottom and midwater trawls combined (pooled data). In 1985 and 1986, however, estimates were also made using midwater trawl samples for the pelagic echo abundance and bottom trawl samples for the echo abundance in the bottom layer (separated data). The latter method is considered the most reliable and the results for cod and haddock in 1986 are given i Table 3 and Table 5 respectively. In Tables 4 and 6, showing the full time series of acoustic estimates, the results for 1985 and 1986 based on separated data are included in the main part of the tables, whereas the results for these two years using pooled data, are added to the bottom of the tables.

It should be noted that the 1985 values based on separated data are not the same as those presented as alternative b in the report from 1985 (Hylen et al. 1985) which were based on other considerations.

Table 3 shows that for the age groups 1 - 3 of cod nearly all the abundance was found in the eastern part (D) of the survey area (Fig. 1). From age 4 onwards the northwestern part (A) becomes increasingly important. In the nearshore areas B and C only the age groups 4 and 5 make up significant parts of the year class abundance.

Table 4 shows that there are substantial differences in the estimates of year class abundance between the two alternatives a and b. The biggest discrepancy in numbers was found for the 1983 year class in 1985, but considerable differences were in both 1985 and 1986 found for nearly all the age groups of young cod. The differences are to some extent dependent on the species distribution of cod and haddock in the trawl catches and are discussed at the end of the section. For alternative a, there is a reasonable continuity from 1984 to 1986, but the results in 1985 deviate from this pattern. A transfer in 1985 of individuals from the year classes 1981 and 1982 to the 1983 year class would have given a more consistent pattern, and it seems that at least some of the discrepancy may be explained by false growth rings in the otoliths.

For both alternatives 1983 still appears as a very strong year class. In the 0-group survey the index for the 1984 year class was nearly on the same level as the 1983 year class (Anon. 1986), but the indications from the acoustic survey so far are that the 1984 year class is of average abundance. For the 1985 year class, the 0-group index was very high. In the acoustic survey the 1985 year class appears to be abundant, though probably less abundant than the 1983 year class. However, the estimates from the acoustic survey have not been very reliable for 1-group fish.

Also for haddock the echo abundance was clearly highest in area D (Table 5). However, compared to the cod relatively more of the abundance occurred in area A and in the nearshore area C. The differences between the alternatives a and b are considerable (Table 6), but in both cases the results from 1985 are more consistent with the 1984 and 1986 estimates than they were for cod. The 1983 year class is evidently very abundant and the year classes 1982, 1984, and 1985 also appear to be stronger than the long-term average.

In 1985, only 25 of 389 trawl stations were taken with midwater trawl. This means that using pooled data (alternative b) the samples from bottom trawl would be dominating in most of the

area. Since 86 per cent of the echo abundance was pelagic (Table 2), the results using separated data (alternative a) would depend most on the midwater trawl hauls. The difference between the two alternatives is therefore mainly caused by differences in the species and size distribution between midwater and bottom trawl catches. The results indicate that a larger proportion of cod than of haddock occurred pelagically. However, the number of hauls with midwater trawl in 1985 was low and sampling errors may have influenced the results.

In 1986, the sampling with midwater trawl was increased (76 of 356 trawl stations). Approximately the same proportion of echo abundance was pelagic in 1985 and 1986 (Table 2) and since samples from midwater trawl in 1986 represent a larger proportion of the pooled data, the difference between the alternatives a and b would be expected to be smaller than in 1985. This turned out to be right as far as the species composition was concerned, but the differences in the age frequency distribution between the two alternatives were bigger than in 1985. For cod, changing from pooled data (b) to separated data (a) both the number and percentage increase for 3 year old fish and decrease for the age groups 1, 2, 4, and 5. For haddock, the increase is mostly on 4 year old fish and the decrease on age 1 and 2, while the 3 year old fish is nearly unaffected. Apparently the 1983 year class of cod and the 1982 year class of haddock were relatively more pelagic than the other year classes. The difference in the total number of cod can to a large extent be attributed to the difference in age composition between the two alternatives. However, for haddock a larger difference in the total number would clearly be expected, and it seems that using separated data has resulted in some transfer from haddock to cod, although not as much as in 1985.

The change in species composition from 1985 may have been caused by inadequate sampling with midwater trawl. The haddock may have been underrepresented and an increase in the abundance of haddock gives a better continuity in the time series of acoustic estimates. For cod, however, the problem is not so much the total echo abundance allocated to the species, but the age composition

which would have to be shifted from the year classes 1981 and 1982 to the 1983 year class in order to improve the time series.

The recent development in the acoustic surveys has showed the need for increased sampling with midwater trawl, and from other experiments it has been demonstrated that representative sampling with trawls, midwater or bottom, is a larger problem than previously suspected. Probably most important to find out is if haddock, as there is some reason to suspect, are more efficiently caught by midwater trawl than cod. If this is the case, the year classes of haddock may be severely overestimated. Improvement in the statistical treatment of the data and better target strength measurements are also likely to improve the results in the future.

The geographical distribution of cod and haddock

The geographical distribution of the different year classes of cod and haddock is given in Figs 8-13 and Figs 14-18 respectively. The main changes from 1985 are a westward shift in the distribution of the youngest year classes of cod and a southeastward movement of haddock toward the Murman coast of the U.S.S.R.

Bottom Trawl Survey Indices

Table 7 gives abundance indices from the bottom trawl survey for each age group of cod by sub-area and total area. Indices for the total area for the period 1981-1986 are given in Table 8. As in previous years there is a considerable difference in abundance between the offshore (A,D) and coastal (B,C) waters The total indices show a rising trend in abundance near the bottom during the period 1982-1986.

The index in 1985 is lower than in 1984 and 1986, and this may have been caused by a more pelagic occurrence of the youngest age groups in that year. Changes in the pelagic occurrence from year to year are probably the main reasons for the considerable variations in abundance indices with time for the 1981, 1982, and

1983 year classes. However, some of the variation may also be explained by the otolith readings and by variation between sampling localities. In the computations performed on the material, age distributions are averaged for each sub-area and this may have caused a bias in the relative distribution of the two year classes 1981 and 1982.

The abundance indices for haddock, total and by sub-area, are given in Table 9. The total indices for the years 1981-1986 are given in Table 10. There is a considerable drop in the abundance of haddock in the bottom layer from 1985 to 1986. This indicates that more of the haddock occurred pelagically in 1986 than in 1985. This is confirmed by the acoustic survey.

With increasing evidence that the proportion of cod and haddock occurring pelagically is variable and that the age distribution of the pelagic fish usually differs from the one found in the bottom layer, it is obvious that the usefulness of the bottom trawl survey as an aid in the stock assessments is limited. The indices will be most useful in years with low stock abundance. However, the data are also used for other purposes than stock estimates and are partly necessary for the acoustic survey.

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Table 1. Trawl hauls taken in the bottom trawl survey 1986.

Stratum	1	2	3	4	5a	5b	6	7	8	9	10	11	12	13	14	15	16	17
Number of hauls	6	4	9	2	5	3	9	10	10	4	5	7	14	12	5	3	8	2
Stratum	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Number of hauls	6	2	5	3	14	8	1	6	6	2	3	6	6	2	2	4	2	

Table 2. Cod/Haddock. Total echo abundance and echo abundance in the 10 m layer above the bottom 1981-1986. (m^2 reflecting surface x 10^{-3}).

Echo Abundance	Year 1981	1982	1983	1984	1985	1986
Total	2097	686	597	2284	5187	5607
Bottom	799	311	169	604	736	743
Ratio bottom/total	.38	.45	.28	.26	.14	.13

Table 3. Cod. Acoustic abundance estimates (alternative a) for each age group/year class in the surveyed areas in 1986. (Numbers in millions).

Area	Age (Year class) 1 (85)	2 (84)	3 (83)	4 (82)	5 (81)	6 (80)	7 (79)	8 (78)	9 (77)	10+ (76)	Total
A	+	+	107	109	101	21	3	+	0	+	341
B	+	+	1	22	28	4	+	+	0	+	55
C	7	9	33	18	15	+	+	+	+	+	82
D	428	352	1551	199	47	2	+	+	0	0	2579
Total	435	361	1692	348	191	27	3	+	+	+	3057
%	14.3	11.8	55.4	11.4	6.3	0.9	0.1	0.0	0.0	0.0	100.2

Table 4. Cod. Estimates of year class abundance from acoustic surveys in the period 1977-1986. (Numbers in millions).

Year of investigation	Year class 1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971+	Total
1977										45	882	104	315	139	111	1596
1978									28	235	797	153	172	25	32	1442
1979								16	14	109	502	77	45	14	6	783
1980							Malfunction of the acoustic instruments									
1981						3	73	58	124	243	270	41	8	3	4	827
1982					1	4	71	86	93	73	74	5	1			408
1983					15	17	45	65	38	17	10	2	1			210
1984			2382	506	174	80	63	46	16	1	+	+				3269
1985a		51	1484	776	624	92	30	15	1	+	+					3073
1986a	435	361	1692	348	191	27	3	+	+	+						3057
1985b		69	878	550	510	109	48	20	2	1	1					2187
1986b	746	668	1473	528	275	33	9	2	+	+						3735

a) Separated data. (Echo abundance bottom/Bottom trawl + Echo abundance pelagic/Midwater trawl).
b) Pooled data. (Total echo abundance/All trawl stations combined).

Table 5. Haddock. Acoustic abundance estimates (alternative a) for each age group/year class in the surveyed areas in 1986. (Numbers in millions).

Area	Age (Year class) 1 (85)	2 (84)	3 (83)	4 (82)	5 (81)	6 (80)	7 (79)	8+ (78+)	Total
A	9	48	166	169	+	+	+	3	477
B	2	4	17	38	4	4	4	+	73
C	34	40	120	257	+	+	+	+	451
D	191	260	1731	669	+	+	+	+	2851
Total	236	352	2034	1133	4	4	4	3	3770
%	6.3	9.3	54.0	30.1	0.1	0.1	0.1	0.1	100.1

Table 6. Haddock. Estimates of year class abundance from acoustic surveys in the period 1977-1986. (Numbers in millions).

Year of investigation	Year class 1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971+	Total
1977										267	755	198	60	10	9	1328
1978									111	149	737	55	1			1053
1979								17	11	181	251	13	+	2		475
1980								Malfunction of the acoustic instruments								
1981						2	25	14	66	160	50	2	1			320
1982					3	4	7	10	12	29	14	1				80
1983					10	7	9	5	4	10	5					50
1984			2148	1002	53	15	7	2	2	2						3231
1985a		470	1724	1007	48	2	2	1	3	+						3254
1986a	236	352	2034	1133	4	4	4	2	+	1						3770
1985b		1034	1972	1187	33	2	1	1	1	1	1					4233
1986b	362	565	2000	873	2	1	1	+	+	+						3806

a) Separated data. (Echo abundance bottom/Bottom trawl + Echo abundance pelagic/Midwater trawl).
b) Pooled data. (Total echo abundance/All trawl stations combined).

Table 7. Cod. Abundance indices from the bottom trawl survey for each age group/year class in the different areas in 1986.

Area	Age (Year class) 1 (85)	2 (84)	3 (83)	4 (82)	5 (81)	6 (80)	7 (79)	8 (78)	9 (77)	10+ (76+)	Total
A	0.2	2.0	48.8	44.2	28.8	2.8	0.9	0.1		+	128.0
B	0.0	0.1	1.7	7.2	8.9	2.3	0.1	0.1	0.0	+	20.8
C	0.2	0.3	6.1	8.1	8.1	1.6	0.3	0.1	0.1	+	24.7
D	82.1	90.7	300.0	59.7	16.9	1.6	0.4	0.1	0.0	0.0	551.0
Total	82.5	93.0	356.0	119.0	62.6	8.3	2.1	0.3	0.1	0.1	724.0
%	11.4	12.8	49.2	16.4	8.7	1.2	0.3	+	+	+	100.0

Table 8. Cod. Abundance indices for each year class from the bottom trawl surveys 1981-1986.

Year of investig.	Year class 1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973+	Total
1981						0.7	11.0	8.6	16.9	34.1	37.9	4.8	1.3	115.3
1982					0.1	0.9	16.1	20.4	21.4	16.0	15.8	1.4	0.2	92.3
1983				44.6	5.9	10.8	28.0	31.9	14.3	4.7	3.0	0.6		143.8
1984			355.3	126.6	60.2	19.2	15.6	9.4	3.0	0.4	0.2			589.6
1985		7.3	168.9	90.3	78.1	15.7	6.3	2.5	0.2	+	0.1			369.4
1986	82.5	93.0	356.0	119.0	62.6	8.3	2.1	0.3	0.1	0.1				724.0

Table 9. Haddock. Abundance indices from the bottom trawl survey for each age group/year class in the different areas in 1986.

Area	Age (Year class) 1 (85)	2 (84)	3 (83)	4 (82)	5 (81)	6 (80)	7 (79)	8+ (78+)	Total
A	7.4	41.8	72.1	22.7	+	+	0.0	0.1	144.0
B	4.0	8.6	11.8	10.2	0.3	+	+	0.1	35.0
C	3.6	6.9	20.3	18.5	0.1	+	+	+	49.5
D	62.8	77.9	210.0	71.7	+	+	+	0.0	423.0
Total	77.9	135.0	314.0	123.0	0.4	0.1	0.1	0.2	651.5
%	12.0	20.7	48.2	18.9	0.1	+	+	+	100.0

Table 10. Haddock. Abundance indices for each year class from the bottom trawl surveys 1981-1986.

Year of invest.	Year class 1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974+	Total
1981						0.3	4.8	2.3	9.5	2.0	6.1	0.7	25.7
1982					0.5	0.9	1.8	2.1	2.2	5.5	2.7	0.2	15.9
1983				314.5	5.7	4.1	3.6	1.9	2.3	3.9	1.6		379.0
1984			663.2	355.8	15.2	1.6	0.7	0.2	0.3	0.4			1037.4
1985		167.8	616.2	380.2	7.2	0.4	0.2	0.3	0.3				1172.6
1986	77.9	135.0	314.0	123.0	0.4	0.1	0.1	0.2					651.5

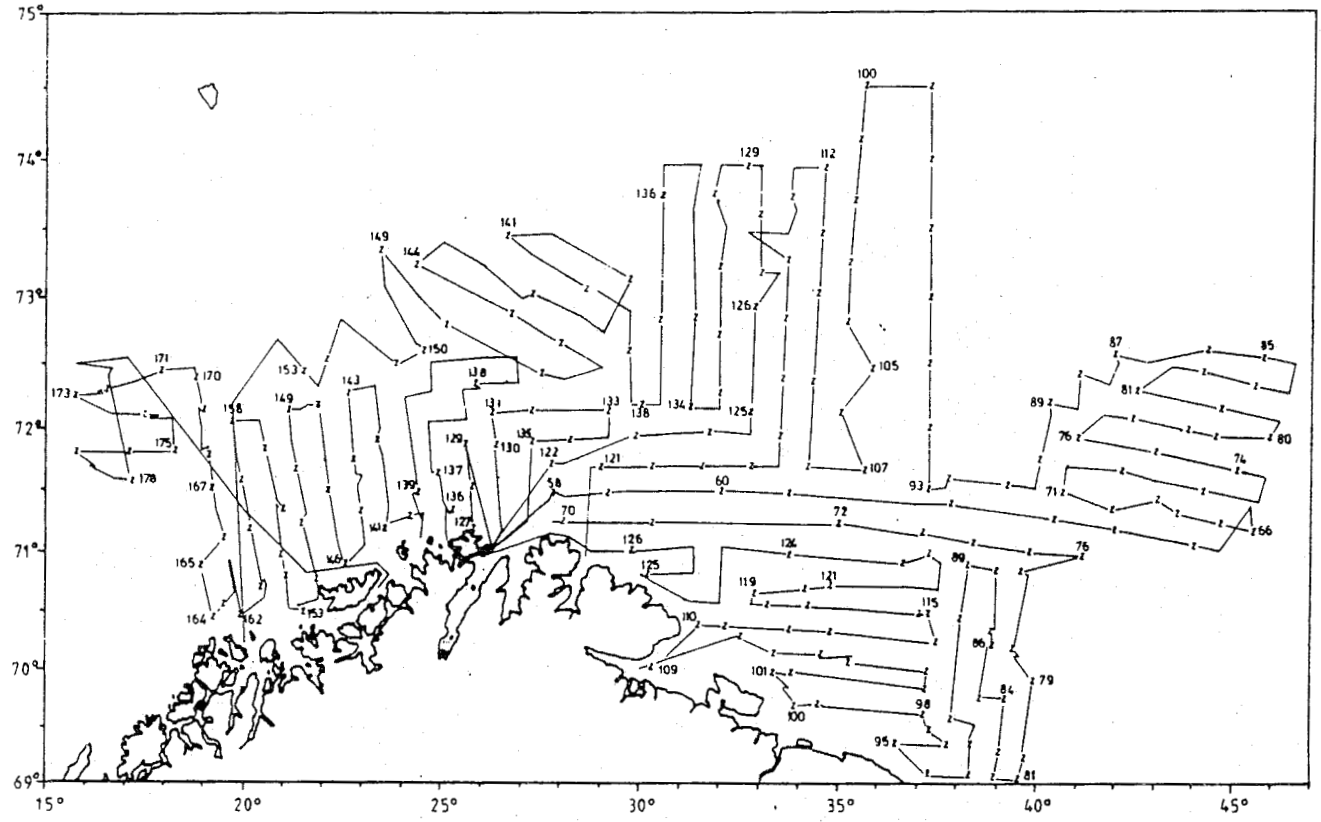

Fig. 1. Survey tracks and hydrographical stations R/V "G.O. Sars", 25.1 - 8.3 and R/V "M.Sars" 23.1 - 2.3.

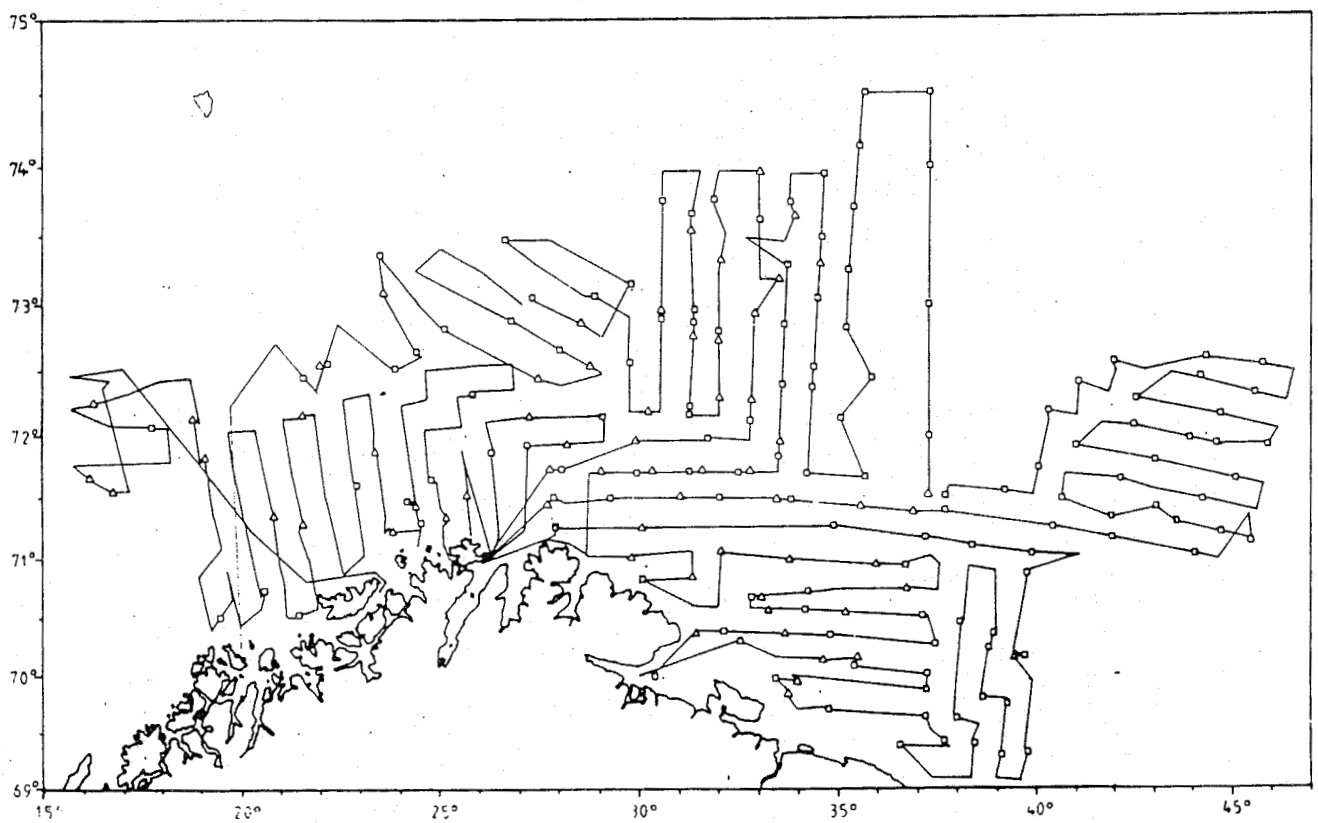

Fig.2. Survey tracks and trawlstations R/V "G.O. Sars" 23.1 - 28.2, and R/V "M. Sars" 23.1 - 2.3.

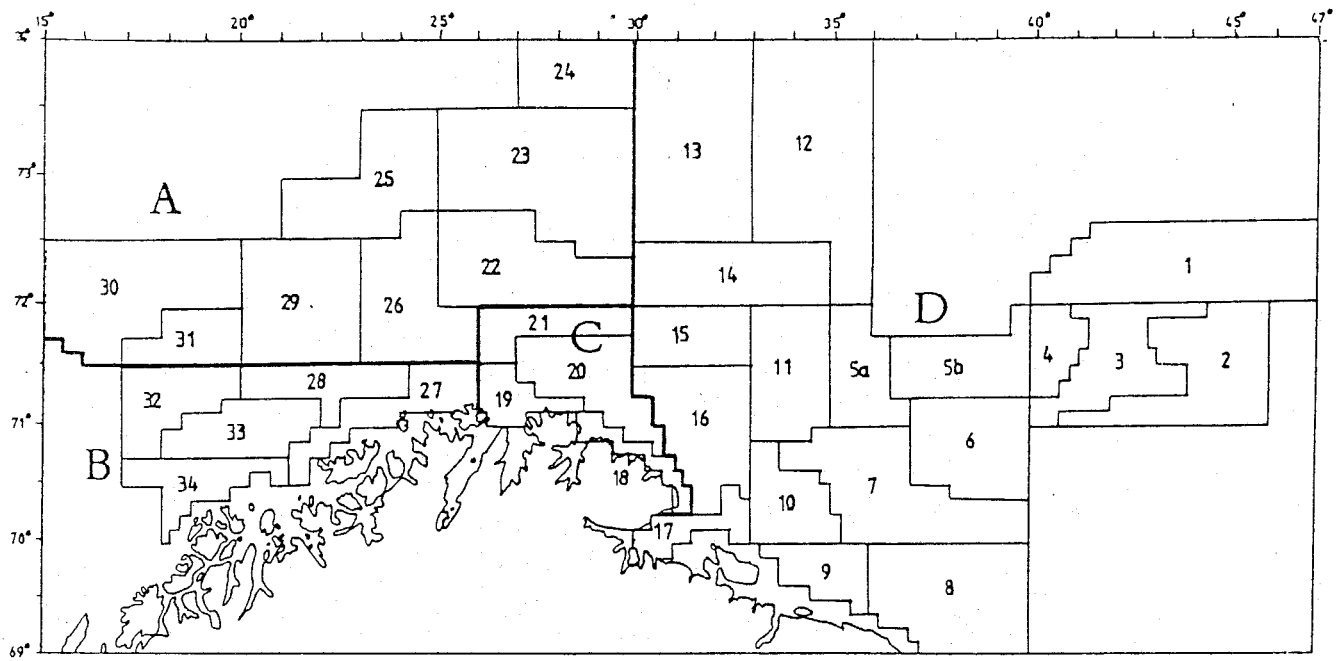

Fig. 3. The survey area with subareas (A,B,C,D) and strata used in the bottom trawl survey.

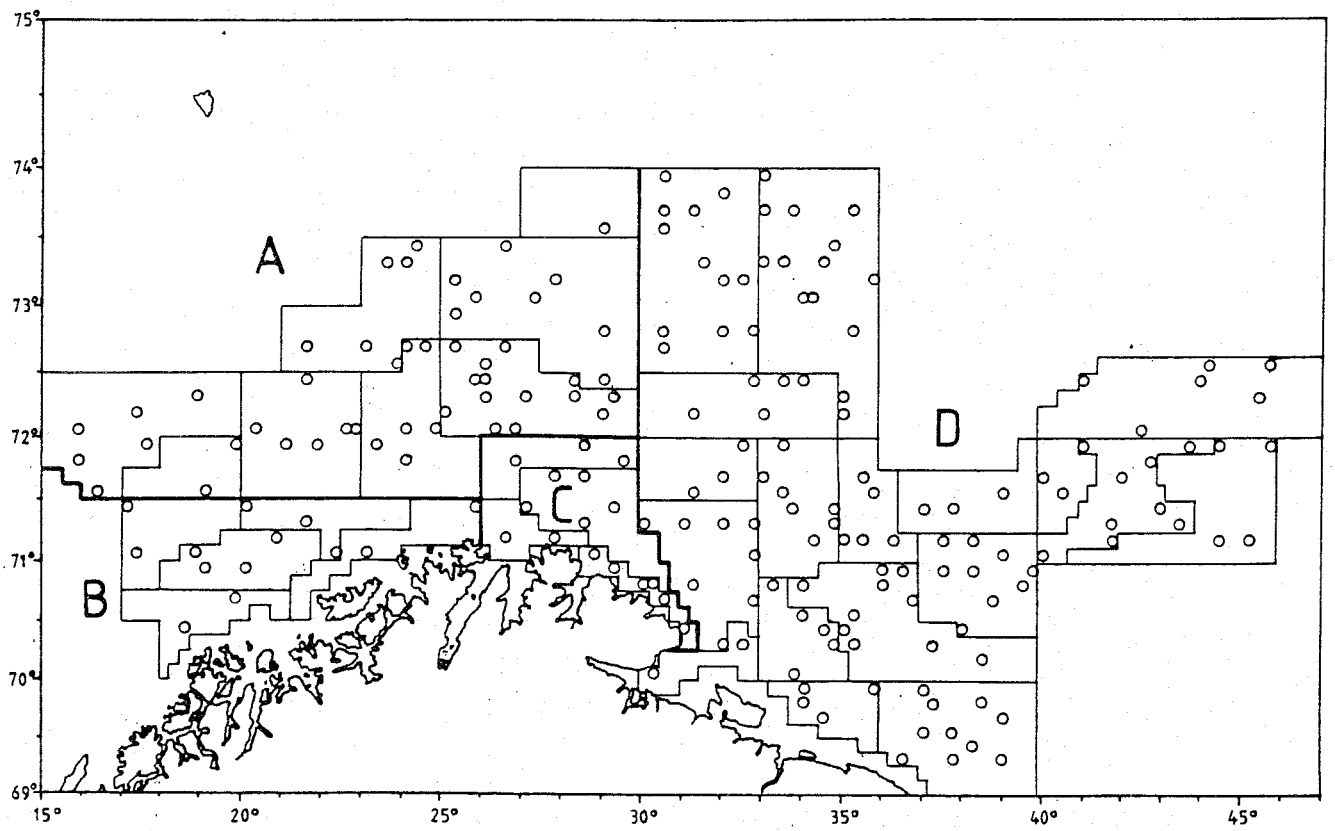

Fig. 4. Bottom trawlstations M/T "Raiti" 27.1 - 28.2, R/V "G.O. Sars" 23.1 - 28.2 and R/V "M. Sars" 23.1 - 2.3.

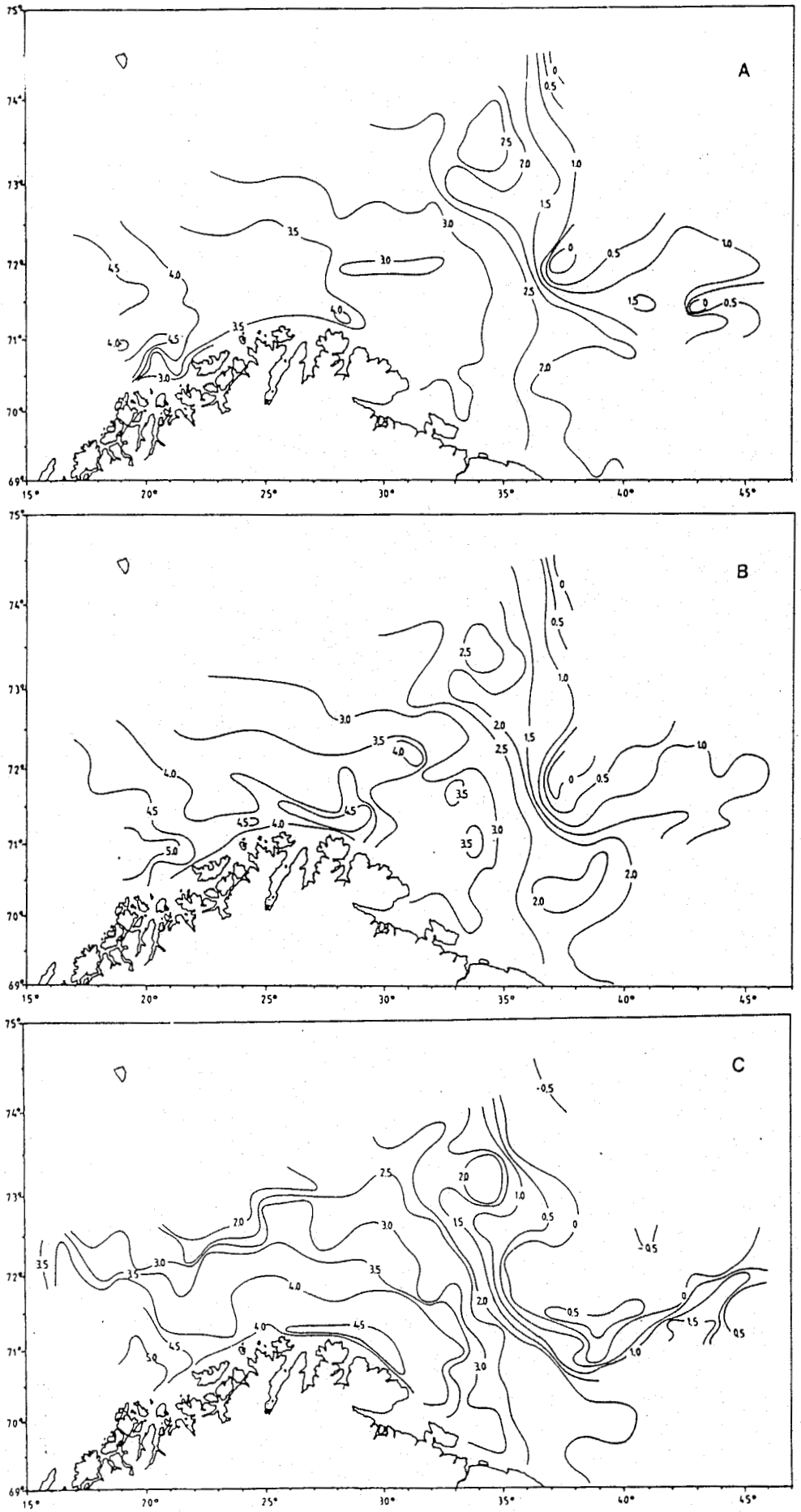

Fig.5. Temperature distribution. A) at the surface, B) at 100 m depth, C) at the bottom. R/V "G.O. Sars" 23.1 - 28.2 an R/V "M.Sars" 23.1 - 2.3

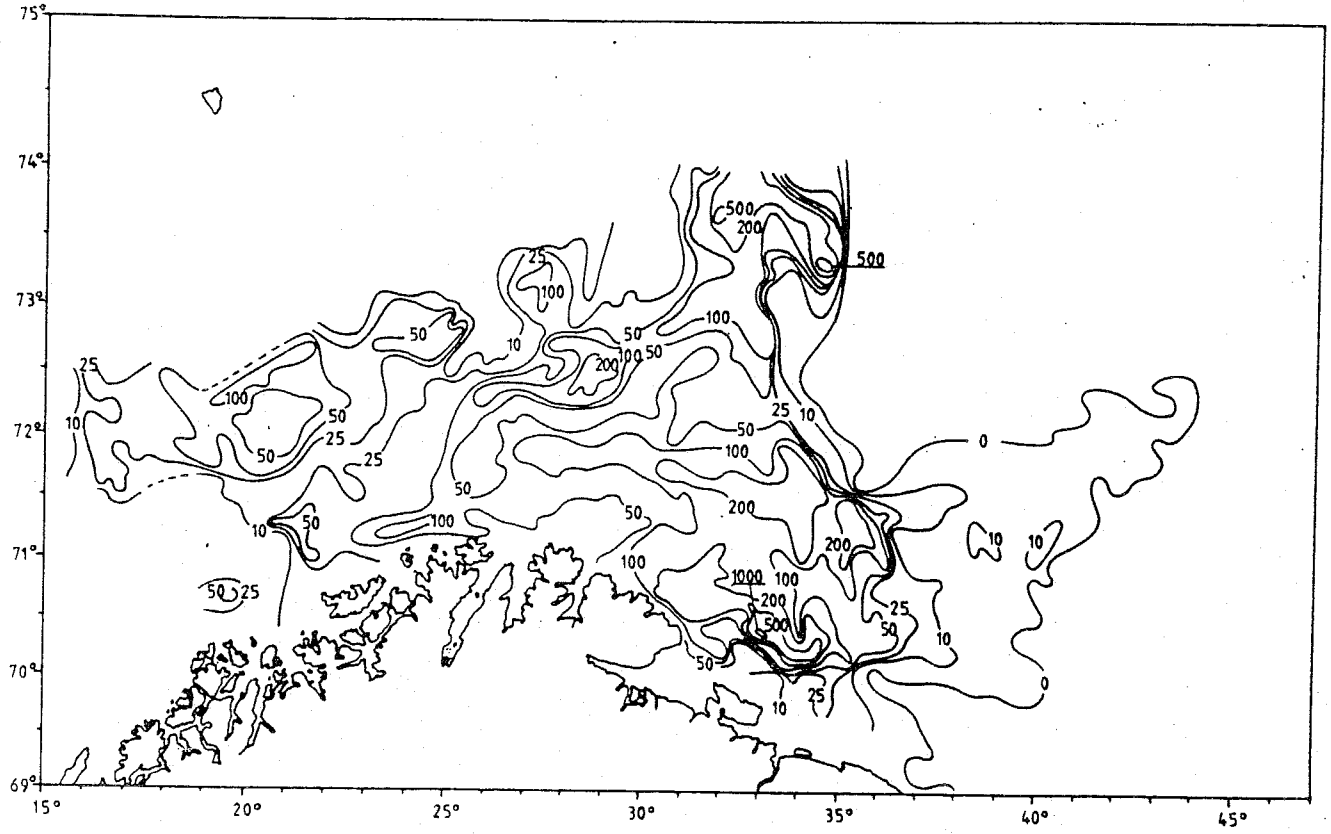

Fig.6. Distribution of total echo abundance, cod and haddock. Units are integrated back scattering cross section pr. square nautical mile. (m/naut. mile^2).

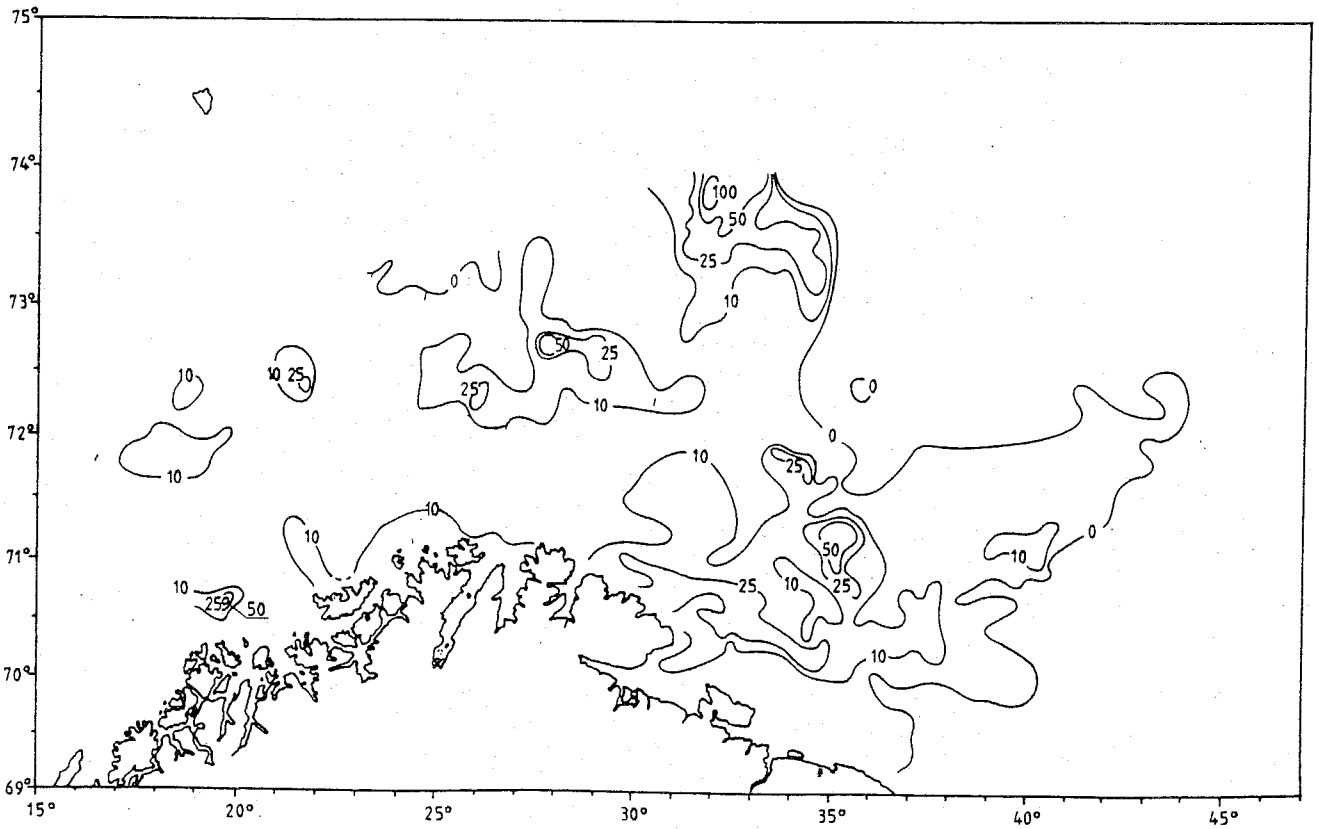

Fig.7. Distribution of echo abundance in the 10 m depth layer above the bottom. Cod and haddock combined.

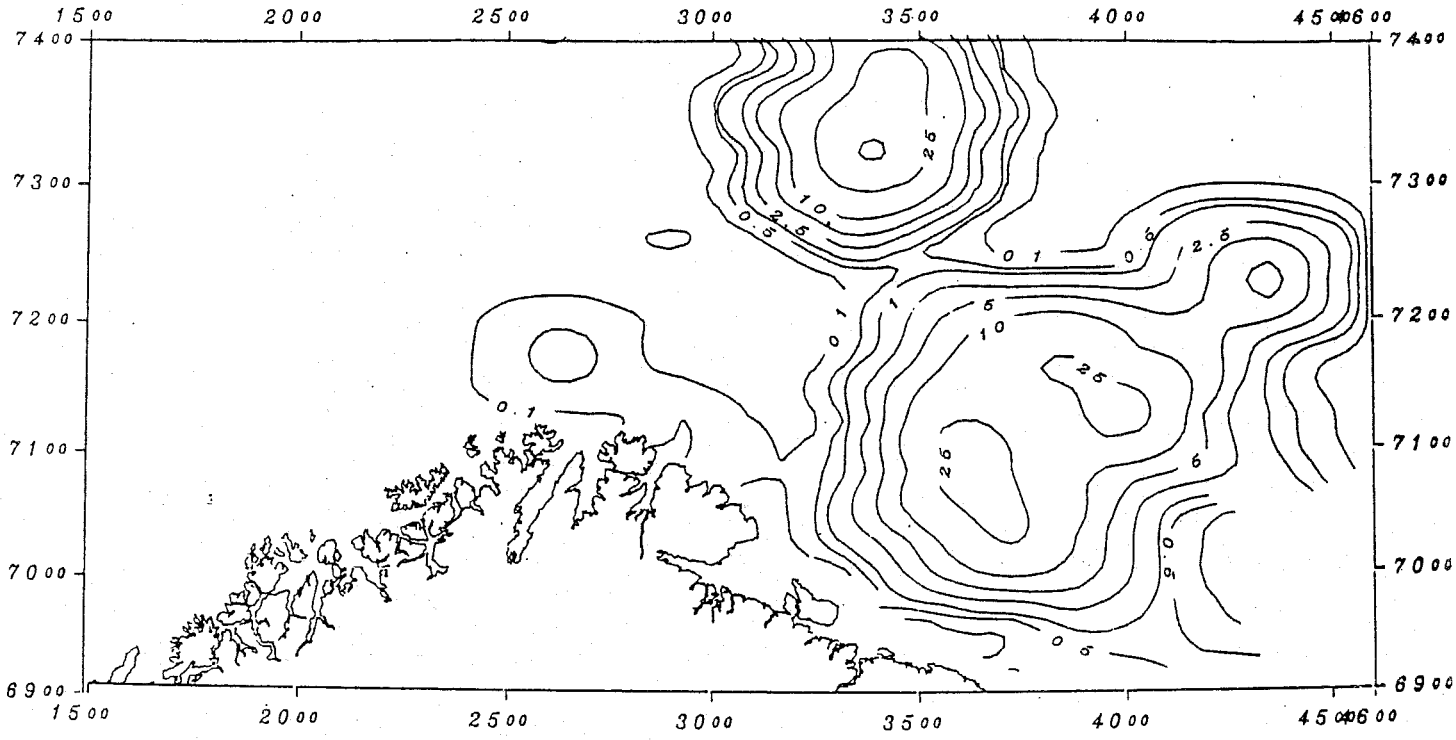

Fig.8. The distribution of 1-year old cod (number of fish in 1000 per square nautical mile).

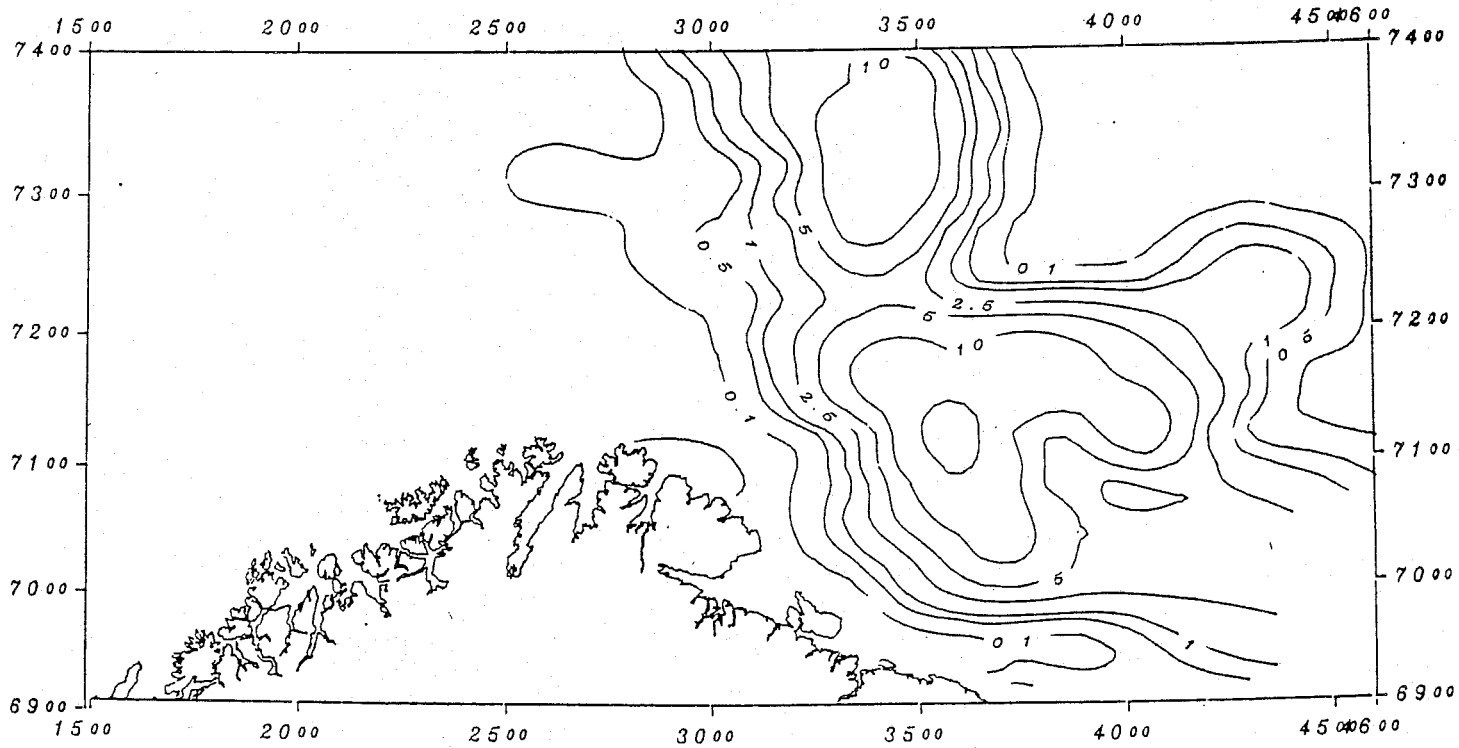

Fig.9. The distribution of 2-year old cod.

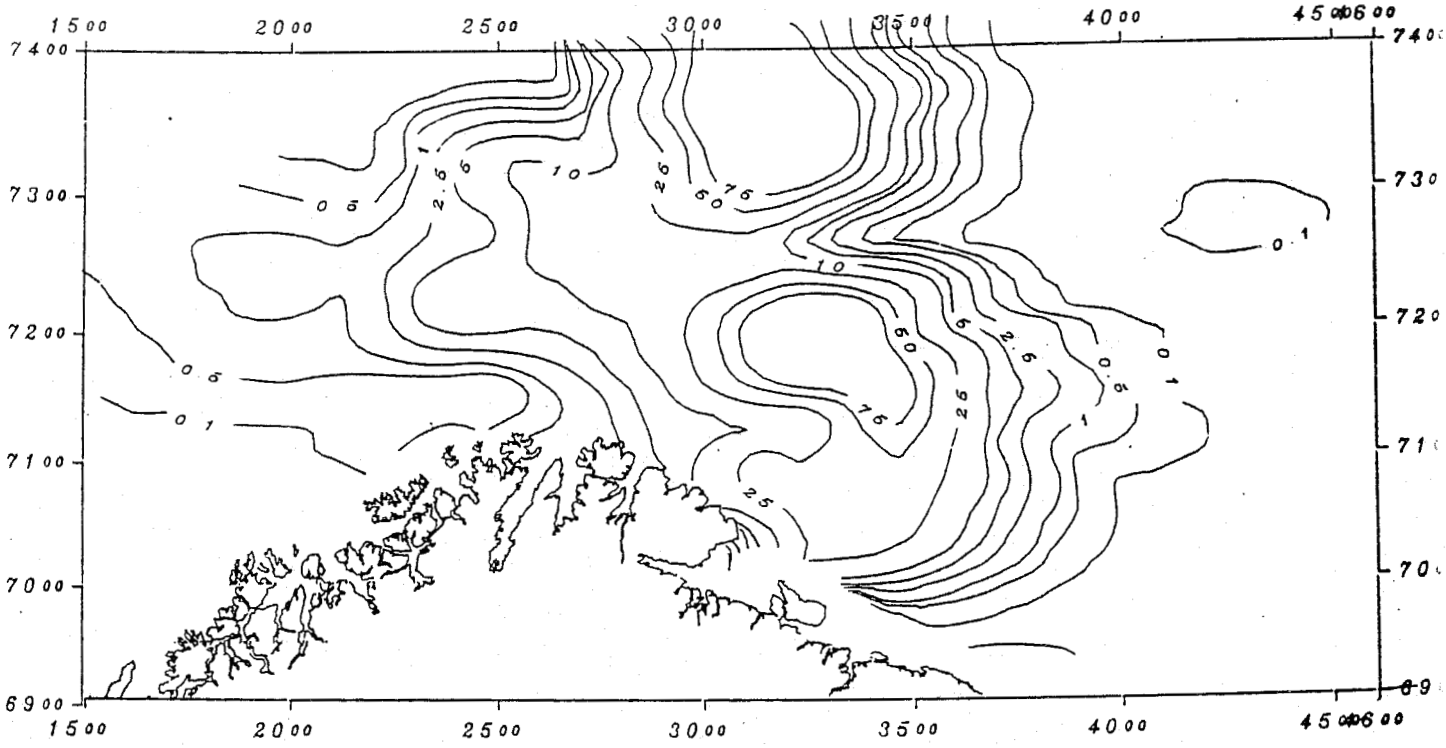

Fig.10. The distribution of 3-year old cod.

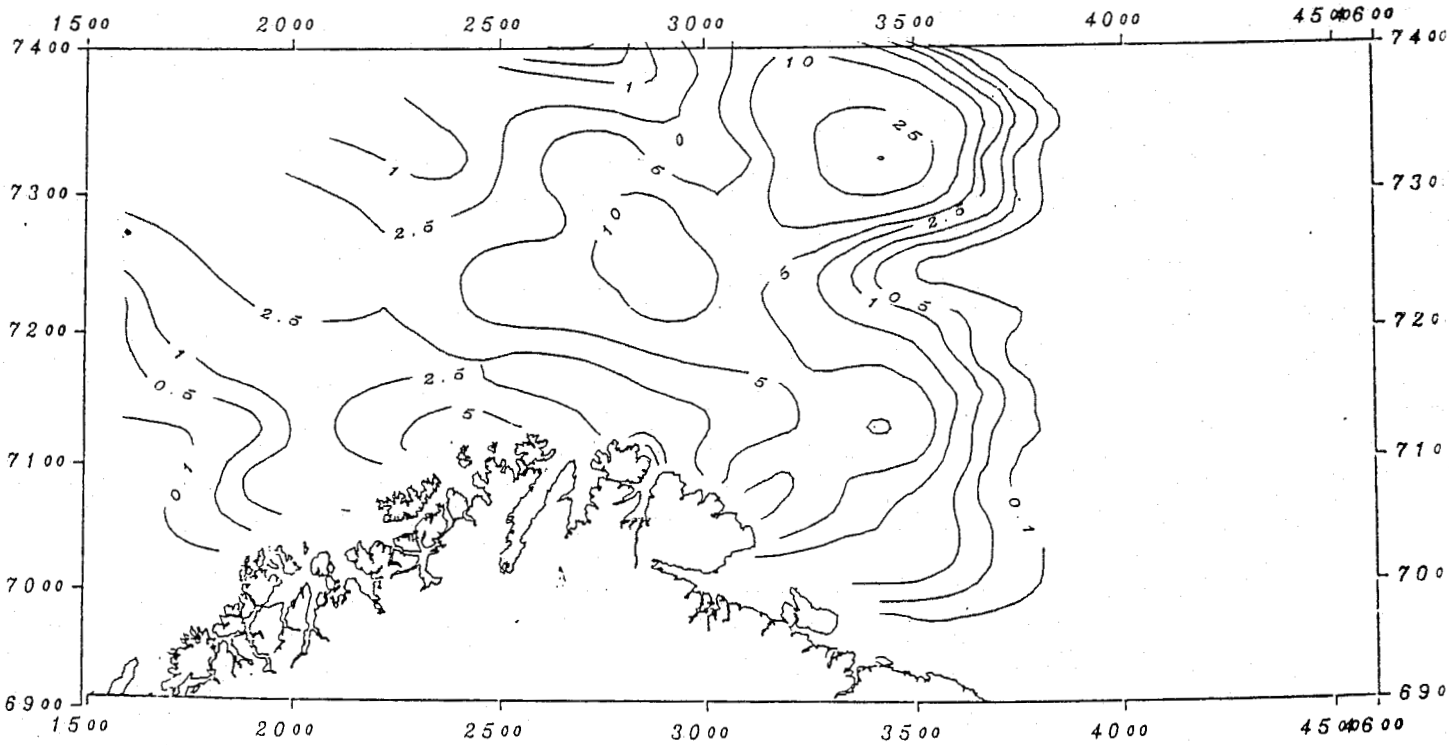

Fig.11. The distribution of 4-year old cod.

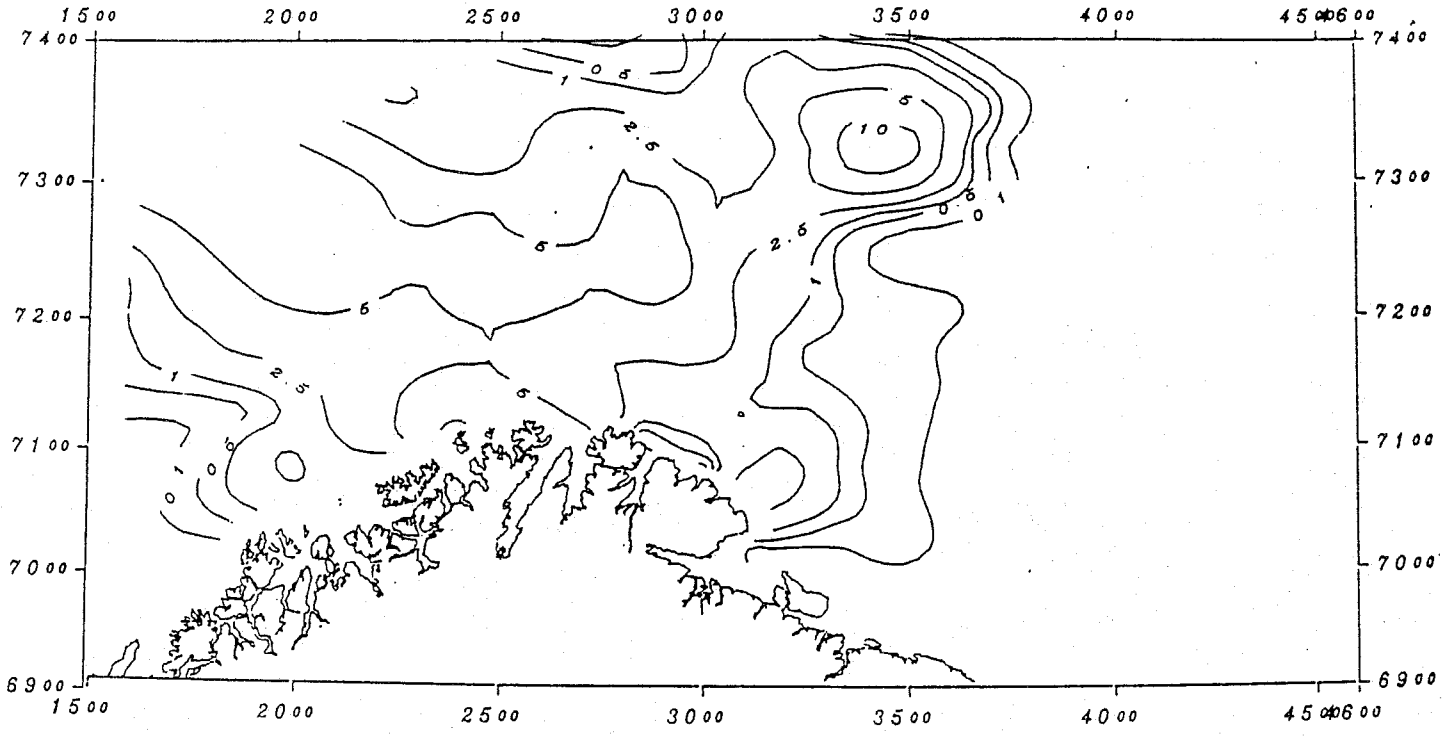

Fig. 12. The distribution of 5-year old cod.

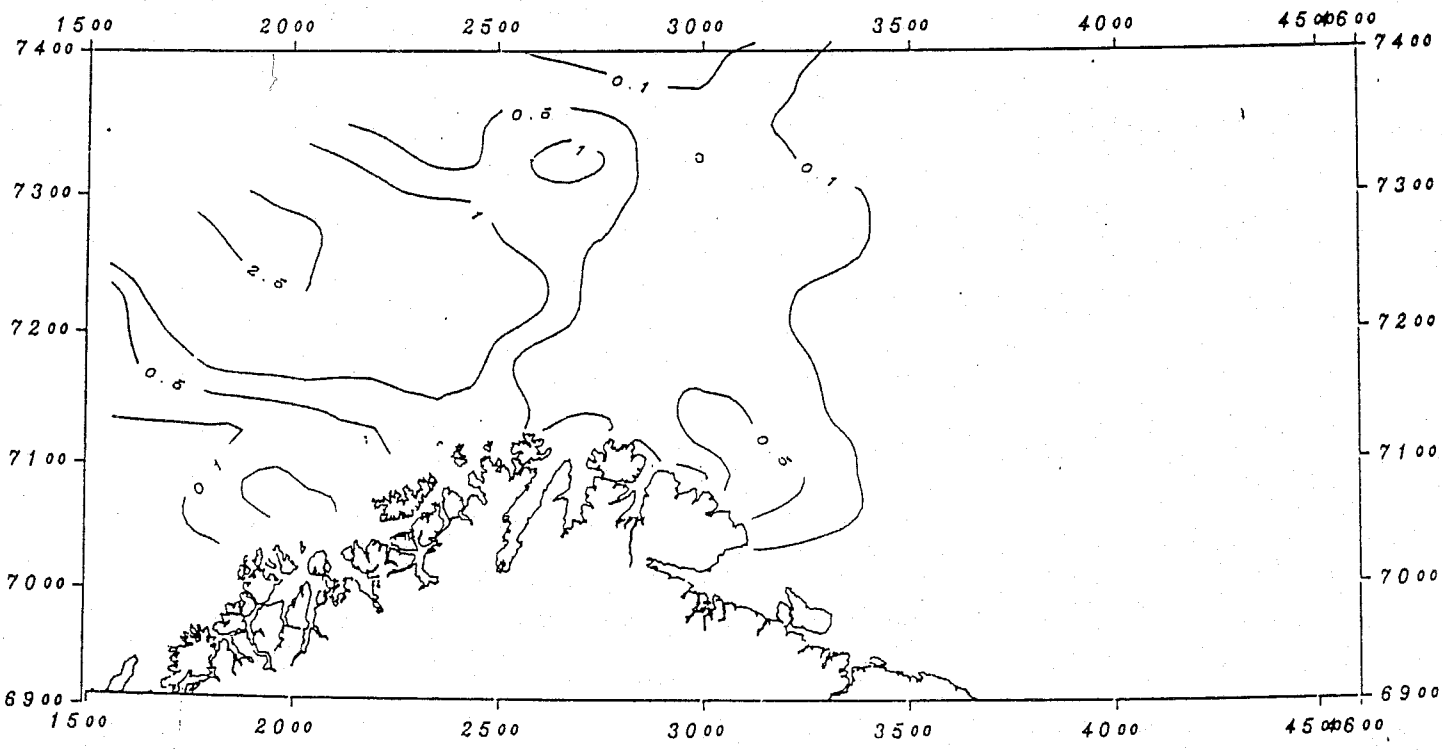

Fig. 13. The distribution of 6-10-year old cod.

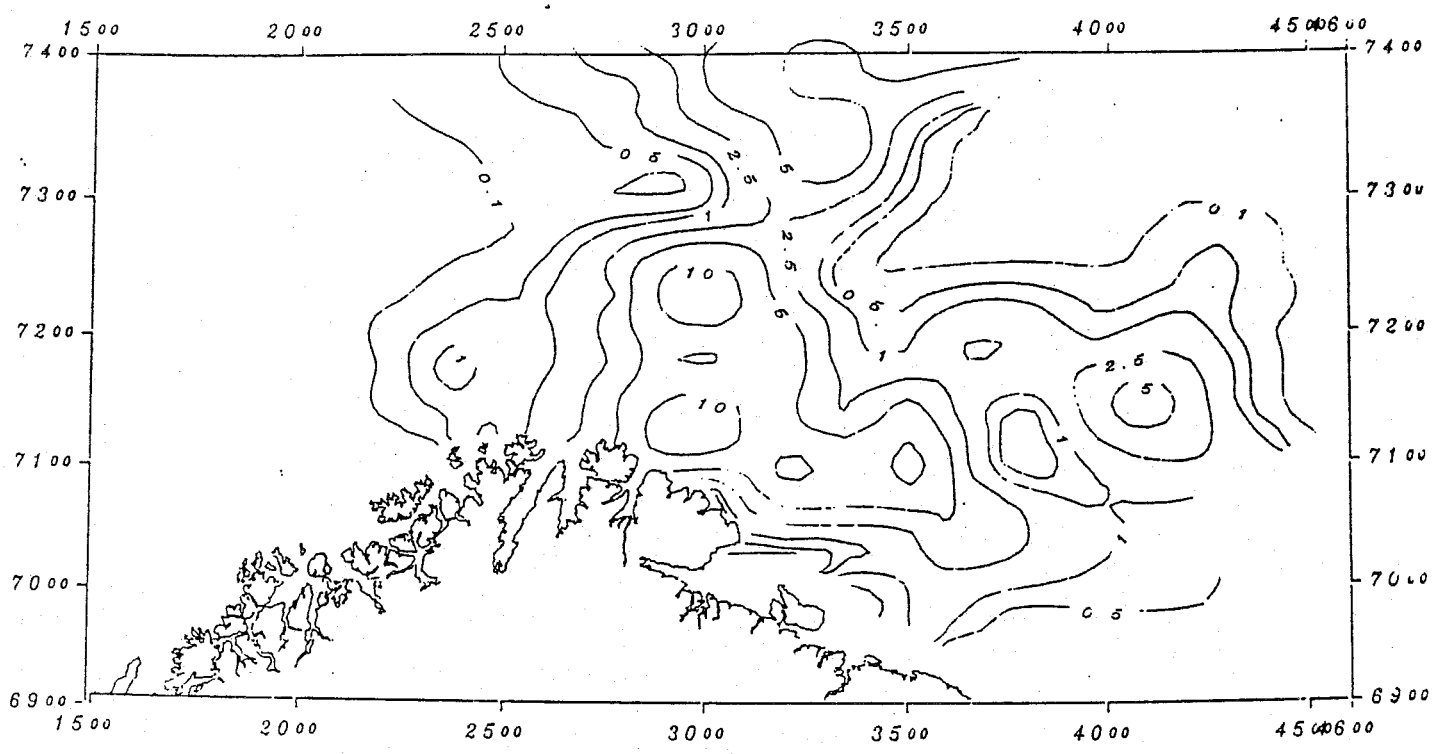

Fig. 14. The distribution of 1-year old hadddock. (Units as in fig. 11).

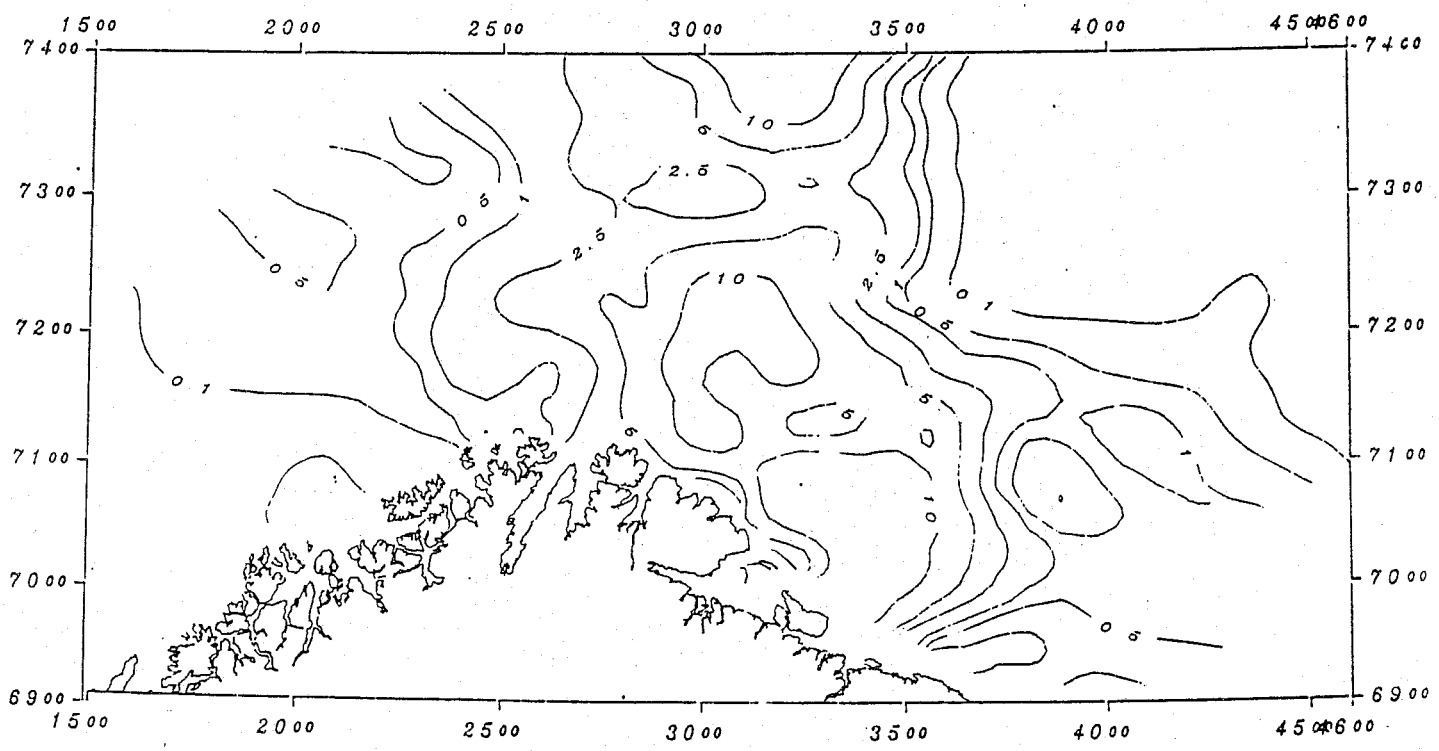

Fig. 15. The distribution of 2-year old haddock.

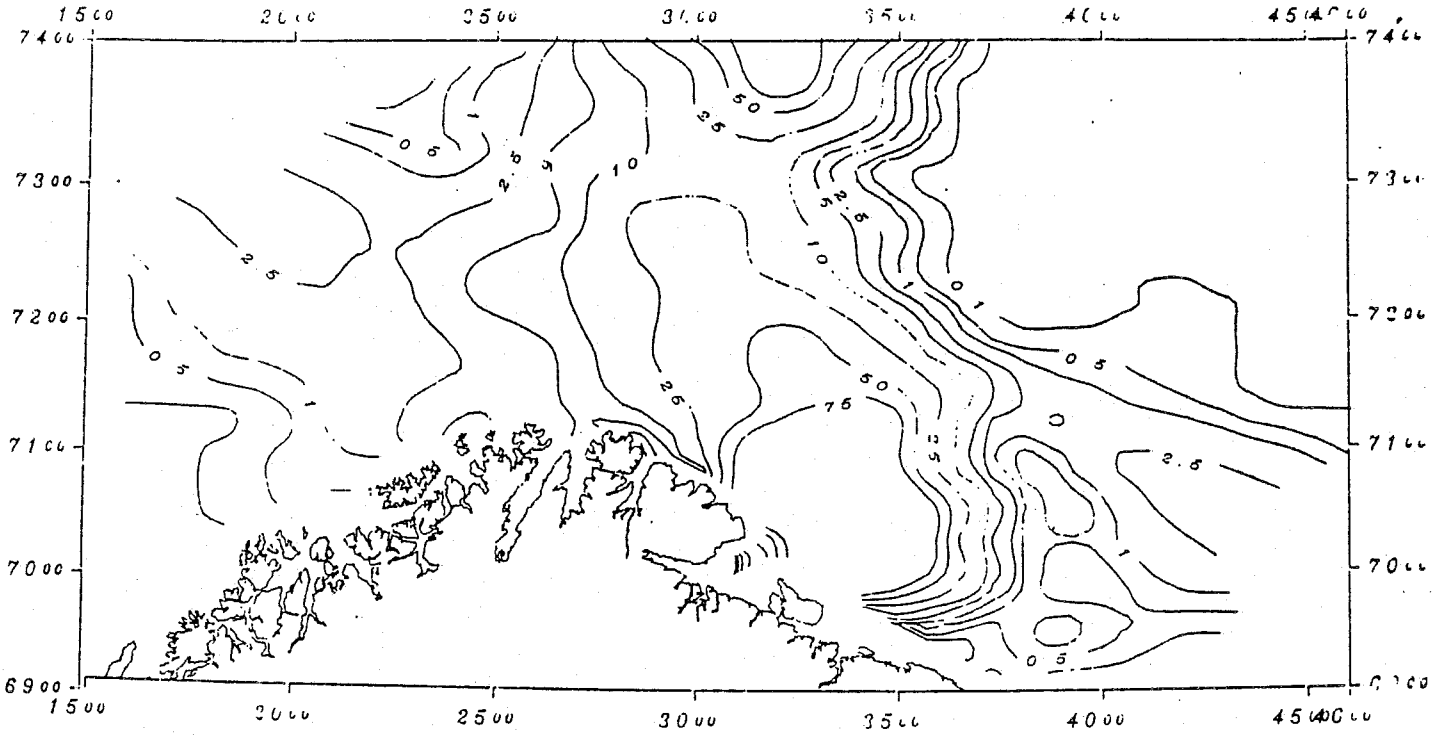

Fig. 16. The distribution of 3-year old haddock.

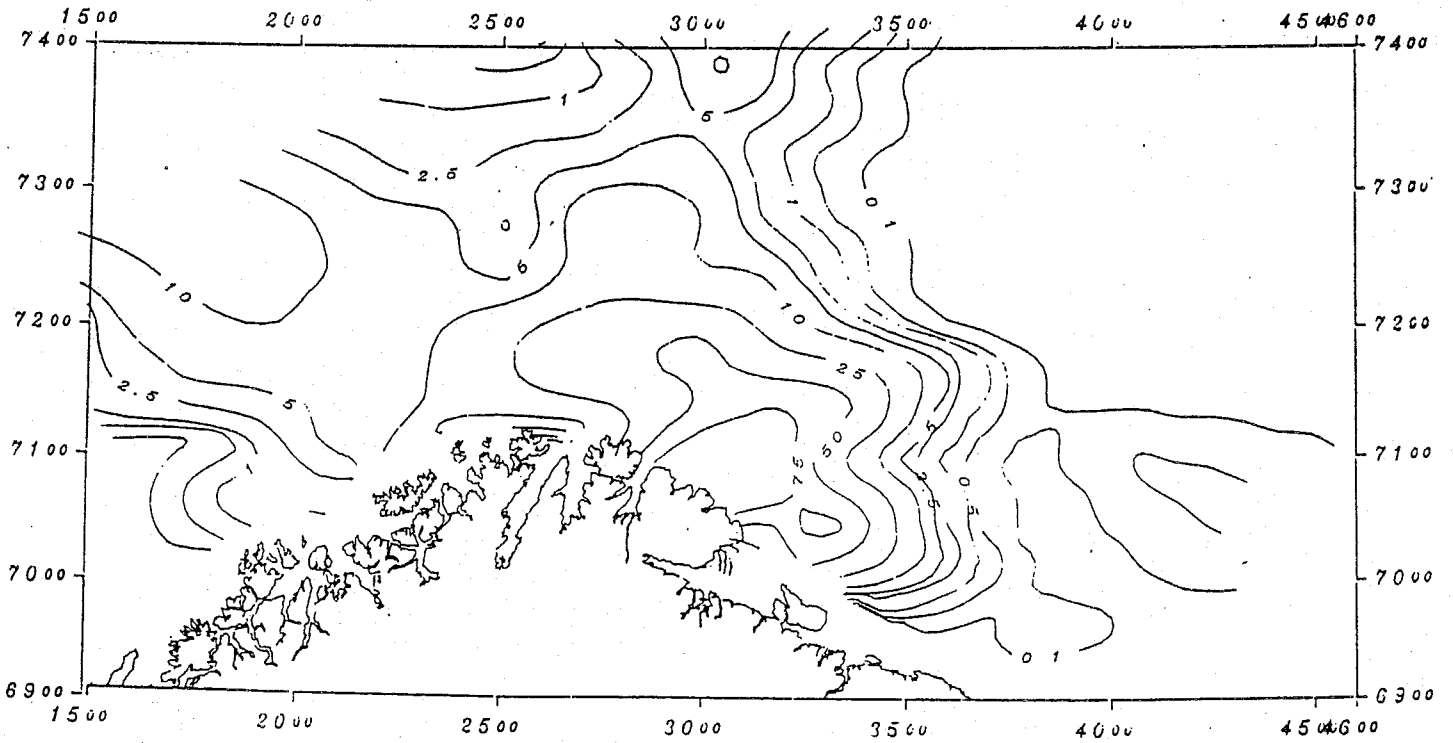

Fig. 17. The distribution of 4-year old haddock.

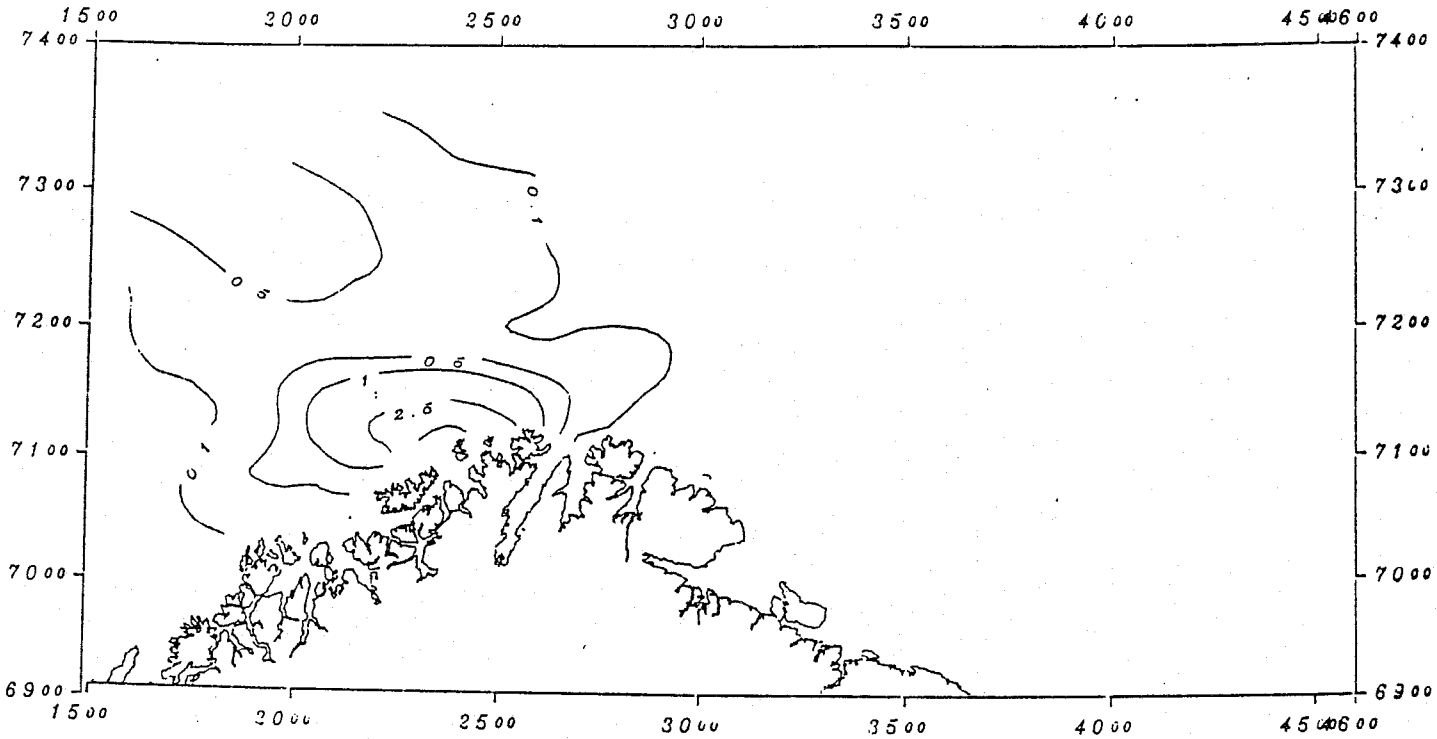

Fig. 18. The distribution of 5-10-year old haddock.