

Fol. 4/ G

Fiskeridirektoratet  
Biblioteket

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

International Council for  
the Exploration of the Sea

C.M. 1982/G/62  
Demersal Fish Committee

ACOUSTIC ESTIMATES OF SPAWNING COD  
OFF LOFOTEN AND MØRE IN 1982

By

O.R. Godø, O. Nakken, A. Raknes  
Institute of Marine Research,  
P.O. Box 1870, 5011 Bergen-Nordnes, Norway

and

K. Sunnanå  
Institute of Fisheries Biology  
P.O. Box 1839, 5011 Bergen-Nordnes, Norway

ABSTRACTS

Acoustic surveys on spawning cod were carried out in Lofoten and off Møre in order to estimate the stock size and structure. The 1975 yearclass made up the bulk of the spawning stock in both areas. In the Lofoten area the total number of spawners was estimated to about 80 million specimens; the corresponding figure for the Møre area was 11 million specimens. Since the northeast arctic cod spawns over considerable larger areas than those covered by the investigations, it is believed that the total spawning stock in 1982 was much 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 is 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 (HYLEN 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 north-east 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 view of the apparent satisfactory results obtained using the acoustic technique for young cod, some preliminary investigations were made in 1982 applying the same method on spawning cod. The main objectives of these investigations were:

- a) to assess whether or not it was possible to arrive at reliable estimates of spawning cod on the spawning grounds,
- b) to specify the requirements to be met regarding period, area coverage and vessel time and capacity in order to obtain such estimates.

The present paper presents some of the results from the acoustic surveys on spawning cod during winter-spring 1982.

#### MATERIAL AND METHODS

Two areas were covered by the surveys; the Lofoten area and the Møre area (Fig. 1).

##### Lofoten

During January-February the research vessel "Johan Hjort" made 7 cruises in this area as follows:

Cruise no.	Period	Area covered
1	29 Jan - 1 Feb	Coastal banks 70°N - 67°15'N
2	3 Feb - 7 Feb	Vestfjord, coastal banks 67°15'N-69°20'N
3	8 Feb - 12 Feb	Vestfjord, coastal banks 67°15'N-68°30'N
4	15 Feb - 17 Feb	Vestfjord, coastal banks 67°15'N-67°50'N
5	17 Feb - 20 Feb	Vestfjord, coastal banks 67°N - 68°30'N
6	21 Feb - 24 Feb	Vestfjord, coastal banks 67°N - 68°30'N
7	24 Feb - 27 Feb	Vestfjord, coastal banks 67°15'N-67°50'N

Fig. 2 shows the approximate sectors covered by the various cruises. In Fig. 3 is presented the grid worked during cruise no. 2. The grid systems used during the other cruises were not quite similar to that in Fig. 3, but slightly adjusted to cover the main fish distribution patterns.

##### Møre

This area was covered twice. The research vessels used and the period of investigation were:

Cruise no.	Period	Research vessel
1	16 Mar - 25 Mar	R/V "Håkon Mosby"
2	25 Mar - 7 Apr	R/V "G.O. Sars"

The survey grid during cruise no. 1 is shown in Fig. 4. The grid worked with "G.O. Sars" during the second cruise did not differ much from that shown in Fig. 4.

#### Sampling and processing of data

The three research vessels had slightly different acoustic sampling systems. "G.O. Sars" and "Johan Hjort" were equipped with Simrad EK-5 echosounders working at 38 kHz, while "Håkon Mosby" had a Simrad EK 400 echosounder at 38 kHz. Onboard "Johan Hjort" and "Håkon Mosby" the 38 kHz sounder worked in conjunction with Simrad QD echointegrators, and onboard the "G.O. Sars" the echointegration was undertaken by a Nord 10-computer. All the three integration systems were calibrated using a coppersphere of 60 mm in diameter as standard target.

The echointegrator values of "Johan Hjort" and "Håkon Mosby" were scaled to "G.O. Sars" values using the following scaling relations:

$$\begin{aligned} \text{Integration value (G.O. Sars)} &= 5.0 \text{ Integration value (H. Mosby)} \\ \text{Integration value (G.O. Sars)} &= 1.46 \text{ Integration value (J. Hjort)} \end{aligned}$$

These relations were obtained from the results of the calibration on standard targets and from the beam pattern functions of the transducers.

Computations of fish densities (number per unit area) were carried out using the technique described by DALEN and SMEDSTAD (1979). Simplified, this technique estimates fish density from echointegration values by applying the formula

$$\rho_A = C \cdot I$$

where:  $\rho_A$  is the number of fish per unit area  
I is the echo integration value  
C is a scaling factor.

The value of the scaling factor,  $C$ , used in the computations was the same which has been applied over a series of years for estimating the abundance of young cod in the Barents Sea (DALEN and SMEDSTAD 1979 and 1982). The value is

$$C = 5.25 \cdot 10^6 \cdot L^{-2.18},$$

and  $C$  has the dimension: Number of fish per square nautical mile per unit integration value.  $L$  is the fish length in cm.

The target strengths corresponding to this value of  $C$ , are:

$TS \approx -40$  dB for a 30 cm fish and  $TS \approx -34$  dB for a 60 cm fish. Or in terms of target strength of 1 kg:  $TS_{1 \text{ kg}} \approx -34$  dB for a 30 cm fish and  $TS_{1 \text{ kg}} \approx -37$  dB for a 60 cm fish.

Integration values were obtained for each nautical mile. In the Lofoten surveys these values were averaged within subareas of 10' latitude by 20' longitude and the average values were used in the computations of fish abundance.

The results from the Møre area were mainly dealt with in the same way, but at the inshore localities with the highest fish density the integration values were plotted in maps and computations of fish abundance were carried out by measuring the areas between isolines.

Sampling of the echorecording 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 trawl onboard "G.O. Sars" and "Johan Hjort" was a 1800 mesh shrimp trawl, 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 were approximately 6 m, lengths of sweep-lines were 40 m and the otterboards were the same as for the pelagic trawl. Onboard "Håkon Mosby" the bottom trawl was slightly smaller (1560 meshes, 80 mm mesh size), but otherwise similar to that used by the two other vessels.

Length- and maturity measurements and age determinations were carried out according to standard procedures.

## RESULTS AND DISCUSSION

### Lofoten

#### Distribution and migration patterns

Fig. 5 shows the details of the distribution during cruise no. 2, and in Fig. 6 is presented distribution maps for each of the seven cruises. The numbers in these maps are the average integration values for each subarea (square). It is seen that both during cruise no. 1 and 2 the fish densities were relatively low in the Vesterålen area. Here the southward migrating cod stayed very close to the bottom and this - in combination with a steep sloping bottom - made poor conditions for echo surveying, since probably much of the fish were within the dead zone of the echosounder. South of  $68^{\circ}40'N$  where the fish moved southward over more even and flat bottom along the outer side of the Lofoten Islands, the recordings were more pelagic and hence more suitable for acoustic surveying. Similar suitable conditions were also experienced in Vestfjorden.

The applied survey grid did not cover completely the distribution of spawning cod in the Lofoten area during any of the surveys. It is evident from the maps that during cruises 3, 5 and 7 when some additional transects were worked outside the main survey area, significant recordings of cod were made also there. On cruise no. 7 for instance, it appeared that the fish were distributed closer to the mainland side of the Vestfjord between  $67^{\circ}40'N$  and  $67^{\circ}50'N$ . It is also seen (cr. 6) that significant amounts of fish were observed far to the south of the entrance of the Vestfjord; thus indicating that fish migrated further southward.

The depth of the cod-layer varied somewhat within the surveyed area. Along the outer side of the Lofoten Islands, the most dense concentrations were observed between 100 and 150 m, in Vestfjorden the upper edge of the recordings were approximately 75 m.

### Length and age distribution

The length distribution of the fish caught by "Johan Hjort" is shown in Table 1. In the lower part of the table is given the corresponding age distribution. Table 1 indicates that the 1975-yearclass, 7 year old fish, was dominant in the spawning stock in the Lofoten area this year. However, since the distributions in Table 1 are based on rather few samples they may not be fully representative for the stock of spawning cod.

### Abundance

The results of the abundance estimation are given in Table 2. The estimates varied between 38 million specimens during cruise no. 5. It is seen that prior to cruise no. 4 the average density of cod in the Lofoten area (Vestfjorden, Yttersida) increased considerably, while during the four last cruises it was constant. The differences between the estimates of cruises 4-7, were thus caused exclusively by the differences in the extension of the surveyed areas; the larger the surveyed area the more fish was observed. None of the cruises covered completely the Lofoten area (Fig. 6) and consequently even the highest of the estimates in Table 2 must to some extent be an underestimate of the number of spawners in Lofoten.

### Møre

#### Distribution and migration patterns

The distributions of integration values of demersal fish (cod, haddock and saithe) are presented in Figs. 7 and 8. In all sectors the recordings were dominated by spawning cod during both cruises. Significant contributions of haddock and saithe were only observed in sector III. The fish was distributed in patches and the concentrations moved south and also into more nearshore waters in sector I and II between the two cruises (Figs. 7 and 8, Table 5). During the second cruise no recordings of cod were observed in sector IV.

The conditions for acoustic surveying of cod seemed more suitable during the second cruise than during the first although some

limitations were experienced on both cruises. During cruise no. 1 the fish was located close to the bottom over large parts of the investigated area and in some localities dense concentrations of spawning herring made the separation of the echo recordings difficult. On cruise no. 2, a significant amount of cod was observed in narrow inshore waters in sector I and II, in areas which were difficult to survey satisfactorily due to safe navigation.

The depth of the cod recordings varied between 150 m in the northernmost area (sector IV) during cruise no. 1 and less than 50 m in the southernmost areas during the second cruise.

#### Length and age distribution

Table 3 and 4 show the length- and age distribution of cod within the Møre area. The contributions of coastal cod - determined from the growth patterns of the otholits - are shown in Table 4. Approximately 10-13 percent seemed to be coastal cod.

In all catches the 7 year old fish (1975-yearclass) was dominant (Table 4). The tables (3 and 4) also clearly demonstrate that in sector II the commercial catches sampled larger and older fish to a greater extent than the research vessel catches. In this sector almost 50 percent of the fish in the commercial catches was older than 7 years as compared to only about 20 percent in the research vessel catches. A similar discrepancy was not observed in sector III where the length distributions from commercial and research vessel catches coincided (Table 3).

#### Abundance

Estimates of abundance are given in Tables 5 and 6. The results indicate a population of spawning cod of about 10-11 million specimens, which is in accordance with the result from previous acoustic surveys (GODØ and TORESEN 1980). There are, however, reasons to believe that both the two estimates are underestimates of the spawning stock of cod in the Møre area. During the first cruise patches of prespawning cod were observed at the very northern limit of the investigation area and it is not known



whether or not all "Møre spawners" had entered the area at that time. When cruise no. 2 was carried out a significant portion of the fish were in nearshore narrow waters where adequate acoustic sampling was difficult due to navigational reasons, and parts of the horizontal distribution obviously could not be satisfactorily covered.

#### FINAL REMARKS

The total number of specimens of spawning cod estimated from the present investigations amounts to about 90 million. Since the fish which spawns off Møre passed the Lofoten area on its southward migration it cannot be excluded that some of the Møre stock also was measured in Lofoten. However, the surveys covered only parts of the total spawning areas of the northeast arctic cod stock (Fig. 1) and the total number of spawners in the stock in 1982 was thus probably much larger than the figures reported here.

#### REFERENCES

- ANON 1982a. Report on minisymposium on spawning, eggs and larvae of cod: A comparison of the Icelandic and Arcto-Norwegian cod tribes. Minisymposium organized by the Working Group on Larval Fish Ecology, Biological Oceanography Committee, ICES. Reykjavik, 8-11 February, 1982.
- ANON 1982b. Report of the Arctic Fisheries Working Group. Coun. Meet. Int. Coun. Explor. Sea. 1982/G:2: 1-53.
- BLINDHEIM, J. and NAKKEN, O. 1971. Abundance estimation of the spawning Lofoten cod 1971. Coun. Meet. Int. Coun. Explor. Sea 1971/B/15: 1-5, 3 Tables, 2 Figs. [Mimeo.]
- DALEN, J. and SMEDSTAD, O.M. 1979. Acoustic method for estimating absolute abundance of young cod and haddock in the Barents Sea. Coun. Meet. Int. Coun. Explor. Sea 1979(G:51): 1-18, 2 Tables, 9 Figs. [Mimeo.]

- DALEN, J. and SMEDSTAD, O.M. 1982. Abundance estimation of demersal fish in the Barents Sea by an extended acoustic method. Symposium on Fisheries Acoustics, Bergen, June 21-24, 1982. Contribution No. 36: 1-28. [Mimeo.]
- ELLERTSEN, B., SOLEMDAL, P., SUNDBY, S. og TILSETH, S. 1980. Årsrapport 1980 fra prosjektet fiskelarvens næringsforhold og transport i kyststrømmen. Report to Institute of Marine Research and The Norwegian Council for Fisheries Research (In Norwegian).
- GODØ, O.R. and TORESEN, R. 1980. Akustisk mengdemåling av bunnfisk på Mørgekysten i mars 1980. [Acoustic abundance estimation of demersal fish in the coastal area of Møre in March 1980]. Fisken Hav., 1981 (1): 21-36.
- HYLEN, A., MIDTTUN, L. og SÆTERS DAL, G. 1961. Torskeundersøkelsene i Lofoten og Barentshavet 1960. Fiskets Gang (5): 101-114.
- JAKOBSEN, T. 1974. Skreiinnsiget i Lofoten i 1973. [The spawning migration of Arctic cod in Lofoten in 1973]. Fiskets Gang, 60: 95-97.
- MONSTAD, T., NAKKEN, O. og NÆVDAL, G. 1969. Skreiinnsiget 1969. Fiskets Gang, 34: 571-573.
- NAKKEN, O. and ULLTANG, Ø. 1982. A comparison of the reliability of acoustic estimates of fish stock abundances and estimates obtained by other assessment methods in the northeast Atlantic. Symposium on Fisheries Acoustics, Bergen, June 21-24, 1982. Contribution No. 38: 1-29. [Mimeo.]
- SUND, O. 1938. Biological and oceanographic investigations. 8. Cod stocks in 1938. Fish movements and replacements. Årsberetning Norg. Fisk., 2: 87-102.

Table 1. Length- and age frequency distributions (percent) of cod for research vessel catches (trawl) in the Lofoten area.

Cm	Length groups									N
	< 60	60-64	65-69	70-74	75-79	80-84	85-89	90-94	> 95	
Percent	2	7	20	32	18	11	5	2	3	383
Years	Age groups					N				
	5	6	7	>8						
Percent	2	13	71	14	383					

Table 2. Acoustic estimates of spawning cod in the Lofoten area in February 1982.

Cruise no.	Investigated area (number of squares)	Total number of fish (millions)	Average number of fish per square (millions)
1	66	38	0.6
2	65	53	0.8
3	48	69	1.4
4	30	52	1.7
5	45	78	1.7
6	41	71	1.7
7	33	56	1.7

Table 3. Length frequency distributions (percent) of cod off Møre according to sectors (Fig. 7) and cruise no. for research vessel catches (trawl) and for commercial catches (purse seine (p.s.) and danish seine (d.s.)).

Sector no.	Cruise no.	Length groups (cm)												N
		< 50	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	≥ 100	
II	2				4	17	34	23	11	3	2	2	4	329
	p.s.				3	6	16	13	10	6	5	10	31	496
	d.s.				4	8	12	10	7	5	3	11	40	74
III	1	3	3	2	9	20	26	18	8	3	3	2	4	386
	2	1	2	3	12	30	29	17	6		1			278
	p.s.		2		5	20	33	26	12		1	1		113

Table 4. Age frequency distributions (percent) of cod off Møre for research vessel catches (trawl) and commercial catches (purse seine and danish seine). The contributions from coastal cod in brackets.

Sector no.	Cruise no.	Age (years)								N
		≤4	5	6	7	8	9	10	≥11	
II+III	1+2	2(2)	3(3)	7(4)	67(4)	15	3	2	1	778
II	p.s.+d.s.		2(2)	6(5)	44(2)	11(2)	15(2)	10	12	566

Table 5. Acoustic estimates of spawning cod in the Møre area in March-April 1982 (N: numbers  $\cdot 10^{-6}$ , W: weight in tonnes  $\cdot 10^{-3}$ ).

Cruise no.	Sectors (see figs 7 and 8)									
	I		II		III		IV		Total	
	N	W	N	W	N	W	N	W	N	W
1	0.5		2.9		5.7		1.3		10.4	
2	1.5	6.2	4.2	17.2	5.3	17.5	-		11.0	40.9

Table 6. Acoustic estimates of spawning cod in the Møre area in March-April 1982 (Numbers in millions).

Cruise no.	Age (years)								Total
	≤4	5	6	7	8	9	10	≥11	
1	0.1	0.4	1.3	6.1	0.7	0.5	0.5	0.6	10.4
2	0.3	0.3	0.6	7.4	1.8	0.3	0.2	0.1	11.0

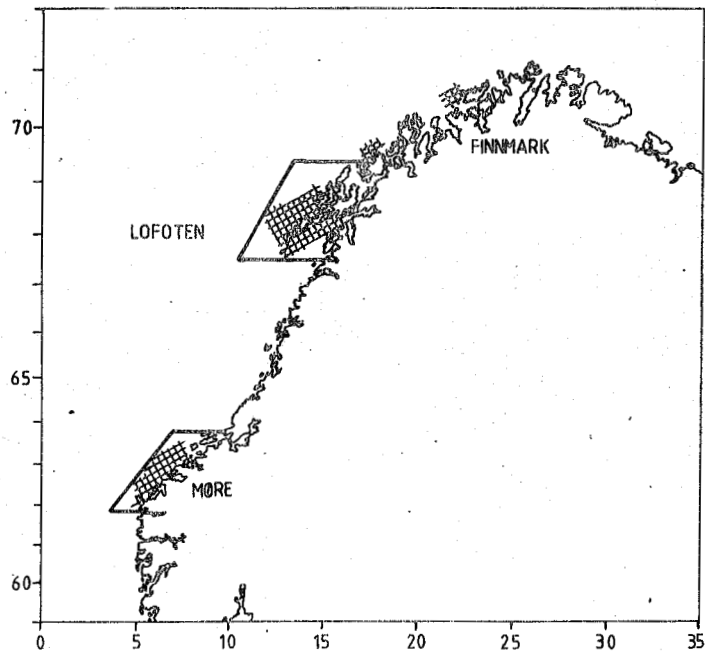


Fig.1. The Norwegian coast. Investigation areas are framed. Spawning grounds of northeast arctic cod are indicated by hatching.

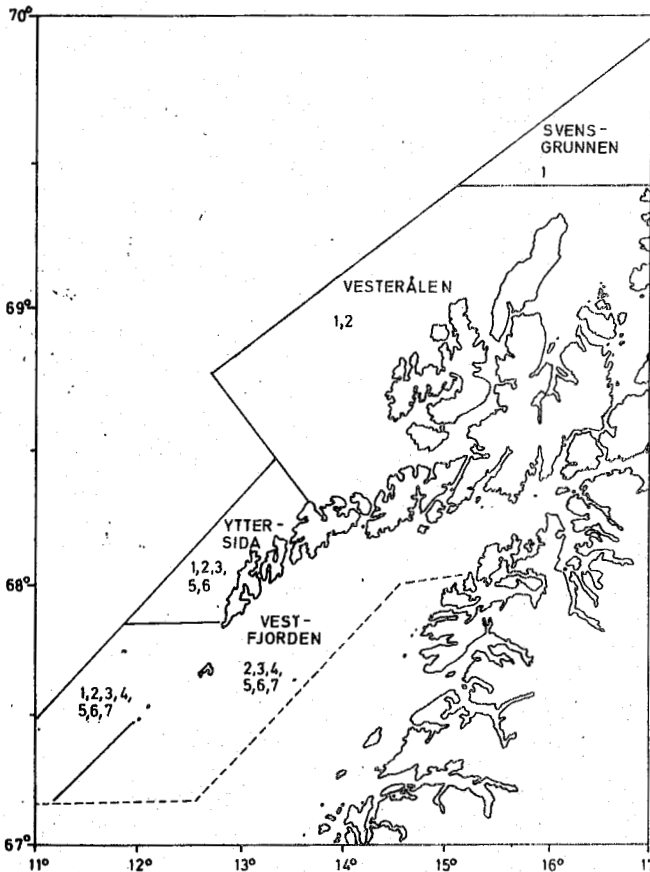


Fig.2. The geographical extension of the different cruises in the Lofoten area. Cruise number are given (see text table page 2).

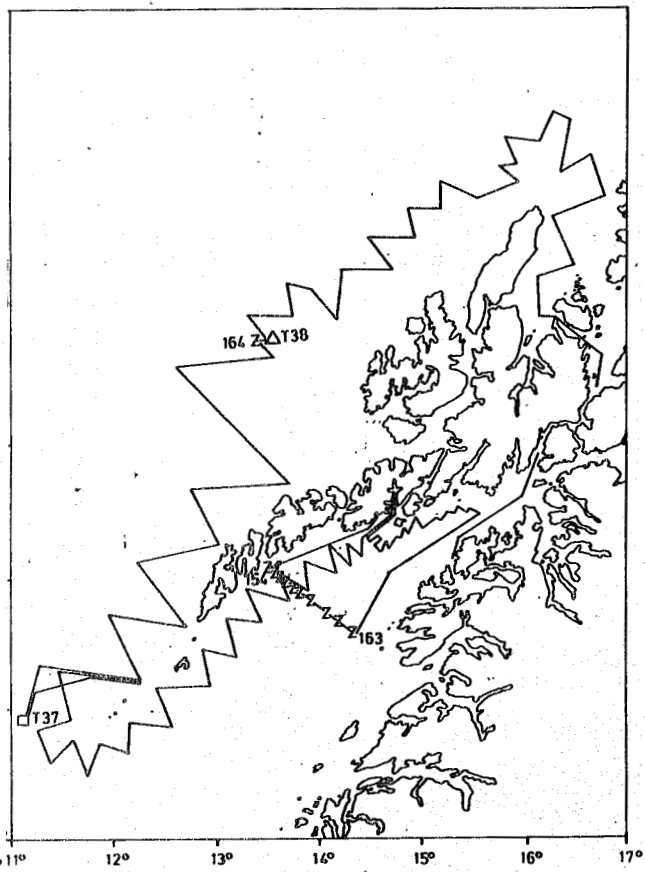


Fig.3. Courselines and stations during cruise no.2 in the Lofoten area. Z: CTD-sonde station, ΔT: Pelagic trawl. □T: Bottom trawl station

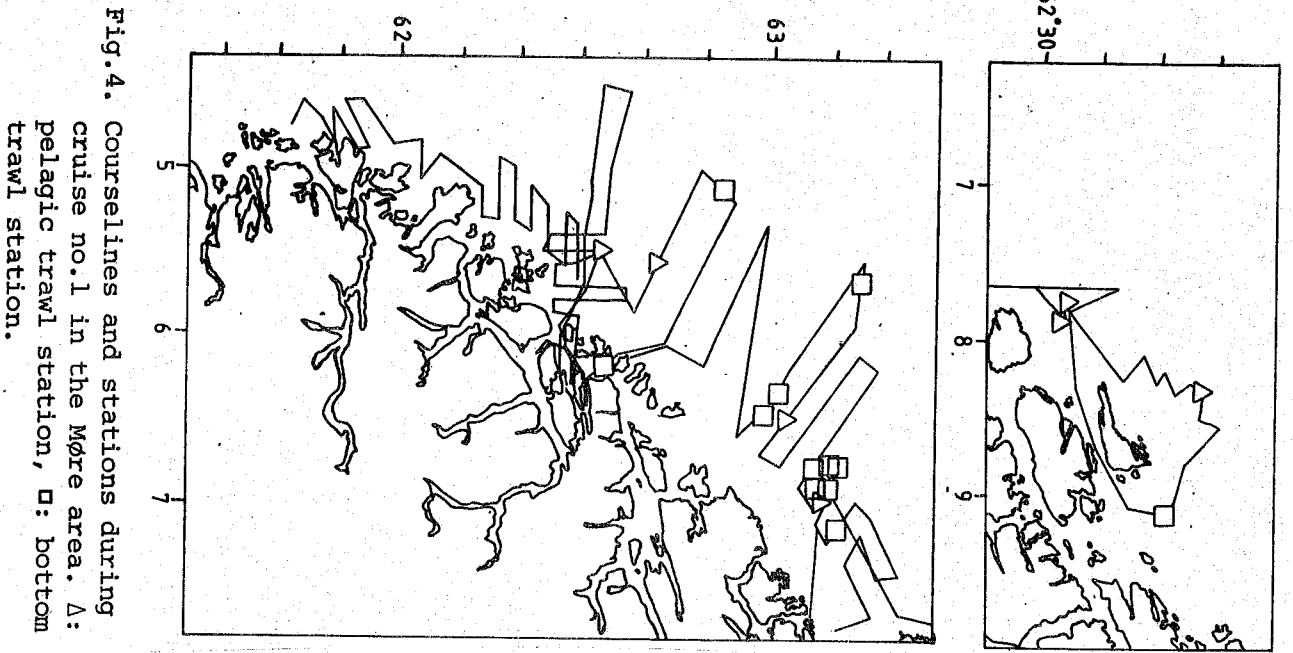


Fig. 4. Courselines and stations during cruise no. 1 in the Møre area.  $\Delta$ : pelagic trawl station,  $\square$ : bottom trawl station.

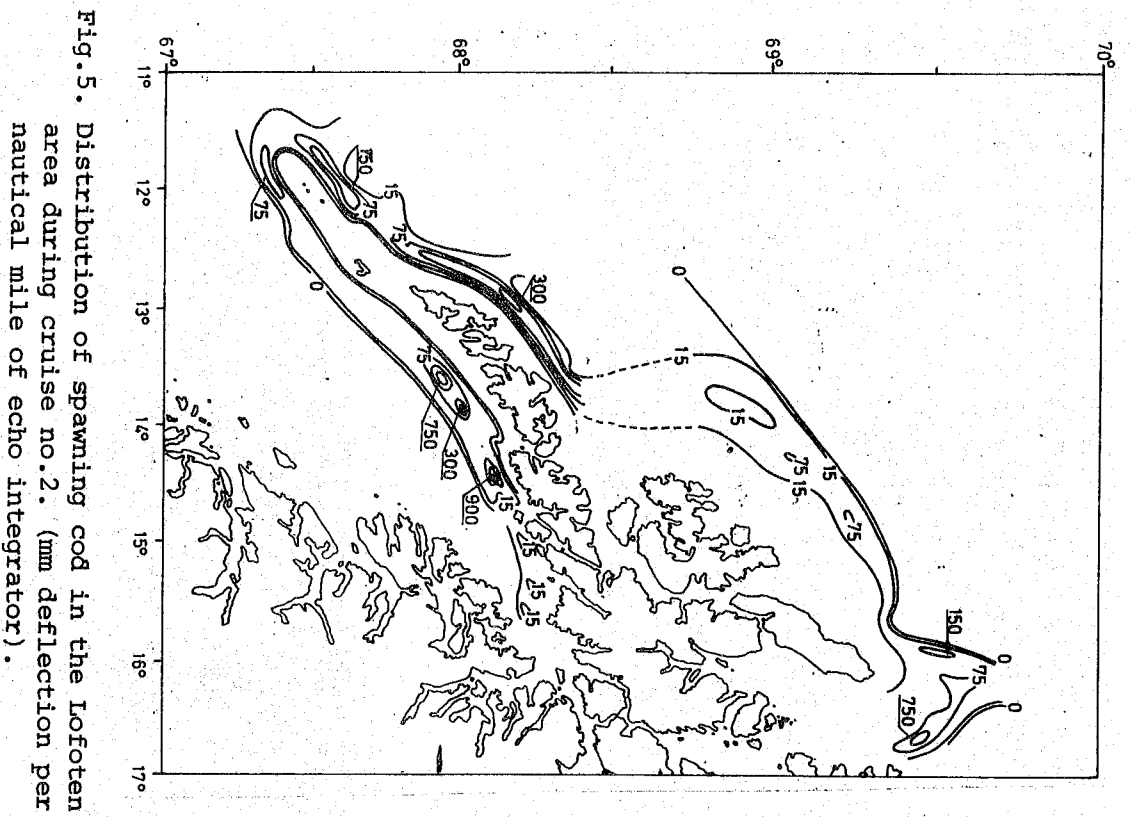


Fig. 5. Distribution of spawning cod in the Lofoten area during cruise no. 2. (mm deflection per nautical mile of echo integrator).

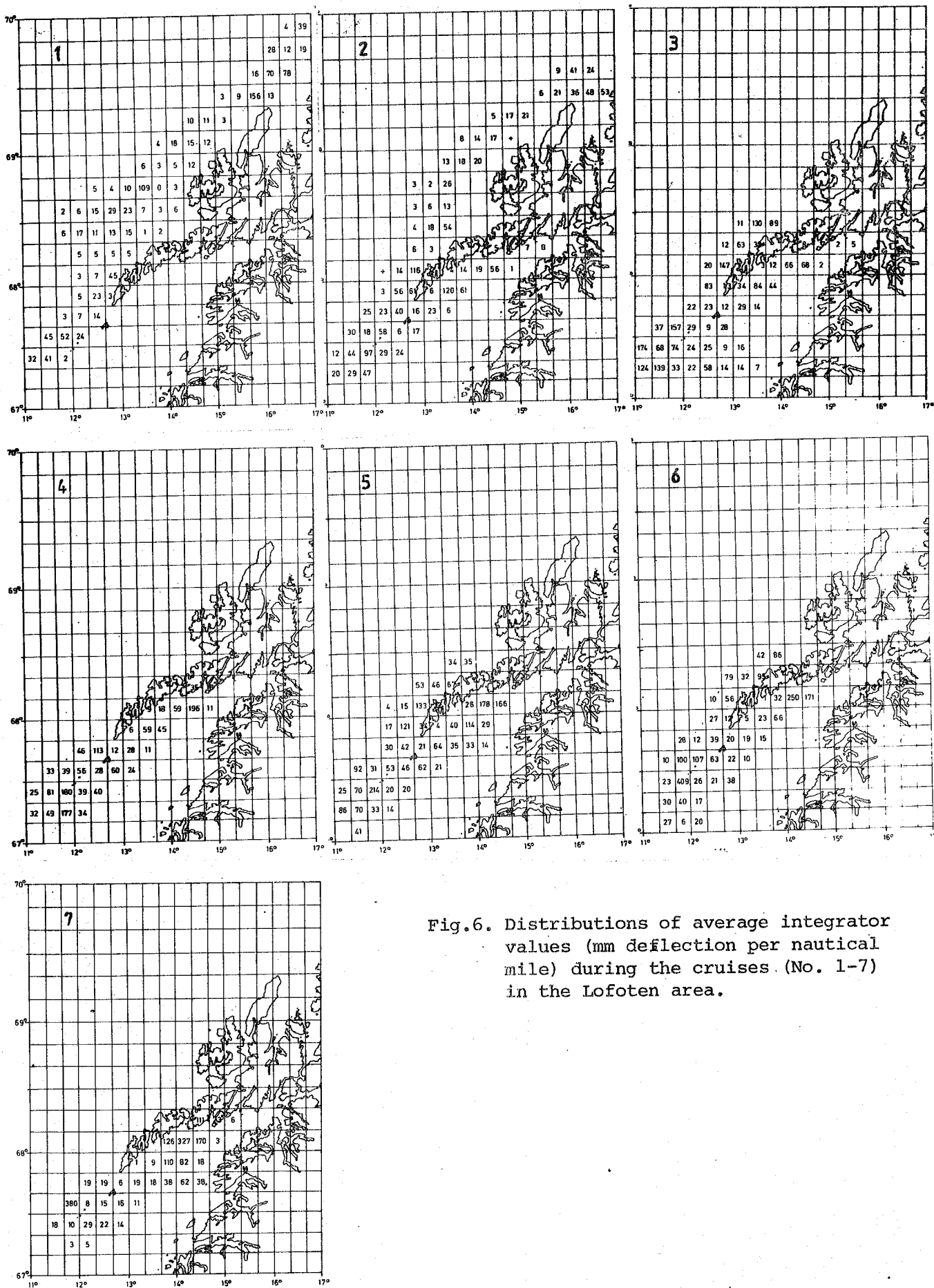


Fig.6. Distributions of average integrator values (mm deflection per nautical mile) during the cruises (No. 1-7) in the Lofoten area.

Fig. 7. Distribution of integrator values (mm deflection per nautical mile) for cod, haddock and saithe during cruise no. 1 in the Møre area.

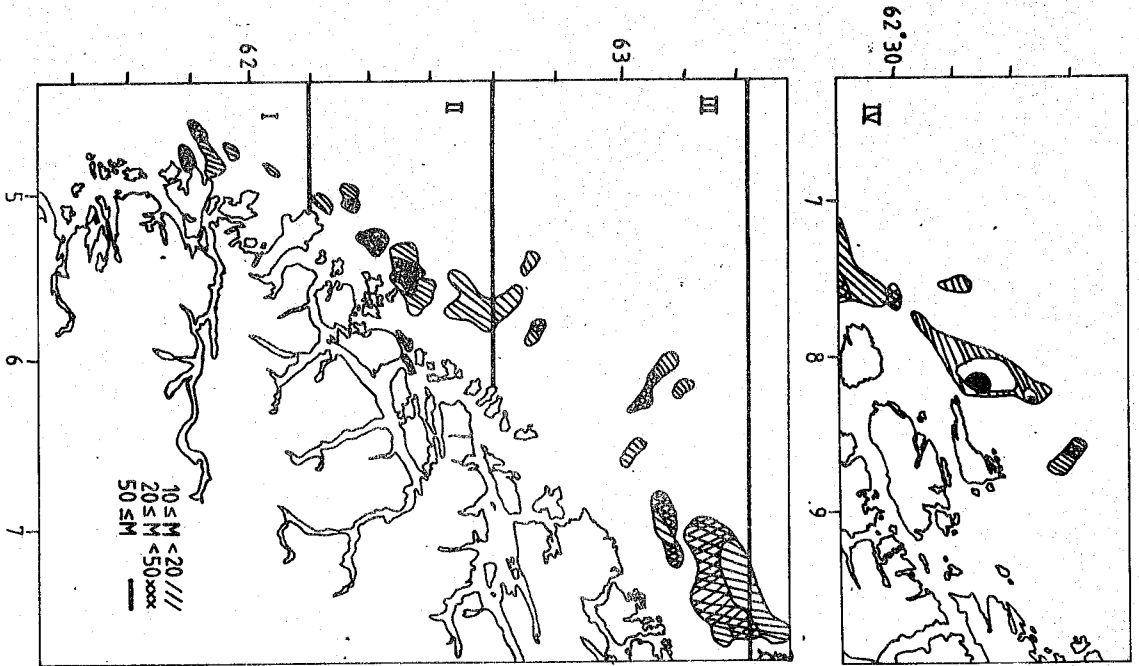


Fig. 8. Distribution of integrator values, M, (mm deflection per nautical mile) for cod, haddock and saithe during cruise no. 2 in the Møre area.

