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Status of Subarea 1 Cod and the Fisheries

(An extract of the Report of the ICES Working Group on Cod Stocks off East Greenland, January 1986)

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with an Introduction by

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INTRODUCTION

At its meeting in June 1985 the Scientific Council of NAFO agreed that a combined assessment of the cod stocks at West and East Greenland rather than separate assessments of the two stocks in NAFO and ICES respectively, would result in a better understanding and evaluation of the stock interactions and their influence on the state of the stocks. It was agreed that this could be achieved by an extended meeting of the ICES Working Group on Cod Stocks off East Greenland, which usually meets in January to provide management advice for the current year (*Scientific Council Reports* 1985, page 83).

At the 1985 Statutory Meeting of ICES, it was decided that the Working Group on Cod Stocks off East Greenland should meet at ICES Headquarters on 14-23 January 1986 to assess the status of the cod stocks off East Greenland and provide catch options for 1986.

In order to be able to make the assessment of East Greenland cod, the Working Group found it necessary to use data derived from the assessment of the West Greenland cod. Consequently, the Working Group agreed to carry out assessments for both East and West Greenland and present both assessments in one report. The report of the Working Group (C.M. 1986/Assess:11), therefore, for the first time, contains the full assessment of the West Greenland stock, with the exception of the catch projections and management options which will have to be carried out by the NAFO Scientific Council at its June 1986 Meeting. The West Greenland part and some general parts of the Working Group report are presented here as a research document to the NAFO Scientific Council by those participants at the meeting which also participated in the meeting of the ICES Working Group (Sv. Aa. Horsted, J. Messtorff, F. F. Riget and A. Schumacher). For practical reasons the catch projections carried out at the present meeting are presented in a separate research document.

The following pages contain extracts from the ICES Working Group on Cod Stocks off East Greenland, Copenhagen, 14-23 January 1986 (ICES C.M. 1986/Assess:11).

1. PARTICIPANTS

The ICES Working Group on Cod Stocks off East Greenland met in Copenhagen, 14-22 January 1986, with the following participants:

H.P. Cornus	Federal Republic of Germany
H. Hovgård Hansen	Denmark
Sv. Aa. Horsted	Denmark
K. Hoydal (Chairman)	Faroe Islands
K. Lehmann	Denmark
J. Messtorff	Federal Republic of Germany
J Møller Jensen	Denmark
F.F. Riget	Denmark
S. Schopka	Iceland
A. Schumacher	Federal Republic of Germany

Dr. E.D. Anderson, the ICES Statistician, also attended the meeting.

2. TERMS OF REFERENCE

At the 1985 Statutory Meeting, it was decided (C.Res.1985:2:3:1) that the Working Group on Cod Stocks off East Greenland should meet at ICES Headquarters 14-23 January 1986 to:

i) analyse the results of the latest groundfish survey;

ii) assess the status and provide catch options inside safe biological limits for East Greenland cod for 1986.

In order to be able to make the assessment of East Greenland cod, it is necessary to use data derived from the assessment of the West Greenland cod. In Section 3, the interrelationships of these two cod stocks are discussed, and it is obvious that there are sound scientific reasons for carrying out the two assessments simultaneously and presenting them in one report. There are also practical reasons for this. The assessments in the two areas are based on data from a groundfish survey which is designed in almost the same way for the two areas, and the scientists involved are the same.

Management advice on the two areas is given by two different international organisations. In the case of West Greenland, the Scientific Council of NAFO scrutinizes the assessment and formulates the advice; in the case of East Greenland, the ACFM of ICES handles the advice.

The Group agreed to carry out assessments for both East and West Greenland and present both assessments in one report. This Working Group report, therefore, for the first time, contains the full assessment of the West Greenland stock, with the exception of the catch projections and management options, which are a matter for the Scientific Council of NAFO. The West Greenland part of the report will be presented by the participants of the meeting as a research document to the NAFO Scientific Council for its further discussion and for catch projections and management advice.

3. THE COD STOCK COMPLEX IN GREENLAND AND ICELANDIC WATERS

It has been known for several decades that there is an interrelationship between the cod stocks at West and East Greenland and at Iceland (Figure 3.1). Tagging experiments carried out at Greenland and Iceland show that a part of the mature cod at West Greenland migrates to East Greenland and some of them further to Iceland. Results of tagging experiments carried out in East Greenland waters also show that mature cod from that area migrate to Iceland. This may also sometimes be the case for immature cod found in the East Greenland area closest to Iceland. On the other hand, in some years, immature cod seem to migrate from East Greenland to West Greenland. At Iceland, tagging experiments show that migration of cod from Icelandic to Greenland waters hardly occurs and, therefore, the migrations from Greenland waters to Iceland can be regarded as a one-way emigration.

However, the interrelationship between the stocks is not only a matter of adult and immature cod migrating and mixing, but also a matter of recruitment to one area originating from spawning in another area. As far as this question is concerned, larval drift with currents from East to West Greenland and from Iceland via East Greenland waters to the banks off West Greenland seems evident.

The magnitude of this drift and the survival rate of the larvae seem to vary much from year to year. In some years, the drift seems negligible, while in other years (e.g., in 1963, 1973 and 1984), considerable numbers of larvae seem to have drifted from Iceland to East Greenland and to the southern part of West Greenland.

This variation is reflected by the abundance indices from the Icelandic 0-group survey in East Greenland waters (Table 3.1).

The magnitude of emigration from West Greenland to East Greenland and Iceland also seems to vary from year to year and between year classes. Up to 1984, the Working Group used an emigration coefficient of E = 0.05 for the West Greenland stock as a whole, which was based on results from tagging experiments carried out mainly in the period 1945-70. New information based on groundfish surveys shows that, in 1983 and 1984, the emigration was much more pronounced than the earlier findings, and the Working Group at its last meeting, therefore, introduced a new emigration coefficient E = 0.15.

Also at East Greenland, the emigration to Iceland varies from year to year. From Danish tagging experiments, the North-Western Working Group concluded (Anon., 1971) that about 45% of the mature cod from East Greenland migrated to Iceland. However, the North-Western Working Group considered the East Greenland stock and the cod in NAFO Divisions 1E-F at West Greenland as being combined and estimated the coefficient of emigration as 0.29, which corresponds to an emigration of 25% per year.

Another attempt to estimate the migration from Greenland to Iceland was made by the Joint ICES/ICNAF Working Group on Cod Stocks in the North Atlantic in 1972 (Anon., 1973). The result of that exercise confirmed previous findings (24%).

4. ENVIRONMENTAL CONDITIONS

The hydrographical conditions in the West Greenland area in 1985 were influenced by the change in the meteorological situation over Greenland which took place in the winter of 1984-85, when the air temperature shifted from a 3-year period of strong negative anomalies to slightly positive anomalies, which was characteristic for all months in 1985. As a result of this climatic change, the surface-water temperatures off West Greenland were raising to values of about normal. The temperature over the top of Fylla Bank by mid-June was 2.07^{0}C, which is a little above average.

In addition to the improved conditions in the surface layer, the deeper layers also experienced positive temperature anomalies, especially during the last half of 1985, when there was a greater-than-normal inflow of warm Irminger water. The intensity of this current was so strong that, in November, the effects of it could be traced to the top of the fishing banks as far north as 68^{0}N.

Preliminary analyses of the Danish plankton samples from West Greenland waters in July 1985 indicate that cod larvae were very scarce in the plankton.

5. GROUNDFISH SURVEYS IN THE AREA

As information available from the commercial fishery does not adequately reflect the situation and the development of the East and West Greenland cod stocks, groundfish survey programmes were designed and introduced off East and West Greenland in 1980 and 1982, respectively, by the Federal Republic of Germany and have been continued since in order to obtain reasonable annual estimates of the trawlable biomass and abundance of cod in both areas.

5.1 Survey Design

The surveys were designed according to the stratified random sampling method by applying the "swept-area" method to the survey results. The trawl parameters of the standard bottom trawl used in all surveys are as follows:

Gear:	140' bottom trawl equipped with a small-mesh (30-mm) liner inside the codend
Horizontal net opening:	22-m wing spread
Vertical net opening:	3.5-m headline height (not considered in the calculations)
Trawling speed:	4.5 knots
Towing time:	30 minutes

The catchability coefficient was taken as 1.0 to avoid overestimation of the stock biomass and abundance. Therefore, the results are expressed in terms of "minimum trawlable" biomass or abundance and refer to the part of the population available to the gear at the survey time.

The survey areas off East Greenland (ICES Division XIVb) and off West Greenland (NAFO Subarea 1) are shown in Figure 5.1. Trial surveys during different seasons proved that cod in both areas were most evenly distributed in the autumn and, therefore, give smaller variances of the survey estimates than at other times of the year.

The survey areas are composed of statistical rectangles (0.50^0 Lat. x 1^0 Long.), as used throughout the ICES area, which form the basis of the stratification schemes. However, according to area-specific reasons, the construction of strata is different in both survey areas.

Since 1983, the stratification of the East Greenland survey area has been based on mean densities of cod per statistical rectangle derived from the previous surveys. So far, substantial changes in the relative density distribution have not occurred in the survey series. A set of five strata was constructed for five increasing ranges of density distribution. Each stratum is composed of statistical rectangles for which the same range of mean relative density distributions has been computed. Consequently, the strata are different in size depending on how many of the whole survey area's 36 statistical rectangles are allocated to them. For the 1985 survey, the allocation of statistical rectangles to strata 1-5 is shown in Figure 5.1, and the corresponding area composition is given in Table 5.1.1.

The West Greenland survey area lies within 51 statistical rectangles containing the shelf outside the 3-mile limit and the continental slope down to 600-m depth extending from the southern part of NAFO Division 1B (south of 67^0 N Latitude) southward as illustrated in Figure 5.1. The area consists of seven main strata equal to NAFO Divisions 1B-F or parts thereof. The main strata are each subdivided by 100 m depth zones between 0-600 m into six substrata, except in Division 1F (stratum 7) where, due to the lack of suitable bathymetric charts, a substratification was possible only by 200-m depth zones. Strata areas (nm^2) are given in Table 5.1.2.

For the purpose of random selection of fishing stations, each statistical rectangle is divided into unit areas equivalent to 7.5' Latitude x 15' Longitude rectangles, with each of these further subdivided into nine smaller random units (2.5' x 5' rectangles). The random units are numbered consecutively but separately inside each main stratum. Of the total number of fishing stations planned for each survey, 50% are allocated proportionally to the stratum sizes and correspondingly inside each stratum to the substrata areas. The remaining half is allocated proportionally to the mean relative densities within each stratum and substratum as derived from previous surveys.

5.2 Discussion of Variation and Possible Biasses in the Results

The basis for the assessments of the cod stocks at Greenland are estimates of trawlable biomass from trawl surveys undertaken by research vessels from the Federal Republic of Germany, combined with catch data.

A working paper presented to the meeting discussed in which way the estimates based on the surveys might deviate from the true stock size.

$$N_{true} = a \times N_{survey}$$

where α is a scaling factor which technically can be compared to a catchability coefficient. The relationship between the true and the survey-based parameters are as shown below (assuming that α is constant from year to year):

Estimates from survey	Z	N	F	$E = Z - F - M$
"True" values		Z	$\alpha \times N$	F/α	$E = Z - M - F/\alpha$

This implies that the use of a wrong value of α introduces biasses into the estimates of N, F and E; however, the trends in the estimates are unbiassed.

The Group assumes a catchability coefficient equal to 1.0 in order to avoid overestimates of the stock size. How ever, catch ability can be both higher and lower than 1.0 as it is related to a range of factors, some of which are described below.

1. Area affected by the trawl: This can be larger than the swept area used because of the herding effect of the trawl doors, sweeping lines, etc. If it is larger, it will be equivalent to a catchability coefficient higher than 1.0.

2. Fish escaping under the gear: This will affect the catchability and tend to reduce it. Recent Norwegian investigations (Engås, pers. comm.)seem to indicate that especially young fish (0-2 years old) escape under the gear.

3. Proportion of the cod off the bottom: Some cod will be above the water layers fished by the trawl. This will also tend to reduce the catchability. Acoustic observations seem to indicate that this source of error is low, at least at the present low stock abundance.

4. Proportion of the stock outside the survey area: Some cod will be in inshore areas or other areas not covered by the survey, and the survey will, therefore, be an underestimate. It is assumed, however, that the proportion of the stock outside the survey area will be small.

Since, however, no quantitative estimate of the catchability coefficient is available at present, the Working Group continued to use the survey estimates without corrections. This implies a catchability coefficient of 1.0. The possibility that the true catchability is different from 1.0 should be kept in mind for the evaluation of the assessment.

6. THE COD STOCK AT WEST GREENLAND

6.1 Trends in Catch and Effort

The fishery for cod in NAFO Subarea 1 is partly an offshore fishery, mainly undertaken by large trawlers using bottom otter trawls, and partly a coastal and fjord fishery. In the latter fishery, the major part of the landings is usually taken by pound nets (mainly during the period May-September); other gears used are handlines and gill nets.

The nominal landings in 1985 were 12,935 tonnes of cod (provisional figures, see Tables 6.1.1, 6.1.2 and 6.1.3), the lowest recorded since 1952. This is about 40% of the 1984 landings, which were the second lowest since 1952. Table 6.1.4 shows the nominal landings since 1975 by trawlers and by other vessels. Also, the TAC's from 1975 to 1985 are given in Table 6.1.4.

The landings of the trawlers were 6,400 tonnes or 50% of the total landings in 1985. Nearly all the trawl fishery took place in NAFO Divisions 1E and 1F, with Division 1E accounting for about 60% of the total trawl landings (Table 6.1.2).

The biggest part of the landings from the coastal and fjord fisheries were taken in NAFO Division 1D (about 30%).

Fishing effort has been reported by only a few trawlers. Their overall catch per unit effort has decreased gradually from 3.3 tonnes per hour in 1981 to 0.7 tonnes per hour in 1985 (Table 6.1.5 and Figure 6.1.1).

6.2 Catch in Numbers at Age and Catch Composition (NAFO Subarea 1)

The commercial catches of the Federal Republic of Germany were well sampled in 1985, whereas commercial Greenland catches were very poorly sampled, especially catches by small vessels (below 80 GRT), including all inshore catches. Thus, no samples are available from catches in NAFO Divisions 1A-C, and catches by gears other than trawl were sampled only in July. It was, therefore, necessary to use the individual samples available for other months and divisions and, in some cases, also for gears other than those represented by the sample. Bearing in mind that the catch statistics also have some deficiencies, especially so far as information on gear is concerned, the figures for catch in numbers by age groups are very roughly estimated (Table 6.2.1). However, there is no doubt that the overwhelming part of both the Greenland catches and those by the Federal Republic of Germany was of age group 6, 1979 year class, as expected. That year class made up about 60% of the total catch in number as well as in weight.

The 1977 year class, which accounted for 20% by number of the 1984 landings, was still a predominating year class in the trawl fisheries in NAFO Division 1F in the first quarter of the year (42% by number in a Greenland sample) and made up 24% by number of the trawl catches by the Federal Republic of Germany. However, of the total catch for NAFO Subarea 1, the 1977 year class accounted for about 9%, while the incoming 1980 and 1981 year classes accounted for 15 and 8%, respectively.

6.3 Mean Weight at Age in the Catches

The mean weights at age in the major Greenland fisheries in 1985 and from the trawl survey by the Federal Republic of Germany are listed in Table 6.3.1. For Greenland trawlers, the figures for the first quarter of the year did not vary much between samples. Figures for Greenland trawlers for the fourth quarter were generally higher than those from the first three quarters, but since the catch by Greenland trawlers in that quarter was very low compared to their catch in the first three quarters, the weighted mean values were close to those for the first three quarters. The weighted mean for Greenland trawlers did not differ much from observations of the mean weight at age in the non-trawl fisheries in the third quarter.

Observed mean weight at age in the trawl survey by the Federal Republic of Germany was lower for age groups 3-5 than in the Greenland samples, but higher for age groups 8-10. The former difference can be explained by differences in selectivity between gears, while the latter may be due to both geographical and temporal variations.

The overall mean weight (nominal catch/numbers caught) was 1.67 kg in 1985, virtually the same as in 1984 (1.65 kg).

A paper on size at age of cod from the Greenland trawl fishery in the period 1979-84 by Hovgård Hansen (to be presented to the NAFO Scientific Council at its June 1986 meeting) demonstrated a substantial decrease in size at age (15 and 45% reduction in length and weight at age, respectively) over that period. Mean size at age in this fishery generally declined further in 1985.

A reduction in size at age from 1984 to 1985 was also found in inshore and survey catches (Table 6.3.1 compared with similar data in Cornus et al.,1985). The decrease in weight at age in these catches was approximately 15-20%.

6.4 Maturity Ogives

Based on data from the groundfish survey in 1985, a maturity ogive was calculated (Figure 6.4.1). The ogive differs only slightly from the ogive previously used in the assessments which was based on data for 1983.

6.5 Groundfish Survey Results

The number of randomly distributed fishing stations occupied during the surveys from 1982 to 1985 amounted to 111, 153, 162 and 133, respectively. The results were based on 98, 142, 158 and 114 valid sets. The reduction in 1985 was caused by an unexpected loss of survey time. In order to compensate for that without diminishing the reliability of the survey results, the necessary

reduction in coverage of the survey area was restricted to NAFO Divisions 1B and 1C where cod biomass and abundance was extremely low in 1983 and 1984. In Divisions 1D-F, however, the coverage was improved compared with all previous years.

Cod biomass and abundance estimates for the total survey area off West Greenland of 19,864 nm^2 in 1982 and 1983 and of 20,133 nm^2 since inclusion of stratum 4 in 1984 and 1985 amounted to:

Year	Tonnes	Nos. ('000)
1982	179,934 ± 37.0%	109,039 ± 36.1%
1983	98,843 ± 28.5%	59,375 ± 26.5%
1984	24,945 ± 39.7%	16,110 ± 39.1%
1985	35,213 ± 68.7%	55,886 ± 34.7%

The confidence intervals are given at the 95% level of significance.

The 1982, 1983 and 1985 surveys were carried out by the R/V "Walther Herwig" in November-December and the 1984 survey by the R/V "Anton Dohrn" in October-November.

From 1982 to 1984, the survey results reveal a drastic decline in cod biomass and abundance which was observed not only for the whole survey area, illustrated in Figure 6.1.1, but for all divisions, as shown in detail in Table 6.5.1. Confirmation of the reduced stock size in 1983 and 1984 was also obtained by continuous echosounder recordings throughout the survey area and by the trends in commercial catch and effort (Figure 6.1.1). Although the commercial catch per unit effort continued to decline in 1985, the survey results obtained at the end of 1985 indicate a slight increase in biomass by a factor of 1.4, but a considerable increase in abundance by a factor of 3.5. The latter was mainly due to the extremely high abundance of 1- year-old cod (1984 year class) and even younger fish (1985 year class) never observed to this extent in previous surveys and accounting for 67% of the total abundance.

According to the 1985 survey results, the year classes predominating in numbers among age 4 and older cod were those of 1981 (43%) and 1979 (36%). The drastic decline of the 1977 year class continued throughout 1985, comprising less than 4% of age 4+ cod. The former good 1973 year class has now disappeared completely from West Greenland waters.

The recent changes in the age composition of the West Greenland cod stock are also clearly reflected in the length frequency distributions obtained from survey data by division and for the whole area for 1985 (Figure 6.5.1a-e) compared to those for the preceding years as shown for 1982-83 in Messtorff and Cornus (1984) and for 1984 in Cornus et al., (1985).

6.6 Future Recruitment

1982 year class

From survey results since 1982, the abundance of that year class in 1985 was the lowest on record for 3-year-old cod, and the previous, already reduced, recruitment estimate of 20 million fish may still be too high.

1983 year class

Survey data indicate somewhat higher abundance compared to the 1982 year class, but the differences seem to be only marginal. The proposed recruitment estimate of 20 million fish at age 3 may, therefore, be maintained.

1984 year class

The Icelandic O-group survey off East Greenland in August 1984 gave a very high abundance index of O-group cod, about 3 times that for the good 1973 year class (Table 3.1). O-group cod were also caught at West Greenland in the R/V "Anton Dohrn" bottom trawl survey in late October-November 1984. This was the first time that these surveys, carried out since 1982, showed occurrence of O-group fish.

The appearance of a good year class was confirmed by the survey results in November-December 1985. The very high abundance of 1-year-old cod all over the survey area off West Greenland gave a minimum abundance estimate of almost 37 million fish. However, as the small cod were still subject to gear selection and moreover to incomplete availability to the survey gear, their absolute abundance will be significantly underestimated. Echosounder traces frequently observed, throughout the survey area indicated, the presence of considerable numbers of small cod in mid-water layers.

1985 year class

The abundance index of 0-group cod off East Greenland from the Icelandic 0-group survey in August 1985 was the third highest observed since 1973, but considerably lower than those of 1973 and 1984 (Table 3.1). However, the abundance of 0-group cod estimated from bottom trawl survey results off West Greenland in November-December 1985 was 4 times higher than in 1984.

6.7 Variation on Estimates of Total Mortality (Z)

The variation on total mortality can be expressed as

$$\mathrm{Var}(Z) = \frac{\mathrm{Var}\ N_{beg}}{(N_{beg})^2} + \frac{\mathrm{Var}\ N_{end}}{(N_{end})^2}$$

where N_{beg} is the stock at 1 January and N_{end} is the stock at 31 December.

To get an idea of the size of the variation, Var(Z) from fully-recruited year classes (age 5+) from West Greenland during 1984 was calculated (Basic data: N_{beg}=54.283 ± 28.5%, N_{end}=10.933 ± 39.7%, where ± indicates 2 x standard deviations). This leads to:

$$Z = 1.602 \pm 0.489 = 1.602 \pm 30.5\%$$

It must be stressed, however, that the standard deviations on single year classes must be expected to be relatively higher than on the age 5+ year classes combined. The variation on Z of single year classes will, therefore, probably be higher than 30.5%.

6.8 Assessment Results (Table 6.7.1)

The stock in numbers at age at the end of 1985 was calculated from the abundance estimate of the November survey with 1/12 of the natural mortality and deducting the December catch in numbers at age. Total mortality (Z) was calculated from this estimate and the corresponding one from the 1984 survey for each age group.

The calculations show that the Z values for age groups 5 and 6 were -0.61 and 0.31, respectively, while Z on older ages was in the order of 1.0 or higher.

The total mortality estimates were apportioned to:

i) Natural mortality (0.2)
ii) Fishing mortality
iii) Emigration coefficient

The average fishing mortality in 1985 for ages 5-9 was estimated as 0.62, somewhat higher than in the previous year (0.49).

The indications of an immigration into the West Greenland area in 1985, referred to below, were not taken into account in the estimation of the fishing mortalities (Table 6.7.1). The estimates of fishing mortality on the 5- and 6-year olds might, therefore, be overestimates. General information on the fishing activity seems not to correspond with the estimated increase in fishing mortality from 0.5 in 1984 to 0.6 in 1985.

The estimated emigration coefficients are very different from the high values of 1984. High negative values were calculated for age groups 5 and 6 of -1.46 and -0.60, respectively, as the result of the higher abundance of these year classes in the 1985 survey.

There are two possible explanations:

(1) The abundance of these year classes was underestimated in the 1984 survey. This possibility would also explain part of the reasons for the high unexplained losses estimated in the 1985 assessment (Cornus et al., 1985).

(2) Cod of these year classes have joined the stock during 1985, either as additional recruitment in the West Greenland area or from East Greenland. The latter hypothesis finds some support from preliminary results of otolith-type studies which indicate that, out of the number of fish caught in the 1985 survey, 28% and 23% of the 1980 and 1979 year classes, respectively, may have spent at least the year 1984 in East Greenland waters. Although the results of this program are very preliminary in quantitative terms, they can still be considered as evidence that such a migration occurs.

For the older age groups (7-9), the emigration coefficient was in the order of 0.4 which is close to the value assumed for 1985 in last year's assessment.

The emigration coefficients referred to above are associated with about 6.7 million fish of ages 5 and 6 joining the stock in 1985 and about 0.6 million older fish emigrating. This order of magnitude is not inconsistent with the results of the assessment of the East Greenland stock which indicates that a relatively small number of cod (0.8 million) immigrated to that stock from West Greenland.

As stated already in last year's assessment of the West Greenland cod, much of the variation in the Greenland cod stock size and distribution can be attributed to the overall temperature regime. The water temperature in both 1983 and 1984 showed strong negative anomalies, and the mass migration out of the Greenland area might be related to it. This situation has reverted to slightly positive anomalies in 1985 (see Section 4). Assuming that the 1985 situation also prevails in 1986 would probably justify to assume a lower emigration rate for that year. Based on these considerations, the emigration rate for 1986 was assumed to be at a level of 0.05 in 1986 at West Greenland, the value derived from earlier tagging experiments.

Spawning stock biomass declined from the high level at the beginning of the 1960's to very low levels in the mid-1970's. This trend has reverted after 1976 when the very abundant 1973 year class reached spawning size. However, the slight recovery of the spawning stock was terminated mainly due to emigration during 1983 and 1984.

The survey results show no significant improvement from 1984 to 1985, and inshore catches, as well as CPUE of Greenland trawlers, declined further in 1985. Therefore, it has to be concluded that the exploitable biomass at West Greenland is now at a very low level.

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Table 3.1 Abundance indices of 0-group cod from the international and Icelandic 0-group survey in the East Greenland/Iceland area, 1971-85 (except 1972).

Year class	Dohrn Bank East Greenland	SE Iceland	SW Iceland	W Iceland	N Iceland	E Iceland	Total
1971	+	-	-	60	214	-	283
1973	135	10	107	96	757	86	1,191
1974	2	-	-	22	30	+	54
1975	+	-	2	50	73	5	130
1976	5	9	30	102	2,015	584	2,743
1977	7	2	+	26	305	94	435
1978	2	-	+	169	335	47	552
1979	2	+	1	22	345	+	370
1980	1	2	+	38	507	10	557
1981	19	-	-	41	19	-	78
1982	+	-	+	7	4	-	11
1983	+	-	+	85	66	2	153
1984	372	5	+	200	826	369	1,772
1985	32	+	+	581	197	2	812

Table 5.1.2 Strata areas in square nautical miles off West Greenland (NAFO Subarea 1).

Depth zone (meters)	Division/Stratum number							Total (nm^2)
	1B	1C	1C	1 C/D	1D	1E	1F	
	1	2	3	4	5	6	7	
0-100	865	593	598	0	1,475	276	+	3,807+
101-200	1,256	1,574	1,902	17	875	1,662	+	7,268+
0-200	2,121	2,167	2,500	17	2,350	1,938	2,568	13,661
201-300	297	259	708	29	628	464	+	2,385+
301-400	209	54	280	45	390	278	+	1,256+
201-400	506	313	988	74	1,018	742	971	4,612
401-500	149	122	156	60	176	33	+	696+
501-600	215	293	78	118	83	24	+	811+
401-600	364	415	234	178	259	57	353	1,860
Total	2,991	2,895	3,722	269	3,627	2,737	3,892	20,133

Table 6.1.1 Nominal catches of cod in NAFO Subarea 1 (1975-85).

Country	1976	1977	1978	1979	1980
Faroe Islands	3,460	7,346	-	38	-
Fed.Rep. of Germany	5,842	2,609	1,057	1,344	1,024
France - M	-	-	-	139	-
Greenland	16,282	24,220	37,420	46,384	45,838
Japan	-	-	-	-	-
Norway	2,825	1,683	4	-	-
Portugal	2,495	1,052	-	-	-
Spain	2,090	-	-	-	-
United Kingdom	155	-	-	-	-
USSR	137	1,086	-	-	-
Total	33,286[a]	37,996[a]	38,531[a]	47,905[a]	46,862[a]
Estimate of the Working Group	-	73,000	73,000	99,000	54,000

Country	1981	1982	1983	1984	1985[d]
Faroe Islands	-	-	1,339	-	-
Fed.Rep. of Germany	417	8,139	10,160	8,941	2,185
France - M	-	-	-	-	-
Greenland	53,039	47,693	50,659	22,041	10,750
Japan	-	-	-	13	-
Norway	-	-	-	5	-
Portugal	-	-	-	-	-
Spain	-	-	-	-	-
United Kingdom	-	-	-	-	-
USSR	-	-	-	-	-
Total	53,456[a]	55,832[a]	62,158[b]	31,000[c]	12,935
Estimate of the Working Group	-	-	-	-	-

[a] ICNAF/NAFO Statistical Bulletin.
[b] NAFO SCS Doc. 84/VI/22.
[c] NAFO SCS Doc. 85/25.
[d] Provisional data.

Table 6.1.2 NAFO Subarea 1 cod. Nominal catch in 1985 (provisional figures) in tonnes Pound net catches are estimated for Division 1B as being 3/4 of the total miscellaneous gear catches June-September. For Divisions 1C-1F, the pound net catches are estimated as being 3/4 of the miscellaneous gear catches June-September plus 3/8 of those in October. A part of the Greenland otter trawl catches (2,453 tonnes) is reported by month only and is allocated to Divisions 1E and 1F in proportion to the Greenland trawl catches reported for these divisions. Catches reported as gill net catches are minimum figures for that gear.

Division	Otter trawl offshore	Gill net inshore and offshore	Miscellaneous gear inshore and offshore	Pound net inshore	Total
1A	-	-	82	-	82
1B	-	63	644	675	1,382
1C	-	27	474	339	840
1D	138	123	631	1,160	2,052
1E	4,075	4	410	767	5,256
1F	2,199	130	380	614	3,323
Total SA 1	6,412	347	2,621	3,555	12,935

Table 6.1.3 NAFO Sub-area 1 cod. Nominal catches 1985 (provisional figures, and no information on Greenland small-boat catches for December) per month and division.

Month	1A	1B	1C	1D	1E	1F	1NK	Total SA 1
Jan	6	21	2	9	571	837	205	1,651
Feb	1	28	6	15	-	749	-	799
Mar	-	49	11	4	20	246	478	808
Apr	2	62	26	44	427	134	750	1,445
May	-	228	256	186	243	67	124	1,104
Jun	6	477	256	212	156	43	179	1,329
Jul	11	349	100	297	74	39	265	1,135
Aug	10	37	9	610	612	119	452	1,849
Sep	13	37	35	406	565	510	-	1,566
Oct	26	72	104	246	170	253	-	871
Nov	7	22	35	23	63	55	-	205
Dec	-	-	-	-	(149)	(24)	-	(173+)
Total	82	1,382	840	2,052	3,050	3,076	2,453	12,935+

Table 6.1.4 Nominal catches of NAFO Subarea 1 cod for 1975-84 ('000 tonnes)

Category	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Trawlers	28	19	46[c]	53[c]	57[c]	16	14	29	42	18	6[d]
Other vessels	20	14	27	20	42	38	39	26	21	12	7[d]
Total	48	33	73[c]	73[c]	99[c]	54[c]	53	55	63	30	13[d]
TAC's	51[b]	45[b]	31[b]	-[a]	-[a]	20[a]	50[a]	62	62	68	28.5

[a] Catches limited to Greenlander's fishery and to by-catches.

[b] Quota for offshore fishery only.

[c] Estimates used for stock assessments.

[d] Provisional data.

Table 6.1.5 NAFO Subarea 1 cod. Effort (hours fished) and catch per unit effort (CPUE = kg/hour) for Greenland trawlers (500 - 999 GRT class) in 1975-84. Only figures for directed cod fishing are used.

Year	1B		1C		1D		1E		1F		Total SA 1	
	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE
1975	1,132	57	6,666	1,467	4,896	293	3,154	422	243	346	16,091	789
1976	236	38	5,071	594	5,912	541	6,319	753	-	-	17,538	626
1977	-	-	2,432	1,019	1,531	986	3,446	1,584	121	2,421	7,530	1,293
1978	-	-	3,562	3,314	815	2,962	873	3,743	70	3,029	5,320	3,327
1979	-	-	2,983	2,155	1,163	3,083	365	1,948	9	2,667	4,520	2,378
1980	727	2,461	1,513	1,088	1,983	892	1,092	1,277	31	613	5,346	1,238
1981	-	-	1,279	3,326	1,856	2,533	952	4,602	5	-	4,092	3,259
1982	100	1,330	1,937	2,077	4,084	1,760	3,221	2,903	17	647	9,359	2,212
1983	927	315	593	948	4,039	984	6,295	1,808	114	982	11,968	1,364
1984	51	20	19	+	1,926	1,004	2,248	1,055	317	584	4,561	985
1985[a]	10	-	3	-	373	370	2,028	752	113	982	2,514	699

[a] Provisional data.

Table 6.2.1 Cod off West Greenland.

CATCH IN NUMBERS UNIT: thousands

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
3	1530	1727	3764	662	49	272	51	131	343	275	10760	634
4	7872	15091	7976	12599	2768	2519	10059	2302	1079	3595	4026	46649
5	62130	30457	36670	3709	10542	10172	9780	10378	2384	2677	2243	6053
6	20941	61848	29824	27435	6465	9283	12020	5065	6958	1803	1210	1515
7	5915	24562	34591	14064	13985	5237	4081	2605	1135	5855	302	618
8	4955	2700	10005	12411	4365	9158	2550	1406	1806	1588	1594	425
9	3912	1990	1725	4784	2810	2077	2000	1203	500	619	139	446
10	1269	5237	835	515	1250	1841	624	552	194	291	148	168
11	253	352	2348	237	149	953	954	165	177	84	53	79
12	130	95	107	704	65	76	709	237	152	58	27	88
13	931	166	37	41	201	51	130	93	272	9	17	22
14	139	455	42	62	27	134	57	37	147	12	14	1
15+	247	85	303	8	41	56	122	44	11	10	26	1
TOTAL	119324	144767	128305	82627	42567	41351	43783	28218	15458	16656	20565	56699

	1978	1979	1980	1981	1982	1983	1984	1985
3	287	286	2999	12	1204	77	595	0
4	5494	10656	4513	10864	1219	12356	2018	652
5	30039	12505	4580	6374	17960	2011	10384	1155
6	1004	18970	1978	2391	2965	17228	6886	4899
7	509	709	8014	1053	2078	1581	3656	225
8	83	400	125	3382	607	995	1006	666
9	41	78	60	45	610	344	365	28
10	13	52	24	65	45	343	97	100
11	7	55	1	1	88	3	69	13
12	7	80	16	1	9	22	0	8
13	7	5	3	0	4	0	3	0
14	1	5	1	0	1	2	0	0
15+	1	16	2	7	13	19	0	5
TOTAL	37493	43817	22316	30195	26994	34981	17981	7751

Table 6.3.1 Mean weight at age in the main fisheries at West Greenland in 1985 (kg whole, round fish). Figures in brackets indicate that less than four fish were weighted.

	Greenland trawlers			FRG survey	Greenland excl. trawlers
Age	Quarters 1-3 (unweighted)	Quarter 4	Overall (weighted by quarterly catches)	Nov - Dec (obs)	Quarter 3
3	-			0.19	-
4	(0.90)	1.26	0.97	0.67	0.78
5	1.19	1.81	1.20	0.98	1.05
6	1.65	2.36	1.66	1.61	1.60
7	2.21	2.70	2.27	2.64	2.14
8	2.61	3.98	2.61	4.50	2.80
9	(3.46)	(3.57)	(3.97)	4.68	3.82
10	4.19	(6.71)	(4.19)	5.53	4.16

Table 6.5.1 Results of the West Greenland (NAFO Subarea 1) trawl survey for cod conducted by the R/V "Walther Herwig" in November-December 1985, including the age composition by division.

Year class	Age	1B+C		1D		1E		1F		Total				
		No.x10^{-3}	Tonnes	No.x10^{-3}	Tonnes	No.x10^{-3}	Tonnes	No.x10^{-3}	Tonnes	No.x10^{-3}		± %	Tonnes	± %
1985	0	124	-	170	-	146	-	462	-	902	(1,080)	-	-	-
1984	1	18,311	-	9,343	-	4,788	-	4,146	-	36,588	(30,612)	-	-	-
1983	2	478	-	277	-	150	-	113	-	1,018	(942)	-	-	-
1982	3	230	-	336	-	49	-	13	-	628	(1,319)	-	-	-
1981	4	124	-	1,180	-	4,444	-	1,529	-	7,277	(8,189)	-	-	-
1980	5	71	-	1,950	-	304	-	109	-	2,434	(3,865)	-	-	-
1979	6	53	-	3,215	-	1,987	-	832	-	6,087	(8,647)	-	-	-
1978	7	-	-	88	-	69	-	135	-	292	(397)	-	-	-
1977	8	18	-	199	-	170	-	248	-	635	(805)	-	-	-
1976	9	-	-	-	-	4	-	17	-	21	(20)	-	-	-
1975	10	-	-	-	-	-	-	4	-	4	(10)	-	-	-
Total		19,409	2,368	16,758	14,236	12,111	12,297	7,608	6,312	55,886	(55,886)	34.69	35,213	68.67

Note: The age compositions for Divisions 1B+C and 1D were obtained using an age/length key from those three divisions, and the age compositions for Divisions 1E and 1F were based on an age/length key from those two divisions. The numbers in parentheses under the total are based on an overall age/length key.

Table 6.7.1 NAFO Subarea 1 cod. Assessment table 1985.

Age	Year class	Stock size		Z	F	1985 catch	M	E	Losses due to	
		1 Jan* (A)	31 Dec (B)	(C)	(D)	(E)	(F)	(G)	M (H)	E (I)
5	1980	1,286	2,367	-0.610	0.652	1,155	0.2	-1.462	354	-2,590
6	1979	7,994	5,873	0.308	0.710	4,899	0.2	-0.602	1,376	-4,145
7	1978	716	282	0.932	0.483	225	0.2	0.249	93	116
8	1977	1,901	610	1.137	0.587	666	0.2	0.351	227	398
9	1976	80	20	1.386	0.647	28	0.2	0.531	9	23
10+	<1976	242	2	4.796	2.518	126	0.2	2.078	10	104
Total	5+	12,177	9,154	0.285	0.669	7,099	0.2	-0.584	2,119	-6,195
Total	6+	10,933	6,787	0.477	0.684	5,944	0.2	-0.407	1,739	-3,537

*From 1984 survey.

Age	Year class	Survey stock	Catch Dec
5	1980	2,434	27
6	1979	6,087	114
7	1978	292	5
8	1977	635	15
9	1976	21	1
10+	<1976	4	2

Steps in the calculations:

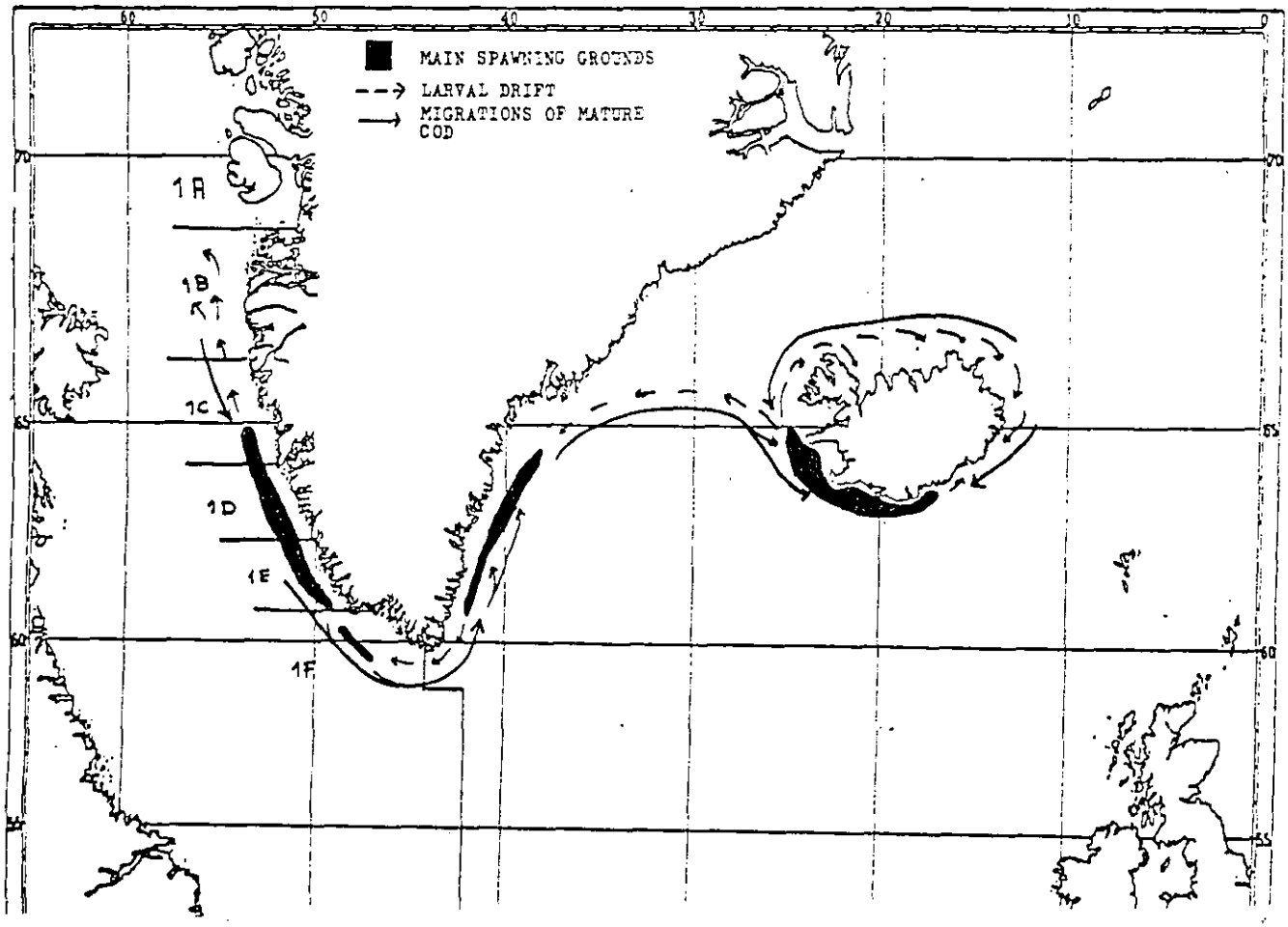
1. Calculation of col. (B) from 1985 November survey estimate
2. Calculation of Z: ln[(A)/(B)]
3. Calculation of col. (H): (A) x 0.2/Z(1 - exp-Z)
4. Calculation of col. (I): (A) - (B) + (E) + (H)
5. Calculation of cols. (D) and (G): Allocation of Z proportionally to cols. (E), (H), and (I).

Table 6.1.2 West Greenland cod. Estimated number of emigrants from West to East Greenland.

Age	Survey stock size 1 Jan 1986	No. of emigrants E = 0.05	E = 0.15	E = 0.30
6	2,367	114	324	604
7	5,873	282	805	1,499
8	282	14	39	72
9	610	29	84	156
10	20	1	3	5
11+	2	-	-	1
Total	9,154	440	1,255	2,337

Assumption: Emigration takes place before the main fishery starts (i.e., in the first two months of 1986). Therefore, no F and M of 0.033 is applied in the calculations.

Figure 3.1 Main spawning grounds, migrations of mature fish and larval drift of the cod stocks at West Greenland, East Greenland and Iceland.



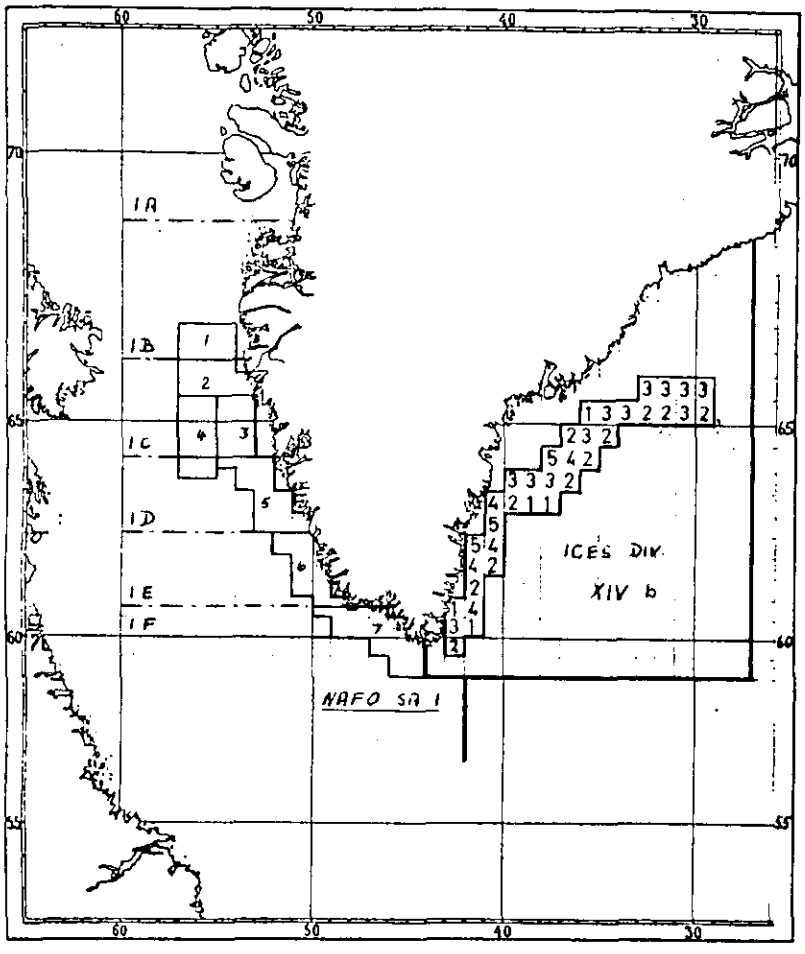


Figure 5.1 Survey areas and stratification off East and West Greenland. Numbers off East Greenland indicate the stratum to which the rectangles are allocated.

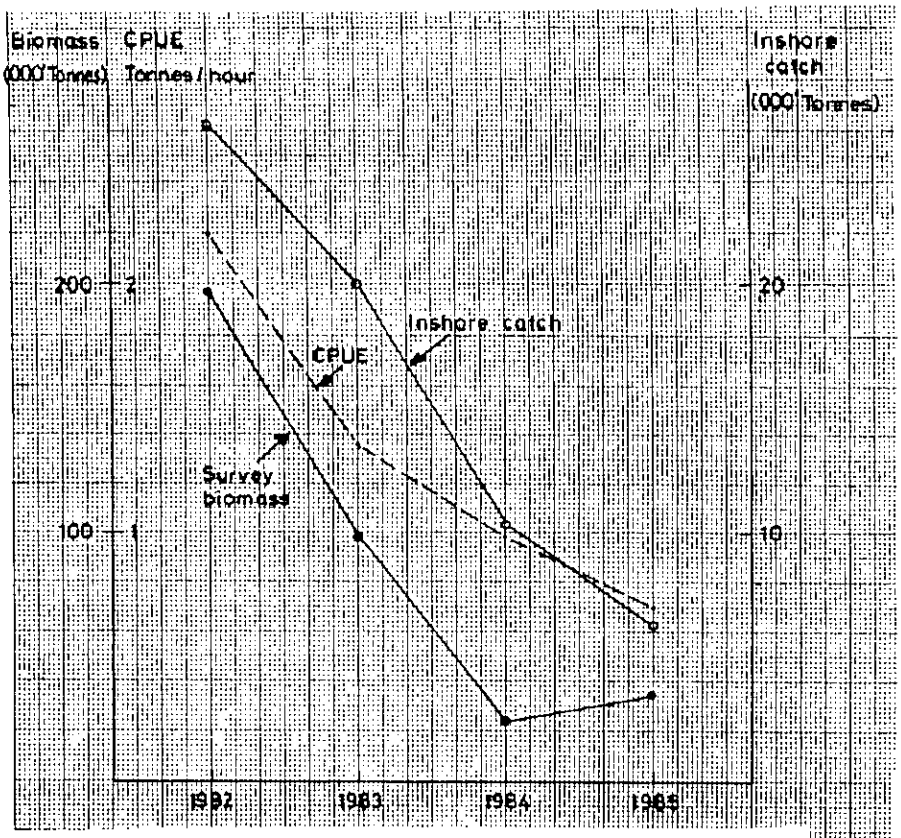


Fig. 6.1.2. Cod - West Greenland. Trends in the total survey biomass, CPUE of Greenland trawlers and inshore catches, 1982-85.

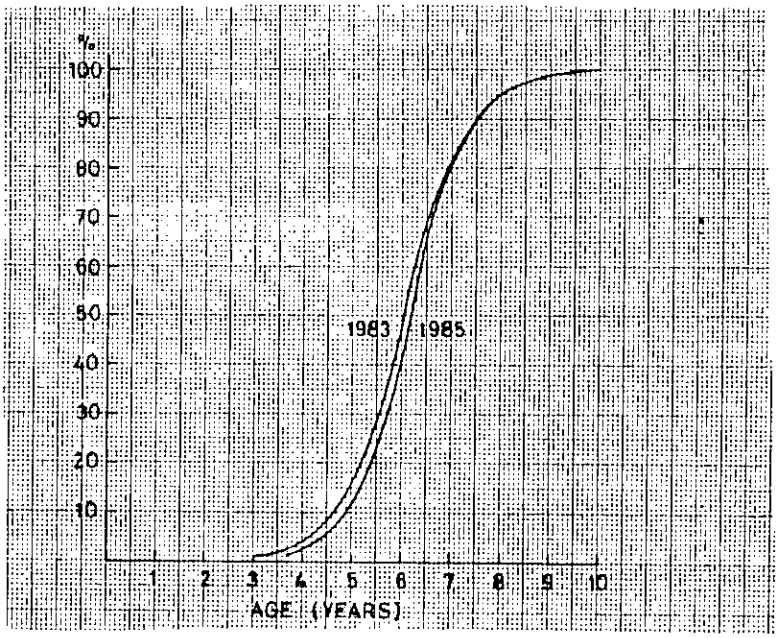
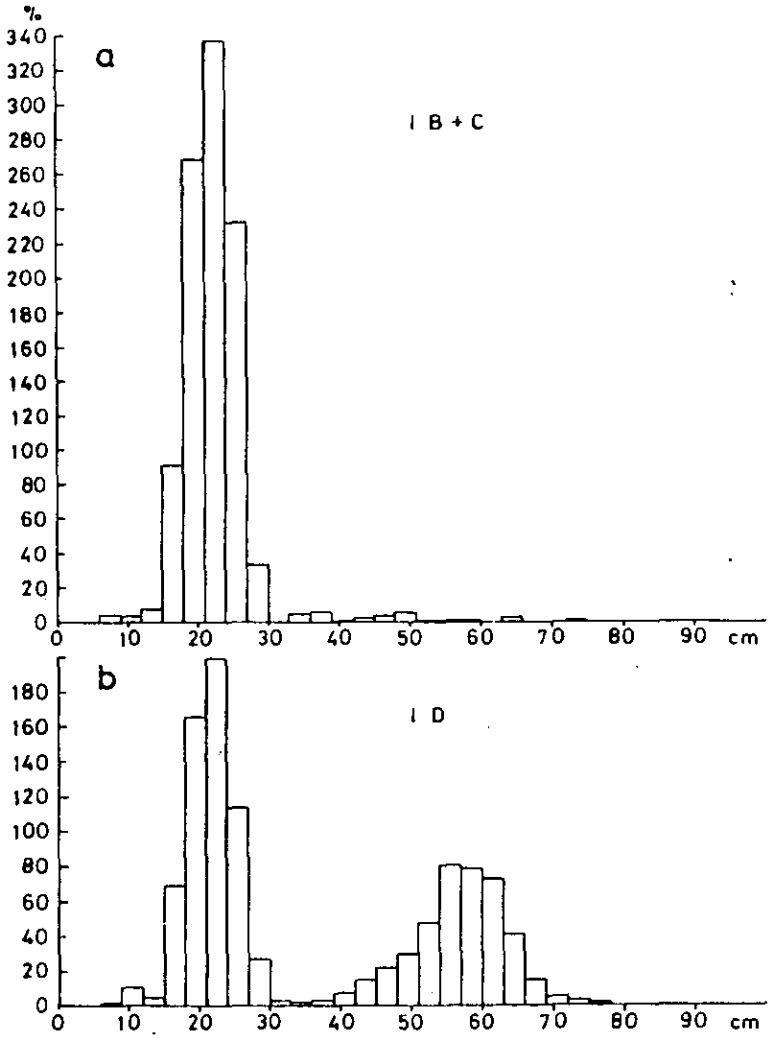
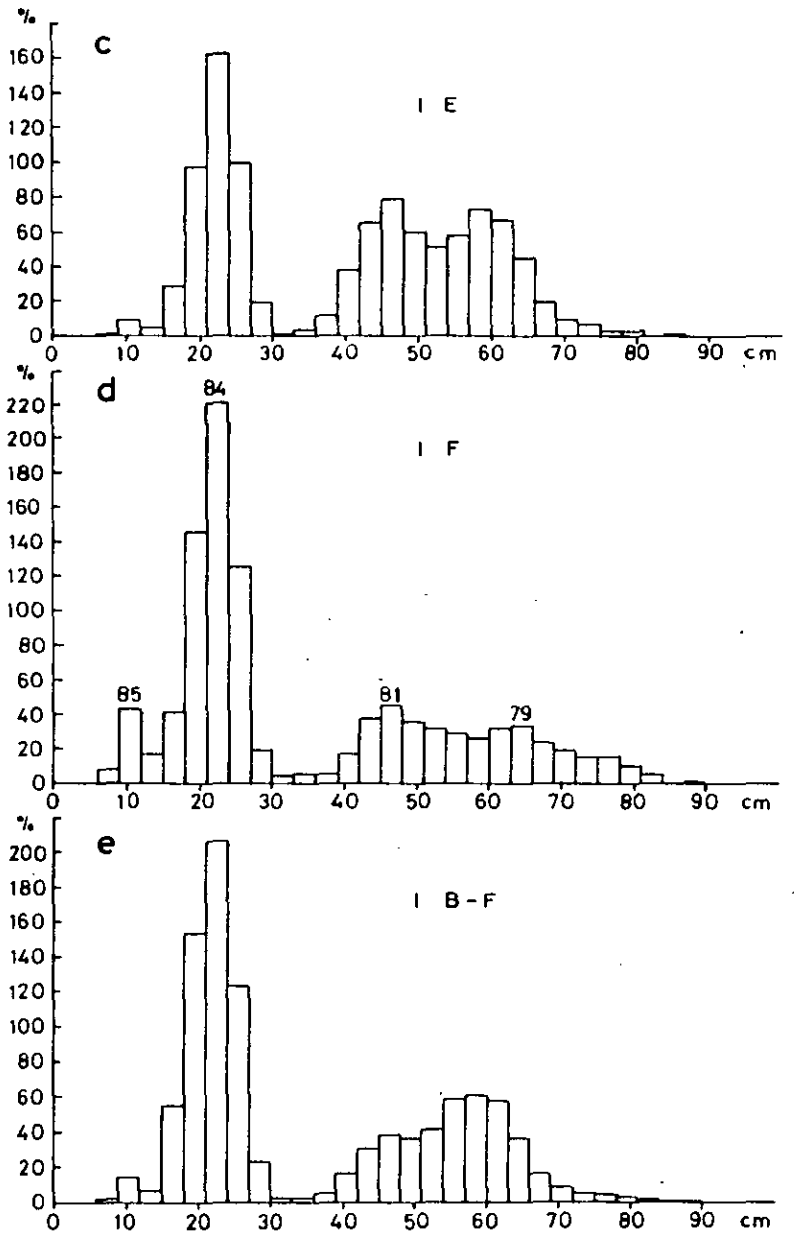


Fig. 6.4.7. West Greenland cod: % maturity at age.

Figure 6.5.1 Length distribution of cod by NAFO divisions, from the groundfish surve, in West Greenland waters in 1985.





APPENDIX 1: METHODS USED IN THE ASSESSMENTS OF GREENLAND COD

1.1 Introduction

The assessments of the cod in both East and West Greenland are based on groundfish surveys undertaken by the Federal Republic of Germany in the last months of the year. The groundfish survey is virtually one survey covering both the east and the west side. There is information available on the catches in addition to the survey data. Further, there are historic data on emigration rates, but not for the recent years. In spite of the similarity between the data available on the eastern and the western sides, the calculations are different. A description of the two different approaches is given below.

1.2 Calculations of Stock Size, Fishing Mortality and Total Mortality

For the years 1980-85, groundfish survey estimates of fishable stock in numbers by age are available. The estimates are absolute estimates, based on the swept-area concept.

The calculations are then done in the following way:

West Greenland	East Greenland
$Z = \ln N(a,beg)/N(a,end)$	$Z(a)=M(a) + E(a) + F(a)$ [1]
$F(a)=C(a) \times Z(a)/[(N(a,beg) - N(a,end)]$	$F(a)=C(a)/N(a,end) \times Z(a)/(1 - \exp[-Z(a)])$
$E(a)=Z(a) - F(a) - 0.2$	$E(a)=Z(a) - F(a) - 0.2$

Note: [1] a refers to age, beg is 1 Jan., end is 31 Dec.

E(1-5) = 0, E(7+) equals 0.29, M(a) = 0.2. These values are used in the iterative solution for the next equation giving F. The difference between the two approaches is, thus, that in the West Greenland case, Z(a) is estimated from two succesive surveys and no assumptions are made on E(a), where in the East Greenland case, only the last survey is used, and E(a) is assumed known and constant for each age group.

1.3 Reason for Different Approaches

The reasoning behind the two different approaches is the difference in the stock situations in the two areas.

At West Greenland, migration is assumed, but it does not lead to major fluctuations during the course of a year.

At East Greenland, old tagging data indicate that, in some years and affecting some year classes, massive migrations to Iceland can take place and immigration from West Greenland can also be significant. The comparison of two surveys may not tell us much about the stock situation in the course of a year.