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Is the West Greenland Cod Mainly Recruited from Icelandic Waters? An Analysis Based on the Use of Juvenile Haddock as an Indicator of Larval Drift

by

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Abstract : Haddock are only infrequently observed in West Greenland waters and always in low quantities, and are not believed to spawn off Greenland. Unusual amounts were, however, recorded off both East and West Greenland during 1985, and this is taken as an indication of a current drift from Iceland to West Greenland that year. Data from the last 15-20 years indicate that larger inflows of haddock have probably only occurred twice in that period, and data on cod show a similar infrequent rate of inflow in the same period. These trends are discussed in relation to hydrographic conditions and 0-group distribution and it is argued that the recent near-collapse of the West Greenland cod stock might have been caused by a cessation of frequent larval drifts from Iceland to West Greenland.

Introduction

During the latest two decades the annual catches of Cod (Gadus morhua) at West Greenland have declined from more than 300.000 tons to the pressent low level of less than 10.000 tons. This decline can be attributed mainly to failures in recruitment (Buch & Hansen, 1986). The West Greenland cod is assumed to be recruited partly from Greenland waters and partly from Icelandic areas - the relative proportions not beeing known.

Haddock (Melanogrammus aeglefinus), on the contrary, shows infrequent occurrence and low abundance at West Greenland and spawning is not believed to take place in the West Greenland area.

However, during the stratified-random bottom trawl surveys, conducted by the Federal Republic of Germany in autumn 1985 off East and West Greenland a remarkable abundance of juvenile haddock (0- and 1-group fish) was observed in both areas. This information was interesting as the survey also showed a very high abundance of the same year-classes of cod.

The purpose of this study is to present various data on haddock distribution and try to evaluate the frequencies and magnitudes of larval/juvenile drift of cod and haddock from Iceland to West Greenland.

2 Occurrence of haddock in Greenland Waters

Four data sources have been used in the evaluation of the occurrence and distribution of haddock in the Greenland area: 1) Trawl surveys, conducted by the Federal Republic of Germany (1982-86), 2) Research trawlings, conducted by Greenland (1968-86), 3) Historical information and catch statistics (1920-86) and 4) Information on haddock 0-group distribution in the Iceland-East Greenland area from Icelandic young-fish surveys (1971-86).

Bottom trawl survey data

Annual stratified-random bottom trawl surveys covering Southeast and Southwest Greenland (fig. 1). have been carried out by the Federal Republic of Germany since 1982. Details on survey design, effort etc. are given elsewhere (Anon. 1986).

Haddock catches from these surveys are shown in Table 1. Off both East and West Greenland the number caught increased remarkcably in 1985 (approximately 30 times) compared to the previous three years.

The length frequencies of haddock caught in 1985 and 1986 are given in tables 2 and 3 and are shown in figure 2. The corresponding age compositions are presented in table 4. The haddock catches were dominated exclusively by the 0- and 1-group fish in 1985 and by 1- and 2-group fish in 1986 (year-classes 1984 and 1985, respectively). Such young fish were practically absent in catches of the 1984 and earlier surveys.

In 1985 and 1986 haddock occurred in all areas off East Greenland whereas their distribution off West Greenland was restricted to Divisions 1 C-F with abundance decreasing from south to north. In none of the survey areas haddock did occur below 400 m. Indices of total survey abundance for 1985 off East Greenland and southern West Greenland (Div, 1D-F) for the depth range 0-400 m. are given in table 5. Compared to cod, haddock abundance at West Greenland was very low as the 1985 survey abundance of haddock were less than 1 percent of the concurrent abundance of 1-group cod alone.

Greenland research trawlings

Research trawlings, have been carried out off West Greenland since 1968. The effort has generally been rather limited and the area coverage varied substantially between years (table 6). A shrimp trawl (mesh size in cod end 18-21 mm) has continuously been used.

Catches of haddock have been very low, totaling only 26 specimens. In this period haddock was caught only between 1975 and 1979 and in 1986 (Table 6). Only 1 haddock was found north of Div. 1D and none were taken below 310 m. No age readings have been made but by using the age-length key in table 4 and assuming a growth pattern as found for cod (i.e. a very low growth during the first two quarters) the most likely age of the haddock can be estimated (table 7). By this procedure the haddocks in the 1970's (except one) can be attributed to the 1974 year-class whereas the catches in 1986 belong to the 1984 and 1985 year-classes.

Historical Information

The first specimen of haddock in Greenland Waters was reported from the Cape Farwel area in 1929 and in the following years haddock were observed from time to time at West Greenland from Nanortalik to Disko Bay (Jensen, 1948, Hansen,1949). In 1945 it is noted that haddock is taken frequently in the cod fishery (Vibe, 1945).

Some catches are indicated in the 30'ties and 40'ties (loc. cit.) but catch statistics are available only since 1952. (Table 8). In this period the reported annual landings were generally less than 100 tons, and in the last 10 years they have been close to nil. Compared to the concurrent cod catches these catch figures are small (less than 1 per thousand).

When scrutinizing the catch statistics it is peculiar that some of the countries with an important cod fishery in the area reported haddock very infrequently. It seems quite possible that the small amounts of haddock in some fisheries have never been recorded. In the 1950'ies and 60'ies some discardings might also have taken place as a large fraction of the fleet produced salted fish at sea. For this fleet haddock was of no interest when large cod were abundant (K. Hoydal, pers. comm). In general, therefore, the reported landings probably underestimate the actual catch, especially in the early years.

Information on juvenile haddock in the Iceland-East Greenland area

At Iceland haddock spawn in the area around the Reykjanes peninsula in May-June (Olafsson, 1985). The 0-group distribution in August is known from Icelandic 0-group pelagic trawl surveys, which have been carried out in Icelandic and East Greenland waters since 1971 (Vilhjalmsson and Fridgeirsson,1976; Vilhjalmsson & Magnusson, 1985). In this period the main area of distribution was found in coastal areas off West and North Iceland (fig. 3). 0-group haddock have only rarely been seen in East Greenland waters (1974, 1979, 1980, 1984 and 1985) and when so, always in very small quantities.

4. Discussion

No indication of spawning of haddock has ever been reported at West Greenland, and the infrequent and limited ocurrence of haddock does not suggest the existence of a spawning population in West Greenland waters. The findings of small haddock in Southwestern Greenland waters therefore lead to some simple interpretations of the relationship between currents and young-fish dispersion in the Iceland-Greenland area.

Most obviously it documents a larval/young-fish drift from Iceland to West Greenland.The occurrence of young-fish in a survey off West Greenland in November indicate that a distance of approximately 2000 km must have been made in about 6 month corresponding to a mean transport velocity of 10 to 15 cm per sec.

The direction carried and the transport velocity are in good agreement with current patterns in the Irminger Sea area. Two currents are of importance in the area : the East Greenland Current of polar origin and the warm saline North Atlantic Current which gives rise to the Irminger Current turning towards East Greenland and to the North Icelandic Current flowing north around Iceland (fig. 4). Both the Irminger and the East Greenland Current flow in a clockwise direction throughout the year, thus moving water from the Irminger Sea towards West Greenland, but the relative intensities vary over the year. Peak intensities of the Irminger current, which sweeps over the haddock spawning grounds, is found in the Irminger Sea around May-June, at Cape Farewell in October and off Nuuk in November, whereas the East Greenland current dominates in the area during spring and summer (peak intensities at the Dohrn Bank in March and off Nuuk in June). Estimates of peak intensities range from about 0.2 to 0.4 m per sec. (Hansen & Buch, 1986).

Within the last two decades there is evidence of only two years where haddock were carried from Iceland to West Greenland i.e. in 1974 and 1985. This indicates that current conditions ,enabling a drift of young haddock from Iceland to Greenland, have been rare in this period.

In the same years it is believed that at least three year-classes of cod have been carried from Iceland to West Greenland, viz. the 1973, 1984 and 1985 year-classes (Anon., 1987). The Icelandic cod spawns in the same area as the haddock but at an earlier date, March to May (Jonsson, 1982). In August the majority of the 0-group cod is found north of Iceland . However, in some years considerable numbers were found in the East Greenland area (fig. 5). Highest numbers were found in 1984 and 1973 with smaller amounts seen in 1985 and 1981 (fig 6).

The difference in distribution of 0-group cod and haddock is probably related to difference in spawning time giving cod a

higher probability of being carried off to Greenland. This might also explain why there is no perfect relation between year-classes of cod and haddock carried off to Greenland. In spite of this one may conclude that in the two latest decades there is evidence of only a few years with a considerable 0-group flux of either cod or haddock from Iceland to Greenland.

During the same two decades the West Greenland cod catches declined from more than 300.000 tons annually to the present level of less than 10.000 tons. Although some overfishing may have taken place during these years the stock decline is caused mainly by recruitment failure (fig 7). In the periode 1953 to 1963 the mean number of recruits, measured as number of 3-year old cod by virtual population analysis (Hansen & Buch, 1986), were approximately 275 million as compared to approximately 65 millions in the 1964 to 79 period. Within the latter period the largest year-class (1973) presumably was of Icelandic origin and the same goes for the present very promising year-class of 1984. A natural hyphothesis is, therefore, that the general poor recruitment in the two latest decades is caused by an infrequent drift of young cod from Iceland to Greenland, and that the previous good recruitment were caused by large and frequent drifts in earlier years.

Temperature and salinity observations indicate a marked change in overall hydrographic conditions both off Iceland and off West Greenland in the mid 60'ies, i.e. at the time when cod recruitment started to fail at West Greenland. For the Icelandic area Malmberg (1986) shows that Atlantic water dominated in spring from 1924 to 1964, in 1972 to 1974, in 1980 and in 1984 to 1985 whereas the intermediate years could be characterized by polar influence. In West Greenland a period with marked positive temperature anomalies was found from the early 20'ies until the late 60'ies (fig 8). Since then, periods of cooling (1969-72, 1978, 1982-84) have alternated with warmer periods (1973-77, 1979-81, 1985-86) (Buch, 1985). These changes in overall hydrographic conditions in the Greenland-Iceland area are probably related to macro climatical changes in the Northern Hemisphere (Malmberg & Svansson, 1982). If these changes have resulted in a general weekening of the Irminger Current then this could simultaneously explain a lowering of temperatures off Iceland and Greenland and a decrease in larval drift from Iceland to Greenland.

It is well documented that cod were almost absent at West Greenland during the first decades of this centuary and then, relatively sudden occured in increasing quantities during the 20's. The availible data suggest that an invasion of cod from Icelandic waters took place during these years. (Harden Jones, 1968). It is possible that these first cod colonized the West Greenland waters and established a selfsustaining cod stock utilizing a vast area now beeing available due to an improvement in environmental conditions. However, the findings of haddock also in the 30'ies and 40'ies may indicate that this period was characterized by frequent and large drifts of young cod and haddock from Iceland to West Greenland.

If the West Greenland cod is recruited mainly from Iceland what then becomes of the eggs spawned off West Greenland? Mature prespawning cod are found all around the southern parts of Greenland during spring and cod eggs and larvae are found widely distributed off West Greenland (Jensen, 1925, Hansen, 1949,1954 and 1968). Larval surveys carried out by Greenland since 1953 have shown that the area of highest abundance is found in NAFO Div. 1C.

The fate of these larval cod are not known. In a current/drift context the most important factors would be transport speed and the length of time subjected to the currents. Direct measurements off West Greenland as well as indirect estimations of current velocities from geostrophic calculations indicate mean velocities of about 0.2 m per sec. during the summer period (Hansen & Buch, 1986). If conservatively choosing a transport speed of just 0.1 m oer sec. and a dermersal setteling time as early as september a length of drift of approximately 500 km is reached. This would carry the larvae up to either Umanak in West Greenland (71 deg. NL) or to the northern pact of Labrador. Thus a choice of resonable modest drift values could easily carry cod larvae from the most important larval distribution area far away from the area inhabited by larger cod in West Greenland.

6. Conclusions

Data on young cod and haddock distribution and abundance indicate that a larval drift of these species from Iceland to Greenland has occured only infrequently during the last two decades. It is well possible that more frequent drifts occurred in ealier years and that the recent near-collapse of the cod stock off West Greenland is due to a cessation of frequent inflows of young cod from the Icelandic area.

However, the evidence for such conclusions is based on rather indirect information. For the historic period a better understanding might be achieved by trying to develop a model relating surface currents to meteorological observations as done by Laevastu et al (1986) in the North Pacific. For the future years direct mesurements of currents should be promoted in the Greenland area and surveys for young fish should be initiated. A pilot survey for young fish is planned by the Grenland Fisheries and Invironmental Research Institute this fall.

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Table 1. Total numbers of haddock caught during recent bottom trawl surveys off East and West Greenland.

	East Greenland			West Greenland			
Year	n	lenght range (cm)	mean length (cm)	n	length range (cm)	mean length (cm)	Divisions of occurrence
1982	12	32-54	44.58	9	21-76	38.5	1 D-F
1983	59	27-74	42.15	4	35-55	42.25	1 D-F
1984	0	-	-	5	12-42	18.7	1 F
1985	749	09-47	20.3	180	10-26	16.34	1 D-F
1986	815	12-57	23.13	106	16-35	23.28	1 C-F

Table 2. Combined length frequencies of haddock contained in bottom trawl survey catches off East and West Greenland in autumn 1985.

	East Greenland		West Greenland					
			Divisions				1D-F	
	TOTAL	o/oo	1C	1D	1E	1F	TOTAL	o/oo
n	749	1000	0	23	74	83	180	1000
8- 9	1	2						
10-11	8	11		9	8	10	27	150
12-13	97	130		7	29	26	62	344
14-15	107	143		2	15	11	28	156
16-17	27	36		1	1	1	3	17
18-19	48	64		1		3	4	22
20-21	138	184		1	3	10	14	78
22-23	155	207		1	8	16	25	139
24-25	119	159		1	8	6	15	83
26-27	36	48			2		2	11
28-29	4	5						
30-31	1	2						
32-33	1	2						
34-35	2	2						
36-37	1	1						
38-39	1	1						
40-41								
42-43	1	1						
44-45	1	1						
46-47	1	1						
mean length	20.30			14.13	16.32	17.05	16.38	

Table 3. Combined length frequencies of haddock contained in bottom trawl survey catches off East and West Greenland autumn 1986.

	East Greenland		West Greenland					
			Division				1C-F	
	TOTAL	o/oo	1C	1D	1E	1F	TOTAL	o/oo
n	815	1000	4	31	40	31	106	1000
12-13	1	1						
14-15								
16-17	22	27	1			1	2	19
18-19	107	131	1	2	2	5	10	94
20-21	240	295	1	8	8	6	23	217
22-23	225	276		13	13	12	38	359
24-25	100	123		5	13	1	19	179
26-27	19	23	1	2	2	1	6	57
28-29	33	41			1	2	3	28
30-31	35	43		1	1		2	19
32-33	21	26				2	2	19
34-35	4	5				1	1	9
36-37	5	6						
38-39								
40-41								
42-43	1	1						
44-45								
46-47	1	1						
48-49								
50-51								
52-53								
54-55								
56-57	1	1						
mean length (cm)	23.1		21.0	23.1	23.6	23.4	23.3	

Table 4. Haddock age compositions from combined survey catches for East and West Greenland in 1985 and 1986.

A) AUTUMN SURVEYS 1985

	East Greenland				West Greenland			
Area								
Year class	1985	1984	not		1985	1984	not	
age	0	1	known	Total	0	1	known	Total
2 cm Gr.								
08-09	1			1				
10-11	8			8				
12-13	97			97	27			27
14-15	107			107	62			62
16-17	27			27	28			28
18-19		48		48		3		3
20-21		138				4		4
22-23		155		155		14		14
24-25		119		119		25		25
25-27		36		36			15	15
28-29		4		4			2	2
30-31			1	1				
32-33			1	1				
34-35			2	2				
36-37			1	1				
38-39			1	1				
40-41								
42-43			1	1				
44-45			1	1				
46-47			1	1				
Total	240	500	9	749	117	46	17	180
mean length (cm)	14.2	22.9	38.3		15.0	23.7	27.2	

B) AUTUMN SURVEY 1986

Year class	1985	1984	not		1985	1984	not	
age	1	2	known	Total	1	2	known	Total
12-13			1	1				
14-15								
16-17	22			22	2			2
18-19	107			107	10			10
20-21	240			240	23			23
22-23	225			225	38			38
24-25	100			100	19			19
26-27	13	6		19	4	2		6
28-29		33		33		3		3
30-31		35		35		2		2
32-33		21		21		2		2
34-35		4		4		1		1
36-37		5		5				
38-39								
40-41								
42-43			1	1				
44-45								
46-47			1	1				
48-49								
50-51								
52-53								
54-55								
56-57								
Total	707	140	4	815	96	10	-	106
mean length (cm)	21.9	31.0	40.0		22.5	30.4		

Table 5: Haddock abundance indices from stratified-random bottom trawl survey results off East and West Greenland in autumn 1985.

Area		nm^2	no of sets	mean catch nos./30'	stand. dev.	abundance nos x 10^{-3}	density nos./nm^2	confid. interval
East Greenland		17377	164	3.60	0.785	2340	134.68	± 43.06
West Greenland								
Divisions	1 D-F	9587	102	1.81	0.473	648	67.62	51.91
Div.	1 F	3539	33	2.24	5.685	297	83.90	89.91
"	1 E	2680	30	2.67	5.441	267	99.77	76.18
"	1 D	3368	39	0.67	2.030	84	24.94	98.69

Table 6 : Effort of Greenland Research Trawlings (hours trawled) by divisions and number of haddock caught, 1968-86. Only trawlings above 400 m. included.

	Hours trawled NAFO Div							
Year	1A	1B	1C	1D	1E	1F	Total	Haddock caught
1968	2	0	0	21	0	0	23	
1969	0	1	0	22	0	0	23	
1970	0	1	0	9	2	2	14	
1971	0	3	0	8	0	0	11	
1972	0	0	0	8	0	0	8	
1973	4	1	0	10	1	2	18	
1974	6	0	0	15	2	0	23	
1975	14	6	1	17	7	6	51	6
1976	11	15	2	17	13	0	58	10
1977	15	16	4	12	7	0	54	1
1978	6	9	2	11	9	0	37	3
1979	2	4	1	9	4	3	23	1
1980	8	8	0	14	3	0	33	
1981	4	8	2	7	3	0	24	
1982	1	12	4	1	3	0	21	
1983	5	13	3	20	7	0	48	
1984	3	16	1	11	13	2	46	
1985	1	15	1	3	3	0	23	
1986	18	25	6	13	0	0	63	5

Table 7 : Lengt and estimated age of haddock caught by Greenland research trawlings with information on year, date and place of capture.

Year	Date	Div.	Depth m	Length of fish	Estimated year-class
1975	6 May	1E	230	12,13,14,15	1974
	26 Aug	1E	230	2 ind.	-
1976	20 Jan	1D	300	22	1974
	27 Apr	1D	310	21,24,25,27 27,29,30	1974
	1 Jun	1E	230	1 ind.	-
	19 Nov	1E	220	30	1974
1977	12 Jan	1D	230	1 ind.	-
1978	8 Feb	1D	220	2 ind.	-
	2 Nov	1D	130	40	1974
1979	14 Jun	1D	125	27	1977
1986	7 Jul	1D	300	17,18,24,27	1984-85
	24 Jul	1C	260	16	1985

Ind. indicates haddock not measured.

Table 8 : Annual haddock catches reported in Nafo Subarea 1, 1952-83. Data extracted from Statistical Bulletin.

	Catch in tons by								
	Fao.I	FRG	Icel.	Nor.	Port.	Spain	U.K.	Othr.	Total
1952						132	3		135
1953			8		10	49	15		82
1954		2	1				1		4
1955	14						45		59
1956			6			167			173
1957	1	2	13			123	27		166
1958					10				10
1959		1					60		61
1960	16	1	45						62
1961	588	77							665
1962	19	9					3		31
1963	35	12					12	62	121
1964	4	48	2	7			14		75
1965	6	33		1			3		43
1966	1	8				64	26		99
1967		2		4		150	2	19	177
1968						34			34
1969							1	9	10
1970						5		1	6
1971		1		1		64	11		77
1972		1				144	1		146
1973							10	28	38
1974							21		21
1975									0
1976									0
1977		4							4
1978		2							2
1979		2						23	25
1980									0
1981									0
1982									0
1983		1							1

Legends : Fao.I: Faroe Icelands; FRG: Germany; Icel.: Iceland; Nor.: Norway; Port.: Portugal; Othr: others: (France, USSR,USA).

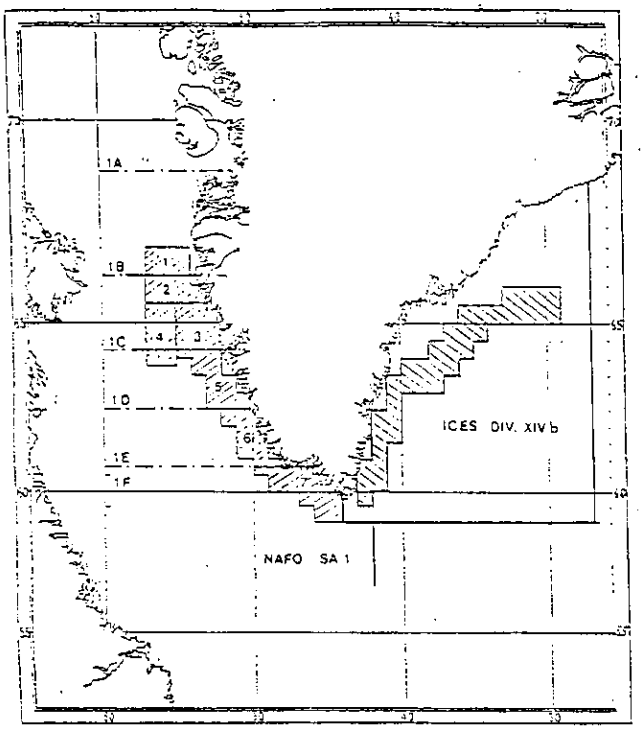


Fig 1: Areas covered by bottom trawl surveys off West Greenland (NAFO Subarea 1) and off East Greenland (ICES DIV. XIV b).

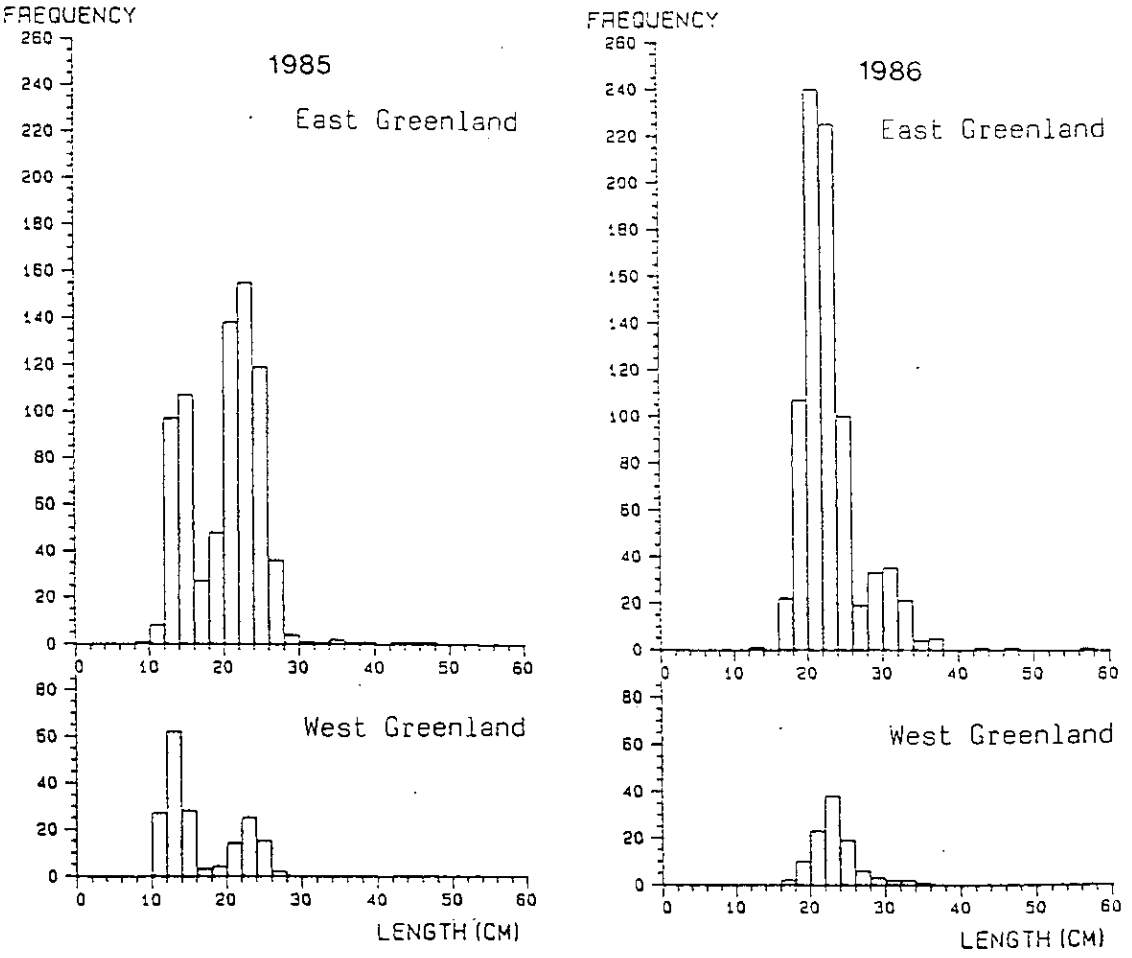


Fig 2: Length frequency distribution of haddock off East and West Greenland from surveys in 1985 and 1986.

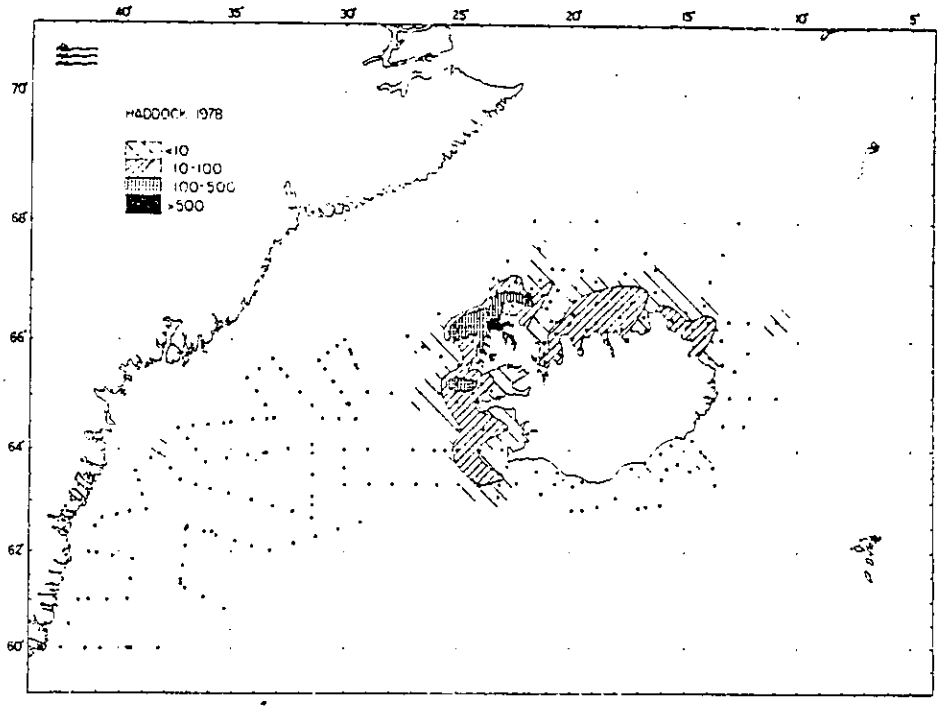
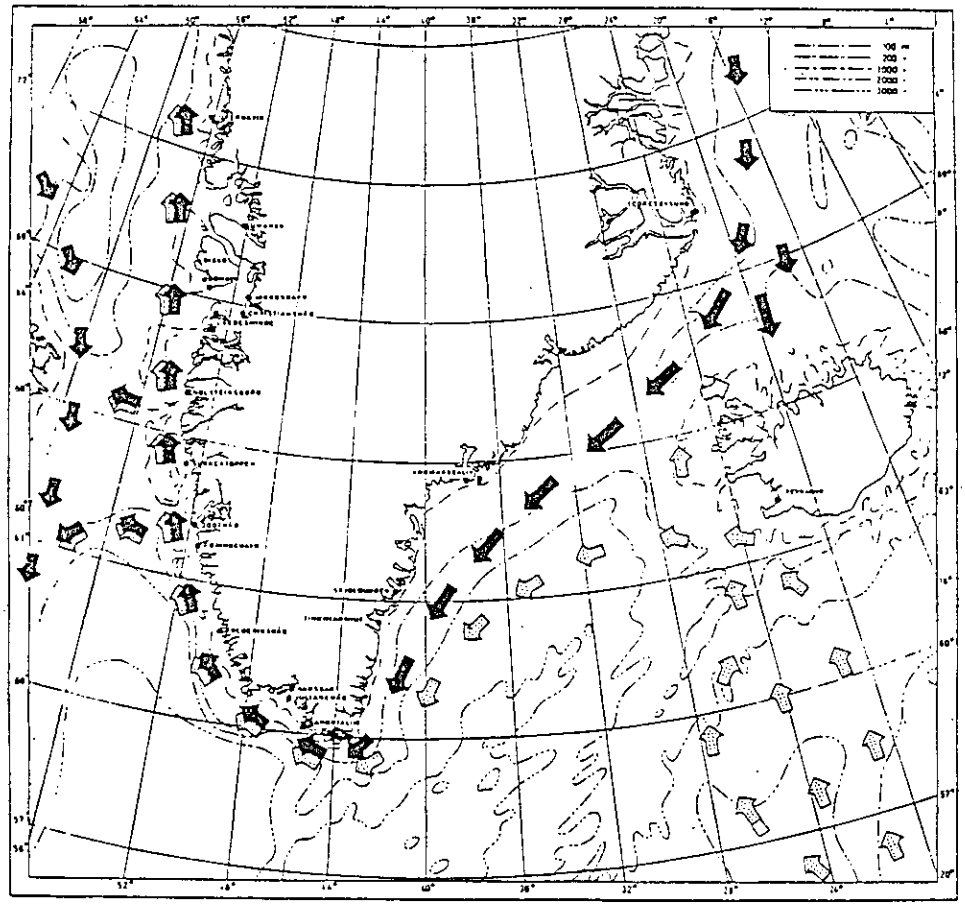


Fig 3: A typical distribution of 0-group haddock off Iceland. August, 1978. (from Anon. 1978)



⇨ North Atlantic Water

➡ Polar water

Fig 4: The main currents in the Iceland/Greenland Area.

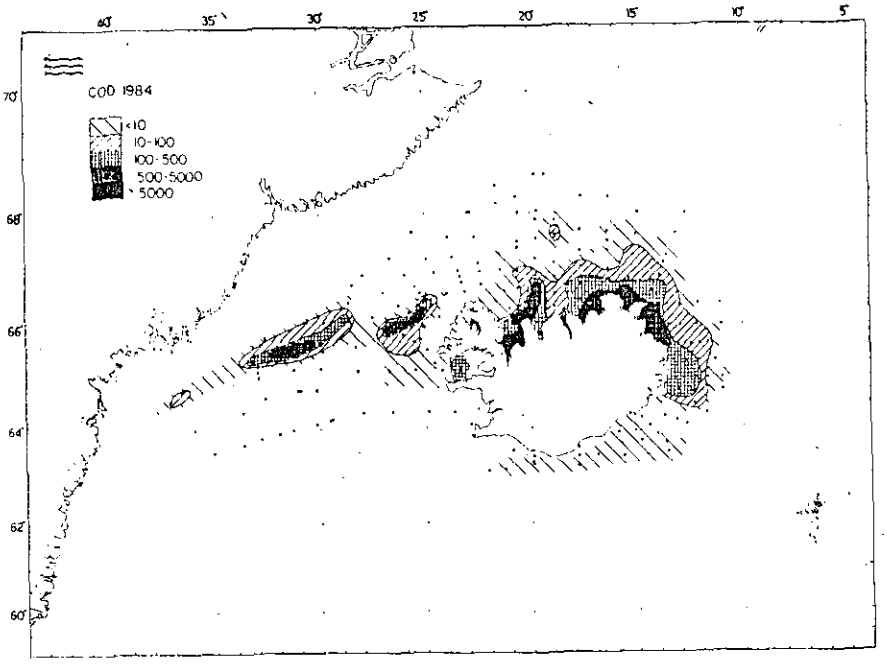


Fig 5: The distribution of 0-year group cod in the year with highest recorded abundance off East Greenland. (from Wilhjalmsson & Magnusson, 1984)

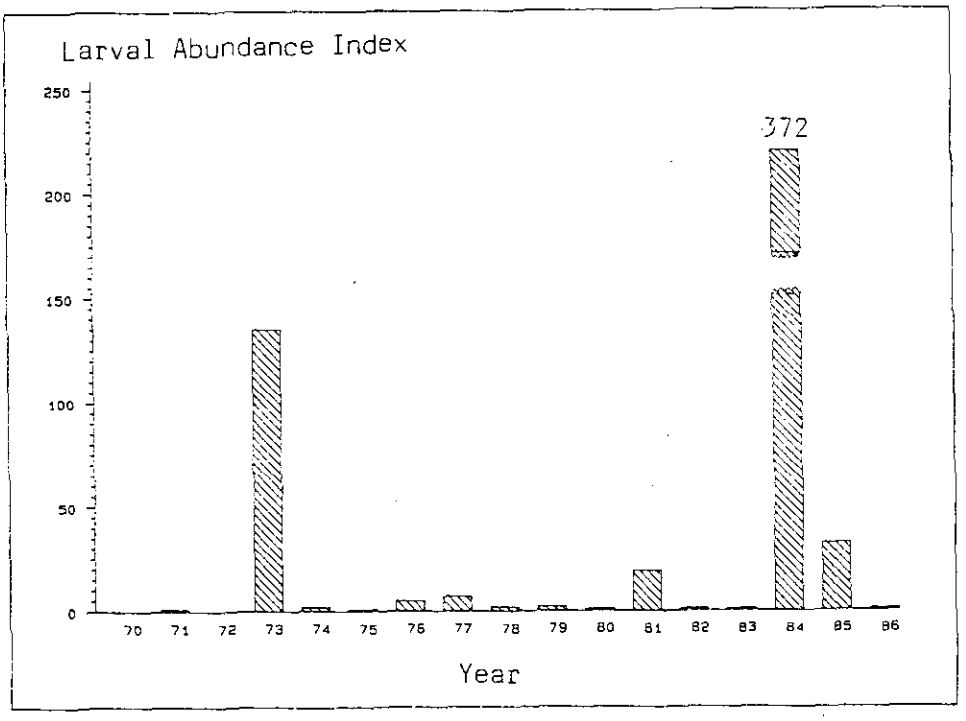


Fig 6: Abundance Indicies of 0-group cod off East Greenland, 1971-1986. (Data from Anon., 1987)

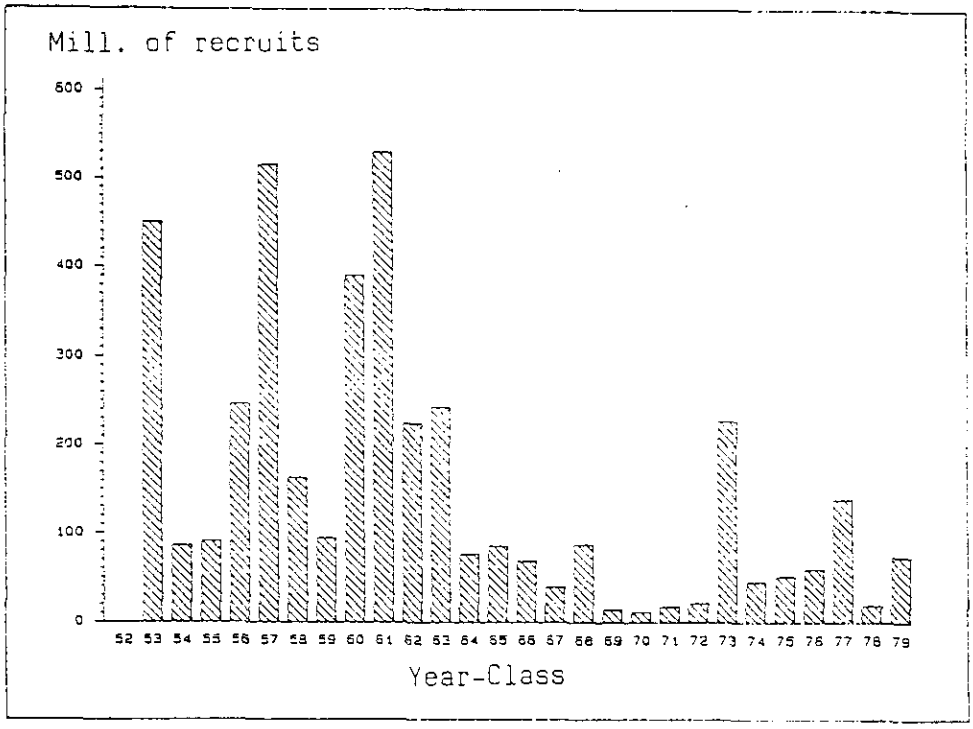


fig 7: Year-Class strength (no. of 3 year old cod) for the cod stock off West Greenland, 1953-1979. (Data from Hansen & Buch, 1986)

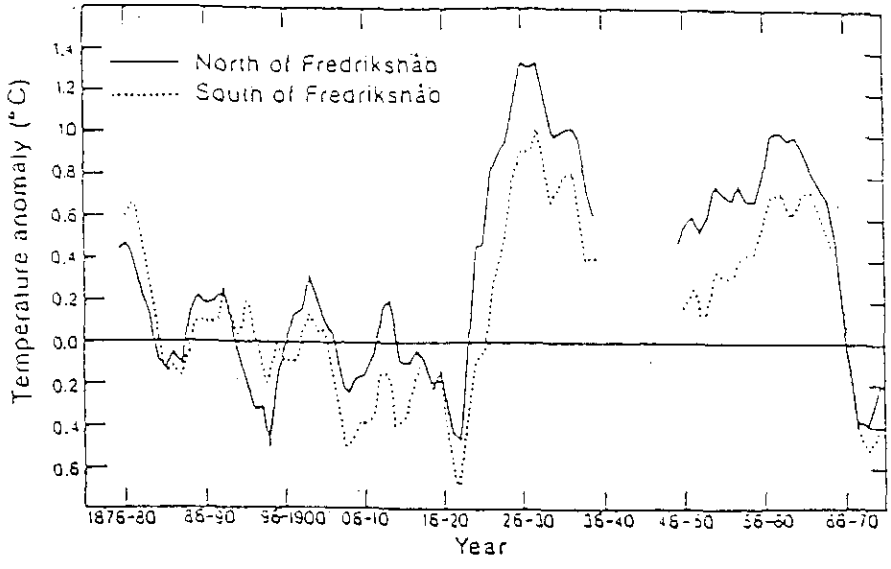


Fig 8: Surface temperature anomalies (5 year running means) for West Greenland 1876-1974.