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ACOUSTIC ESTIMATES OF SPAWNING COD  
OFF LOFOTEN AND MØRE IN 1983

by

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ABSTRACT

Acoustic surveys on spawning cod were carried out in Lofoten and off Møre in order to estimate the stock size and structure. The 1975 year class made up the bulk of the spawning stock in both areas. In the Lofoten area the total number of spawners was estimated to about 50 million specimens; the corresponding figure for the Møre area was 6 million specimens. Since the northeast Arctic cod spawns over considerably larger areas than those covered by the investigations, it is believed that the total spawning stock in 1983 was larger than the figures arrived at during the investigations reported here.

## INTRODUCTION

The spawning grounds of north-east Arctic cod (Fig. 1) are located in nearshore waters from Møre to Finnmark (Anon 1982a, Ellertsen et al. 1980), and the mature fish, usually fish which are 7-8 years and older, spawn in March-April. The main spawning area, Lofoten, has been more or less regularly echo surveyed since 1935 during the spawning season (Sund 1938). These surveys have provided information on relative density distribution and migration patterns (Hysten et al. 1961, Monstad et al. 1969, Jakobsen 1974), but few attempts have been made to estimate the number of cod actually present within the surveyed areas. Blindheim and Nakken (1971) estimated the number of cod on the spawning grounds in the inner Lofoten area from a series of surveys in 1971. They concluded that even the highest of these estimates, approximately 14 million fish, due to insufficient area coverage amounted to only a fraction of the total spawning stock which that year was about 70 million fish (Anon 1982b).

Since 1976 acoustic surveys have been carried out in the Barents Sea annually in order to estimate the abundance of young cod and haddock (Dalen and Smedstad 1979 and 1982). These surveys have contributed largely to the knowledge of the stock state of northeast Arctic cod during recent years (Nakken and Ulltang 1982), and in 1981 the results were used to calibrate the Virtual population analysis (VPA) (Anon 1982b) in order to arrive at the best estimates of stock size and structure.

In the period February-April 1982 a series of surveys were carried out in the Lofoten and Møre areas aiming at acoustic abundance estimates for spawning cod (Godø et al. 1982). The results were promising and the investigations were continued in 1983 with minor changes in survey design and technique.

In the present paper the results and experiences from the 1983 surveys are presented and discussed.

## MATERIAL AND METHODS

The two areas covered by the surveys are shown in Fig. 1.

### Lofoten

The Lofoten area was divided into five subareas (Fig. 2). In Table 1 are given the names of the vessels used and the periods and subareas covered by the 12 cruises. The cruise tracks of cruise no. 7-12 are presented in Fig. 3. Lack of time and unsuitable weather conditions limited the coverage of the outer banks to a greater extent than in the Vestfjord (subarea 3 and 4).

The Vesterålen-Troms area (Fig. 1) (north of subarea 1) was covered only once during cruise no. 9.

### Møre

The area was divided into four subareas (Fig. 5). Table 2 shows which vessels were used and the time periods and subareas which were covered by the four cruises. The cruise tracks during the various cruises are shown in Fig. 6. Bad weather prevented a satisfactory coverage and caused difficult observation conditions during cruise no. 1.

### Sampling and processing of data

All the five research vessel which took part in the investigations used echosounders at a frequency of 38 kHz in conjunction with digital echointegrators. "G.O. Sars", "Eldjarn" and "Haakon Mosby" carried echosounders of the type Simrad EK-400, while "Michael Sars" and "Johan Ruud" were equipped with Simrad EK-S and EK-A respectively. Onboard "Haakon Mosby" the echointegrator was a Simrad QD; the other vessels used the integration systems developed by the Institute of Marine Research (Blindheim, Eide, Knudsen and Vestnes, 1982).

The acoustic systems were calibrated using a standard target (coppersphere 60 cm in diameter, Foote, 1983). On the basis of these calibrations and an intercalibration between "G.O. Sars" and "Michael Sars" a series of scaling factors were computed for the purpose of scaling the observed echointegration values to "G.O. Sars" standard. The relations used for this scaling were:

Integration value (G.O. Sars) = 2.52	Integration value (M. Sars)
Integration value (G.O. Sars) = 2.95	Integration value (J. Ruud)
Integration value (G.O. Sars) = 2.63	Integration value (Eldjarn)
Integration value (G.O. Sars) = 3.58	Integration value (H. Mosby)

Integration values were recorded for each nautical mile and averaged within squares of 10' latitude by 20' longitude. Indices of echo abundance were calculated for each subarea as follows:

$$\text{Echo abundance index} = \sum_{i=1}^{i=n} \bar{I}_i \times A_i \text{ [(mm per n.m} \times (\text{nm})^2\text{)]}$$

where:  $\bar{I}_i$  is mean integration value in square  $i$

$A_i$  is the area of square  $i$

$n$  is the number of squares in the subarea.

The number of fish within each subarea was computed from the formula:

$$\text{Number of fish} = \text{Echo abundance index} \cdot C$$

where  $C$  is the scaling factor for the integration system. The dimension of  $C$  is: Number of fish per square nautical mile per unit integration. Previously a value,  $C = 5.25 \cdot 10^6 \cdot l^{-2.18}$  ( $l$  is fish length in cm), has been used for cod and for the integration system onboard "G.O. Sars". In summer 1982 the echosounder onboard the vessel was replaced resulting in an increased performance of the system. The value of  $C$  corresponding to the new performance is:

$$C = 1.87 \cdot 10^6 \cdot 1^{-2.18}$$

The computations of number of fish were carried out as described by Dalen and Smedstad (1979 and 1982).

Sampling of the echo recordings were carried out with bottom trawls or pelagic trawls. The pelagic trawl used was a 1600 mesh capelin trawl with 200 mm mesh size in the front part decreasing gradually to 20 mm in the cod-end. Size of otterboards, length of sweep-lines and weights on lower sweep-lines were respectively: 7-8 m<sup>2</sup>, 80 m and 150-300 kg. When towed at a speed of 3 knots the vertical opening was 15-20 m measured on the net sonde, depending on weights and warp lengths. The bottom trawls applied were 1500-1800 mesh shrimp trawls, 80 mm mesh size in the front part and 20 mm in the cod-end. Towed at a speed of 3 knots the distance between headline and bottom was approximately 6 m, lengths of sweep-lines were 40 m and the otterboards were the same as for the pelagic trawl. Length- and maturity measurements and age determinations were carried out according to standard procedures.

## RESULTS AND DISCUSSION

### Lofoten

#### Distribution and migration patterns

The details of the cod distribution during cruise no. 9 are shown in Fig. 8. The echo abundance indices obtained during the 12 cruises for the sub areas 1-4, are shown in Table 3 and summarized in Fig. 9. A large increase of the indices was observed in the end of February indicating the arrival of the bulk of the spawning stock. From then on to the completion of the surveys the indices remained more or less stable. The abrupt increase between cruise 6 and 7 may, however, partly be due to underestimation of the indices at cruise no. 3-6. During these cruises the weather conditions were very difficult especially on the western side (sub area 1-2) where the major part of the spawning cod could have been distributed at that

time. Consequently, the fish abundance in the area probably increased more smoothly than indicated by Fig. 9. The main immigration of cod to the Lofoten spawning grounds seem thus to have taken place in the second half of February.

The other main tendency in Fig. 9, the more or less stable level of the indices during the period February 26 - April 8, is more significant as all the cruises 7-12 were run during good weather and recording conditions.

None of the echo abundance indices do include all the cod which spawned in the Lofoten area in 1983. Cruise no. 9 showed prespawning cod north of the investigation area in the middle of March; and in the eastern part of Lofoten the fish occurred in nearshore waters with steep bottom slopes, conditions which were unsuitable for acoustic surveying. In addition it is believed that spent fish started to leave the spawning grounds in the end of March. Even the highest of the observed indices will therefore tend to underestimate the Lofoten spawning stock.

During cruise no. 9 it was observed that cod north of about  $N69^{\circ}30'$  were mainly immature, while the recordings further south were mainly made up of spawning cod.

#### Abundance

The length distributions used in the abundance calculations are given in Table 4. A) is from a number of trawl stations (bottom trawl) taken by "Michael Sars" in February (Fig. 2). B) is from purse seine catches taken in sub area 4 (Fig. 2) in March.

Abundance estimates for the six last cruises are presented in Table 5.

The estimates from cruise nos 7-9 were calculated using length distribution A), while the B)-distribution was used for the three last cruises. Mean integration values during cruise no. 7-12 are shown in Fig. 4.

The total estimate for cruise no. 10 is put in brackets as that cruise only covered subareas 3 and 4. During cruise no 9 and 11 approximately 6-8 million fish were recorded in subareas 1 and 2 which were not covered during cruise no 10. Consequently the results from cruise no. 10 is in accordance with the other cruises. Hence, the variation in the total estimates in Table 5 is surprisingly small, especially when taking into consideration that the results are achieved with three different vessels within a period of more than one month.

If we can assume that the emigration and immigration are limited during cruises no. 7-12, one and the same length distribution should be applied for all these cruises. Length distribution A (Table 4) would then give the highest figure of 52 million specimen during cruise no. 11 while length distribution B would give a minimum estimate for cruise no. 9 of about 40 million cod. Taking into consideration the sources of underestimation mentioned previously, an estimate of about 50 million specimen spawning cod in the Lofoten area (subarea 1-4) in the last half of March is probably the best which can be given from the present data.

The recordings made north of Lofoten during cruise no. 9, mainly immature cod, resulted in 9.1 million individuals.

In subarea 5 and north of subarea 2 an estimate of 5.1 million prespawning cod was calculated based on cruise no. 9. These fishes might have entered the main spawning grounds, subarea 1-4, in late March and included in the estimates from the last cruises.

The 1975 year class was predominant in the Lofoten area according to age frequencies analysis by Hylén and Nakken (1983).

Møre

## Distribution and migration patterns.

The details of the cod, haddock and saithe distribution during cruise no. 3 are presented in Fig. 10. The number of cod estimated in the various squares during the cruises 1, 3 and 4 are shown in Fig. 7. Cruise no. 2 was designed as a trawl survey, and the acoustic data are thus not presented. A southward displacement from the Buagrunn (Subarea III) to the main spawning grounds (Godø and Sunnanå 1983) in subarea I and II was observed. This was in accordance with the observations from 1982 (Godø et al. 1982). Inconsiderable cod recordings were seen in subarea IV during all cruises in 1983, which may indicate a more southern immigration from the ocean to the coastal area than observed last year (Godø et al. 1982). As during the 1982 cruises the conditions for acoustic surveying both due to the vertical distribution and mingling with haddock, saithe and herring were best during late March.

On the main spawning grounds the cod were partly distributed too close to the shore to permit reliable acoustic surveying. This, in addition to the effect of the echosounder deadzone at the bottom, particularly significant in areas with steep slopes, will cause underestimation of the cod abundance.

## Abundance.

The calculations of abundance were done using the length distributions in Table 6. A) and B) are from bottom trawl stations in subarea III. C) is from pelagic trawl stations in subarea II. The estimates in subarea III and IV were obtained using the length distributions A) and B) and those in I and II using C). The results are shown in Fig. 7 and Table 7.

The conditions for acoustic surveying were, as already discussed, best during the two last cruises. The estimates in the subareas covered by both cruises are consistent and the best



abundance estimate of spawning cod off Møre based on the acoustic surveys are 6 million specimens.

As shown by Fig. 11, the 1975 yearclass dominated the catches.

#### FINAL REMARKS

Based on the experiences from the acoustic surveys off Lofoten and Møre in 1982 and 1983 it is concluded that the most favourable time of estimating the number of spawning cod probable will be the last half of March and beginning of April.

The "best" estimate arrived at for 1983 was 56 million individuals. Since this figure covers only the two main spawning grounds, Lofoten and Møre, it is an underestimate of the total spawning stock of northeast Arctic cod.

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Table 1. Acoustic surveys in the Lofoten area in February-April 1983. Sufficient coverage (+). Insufficient coverage (-).

No.	Time	Vessel	Area				
			1	2	3	4	5
1	1-5 Feb	M. Sars	+	+	+	+	-
2	6-9 Feb	M. Sars	+	+	+	+	-
3	10-12 Feb	M. Sars	-	(+)	+	+	-
4	13-17 Feb	M. Sars	+	+	+	+	-
5	17-19 Feb	M. Sars	+	+	+	+	-
6	20-23 Feb	M. Sars	+	+	+	+	-
7	24-27 Feb	M. Sars	+	+	+	+	-
8	28 Feb - 2 Mar	M. Sars	+	+	+	+	-
9	8-13 Mar	G.O. Sars	+	+	+	+	+
10	15-18 Mar	J. Ruud	-	-	+	+	-
11	21-25 Mars	J. Ruud	+	+	+	+	-
12	8-11 Apr	M. Sars	-	(+)	+	+	-

Table 2. Acoustic surveys off Møre in March 1983. Sufficient coverage (+). Insufficient coverage (-).

Cruise no	Time	Vessel	Area			
			I	II	III	IV
1	6 - 15	Haakon Mosby	-	+	+	+
2	14 - 17	Eldjarn	-	+	+	-
3	18 - 24	Eldjarn	+	+	+	+
4	25 - 27	Eldjarn	+	+	-	-

Table 3. Echo abundance indices (mm per n.m.  $(x(nm)^2)$ ) of cod in the Lofoten area during the period February - April 1983.

Area	Cruise no.											
	1	2	3	4	5	6	7	8	9	10	11	12
1	50	15	-	6	2	5	38	19	29	-	30	29
2	5	3	3	15	37	1	103	18	15	2	22	23
3	6	11	13	15	43	14	38	84	30	64	118	53
4	16	1	17	16	21	83	178	239	271	307	240	246
Total	77	30	33	52	103	103	357	360	345	373	410	351

Table 4. Length distribution in catches from Lofoten in February-March 1983.

Length in cm	A		B	
	TRAWL		PURSE SEINE	
	"M. SARS"		(Hølla-H.str.)	
	8-28 FEB		15-21 MAR	
	No.	%	No.	%
< 60	32	3.5	23	0.5
60-64	37	4.1	100	2.1
65-69	105	11.5	325	6.8
70-74	159	17.5	695	14.5
75-79	196	21.5	891	18.5
80-84	170	18.7	794	16.5
85-89	79	8.7	545	11.3
90-94	61	6.7	409	8.5
95-99	34	3.7	235	4.9
100-104	15	1.7	242	5.0
105-109	7	0.8	210	4.4
110-114	16	1.8	152	3.2
115-119			98	2.0
120-124			44	0.9
> 125			45	0.9
<b>Total</b>	<b>911</b>	<b>100.2</b>	<b>4808</b>	<b>100.0</b>

Table 5. Estimated number of cod (millions) in the Lofoten area in the period 24 February - 8 March 1983.

Length in cm	Cruise No.					
	7 M.Sars 24-27 Feb	8 M.Sars 28 Feb-2 Mar	9 G.O.Sars 5-13 Mar	10 J.Ruud 15-18 Mar	11 J.Ruud 21-25 Mar	12 M.Sars 8-11 Apr
< 60	1.7	1.7	1.6	0.2	0.2	0.2
60-64	1.9	2.0	1.9	0.9	1.0	0.8
65-69	5.4	5.5	5.3	2.9	3.1	2.7
70-74	8.3	8.4	8.0	6.0	6.6	5.7
75-79	10.2	10.3	10.0	7.7	8.4	7.3
80-84	8.9	8.9	8.6	6.9	7.6	6.5
85-89	4.1	4.2	4.0	4.7	5.2	4.4
90-94	3.2	3.2	3.1	3.5	3.9	3.3
95-99	1.8	1.8	1.7	2.0	2.2	1.9
100-104	0.8	0.8	0.8	2.1	2.3	2.0
105-109	0.4	0.4	0.4	1.8	2.0	1.8
110-114	0.8	0.9	0.8	1.3	1.5	1.3
115-119				0.8	0.9	0.8
120-124				0.4	0.4	0.4
> 125				0.4	0.4	0.4
<b>Total</b>	47.4	47.8	45.8	[41.7]	45.8	39.2

Table 6. Length distributions in catches from Møre in March 1983.

Length in cm	A	B	C
	BOTTOM TRAWL "Håkon Mosby" 6-15 March Subarea III, IV %	BOTTOM TRAWL "Eldjarn" 14-24 March Subarea III %	PELAGIC TRAWL "Eldjarn" 18-27 March Subarea II %
< 40		4.9	
40-44		9.7	
45-49		29.5	
50-54	1.6	2.4	
55-59	4.8	9.7	
60-64	3.2	12.1	1.9
65-69	9.7	9.7	3.3
70-74	6.5	.0	14.1
75-79	25.8	7.3	17.7
80-84	29.0	.0	15.0
85-89	9.7	9.7	8.0
90-94	.0	.0	11.1
95-99	6.5	2.4	6.9
100-104	3.2	2.4	6.7
105-109			5.8
110-114			3.9
115-119			3.9
120-124			0.8
> 125			0.8

Table 7. Estimated numbers of cod (millions) at Møre for the various cruises and subareas.

Subarea	Cruise No.			
	1	2	3	4
I	0.0	-	0.8	-
II	2.6	-	4.0	3.61
III	2.6	-	0.8	-
IV	3.2	-	0.3	-
Total	5.8	-	5.9	-

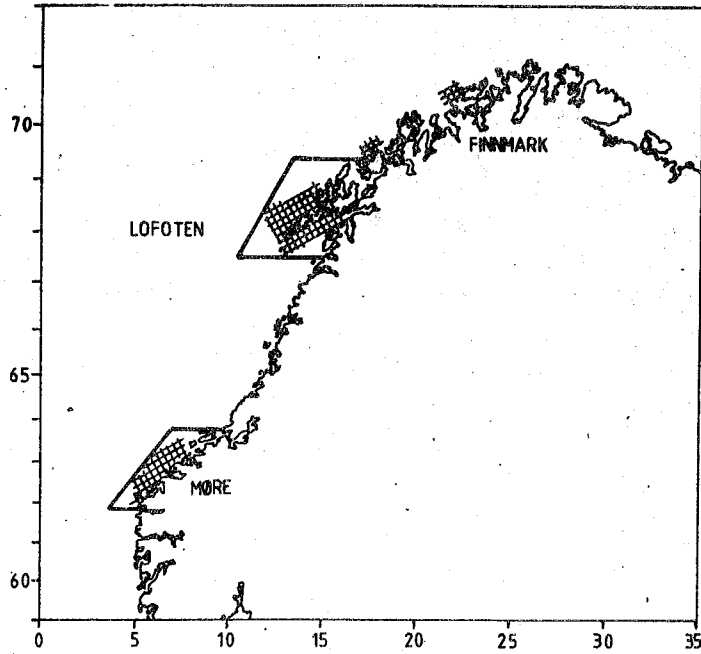


Fig. 1. The Norwegian coast. Investigation areas are framed. Spawning grounds of north-east arctic cod are indicated by hatching.

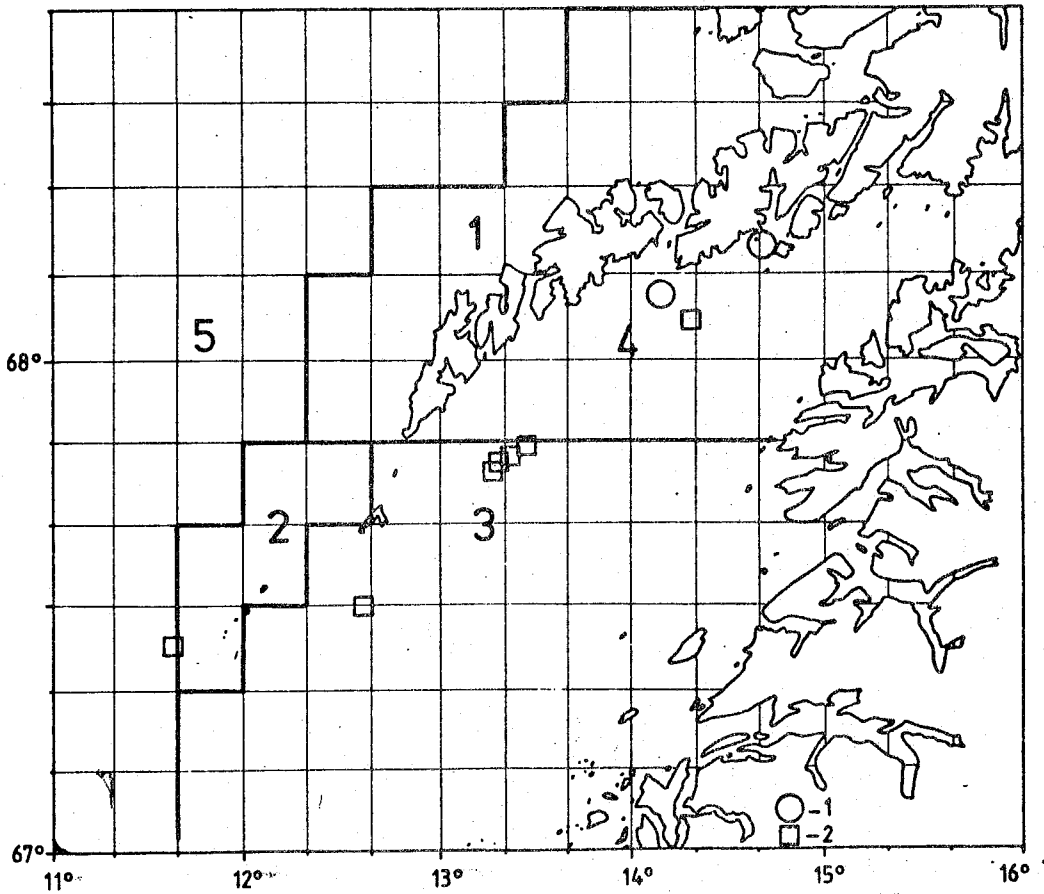


Fig. 2. The Lofoten area, subareas and fishing stations.  
 (◻) Bottom trawl (○) Purse seine.



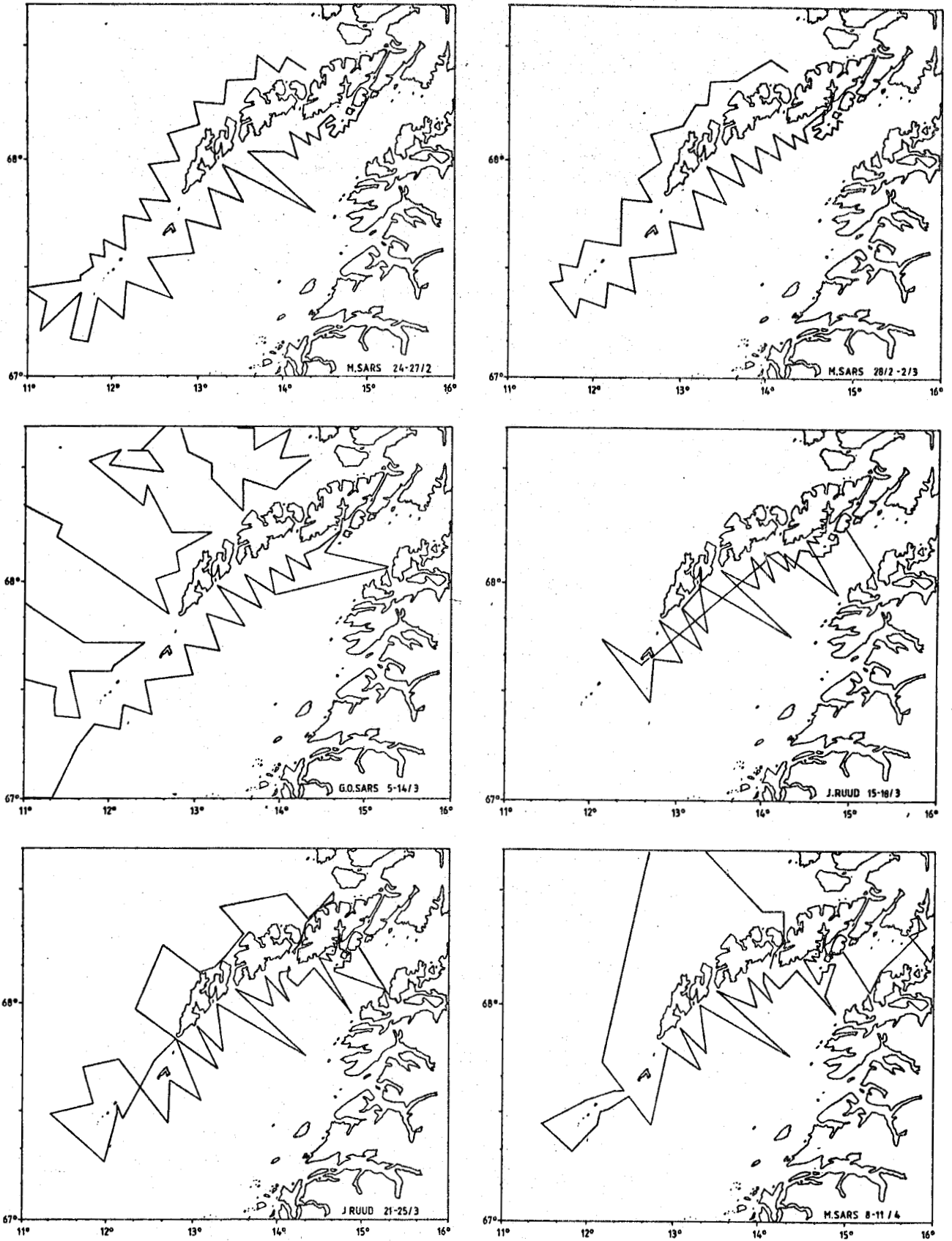


Fig. 3. Cruise tracks for cruise No. 7-12 in the Lofoten area.

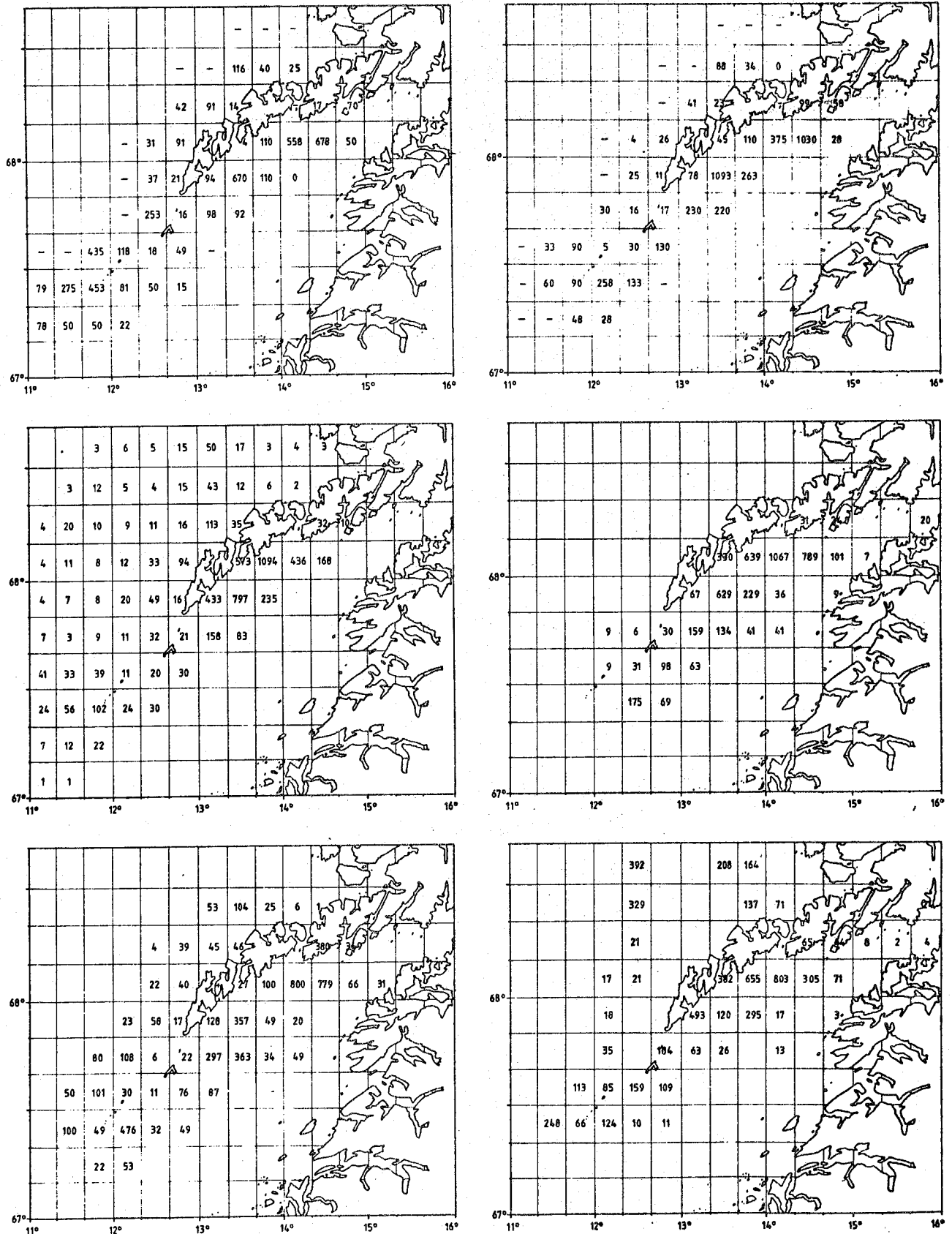


Fig. 4. Mean integration values (mm per n.m.) from the cruises no. 7-12.

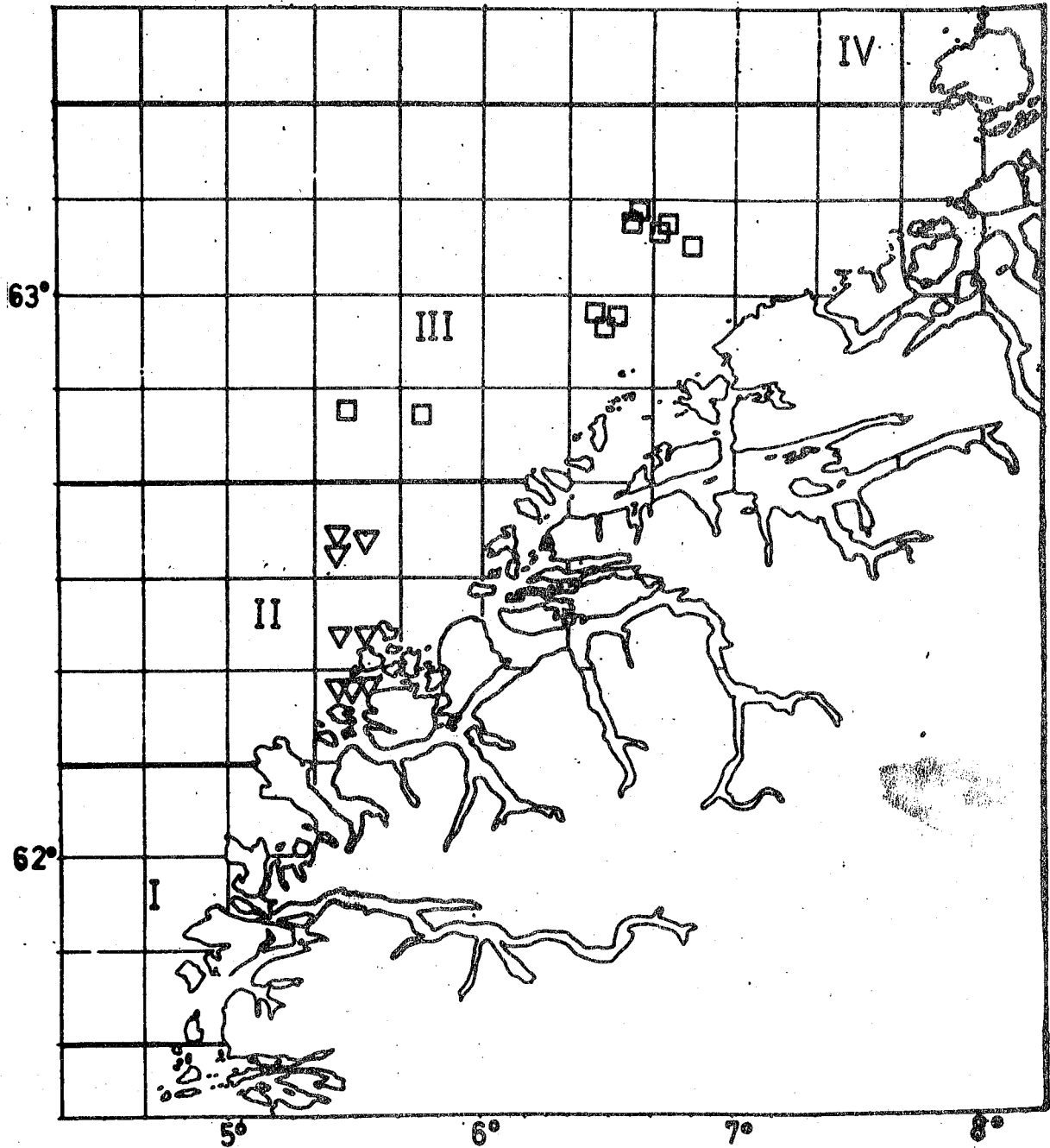


Fig. 5. The Møre area, subareas and fishing stations. (□) Bottom trawl, (Δ) Pelagic trawl.

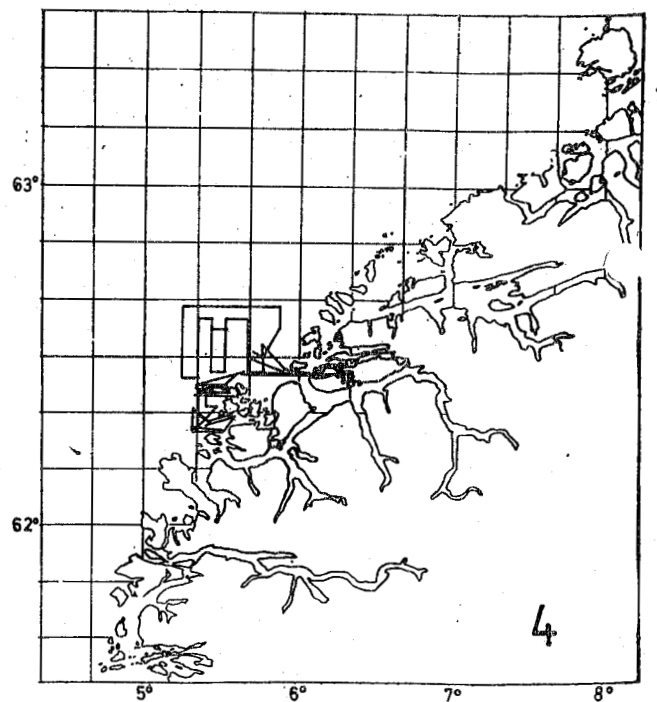
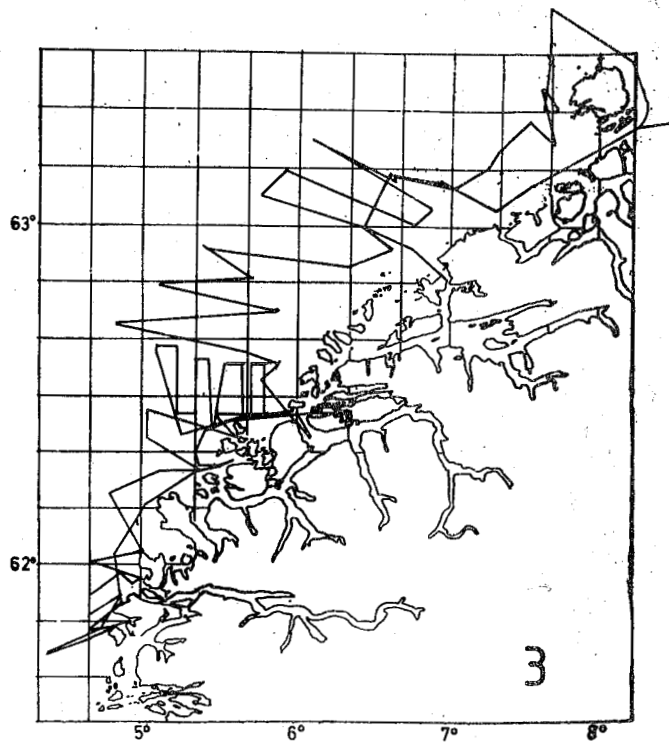
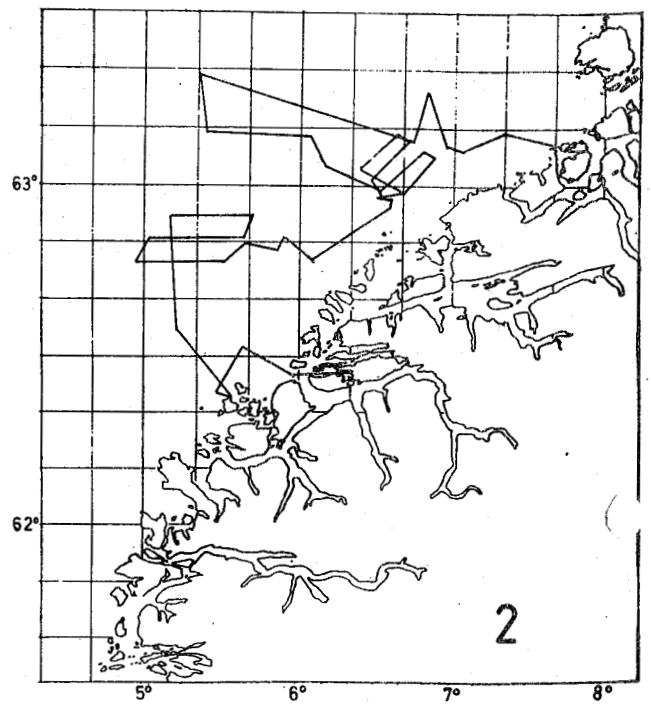
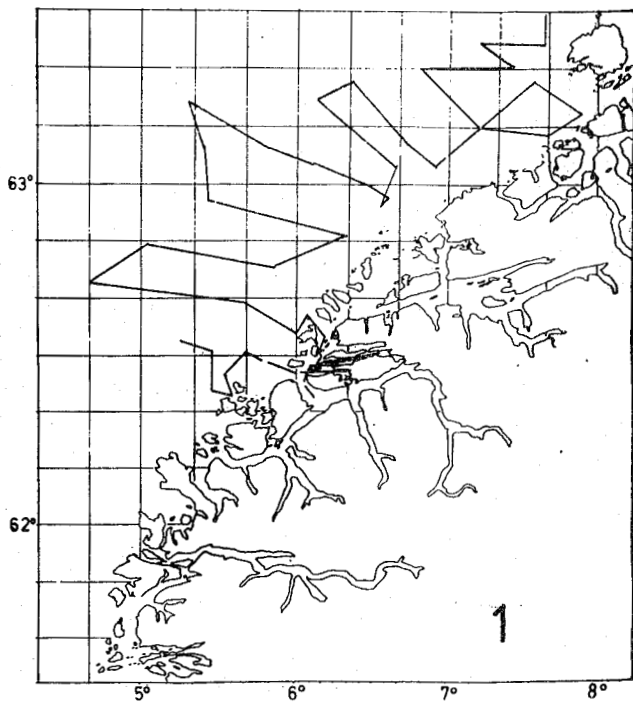


Fig. 6. Cruise tracks for the cruises no.1-4 in the Møre area in March 1983.

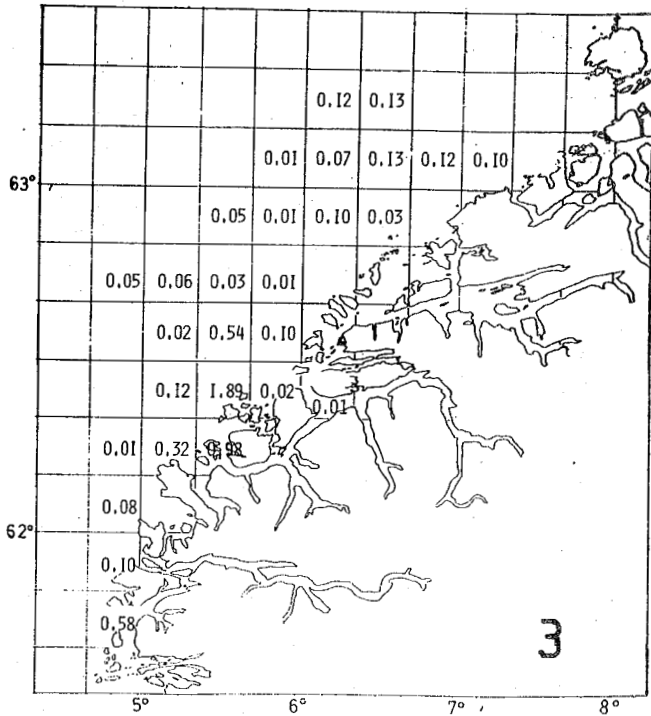
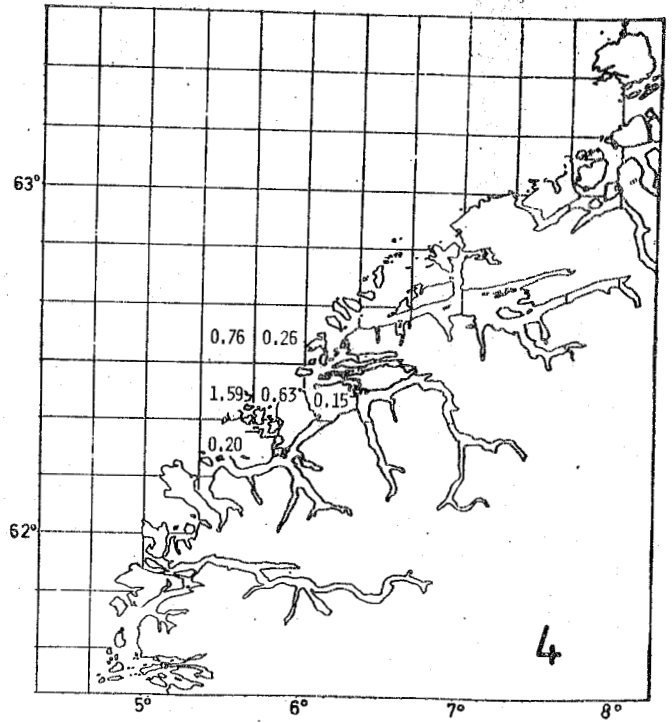
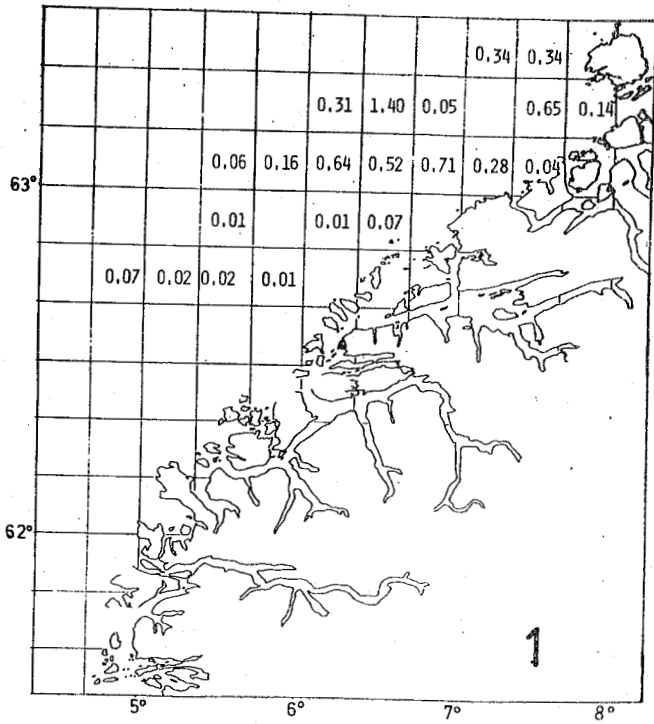


Fig. 7. Number of cod estimated in the various squares during cruise no. 1, 3 and 4 off Møre.

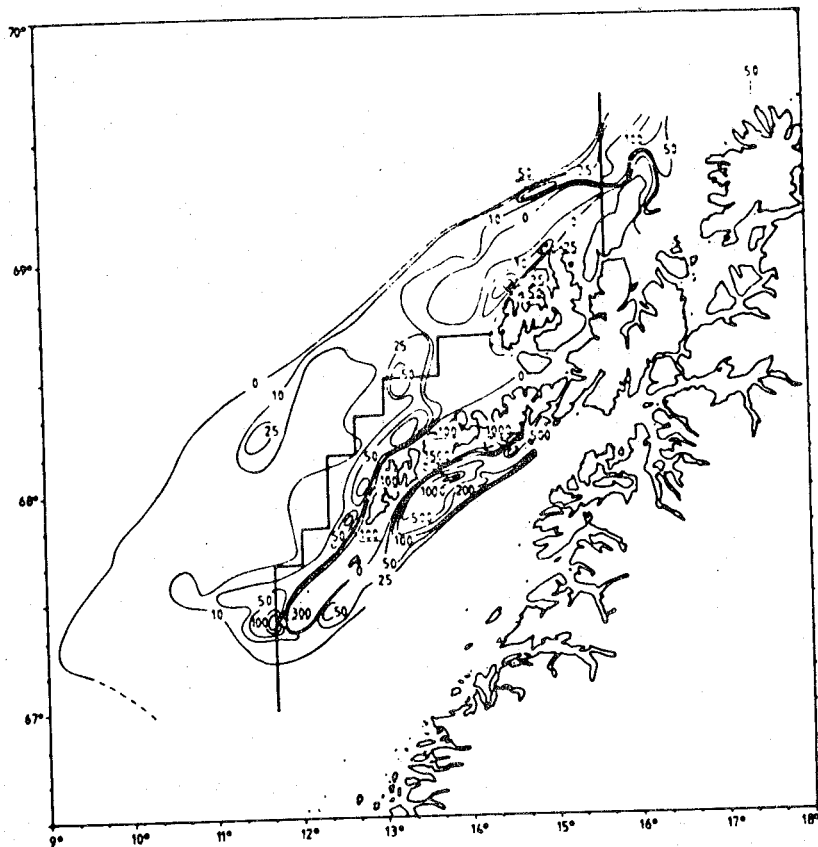


Fig. 8. The distribution of cod during Lofoten cruise no. 9. The figures are integration values (mm per n.m.).

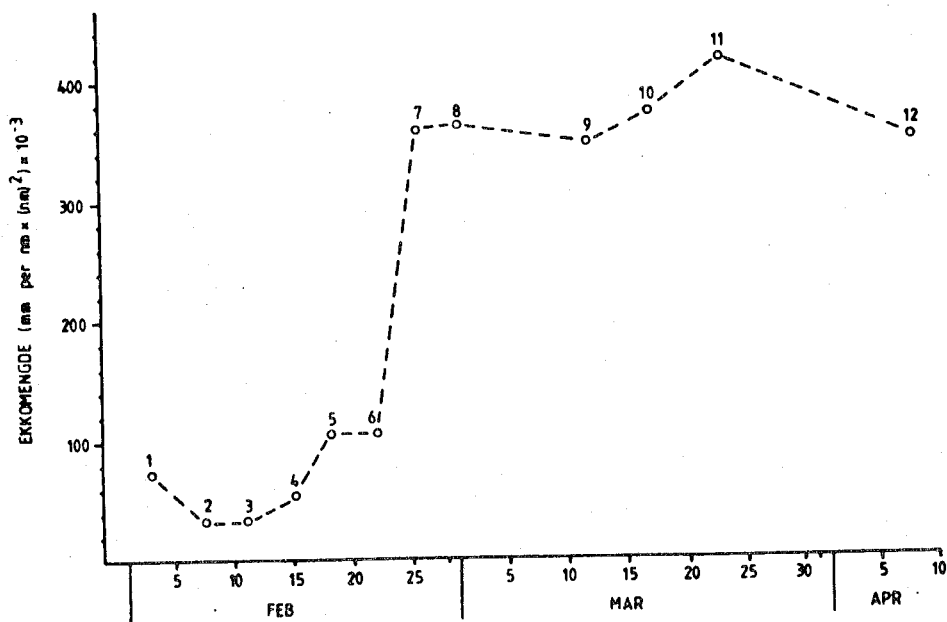


Fig. 9. Total echo abundance (sub area 1-4) in Lofoten during the various cruises in 1983. Figures indicate cruise number (see Table 3).

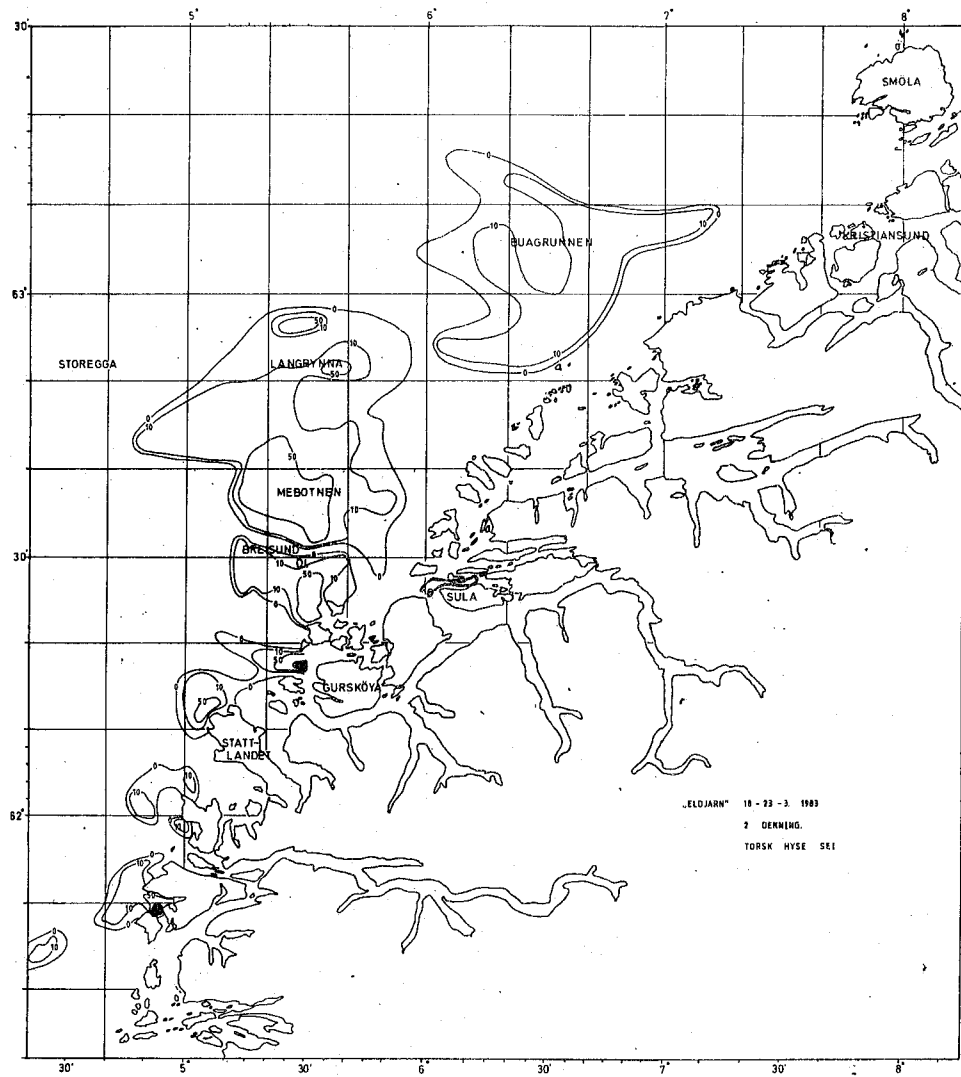


Fig. 10. The distribution of cod, saithe and haddock during the Møre cruise no. 3. The figures are integration values (mm per n.m.).

Pelagic trawl, March 1983 Sunnmøre. N=318

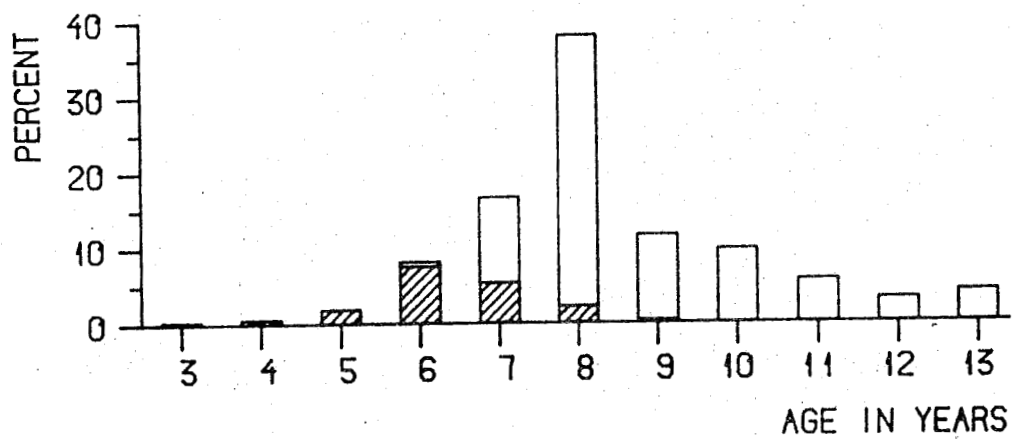


Fig. 11. Age composition in the pelagic trawl catches off Møre in March 1983. Hatched bars are coastal cod.