

## SECTION II

## Stock assessment

ACOUSTIC ESTIMATES OF SPAWNING COD  
IN THE LOFOTEN AREA IN 1982 AND 1983

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## ABSTRACT

The main spawning grounds for Arctic cod, the Lofoten area, were covered by acoustic surveys 7 times in 1982 and 12 times in 1983 during the prespawning and spawning season. The results indicated a spawning stock in the area of approximately 80 million specimens in 1982 and 50 million specimens in 1983. These figures were less than half the estimated total spawning stock of Arctic cod these years. The acoustic data were analyzed in order to estimate the migration rate in and out of the Lofoten area during the surveying period. The results indicate that in 1983 spent cod started to leave the grounds in the middle of March, and that the fish flux in and out of the area is an important factor to be considered when evaluating the acoustic survey results. In general acoustic surveys will tend to underestimate the number of spawners in the area under such circumstances.

## INTRODUCTION

The main spawning grounds of Arctic cod, the Lofoten area, have been more or less regularly echo surveyed during the spawning season for almost 50 years (Sund, 1938). The surveys have pro-

vided valuable information on the relative density distribution and migration patterns of spawning cod (Hysten et al., 1961; Monstad et al., 1969; Jakobsen, 1974), but few attempts have been made to estimate the number of fish actually present on the spawning grounds. From a series of surveys in 1975 of the inner Vestfjord, Blindheim and Nakken (1971) arrived at estimates of the number of spawners within that area. They concluded that even the highest of the obtained estimates, 14 million fish, amounted to only a fraction of the total spawning stock which that year was about 70 million specimens (Anon, 1982).

During the past 6-7 years the Institute of Marine Research has increased the survey activity on cod considerably in order to meet the need for fishery independent data for stock assessment (Hysten and Nakken, 1982). Since 1976 acoustic surveys have been carried out annually in February-March in the Barents Sea with the purpose of estimating the abundance of young cod and haddock (Dalen and Smedstad, 1979 and 1982). These surveys have contributed significantly to the knowledge of stock state and structure and the results have been used by the Working Group of Arctic Fisheries, ICES (Anon, 1982, Ulltang and Nakken, 1982), to calibrate the virtual population analysis. Because of the promising results obtained on young cod by using the acoustic technique, a series of acoustic surveys of the spawning grounds was undertaken both in 1982 and 1983. The aim of the surveys was to collect a data set which enabled us to estimate the number of spawners present at the Lofoten grounds throughout the main spawning season. The results have been reported by Godø et al. (1982 and 1983), and further used by Hysten and Nakken (1982 and 1983) in their assessments of both the total stock and the spawning stock of Arctic cod.

In the present paper the results from the acoustic surveys of spawning cod in the Lofoten area in 1982 and 1983 are summarized and discussed. In particular the reliability of the estimates are dealt with as to how well they represent the total spawning stock over the whole spawning season in the area.

## THE QUALITY OF THE SURVEY DATA

The Lofoten region was covered 7 times in 1982 and 12 times in 1983 during the prespawning and spawning season. Details of the cruises such as survey grids and data sampling and processing schemes were reported by Godø et al. (1982 and 1983). The timing of the surveys and the research vessels used in the investigations appear from the text table below:

Cruise no.	1982		1983	
	Date	Vessel	Date	Vessel
1	29 Jan-1 Feb	Johan Hjort	1-5 Feb	Michael Sars
2	3-7 Feb	" "	6-9 Feb	" "
3	8-12 Feb	" "	10-12 Feb	" "
4	15-17 Feb	" "	13-17 Feb	" "
5	17-20 Feb	" "	17-19 Feb	" "
6	21-24 Feb	" "	20-23 Feb	" "
7	24-27 Feb	" "	24-27 Feb	" "
8			28 Feb-2 Mar	" "
9			8-13 Mar	G.O. Sars
10			15-18 Mar	Johan Ruud
11			21-25 Mar	" "
12			8-11 Apr	Michael Sars

The cruises in February both years were a part of the scouting service under the Director of Fisheries, and the main objective of these cruises was to map the fish distribution in order to advice the fishermen about the migration of the mature cod. However, the survey grids applied within the Lofoten area were more or less the same for all cruises, and quite suitable for estimation of the abundance, and therefore approximately the same survey grid was adopted for the cruises in March-April 1983.

Reliable identification of the echo traces is one of the most important requirements to be met in acoustic abundance estimation. Usually such identification is undertaken by sampling the recorded fish layers by trawling. During the Lofoten cruises the research vessels were able to carry out trawling only to a limited extent due to the vast amount of gillnets and

longlines in the area. Yet, as a rule it was not difficult to discriminate between traces from cod and other scatterers, due to the echo strength (target strength) of the specimens. Most of the mature cod is more than 70 cm in length and has thus a significantly higher target strength than the other fish specimens in the area; saithe 40-50 cm in length and small redfish, Norway pout, blue whiting and herring all less than 35-40 cm in length and with considerably lower target strength than the mature cod. Thus, the separation of echo integration values for mature cod and other species and groups was a quite straight-forward process with a high degree of reliability.

The largest source of errors were the weather conditions, which caused two different types of errors to the estimates. In bad weather the upper layers of the sea are aerated. The airbubbles in the watermasses will significantly reduce the amount of acoustic energy which reaches the fish and the fish density will be underestimated unless some correction of the echo intensity is undertaken (Dalen and Løvik, 1982). If the transducer is towed at a depth below the aerated water no correction is needed. However, due to the large amount of fishing gears in the Lofoten area in February-March it is impossible to apply the towed transducer systems of the research vessels. The echo integration values were therefore corrected according to the method described by Løvik and Dalen (1982). The values for February 1983, cruise 1-6 have not been used in the present analysis since all these cruises were carried out under extremely bad weather conditions. In February 1982 and in March-April 1983 weather conditions were favourable for acoustic density measurements and only minor corrections of the observed integration values were undertaken on some of the cruises.

On some cruises bad weather prevented a satisfactory coverage of parts of the area (Godø et al., 1983). The estimates of abundance from these cruises are therefore too low and appear in brackets in the figures and tables.

## RESULTS AND DISCUSSION

## DISTRIBUTION OF PRESPAWNING AND SPAWNING COD

Godø *et al.* (1982 and 1983) presented detailed distribution maps from each survey. In Fig. 1 and Fig. 2 are presented two maps of the cod distribution, one from each year, and Fig. 3 shows how the Lofoten area was divided into subareas in order to study the movement of the fish.

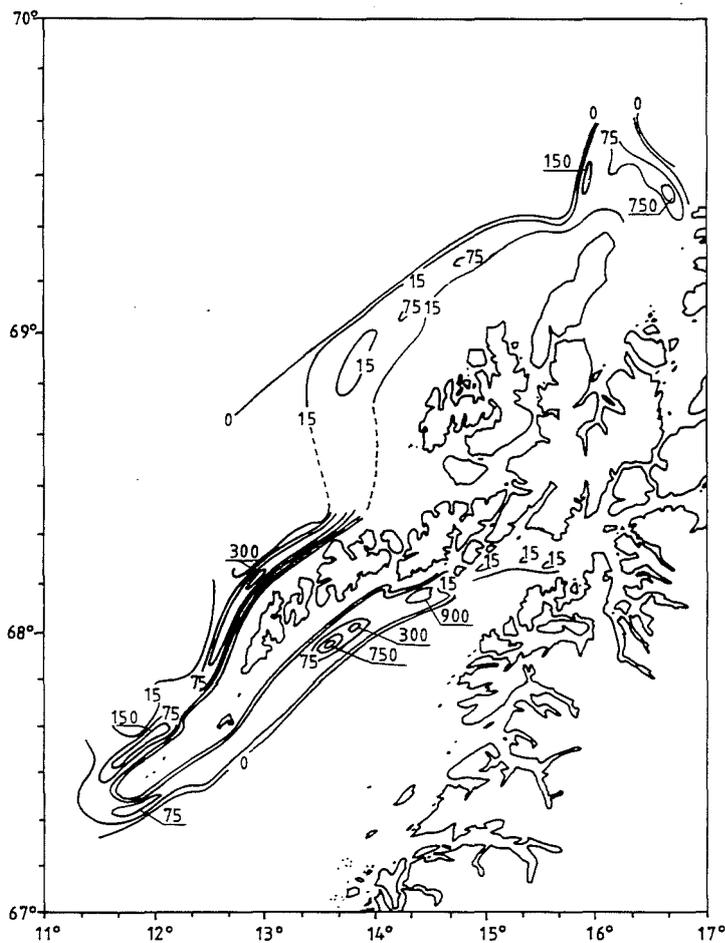


Fig. 1. Distribution of mature cod in the Lofoten area 3-7 February 1982 (mm deflection per nautical mile of echo integrator).

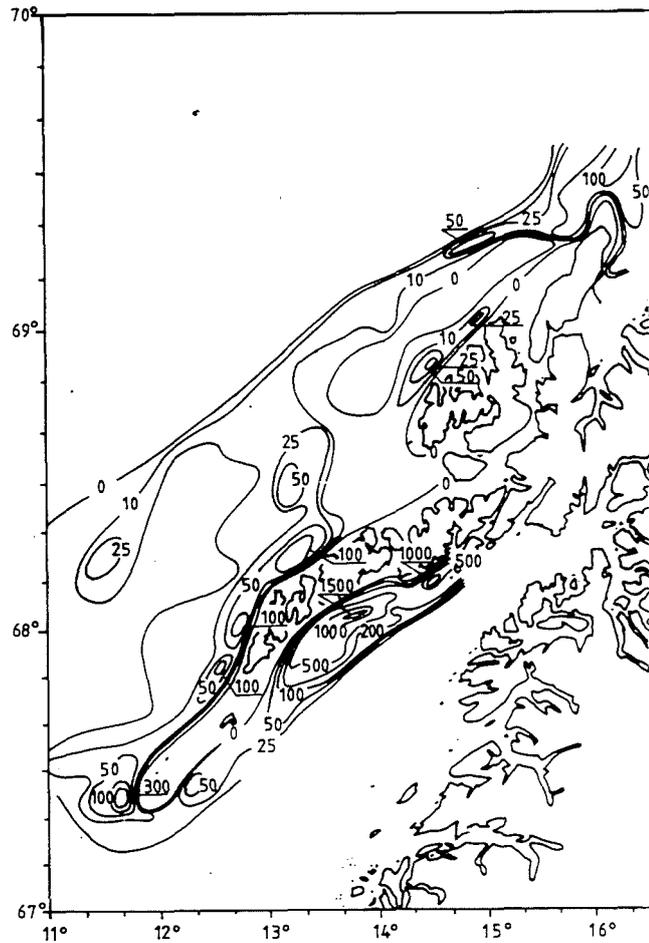


Fig. 2. Distribution of mature cod in the Lofoten area 5-14 March 1983 (mm deflection per nautical mile of echo integrator).

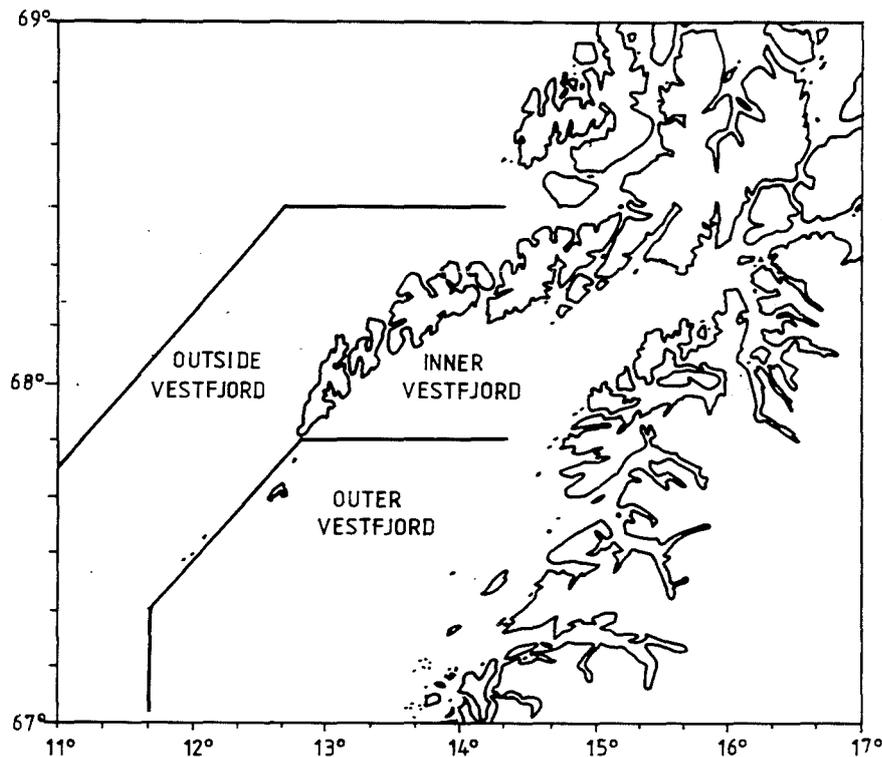


Fig. 3. The Lofoten area. The subareas referred to in Tables 2 and 3 are framed.

Fig. 1 shows the distribution in the Lofoten-Vesterålen area in early February 1982. Dense patches, but very limited in extension, were observed on the main spawning grounds in the inner Vestfjord but the average fish density in the fjord was low; the bulk of the fish being found west of the Lofoten Islands and to the north of Vesterålen. Table 1A shows how the number of fish in the inner Vestfjord increased during February 1982. Outside the Vestfjord at the western coast of the Lofoten Island the highest abundance was observed in the middle of February.

Fig. 2 shows the distribution at about 10 March 1983. The general trend is almost the same as in early February 1982; the fish being distributed in a narrow belt along the Lofoten Island and into the Vestfjord, but the quantities on the spawning grounds in the inner part of the fjord were much higher in March 1983 than in early February. Table 2B indicates the migration of fish within the Lofoten area in the period 25 February-9 April 1983. The total number of fish in the whole

area remains nearly constant, but significant changes takes place within each sub area. Outside the Vestfjord the number of fish was reduced during the first half of March reaching the lowest value around the middle of the month. In the inner Vestfjord the number of fish reached the highest value in mid-March.

The main impression we are left with from Figs 1 and 2 and Table 1 is as follows: On its spawning migration the bulk of the fish follows the edge of the continental shelf south to latitudes  $68^{\circ}40'$ - $68^{\circ}50'$ , the south-westernmost part of the shallow Vesterålen banks. Then it migrates across the banks to the northwestern part of the Lofoten Islands and from there on it follows the 100 m contour line into the Vestfjord. Here the amount of fish increases rapidly during the month of February and reaches a maximum in the middle of March.

Table 1. Acoustic estimates of mature cod (numbers in millions) in the Lofoten area in February 1982 and in February-April 1983. Figures in brackets are underestimates due to insufficient area coverage.

A		1982						
		February						
Date:		1	5	10	16	19	22	26
Outside Vestfjord	(11)	24	48	(22)	43	40	(13)	
Outer Vestfjord	?	6	10	15	13	10	10	
Inner Vestfjord	?	10	11	15	22	21	33	
Total	(11)	40	69	(52)	78	71	(56)	

B		1983					
		Feb		March		April	
Date:		25	1	12	17	23	9
Outside Vestfjord		20	8	7	( 2)	10	( 8)
Outer Vestfjord		5	10	4	7	12	5
Inner Vestfjord		22	30	35	33	24	26
Total		47	48	46	(42)	46	(39)

## THE ABUNDANCE OF COD

The three main factors influencing the abundance of cod in the total Lofoten area as well as the subareas are: The size of the spawning stock, the catch (fishery) and the migration in and out of the Lofoten area as a whole or between the subareas (Fig. 3).

The results from the 1982 and 1983 surveys were used by Hylén and Nakken (1982 and 1983) to assess the spawning stock sizes the two years. In Fig. 4 the total estimates from table 1 are plotted, and the estimates used by Hylén and Nakken are indicated by the horizontal lines called the best estimate.

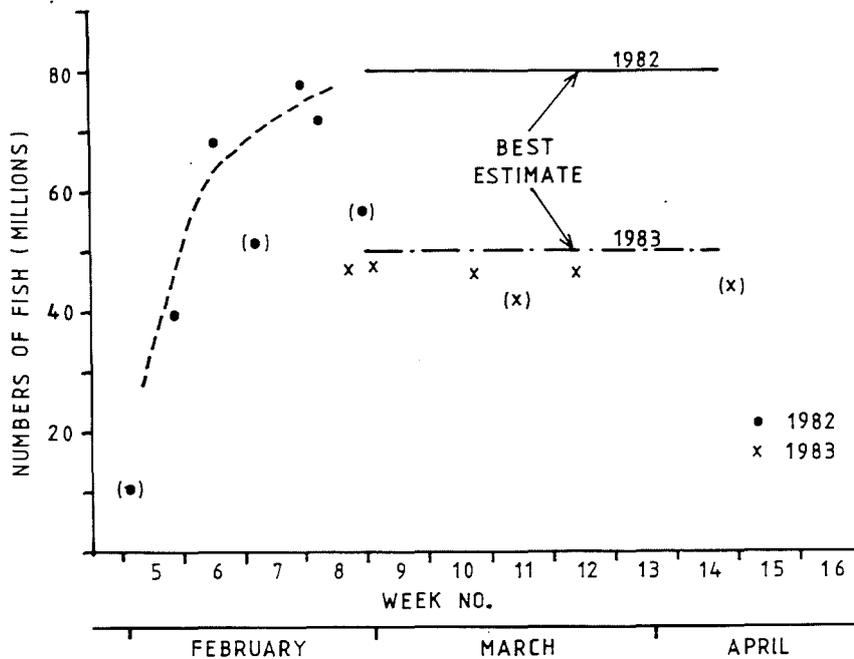


Fig. 4. Acoustic estimates of mature cod in the Lofoten area (Table 1) in 1982 and 1983. The figures used by Hylén and Nakken, 1982 and 1983 are indicated.

Table 2 and Fig. 5 show the weekly catches in the Lofoten area the two years. Both years the catches reached a maximum in the middle and latter half of March and the 1982 catches were higher than the 1983 catches in terms of number of fish. The ratio between the total catches in 1982 and 1983 (1.4) is slightly less than the ratio between the best estimates of the

total number of fish the two years (1.6). This may partly have been caused by the "undercatching" by gillnets in 1982. That year a large portion of the spawning cod was too small sized to be effectively caught by the rather large meshed Lofoten gillnets. Thus, there appears to be good accordance between the estimated number of fish and the catches the two years from the rather rough comparison made here.

Table 2. Catches of spawning cod in the Lofoten area in 1982 and 1983.

Week no.	Date	Weight (tonnes)		Number (millions)	
		1982	1983	1982	1983
5	31 Jan-6 Feb	4 806	6 269	1.3	1.2
6	7 Feb-13 Feb	4 562	3 408	1.2	0.7
7	14 Feb-20 Feb	5 802	4 190	1.6	0.8
8	21 Feb-27 Feb	7 104	5 122	1.9	1.0
9	28 Feb- 6 Mar	7 787	9 781	2.1	1.9
10	7 Mar-13 Mar	8 954	9 553	2.4	1.8
11	14 Mar-20 Mar	12 518	12 194	3.4	2.4
12	21 Mar-27 Mar	12 379	15 309	3.4	3.0
13	28 Mar- 3 Apr	10 331	-	2.8	-
14	4 Apr-10 Apr	-	7 682	-	1.5
15	11 Apr-17 Apr	3 541	6 034	1.0	1.2
16	18 Apr-24 Apr	3 530	2 152	1.0	0.4
Total		81 314	81 689	≈22	≈16

Sources: Lofotfisket 1982, Årsberetning Norges Fiskerier 1982, No. 5., Fiskets Gang 1983, No. 7-12.

Mean weights are taken from Hylén and Nakken (1982 and 1983).

In Table 3 is summarized the information on the spawning stock of Arcto-Norwegian cod in 1982 and 1983 as given by Hylén and Nakken (1982 and 1983). It is seen that the distribution of the total spawning stock is similar the two years. Somewhat less than half the stock was observed in the Lofoten area while an almost equal share was further to the north and less than 10 per cent to the south of Lofoten. The small differences between the two distributions are obviously not significant. Both years the 1975-yearclass made up the bulk of the total stock, in 1982 about one half and in 1983 about one third. It should, however, be noted that the 1982-spawning stock to the north of Lofoten was overestimated in Hylén and Nakken's 1982-assessment (Hylén

and Nakken, 1983). For the Lofoten area the corresponding numbers were 55 and 48 per cent, and the mature fish here were significantly older than in the areas further north (Table 3) both years.

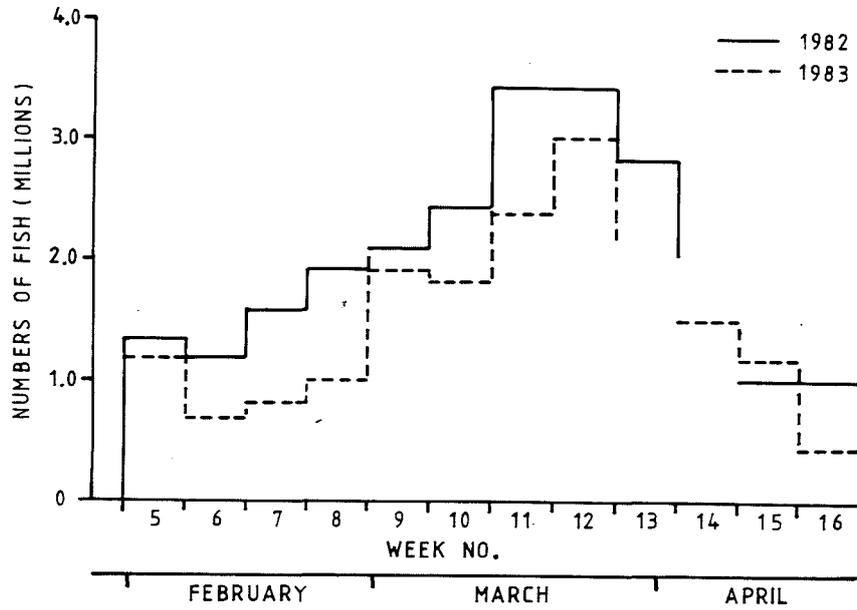


Fig. 5. Landings of mature cod in the Lofoten area in 1982 and 1983.

Table 3. Number (in millions) by age of mature cod in various areas. Estimated from survey data (Hysten and Nakken 1982 and 1983).

	1982								Total	%
	Age in years									
	4	5	6	7	8	9	10	11+		
North of Lofoten:	4	8	22	36	5	2	-	-	77	45
In Lofoten:		1	7	44	9	8	5	6	80	47
South of Lofoten:		-	1	9	2	-	-	-	13	8
<b>Total:</b>	<b>4</b>	<b>9</b>	<b>30</b>	<b>89</b>	<b>16</b>	<b>10</b>	<b>5</b>	<b>6</b>	<b>170</b>	<b>100</b>

	1983								Total	%
	Age in years									
	4	5	6	7	8	9	10	11+		
North of Lofoten:	6	7	10	11	7	3			44	43
In Lofoten:			3	11	24	8	3	1	50	48
South of Lofoten:			1	2	3	1	1	1	9	9
<b>Total:</b>	<b>6</b>	<b>7</b>	<b>14</b>	<b>24</b>	<b>34</b>	<b>12</b>	<b>4</b>	<b>2</b>	<b>103</b>	<b>100</b>

Fig. 6 shows the number of fish on the main spawning grounds in the inner Vestfjord in per cent of the total number of fish in the Lofoten area. The bulk of spawners reached the inner part of the fjord during the last week of February, and the amount of fish in this area increased upto 75 per cent in the middle of March whereafter the percentage decreased. The number of observations in late March and early April were not sufficient to permit safe drawing of the curve for this period.

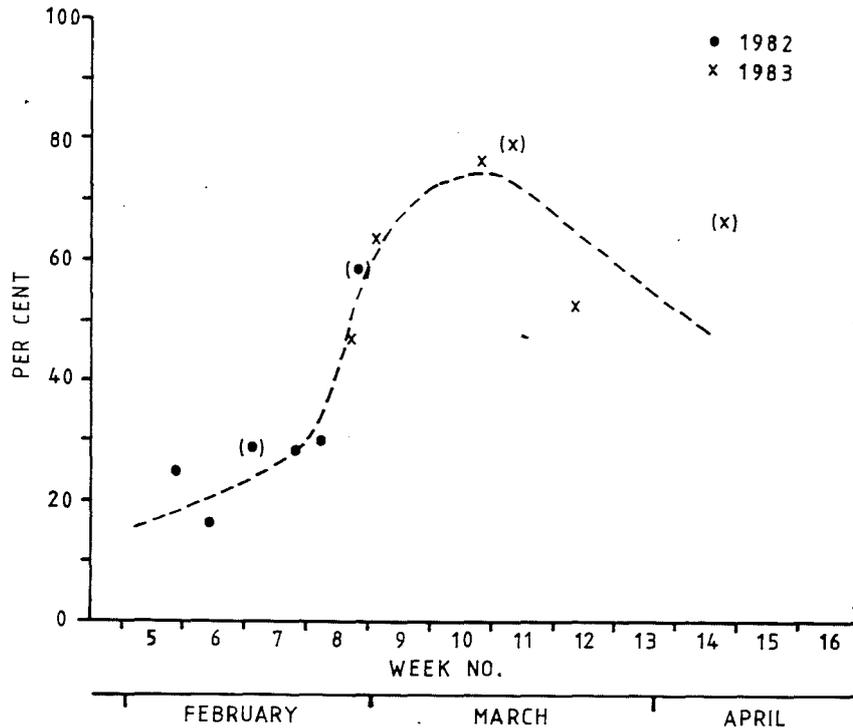


Fig. 6. The ratio (in per cent) between number of fish in the inner Vestfjord and the total number of fish in the Lofoten area as a function of time. Brackets indicate overestimation due to insufficient area coverage.

#### MIGRATION OF FISH IN AND OUT OF THE LOFOTEN AREA

Table 1 and Fig. 4 indicated that the total number of fish in the Lofoten area was approximately constant from 25 February to 23 March in 1983. During these four weeks about 8 million specimens (Table 2) were removed from the stock by the fishery. Thus there must have been a net influx of fish into the area of about 8 million specimens during this period.

At what time start the first specimens to leave the spawning grounds? As a rule spawning starts during the first week of March and reaches its maximum 1 month later (Ellertsen *et al.*, 1983). Fig. 6 and Table 1 show that the abundance of fish in the inner Vestfjord was reduced by 9 million specimens from 17 to 23 March 1983. This reduction is 3 times greater than the amount removed by the fishery during the same period and it may thus be an indication that spent fish started to leave the spawning grounds in inner Lofoten in significant numbers about 15-20 March. If this is so, then the influx of fish, which compensated both the outflux and the catch, must have been larger than indicated above. As stated previously the observations in March and April are too scanty to throw light on this problem. But the data seem to indicate that the dynamics of the spawning population - the rate of migration to and from the spawning grounds - is an important factor to be considered when evaluating the results from acoustic surveys. If the exchange of fish is large during the survey period, it simply means that the acoustic surveys grossly underestimate the total number of spawners in the Lofoten area. It also implies that a significant number of the fish observed to the north of Lofoten in early March (Table 3) will spawn in Lofoten. Hence, the percentages in Table 3 do not reflect the importance of the Lofoten area as spawning grounds for Arctic cod.

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