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Some further analyses of Subarea 1 cod

by

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1. Introduction

At its June 1980 Meeting STACFIS, having discussed the status and recruitment prospects for Subarea 1 cod on the basis of NAFO SCR Doc. 80/VI/72 (hereinafter referred to as Doc. 72), and having pointed out discrepancies between the size of year-class 1975 as it turns out in the VPA runs and as it is estimated from observations of catches and discards, requested that further analyses be made. Analyses of present level of fishing mortality by the upper catch level, and of partial recruitment (partial F) in recent years were specifically requested.

A small working group consisting of the authors to this paper undertook to make further analyses. Also, some further material from surveys by the Federal Republic of Germany is presented in this paper.

2. Analyses of fishing mortality and partial recruitment

Analyses of total mortality were made mainly by using various catch curves from recent years.

Table 1 lists the numbers landed per unit effort as obtained from Doc. 72, table 6 and table 14a. The table is used to obtain values of Z for each age-group from one year to the next. It occurs that, for the major age-group 5, the Z value in 1977 was about 1.17, and about 0.65 in 1978. The corresponding total effort figures were 48,048 and 25,927 standard hours (Doc. 72, table 6). Preliminary effort estimate for 1979 is 31,219 hours. Taking M as = 0.20, the 1979 effort would correspond to Z values of 0.83-0.74 based on the 1977 and 1978 catch/effort data, respectively. If the age-group 4 were to obtain the same Z values as age-group 5, the number of 4-year-olds caught would have to be raised by a factor of 3.6-3.8, thus indicating that the partial recruitment at this age was about 0.26-0.28 in 1977-78.

Analyses of F were also made on the basis of catch curves over some years. Table 2 gives the sum of catch per unit effort for the years 1977-79 (see Table 1) when the 1973 year-class is reduced to one-fifth to minimize year-class fluctuation in the catch curve. The catch curve obtained in this way is illustrated in Fig. 1. Regression line calculated for ages 5 to 9 gives a Z value of 1.01.

A further approach is illustrated in Fig. 2 giving the catch curve for 1978-79 for age-groups 7-10 (average number caught), thus avoiding disturbance of high year-class fluctuation by omitting year-class 1973. Regression gives a Z value of 1.07. With M = 0.25 (including emigration), F would be 0.82. This value was considered to be the best estimate of F by 1979.

Table 2 and Fig. 1 were used to estimate partial recruitment for 4-year-olds. If the plot of these were to fall on the regression line, the catch figure would have to be 1,588 against the recorded 747. Partial recruitment is, thereby, 47% for this age in 1977-79. The partial-F values corresponding to this partial recruitment would be 38%, see footnote. Considering that the partial recruitment for age-group 4 was found to be somewhat lower in Table 1, it is suggested that for forecasts a partial F for age-group 4 could be one-third of that for fully recruited age-groups. In practice, however, the value is likely to vary between years, depending on the actual stock composition. If a good number of older fish occurs, the partial F for age-group 4 and younger is likely to be at a minimum. For age-group 3 the catches compared to estimated number of recruits point to a partial F of about 0.02 (Table 3). It was felt that there was not sufficient data to suggest possible lower partial-F values for older age-groups, and these were therefore given full F value in forecasts. The limited number of older fish in the stock means that the partial-F values for these age-groups is of little importance for the results.

3. Analyses of stock

Estimates of recruiting year-classes were taken as in Doc. 72, page 10, and weight by age as in Doc. 72, table 12. VPA was carried out so that recruitment of year-classes 1975 and 1976 corresponds to the estimates of these two year-classes. The analyses are presented in Table 3. As will be seen, the terminal-F value for oldest age-groups is set at 0.82 for all years 1975-79. For the years 1975-77, this was made just for convenience of calculations, but this has no bearing upon the results so far as the stock situation by 1979 and 1980 is concerned.

It will be seen that the important 1973 year-class may have been equal to a strength of 211,000 3-year-olds. In practice, it may have been lower but had immigration of fish in its first years in the fishery, followed by some emigration of mature fish.

The stock biomass clearly improved when the 1973 year-class recruited in 1976 with some further improvement in 1978 when the 1975 year-class recruited. The spawning biomass showed continuous decline in the years 1975-78 but had some improvement in 1979 when the residuals of the 1973 year-class recruited to the spawning component of the stock. In practice, this recruitment started already in 1978 but, for analysis purposes, maturation is regarded as knife-edge 100% at age 6. It will further be seen that spawning biomass decreased again in 1980 to a level as in 1975 but, as will be seen in the forecasts, it is supposed to increase again in 1981, provided the 1980 catch is not exceeding the supposed 55,000 tonnes. The spawning biomass was at an extremely low level in 1976-78.

4. Forecasts

Based on the residuals by 1980 given in Table 3 of the present paper and on number of recruits as estimated in Doc. 72 (page 10), forecasts for catches up to 1983 and for spawning biomass by the beginning of 1984 are given for various options of fishing mortalities and for a constant catch level around 55,000 tonnes. Catch in 1980 is estimated to be about 55,000 tonnes. The F corresponding to this is equal to 0.35. The results are set out in Table 4 and illustrated in Fig. 3. The strong dependency of catches upon the estimates of forthcoming recruitment should be recalled (see Doc. 72, page 13, last line). This dependency is relatively high when recruitment has failed over a period and/or when a stock is fished down to a depressed state.

5. Yield and spawning biomass per recruit

On the basis of the various parameters referred to in this paper and Doc. 72, a yield-per-recruit curve was constructed. The curve is shown in Fig. 4 together with the curve for spawning stock biomass per recruit. The F_{max} is at 0.48, while the $F_{0.1}$ value is 0.25. For these two reference points the contribution to the spawning stock for each recruit decreases from 3.8 kg to 1.9 kg or by 50% by increasing F from $F_{0.1}$ to F_{max}. While Table 4 and Fig. 3 are influenced by the actual stock composition and expected recruitment, the curve in Fig. 4 will show the long-term difference in catch and spawning stock size between the various options of future F under the assumption that the actual level of spawning stock does not influence recruitment. Since this assumption is unlikely to hold for low levels of spawning biomass, the difference between options is, at present, likely to be more pronounced than indicated by Fig. 4.

6. Recent observations on stock composition

Results from groundfish surveys conducted by R/V *Walther Herwig* and *Anton Dohrn* in autumn 1976-79, as well as in spring 1979 and 1980 in Subarea 1, confirm the major role of the 1973 year-class in the West Greenland cod stock until the end of 1979. This is clearly illustrated by the percentage age

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Footnote: Calculation of partial F

$\frac{F}{Z}(1 - \ell^{-Z}) = 0.510$ when M = 0.20 and Z = 1.01. To obtain value of 0.47 x 0.510 = 0.240, F has to be 0.305. Partial F = $\frac{0.305}{0.81} = 0.376$.

compositions shown in Fig. 5. The corresponding length frequencies are given in Fig. 6, where the main peaks of the curves represent the outstanding 1973 year-class from ages 3 to 6. As an example, this is shown in detail for spring 1979 in Fig. 7. However, the predominance of this year-class in the relative age composition of the stock did not continue into 1980 due to increased abundance of younger cod of ages 3-5 (year-classes 1975-77), as illustrated in Fig. 8 by length frequencies and corresponding age compositions from research catches obtained by R/V *Anton Dohrn* in April/May 1980 in Div. 1C-1E. The age compositions were derived by applying the combined age-length keys given in tables 7 and 8 of Doc. 72.

Table 1. Subarea 1 cod. Numbers landed per unit effort for 1977-79 used to estimate Z for each age-group between pair of years.

Age-group	1977	1978	1979	Z_{77-78}	Z_{78-79}
3	13	11	9	-2.79	-3.43
4	971	212	341	-0.18	-0.64
5	126	1159	401	1.17	0.65
6	32	39	608	0.47	0.53
7	13	20	23	1.40	0.43
8	8.8	3.2	13	1.70	0.25
9	9.3	1.6	2.5	-	-

Numbers of age-group 4 in 1977 to give Z = 1.17 would be 3734.
Partial recruitment = $\frac{971}{3734}$ = 0.26.

Numbers of age-group 4 in 1978 to give Z = 0.65 would be 768.
Partial recruitment = $\frac{212}{768}$ = 0.28.

Table 2. Subarea 1 cod. Catch per unit effort by age summarized for the period 1977-79 when the 1973 year-class is reduced to 20% to minimize year-class fluctuations in the catch curve. See Table 1 and Fig. 1.

Age-group	Number
3	33
4	747
5	759
6	193
7	56
8	25
9	13
10	15.5

Table 3. Subarea 1 cod. Analysis of the stock, 1975-80, based on numbers caught by age-groups and on estimates of F values in 1979.

	1975			1976			1977			1978			1979			1980
Age	Stock No.	Catch No.	F	Stock No.	Catch No.	F	Stock No.	Catch No.	F	Stock No.	Catch No.	F	Stock No.	Catch No.	F	Stock No.
3	23287	275	0.01	211500	10760	0.061	49000	634	0.015	115000	287	0.003	20000	286	0.017	90000
4	12621	3595	0.38	17015	4026	0.30	147469	46649	0.43	35759	5494	0.19	84947	10656	0.15	14571
5	6330	2677	0.63	7080	2243	0.43	10288	6053	1.05	78902	30039	0.54	24337	12505	0.82	59950
6	3656	1803	0.82	2760	1216	0.69	3767	1515	0.61	2946	1004	0.48	37709	18970	0.82	8777
7	10115	5855	1.07	1256	302	0.32	1076	618	1.05	1597	509	0.45	1408	709	0.82	12947
8	2538	1388	0.97	2711	1594	1.10	712	425	1.13	293	83	0.39	794	400	0.82	483
9	1173	619	0.91	751	139	0.24	704	446	1.26	179	41	0.30	155	78	0.82	272
10	591	291	0.82	368	148	0.61	463	168	0.53	155	13	0.10	103	52	0.82	53
11	182	84	0.74	203	53	0.35	156	79	0.86	212	7	0.04	109	55	0.82	35
12	139	38	0.37	67	27	0.60	111	88	2.25	51	7	0.17	159	80	0.82	37
13+	62	31	0.82	74	57	0.82	29	22	0.82	9	7	0.82	34	26	0.82	67
Spawning stock biomass - age 6+ (000 t)	76			36			29			20			116			79
Total recruited biomass - age 3+ (000 t)	121			224			266			306			284			282

Table 4. Subarea 1 cod. Catch, stock, and spawning biomass (tonnes x 10^{-3}) projections for 1981-83/84 by various fishing strategies.
Option 1: F = 0.1 in all years
Option 2: F = 0.2 in all years
Option 3: F = 0.6 in all years
Option 4: F = $F_{0.1}$ = 0.25 in all years
Option 5: Catch level about 55,000 tonnes in all years; F value in brackets.

		Option					
		1	2	3	4	5	
1981	Stock biomass	268	268	268	268	268	
	Spawning biomass	151	151	151	151	151	
	Catch	17	33	83	40	55	(0.36)
1982	Stock biomass	344	325	263	316	297	
	Spawning biomass	165	150	100	142	127	
	Catch	24	42	81	50	55	(0.304)
1983	Stock biomass	384	343	233	325	300	
	Spawning biomass	256	216	110	198	174	
	Catch	26	43	64	49	55	(0.325)
1984	Spawning biomass	262	202	74	178	147	

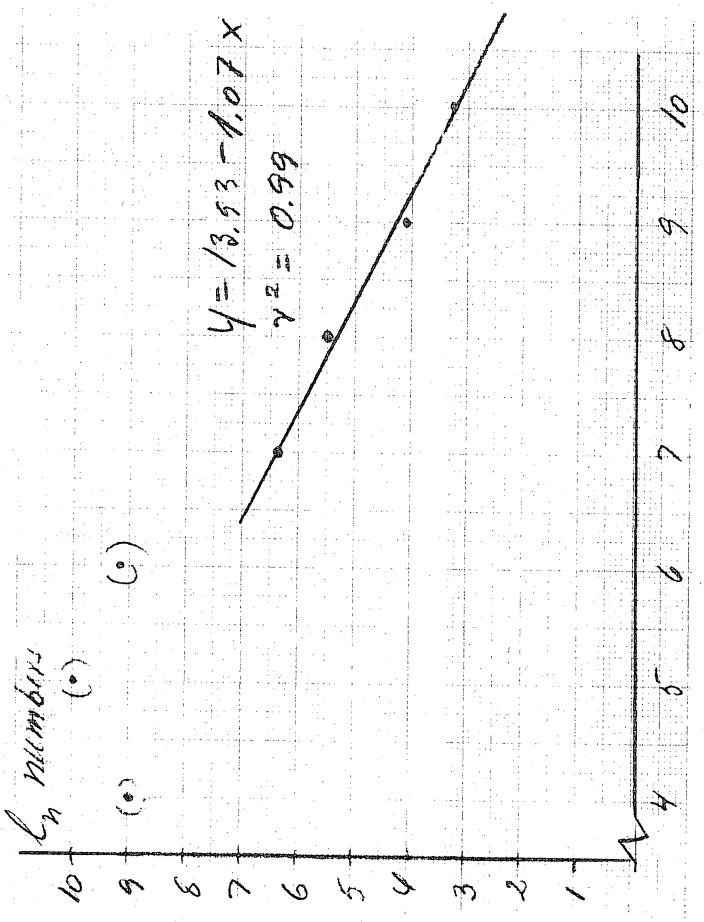

Fig. 2. Subarea 1 cod. Catch curve, ages 7-10, average 1978-79.

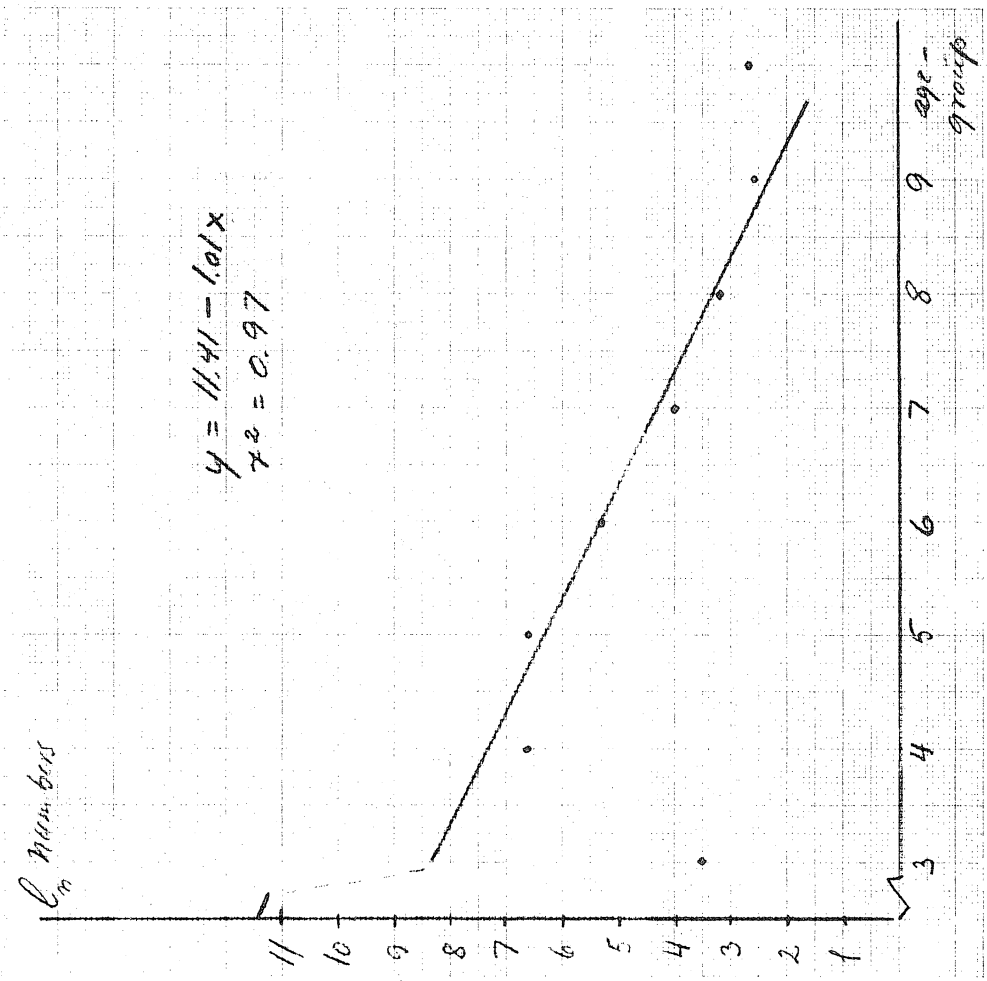

Fig. 1. Subarea 1 cod. Catch curve, 1977-79 (numbers caught per hour) when year-class 1973 reduced to 20%. Regression age 5-9.

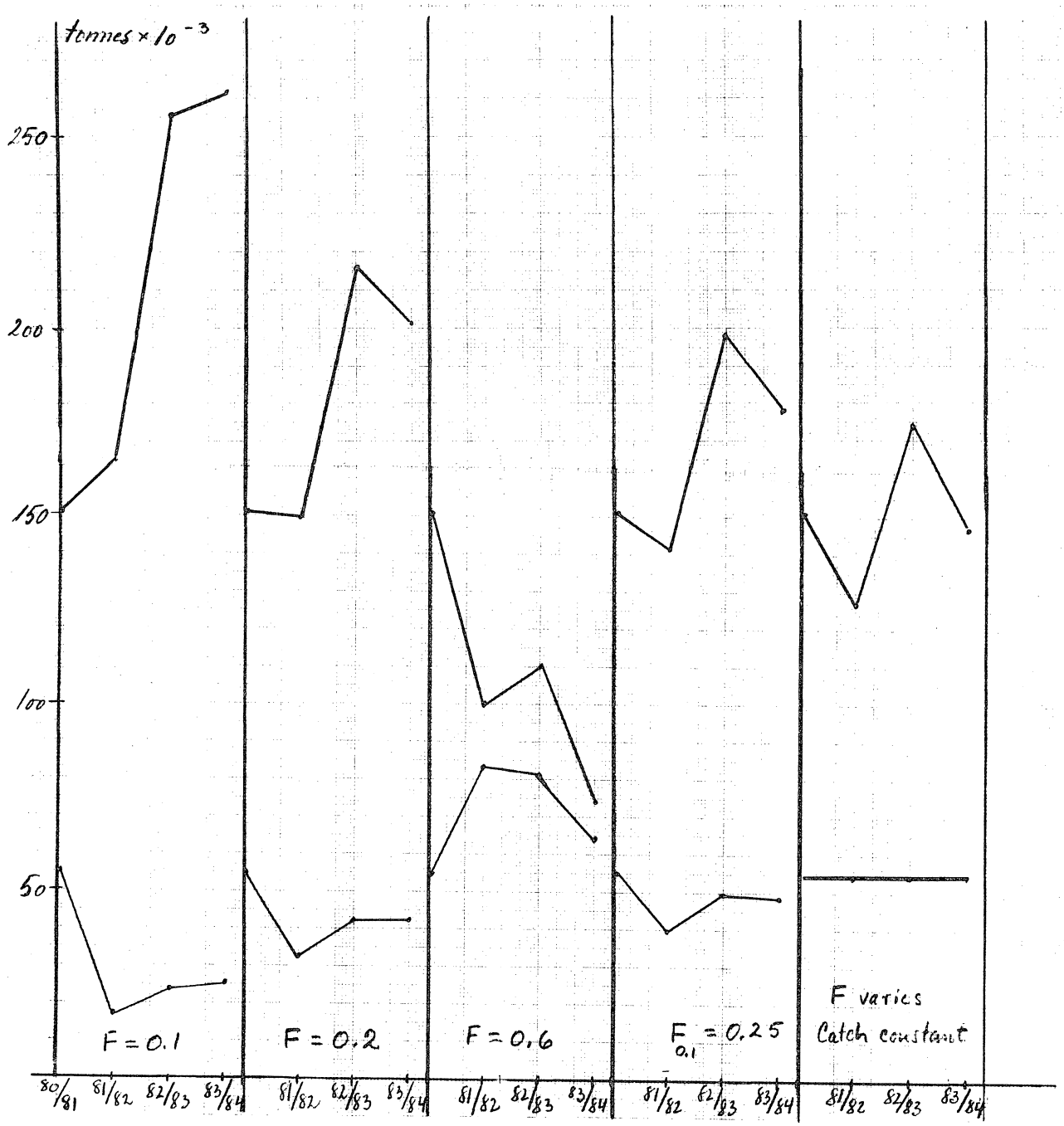

Fig. 3. Projected catches (lower curve) and spawning biomass (upper curve) by various fishing strategies and by catch in 1980 assumed to be 55,000 tonnes. The figure corresponds to Table 4. Catches are for first year, spawning biomass at the beginning of the following year, as indicated by the coupled years at the bottom of the figure.

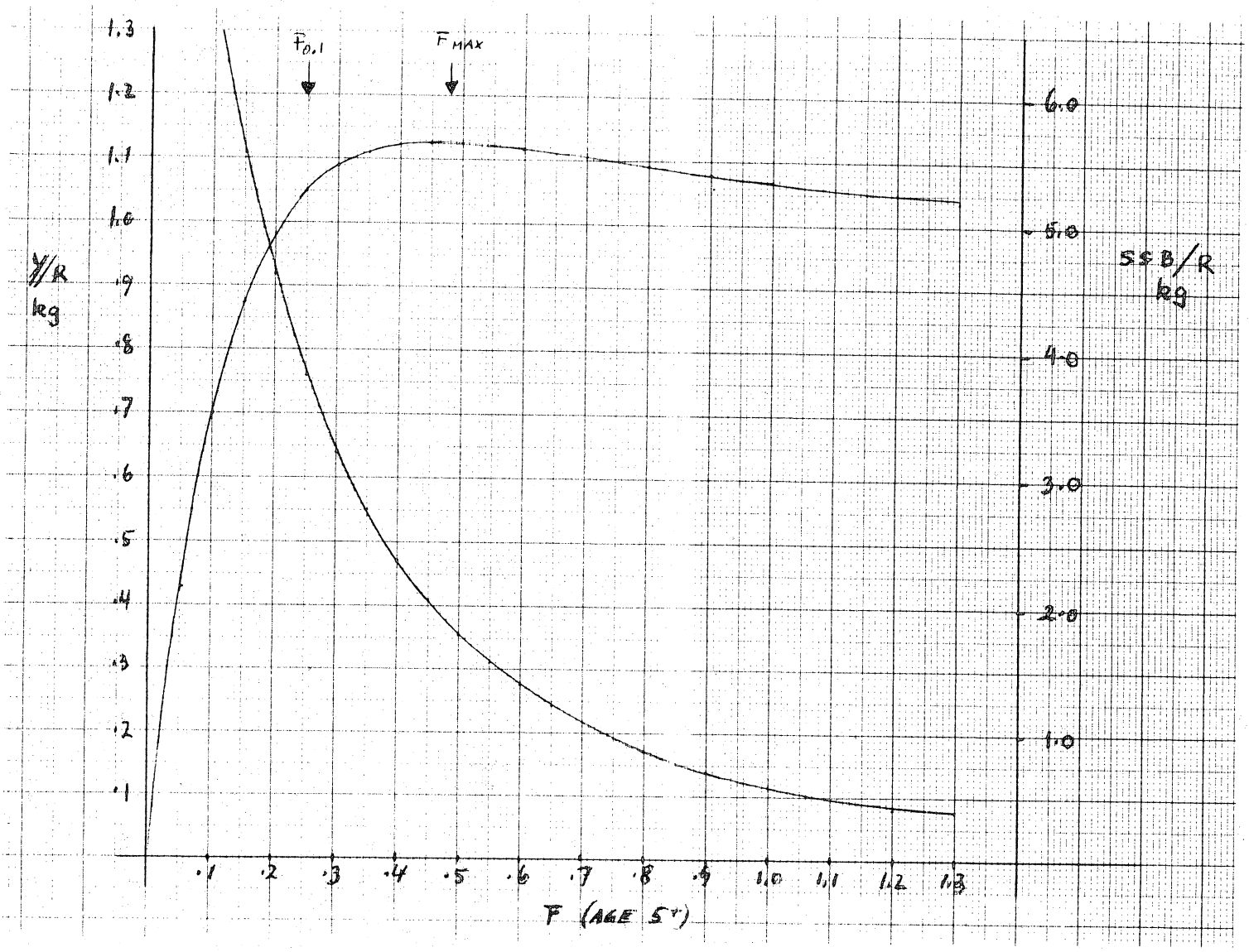

Fig. 4. Subarea 1 cod. Yield and spawning stock biomass per recruit.

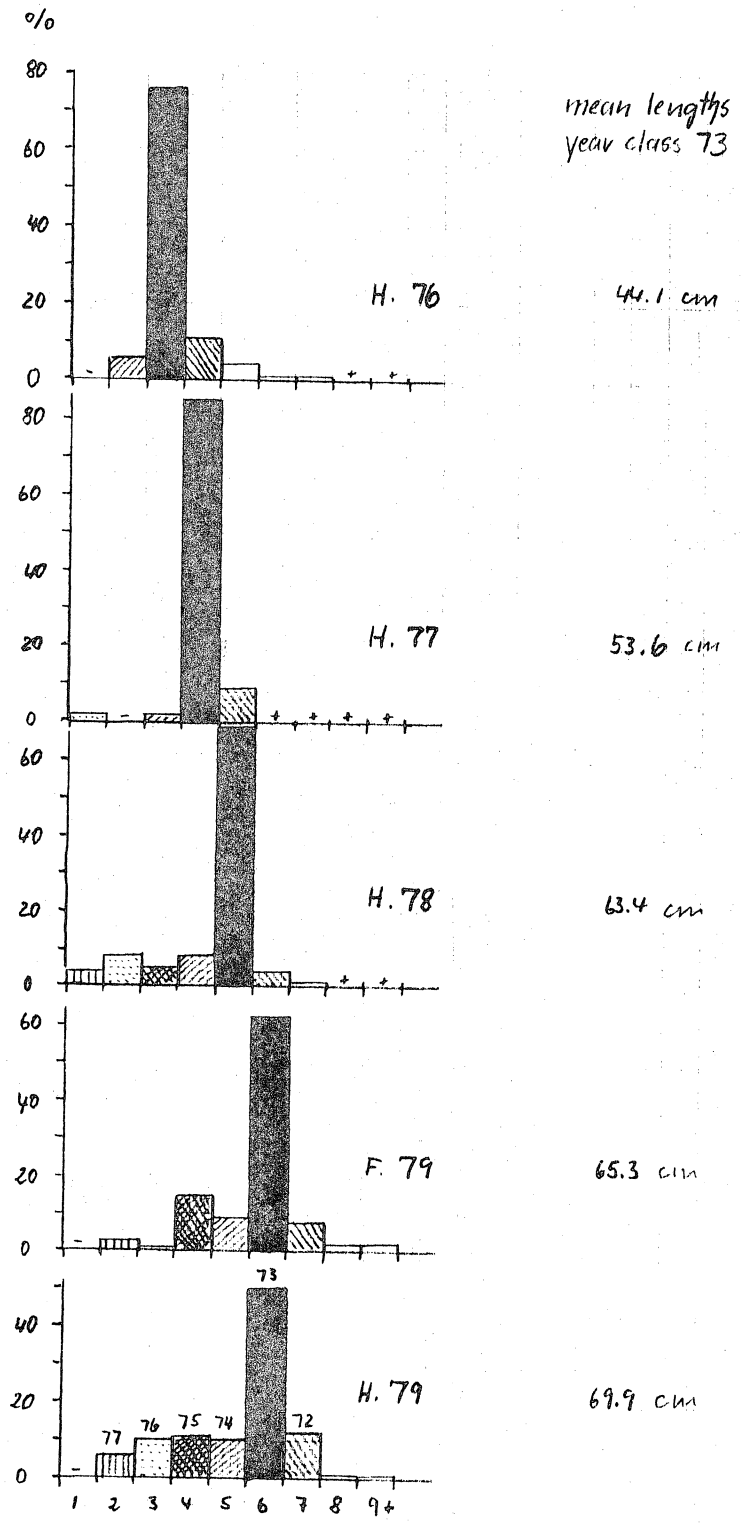

Fig. 5. Percentage age compositions of the West Greenland cod stock, 1976-79, from research catches of the Federal Republic of Germany.

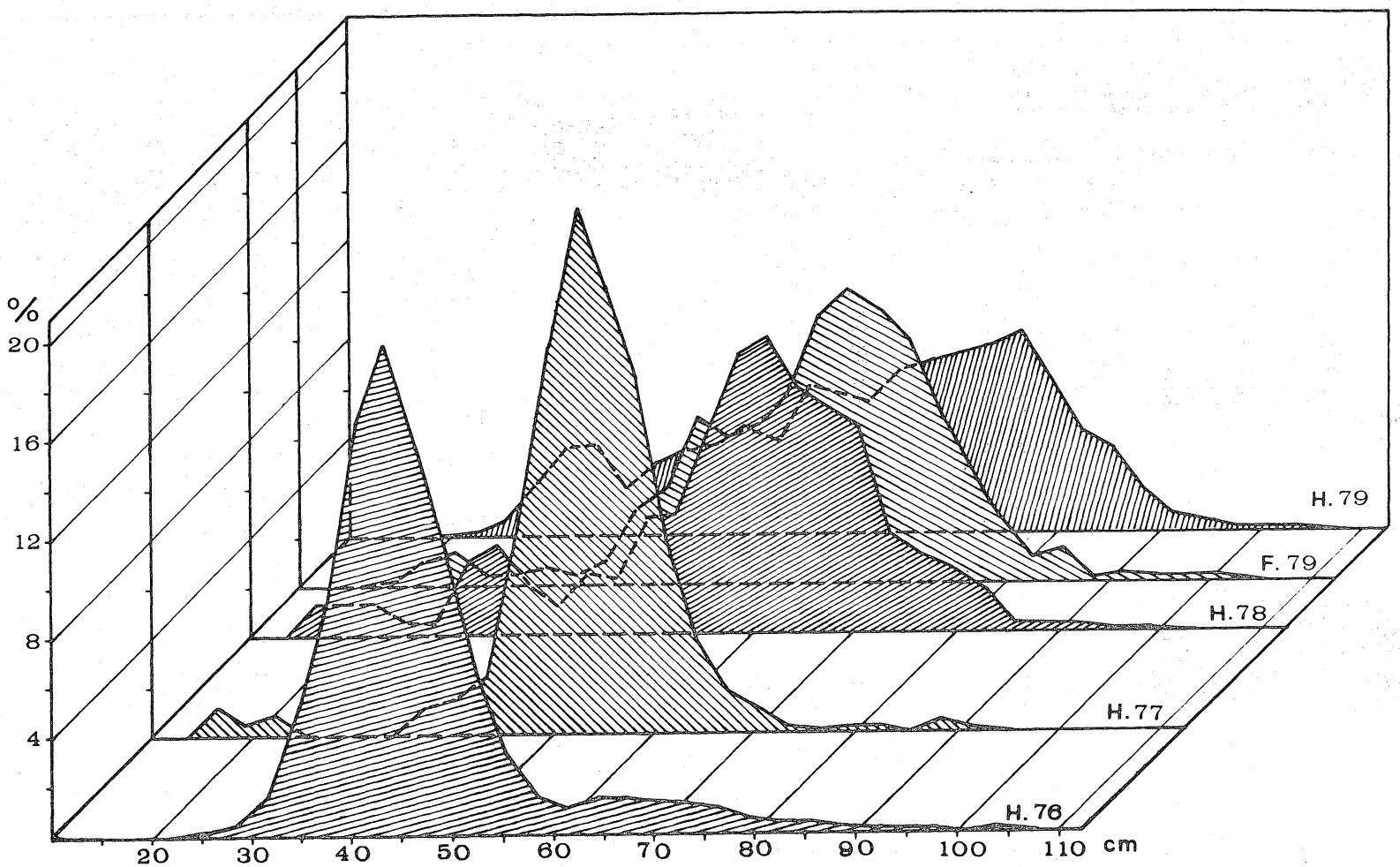

Fig. 6. Length frequencies of the West Greenland cod stock, 1976-79, from research catches of the Federal Republic of Germany.

Mean lengths: Autumn 1976 - 46.7 cm, n = 6,058
Autumn 1977 - 53.6 cm, n = 1,397
Autumn 1978 - 58.2 cm, n = 3,228
Spring 1979 - 61.5 cm, n = 2,408
Autumn 1979 - 62.1 cm, n = 3,775

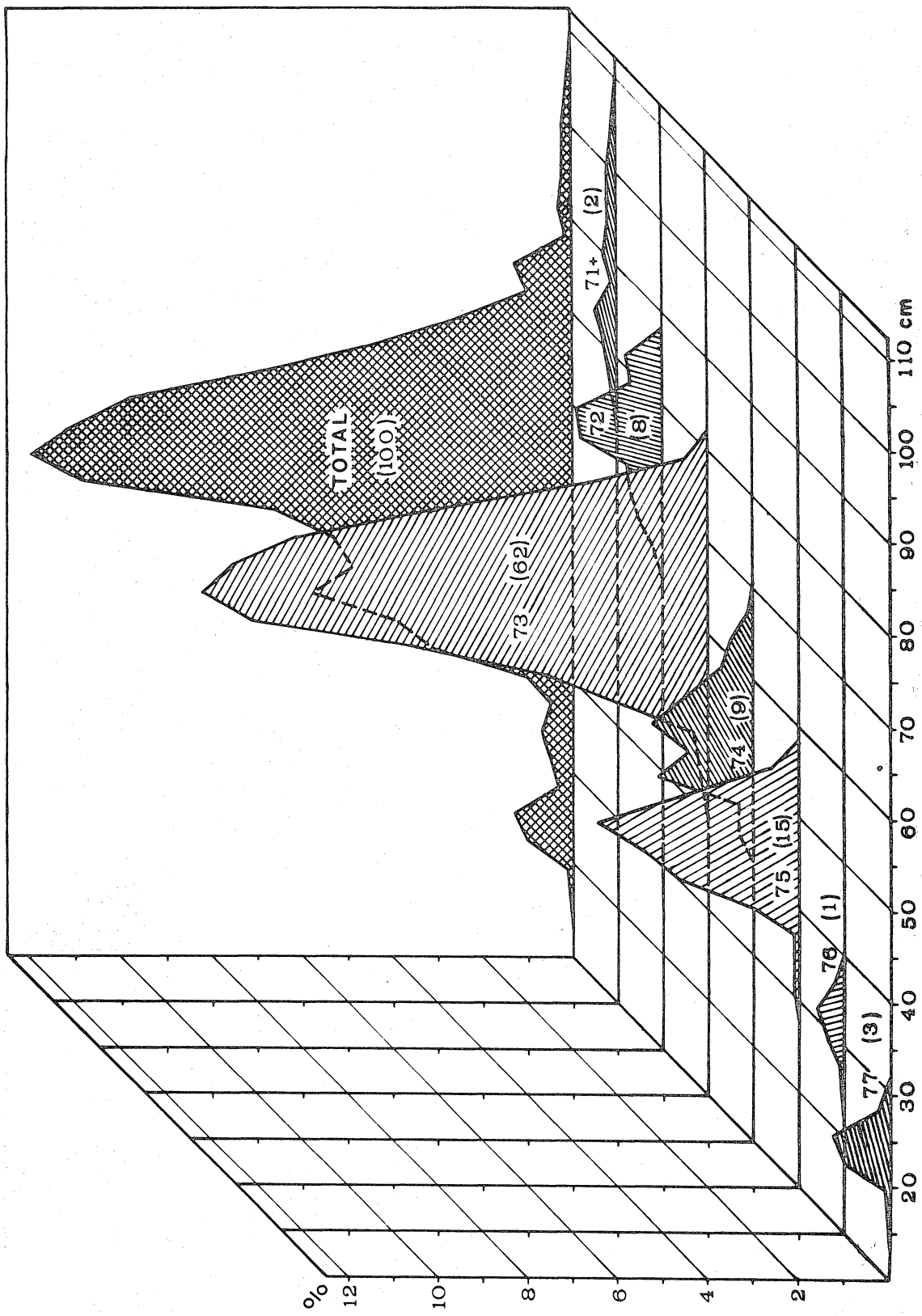

Fig. 7. Length frequencies of year-classes of the West Greenland cod stock from research catches of the Federal Republic of Germany in April/May 1979. Figures in brackets = %.

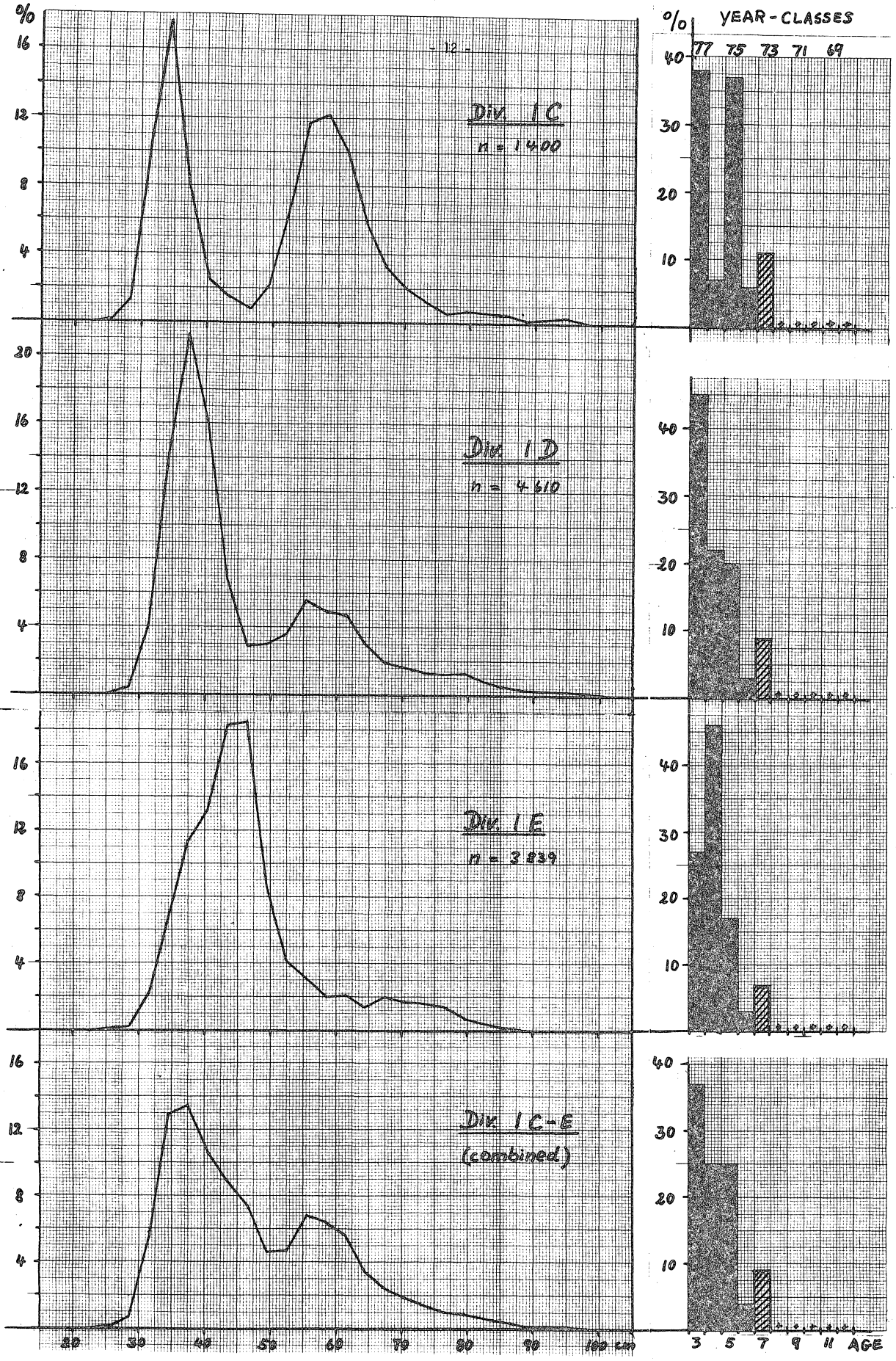

Fig. 8. Cod length frequencies and age compositions of research catches obtained by R/V *Anton Dohrn* in April/May 1980 in Div. 1C-1E.