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Changes in Size-at-age of Cod off West Greenland, 1979-84

by

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Abstract

Changes in mean size at age of cod off West Greenland in the period 1979-84 are calculated from a limited data base containing offshore data from 1st and 2nd quaters. During this period length and weight at age of the important age groups declined by 15 and 45%, respectively.

Both hydrographical conditions and distribution and migration pattern of cod have shown substantial changes over the period in question. The change in size-at-age can be caused by both of these factors, i.e. as a change in growth or as an effect of changes in distribution pattern.

1. Introduction

Over the last two to three years substantial changes in size and structure of the cod stocks off West Greenland have been observed. These changes can be explained by a combination of low recruitment and vast migration out of the West Greenland area (Cornus et al., 1985). Both processes are, at least partly, believed to be influenced by water temperatures which in the same period have been unusually low (Rosenørn et al, 1985 ; Buch, 1986).

During the last two years considerable decreases in mean size - at-age have also been recognised. The purpose of the present work is to present more data on this subject and to discuss briefly the possible causes for this decline in size.

2. Material and methods

2.1 Selection of data

As age-length-weight data for the period 1979-84 have been computerized this period was chosen for analysis.

During that period there have been few problems with sample coverage of the offshore trawl fishery. This fishery is conducted mainly by a fleet of goverment trawlers usually fishing on the same grounds but landing their catches at various places at West Greenland, including Nuuk where most of the sampling for practical reasons takes place. The coverage of the inshore fishery, on the other hand, is very patchy due to sampling difficulties caused by the many landing places and the large distances between theese.

As size at age differs considerably between in- and offshore fisheries, data from the inshore fishery are omitted in an attempt to reduce the effect of an unbalanced geograpical sampling coverage over the years.

Most of the trawl catches are taken in Div. 1C-1E (Fig 1) which is also reflected in the sampling coverage (Table 1). In order to exclude effects caused by possible different growth in various areas only data from Div. 1C-1E are used. 88% of the total age readings are from these three divisions.

Seasonally, most of the offshore fishery and hence sampling effort takes place in the 1st, 2nd and 4th quarters (Table 2). As the sampling has not been evenly distributed on quarters over the years it was decided to use only data from 1st and 2nd quarters.

The resulting data base, used in the analysis, consists of approx. 12.000 age readings.

2.1 Size variables

In an assessment context the most interesting size variable is weight at age. However, the entire reproduction cycle (maturing, spawning and refatening) is anticipated during the first two quarters and changes in condition does therefore occur. For this reason the analyses were performed on length-at-age data, which then later are converted to weight-at-age by using condition factors from the period prior to spawning i. e. January and February. As practically no growth in length takes place during the first two quarters these calculated weights at age will be close to 1st January values.

3.0 Results

3.1 Changes in length at age

Mean length at age, sample size, and standard error by age groups are given in Table 3 .Moreover, mean length for the most numerous age groups (age 4 to 8) is shown in Fig. 2.

A substantial reduction in mean length-at-age is observed over the period. The trend for the 4 year old cod is somewhat different to the 5- 8-year old cod. One should, however, bare in mind that a minimum landing size of 40 cm is in force which will bias mean length in an upward direction, when the population mean approaches the minimum landing size.

The decrease in mean length-at-age is approximately linear for each of the age-groups 5-8, but is greater the older the agegroup is. Linear regression was made for each age group (Table 4), and the predicted values were calculated for 1979 and 84. For the age groups in question the reductions in predicted length-at-age were between 14.9 and 17.4%.

3.2 Condition factors

Condition factors from January and February each year were calculated and regressed against length to check any relationship between length and condition, Table 5. For the years 1979, 81 and 84 no significant effects were found. For the other years small, but significant effects were seen. In 1982, condition increased with length whereas in 1980 and 83 it decreased. The most simple interpretation of these somewhat ambiguous results is to assume that condition is independent of length. The significant effects in some years must then be attributed to unbalanced sampling (on the small scale, however, cf. sect. 2) or could be due to outliers caused by errors in the length/weight registrations. As a illustration of the possible errors involved when applying constant condition factors the condition-length relationship for 1980 (the year having the highest numerical value of the slope in the condition-length regression) is shown in Fig 3.

3.3 Calculated weight-at-age

Calculated mean weight-at-age is given in Table 6 . The decrease in weight is substantial which is also shown in the extracted key figures below.

Age	Weight 1979 kg	Weight 1984 kg	Difference in weight kg	% reduction in weight
4	1.07	0.57	-0.50	47
5	2.04	1.13	-0.91	45
6	3.51	1.98	-1.53	44
7	4.76	2.62	-2.14	45
8	6.52	3.46	-3.06	47

4.0 Discussion

Change in size-at-age can be interpreted as a change in growth but can also be caused by other factors, such as fx. a selective migration of larger fish.

4.1 Changees in growth

The most important factors regulating growth are temperature and food availability. Our knowledge of the latter of these two factors off West Greenland is scarce. No feeding studies on cod have been carried out recently, and none of the fish stocks believed to be of major importance as prey species are presently assessed.

The overall temperature regime in West Greenland waters has undergone substantial changes in the period in question with pronounced coolings from 1982 to 1984 (Rosenørn et al, 1985). This temperature decline might be responsible for the observed reduction in size at age.

However, it might be misleeding to use overall temperature indicees as explaining factors since the cod might actually be able to seek out water stratas with suitable temperatures.

The cod at West Greenland shows some fairly regular annual migrations, from deeper offshore areas where they stay from autumn to early summer to more coastal areas where they are fished during late summer and early fall. To get an idea of the changes in temperature conditions during this migration, three hydrographic situations have been illustrated, two from the offshore area (February and November) and one from the coastal area in July. Average temperatures fore the period 1979-84 are then compared to that of the preceeding six years period (Table 7).

In general, little difference is seen between the two periods. Warmer temperatures in the early period are seen in only two cases viz. in the deeper layer in February (+0.5 C) and in the surface layer in November (+0.8 C). As mentioned practically no growth takes place in the first of these situations.

Another question is, however, how much temperature change will be necessary to explain a change in size as large as the observed one. This is a difficult question but one can as a starting point assume that growth rate is proportional to temperature (the degree-day modell) i.e.

$$\text{Time} \times \text{Temperature} = \text{constant}$$

where time refers to the time necessary to reach a certain size. If comparing two different growth situations then

$$\frac{\text{Time(1)}}{\text{Time(2)}} = \frac{\text{Temp(2)}}{\text{Temp(1)}}$$

By using weight-at-age from 1979 and 1984 it is possible to calculate the time(1)/ time(2) ratios.

Time to reach	1979	1984	Time(1)/Time(2)
1 kg.	3.90 yr.	4.75 yr.	.82
1.5 -	4.45 -	5.48 -	.81
2.0 -	4.95 -	6.05 -	.82
2.5 -	5.32 -	6.75 -	.79
3.0 -	5.65 -	7.45 -	.76
3.5 -	5.99 -	8.05 -	.74

That means, broadly speaking, that a temperature reduction of 20% will be sufficient to account for a reduction in size as big as the observed one. At the prevailing temperature regime this could be fx. in the size-range from 5 to 4 deg. C.

There is, however, no a priori reason to expect a simple proportionality, and in many cases (cf. Ricker, 1979) it has been suggested to modify the degree-day model to :

$$\text{Time} \times (\text{Temperature} - t(0)) = K$$

where t(0) is a positive temperature below which no growth takes place. If in the present case t(0) is taken as 2 C a reduction in temperature from fx. 4.5 to 4 C will be sufficient to explain the observed reduction in size .

If these very rough considerations reflect reality, i.e. that a temperature reduction on say 0.5-1 degree can explain a size reduction as big as that observed it will be quite difficult in practice to verify such a growth model due to the magnitude of both spatial and temporal variations in temperature.

4.2 Changes in size caused by selective migrations

In the assessment work dealing with the cod stocks off West Greenland large migrations have recently been argumented (Horsted et al., 1984; Anon., 1985; Cornus et al., 1985). These migrations are interpreted as spawning migrations.

Maturity data from West Greenland do indicate that the mean size-at-age is a litle bigger in the mature part of the population compared to the immature part (Cornus and Lehmann, pers. comm.). Thus it can not be excluded that the reduction in mean size is caused, at least partly, by increased migrations of large mature individuals out of the West Greenland area. Never the less, the reduction in size-at-age seems to affect all age groups rather uniformily, i.e. irrespective of the proportion mature in each age group.

Concurrent with the large migration in recent years there has been a gradual southern displacement of the cod fishery off West Greenland. This trend is clearly reflected in the catch distribution of the Greenland Governement trawlers for the years 1979-84, as seen in the text table below.

Division	1B +1C	1 D	1 E	1 F
Year				
1979	60.3	32.9	6.6	0.2
1980	50.8	28.4	20.7	0.1
1981	31.4	35.9	32.7	0
1982	20.0	35.3	44.7	0
1983	5.5	38.8	55.0	0.7
1984	0	41.6	54.6	3.7

Percent distribution of total catch in various divisions off West Greenland , 1979-84.

A southern movement of the stock may have affected the mean size-at-age in the area investigated (Div. 1C - 1E). Size frequencies from the autumn groundfish survey by the Federal Republic of Germany have shown that the smaller cod are found in the northern

areas (divisions 1B-1C) and that the size gradually increases when going southernly and finally attaining highest values at East Greenland (Messtorff & Cornus, 1984 ; Cornus et al , 1985). This might well work on both an age level, giving gradually older fish when going south, but also on a within-age level giving rise to findings of bigger fish of each year-class in the southern areas. Thus, a generel southern displacement of the stock could have moved relatively small fish into the area and relatively large fish out of the area investigated.

5. References

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Table 1. Number of age readings from offshore catches of cod at West Greenland 1979-84 by divisions.

Year / Div.	1979	1980	1981	1982	1983	1984	Total
1B	0	483	0	990	501	0	1974
1C	1134	387	502	748	0	14	2785
1D	1449	604	682	2368	2434	218	7755
1E	0	1325	152	1443	2174	1708	6802
1F	314	0	0	0	0	185	499
Total	2897	2799	1336	5549	5109	2125	19815

Table 2. Number of age readings of cod in offshore areas in Div. 1C-1E, 1979-84 by quarters of the year.

Year / Quarter	1979	1980	1981	1982	1983	1984	Total
1	1416	1334	297	2295	1512	1170	8024
2	1167	415	456	669	1109	14	3830
3	0	46	0	811	512	500	1869
4	0	521	583	784	1475	256	3619
Total	2583	2316	1336	4559	4608	1940	17342

Table 3 : Mean length-at-age of cod from offshore areas in Div. 1C-1E, 1st and 2nd quarter, 1979-84.

Year 1979

Age group	mean length	N	Std.err.
3	38.00	2.00	5.00
4	47.61	520.00	0.18
5	58.96	736.00	0.20
6	70.65	1052.00	0.21
7	78.04	55.00	1.17
8	87.23	133.00	0.53
9	89.14	28.00	1.39
10	95.38	26.00	1.09
11	97.82	17.00	1.83
12	115.67	3.00	4.33
13	104.60	5.00	3.25
14	110.00	4.00	2.38
15	115.00	1.00	.
17	108.00	1.00	.

Year 1980

Age group	mean length	N	Std.err.
3	34.30	46.00	0.81
4	47.63	233.00	0.19
5	57.66	533.00	0.26
6	68.11	277.00	0.44
7	76.38	590.00	0.31
8	85.26	19.00	1.90
9	86.63	40.00	1.06
10	91.00	5.00	2.05
11	94.00	1.00	.
12	86.50	4.00	3.86
13	102.00	1.00	.

Year 1981

Age group	mean length	N	Std.err.
4	48.00	234.00	0.27
5	58.85	86.00	0.43
6	65.15	207.00	0.36
7	74.42	50.00	0.97
8	81.53	156.00	0.60
9	80.75	4.00	4.61
10	88.77	13.00	3.14
11	95.50	2.00	2.50
14	86.00	1.00	.

Year 1982

Age group	mean length	N	Std.err.
2	22.00	1.00	.
3	32.17	118.00	0.34
4	41.90	40.00	0.85
5	54.57	1527.00	0.16
6	64.67	293.00	0.24
7	72.54	503.00	0.27
8	81.16	232.00	0.54
9	86.08	166.00	0.86
10	95.50	16.00	2.53
11	98.66	50.00	1.08
12	115.00	1.00	.
13	108.91	11.00	3.09
14	101.25	4.00	2.78
15	113.00	2.00	7.00

Year 1983

Age group	mean length	N	Std.err.
3	27.00	1.00	.
4	45.21	471.00	0.16
5	50.79	159.00	0.29
6	59.79	1437.00	0.16
7	70.38	161.00	0.35
8	76.07	229.00	0.40
9	80.97	97.00	0.75
10	79.85	53.00	1.37
11	103.50	2.00	5.50
12	87.29	7.00	5.35
13	111.00	2.00	4.00
14	81.50	2.00	2.00

Year 1984

Age group	mean length	N	Std.err.
2	16.00	1.00	.
3	26.10	93.00	0.34
4	39.33	92.00	0.38
5	49.28	486.00	0.26
6	59.80	50.00	0.66
7	65.59	368.00	0.29
8	72.18	17.00	1.23
9	78.32	40.00	1.10
10	80.64	11.00	2.87
11	82.48	23.00	2.52
13	78.00	3.00	4.04

Table 4. Regression parameters from the model: Mean length = a + b x year for 5-8 year old cod (years 1979-84)

Age	a ± 2 x SE	b ± 2 SE	Predicted length (cm) 1979	1984	% decrease
5	226.20 ± 66.36	-2.10 ± 0.81	60.3	49.8	17.4
6	250.77 ± 41.92	-2.28 ± 0.51	70.4	59.0	16.2
7	263.59 ± 40.81	-2.34 ± 0.50	78.7	67.0	14.9
8	330.19 ± 49.16	-2.94 ± 0.60	87.9	73.2	16.7

Table 5. Regression parameters and test statistics for the model: condition = a + b x Length (cm)

Year	a	b	P (b=0)
1979	0.99	-.0003	0.31
1980	1.15	-.0021	<0.001
1981	0.92	.0003	0.64
1982	0.98	.0010	<0.001
1983	1.00	-.0020	<0.001
1984	0.94	-.0005	0.18

Table 6. Calculated mean weight-at-age using mean condition factors. Figures in brackets indicate number of cod measured.

Year	1979	1980	1981	1982	1983	1984
Age						
4	1.07(520)	1.11(233)	1.06(234)	0.81(40)	0.83(471)	0.57(92)
5	2.04(736)	2.00(533)	1.94(86)	1.77(1527)	1.17(159)	1.13(486)
6	3.51(1052)	3.31(277)	2.65(207)	2.87(293)	1.94(1437)	1.98(50)
7	4.77(55)	4.64(590)	3.96(50)	4.09(503)	3.10(161)	2.62(368)
8	6.53(133)	6.43(19)	5.22(156)	5.78(232)	3.95(229)	3.46(17)
1	7.00(28)	6.68(40)	5.09(4)	7.02(166)	4.79(97)	4.47(40)
10	8.49(26)	7.66(5)	6.86(13)	9.42(16)	4.69(53)	4.94(11)
11	9.22(17)	8.40(1)	8.20(1)	10.25(50)	9.84(2)	5.43(23)
Mean condition	0.97	1.01	0.94	1.05	0.88	0.91

Table 7 : Mean temperature (°C) 1973-78 and 1979-84§

Station Fylla 4 (63°53´N, 53°22´W) February

Depth (m)	1973-78	1979-84
0-30	-0.72	-0.45
50-200	0.95	0.99
200-500	3.32	2.83

Station Fylla coastal (64°01´N, 52°10´W) July

Depth (m)	1973-78	1979-83
0-30	2.53	2.62
50-200	1.54	1.66
200-300	0.86	1.15

Station Fylla 4 (63°53´N, 53°22´W) November

Depth (m)	1973-78	1979-83
0-30	2.06	1.15
50-200	3.50	3.40
200-500	5.11	5.11

§ 1984 values for temperature in July and November excluded as last size-at-age data is from spring 1984.

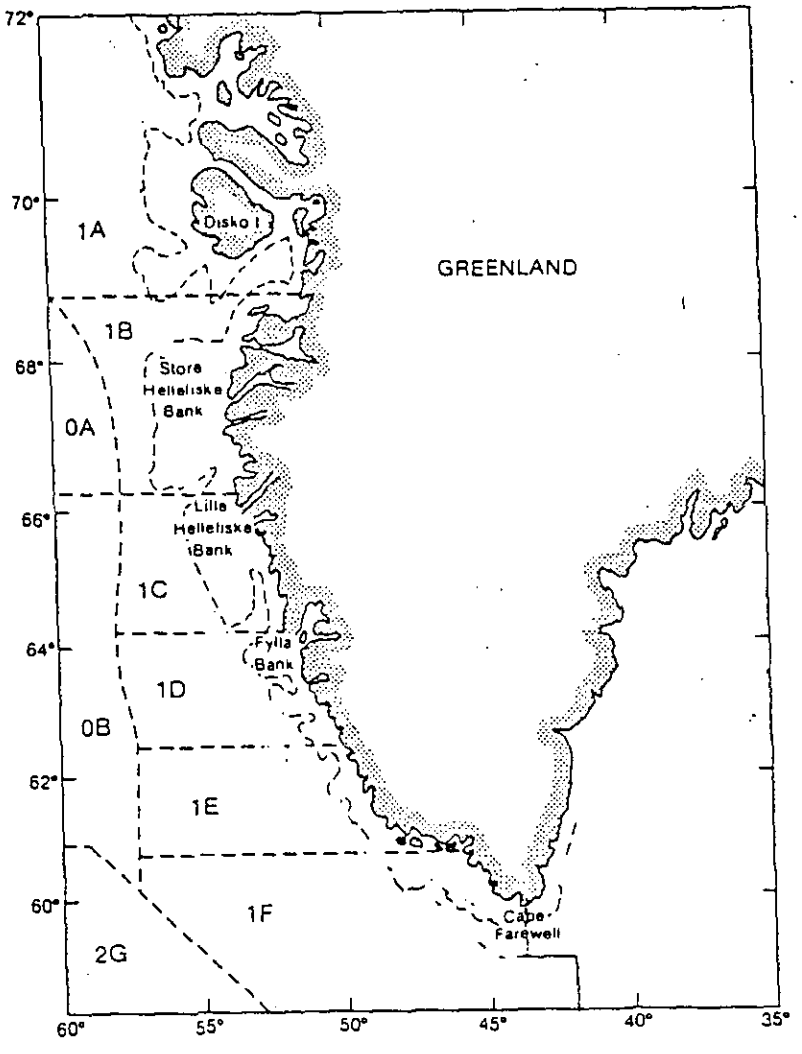

Fig. 1 : Map of Greenland showing NAFO divisions.

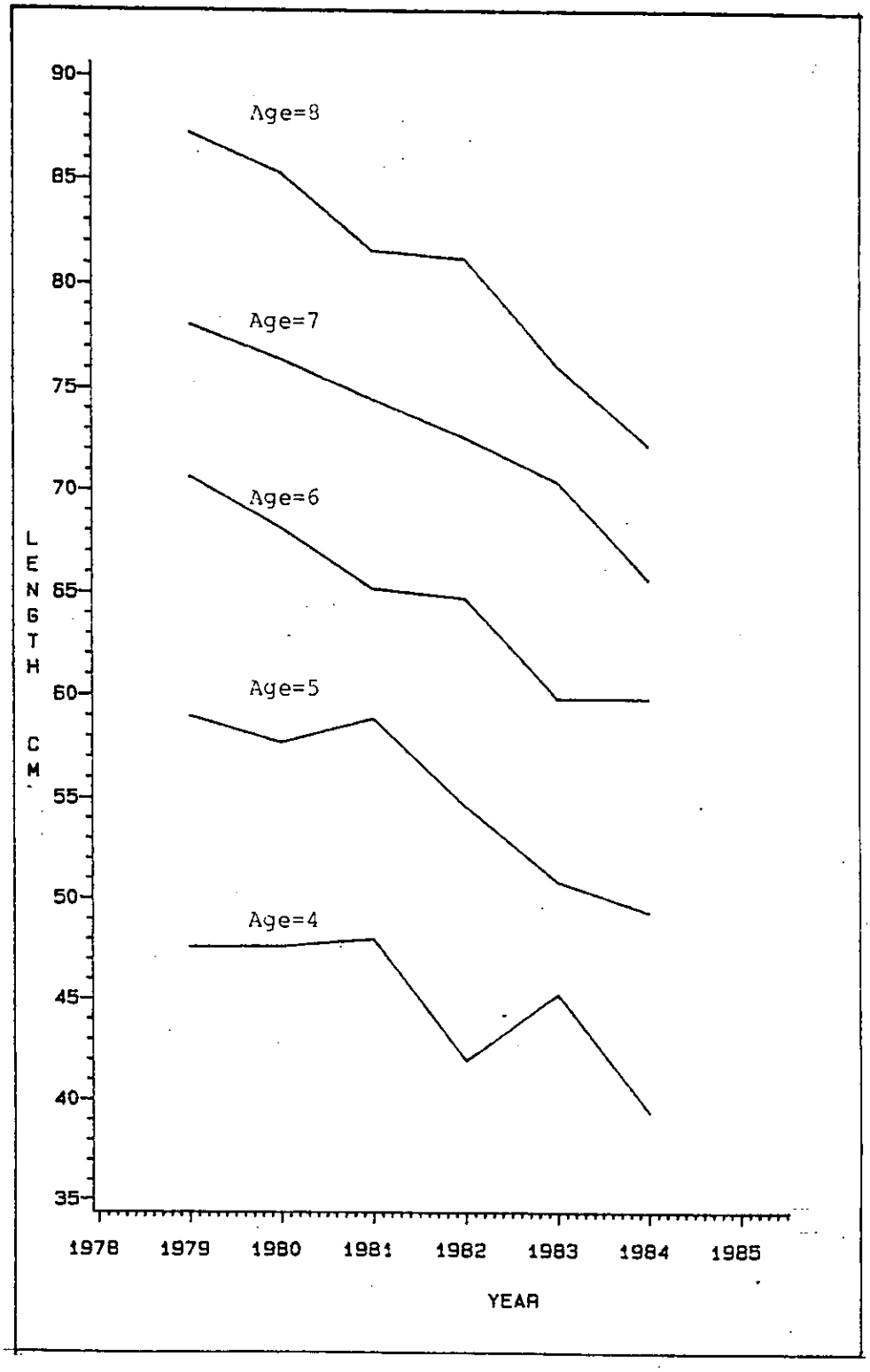

Fig 2 : Length at age for offshore cod, 1979-84

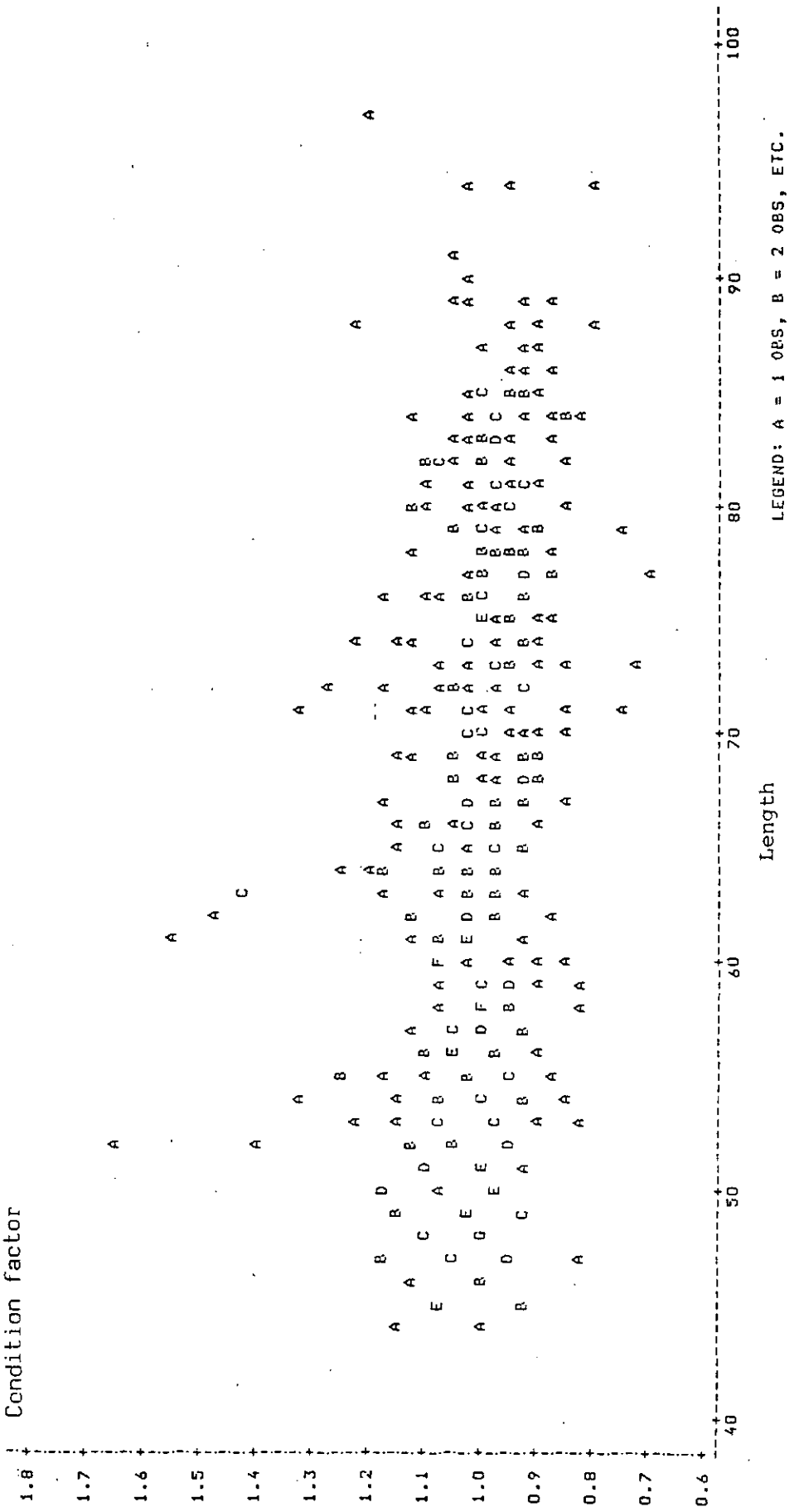

Fig 3 : Condition vs. length for offshore cod in 1980.