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Abundance and Present Length Structure of Demersal Fish Stocks off West Greenland (Divisions 1B-1F, 0-400m)

by

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Abstract

During the periods 1982-84 and 1988-92 the demersal ichthyofauna off West Greenland (Divisions 1B-1F, 0-400m) showed pronounced negative trends both in aggregate fish abundance and biomass in coherence with fundamental shifts in species dominance. Since 1987 overall decrease in aggregate abundance and biomass amounted to -85% and -98%, respectively. From 1991 to 1992 these values decreased by -29% and -41%. Ecologically and economically important fish species cod (*G. morhua*), American plaice (*H. platessoides*), golden and beaked redfish (*S. marinus*, *S. mentella*), Atlantic and spotted wolffish (*A. lupus*, *A. minor*) and starry skate (*R. radiata*) inhabiting the shelf and the continental slope off West Greenland (0-400m) contributed most to the decline in total fish abundance and biomass. Length distributions revealed that at present very small individuals dominate most of demersal fish stocks.

Significant negative correlations were found between annual change in aggregate fish abundance, fish biomass indices (production) and fishing effort. Relationships between changes in cod abundance, biomass indices and fishing effort were statistically insignificant indicating multi species effects of fishing activities. These data series varied independently with trends in temperature.

Introduction

Regular German survey data revealed that during last decade aggregate abundance and biomass of demersal fish species off West Greenland changed significantly and were accompanied by fundamental shifts in species dominance (Rätz, 1991 a and 1992). For the period 1982-92, the present paper compiles changes of abundance and biomass indices as well as length structure of the ecologically most important fish stocks inhabiting the continental shelf and slope off West Greenland (0-400m depth, south of 67°N). Annual changes in aggregate abundance and biomass estimates are compared with trends in temperature and fishing effort.

Materials and Methods

Analyses are based on data derived from annual groundfish surveys established in 1982. Stratified-random surveys covered shelf area and continental slope off West Greenland (NAFO Subdiv. 1B-1F) outside the 3-mile limit to the 600m isobath. Because of favourable weather and ice conditions and to avoid spawning concentrations, the autumn season was chosen for the survey.

Figure 1 shows the area of investigation and the geographic stratification. 4 geographic strata were subdivided into 3 depth strata covering the 0-200m, 201-400m and 401-600m zones, respectively. Thus, this stratification scheme produces 12 strata. Table 1 specifies strata boundaries, depth zones and stratum areas.

Standard gear used was the 140-feet bottom trawl rigged with a heavy ground gear and equipped with a small mesh liner inside the cod end. Detailed information about geometry of the trawl is given by Rätz (1990). Standard towing required 30 minutes and 4.5 knots were aimed as towing speed. In case of net damage or hangup before 15 minutes towing time, the haul was rejected from evaluation. In 1987 and 1988, some hauls were not excluded although their towing time was intentionally reduced to 10 minutes due to large catches which were to be expected from traces of the echo sounder.

Survey was primarily designed for assessment of cod (*Gadus morhua*). Strategy was to allocate sampling effort proportionally to cod abundance and to area of the strata. Hauls were randomly distributed within strata. During 1982-92, 1,215 successful sets were carried out. Numbers of valid hauls per stratum are listed in Table 2. Main feature of effort distribution shown in Table 2 is the high number of tows allocated in shallow strata 1.1, 2.1, 3.1 and 4.1 (0-200m). Strata 1.2, 2.2, 3.2 and 4.2 (201-400m) are distinguished by lower numbers of hauls, especially southern strata 3.2 and 4.2 which are characterized by extremely rough trawling grounds. Apart from the northern stratum 1.3, remaining deep strata 2.3, 3.3 and 4.3 (401-600m) are covered inadequately with hauls. Therefore, sampling within very deep strata was stopped and effort was shifted to shallow strata in 1991. In December 1992, only 47 hauls were carried out due to technical reasons.

Fishes were identified to species or lowest taxonomic level and catch number and weight was recorded. Total length measurements were determined to the centimeter below.

Stratified abundance and biomass estimates were calculated using the "swept area" method (Cochran, 1953; Saville, 1977). Coefficient of catchability was set arbitrarily to 1.0 for all species. Consequently, estimates can be considered only as indices of abundance and biomass (relative abundance and biomass). Trawl parameters are listed in Table 3. Confidence intervals are given at the 95% level of significance in per cent of the stratified mean. Strata including less than 5 hauls were excluded from calculation of stratified mean abundance and biomass. The variation in survey area arising therefrom is negligible as the haul distribution was fairly consistent over the total time series. Before summing up, length distributions were standardized, pooled by stratum and weighted by stratum abundance.

Linear correlation and regression analyses between annual changes in cod and aggregate abundance and biomass indices and trends in effort and temperature were calculated using statistical software (CSS Statsoft, Inc.). Changes in aggregate abundance and biomass were computed by subtraction of respective estimates of the preceding year. Annual fishing effort (hours fished) directed to groundfish (Greenland halibut and shrimp excluded) for otter-trawls>500 GRT were adopted from the report of the ICES North-Western Working Group (Anon. 1992) and the NAFO Statistical Bulletin (Vol. 32-38, Anon. 1982-88). Due to extremely low catch rates fishing effort in 1992 was low. 1,000 hours were speculatively inserted for calculations. This value is lower than in 1986 and 1987 when offshore trawling was banned for the whole year and the first 10 months, respectively. Mean water temperatures of Fyllas Bank Station 4 (63°48'N, 53°56'W; 0-200m) were obtained by oceanographic standard measurements exept for 1992 (Stein, 1992).

Results

Abundance and biomass estimates for cod (*Gadus morhua*), American Plaice (*Hippoglossoides platessoides*), golden and beaked redfish (*Sebastes marinus*, *S. mentella*), Atlantic and spotted wolffish (*Anarhichas lupus*, *A. minor*), starry skate (*Raja radiata*), others and total are illustrated in Figures 2 and 3 and listed in Tables 4 and 5, respectively. Precision of these estimates is low. Usually, confidence intervals vary among 30-60% of the stratified mean and some cases exceed 100%.

Pronounced negative trends in aggregate fish biomass were observed during the periods 1982-84 and 1988-92. Maximum biomass was calculated to be 691,488 tonnes in 1987. Compared to 1991, total fish biomass decreased by -41% to 11,151 tonnes in 1992. The trend in total abundance is very similar. Maximum abundance amounted to 1,319 million fish in 1987. Abundance in 1992 decreased by -29% to 195 million compared to previous year's estimate (1991).

Both trends in aggregate abundance and biomass were determined by the occurrence of cod (*G. morhua*). During 1982-84, cod showed a declining trend both in abundance and biomass (Fig. 2 and 3, Tab. 4 and 5). The following enormous increase until 1987 was caused by recruitment of strong 1984 and 1985 year classes. Since 1988, this species decreased in abundance and biomass from 786 million to 2 million individuals and from 638,622 tonnes to 607 tonnes in 1992. The last year's decreases amounted to -58% and -88%, respectively. Significant changes in length structure were also detected (Fig.4). Strong year classes 1984 and 1985 were found to be absent from the stock and 1-3 year old fish to be dominant (19-37 cm).

American plaice (*H. platessoides*) is the second dominating species. During early years of the last decade, abundance and biomass indices varied between 57 million and 115 million individuals and 8,354 and 22,246 tonnes, respecively (Fig. 2 and 3, Tab. 4 and 5). Since 1987, these values decreased to 24 million and 2,246 tonnes in 1991. The last year's estimates (1992) showed insignificant changes both in abundance (+1%) and biomass (-11%) as well as in length structure (Fig. 5).

Golden redfish (*S. marinus*) and beaked redfish (*S. mentella*) showed extremely low precision in abundance and biomass indices (Fig. 2 and 3, Tab. 4 and 5). During the period 1982-84, golden redfish decreased in abundance and biomass. The last 5 years showed again a strong decline from 65 million to 2 million individuals and from 7,420 tonnes to 946 tonnes. Last year's decrease in biomass amounted to -47% whereas abundance decreased by -41%. This pronounced decrease is reflected in the total length distribution (Fig. 6). Beaked redfish showed pronounced maximum abundance and biomass indicesin 1987. These values decreased significantly to minimum estimates by -94% and -95% during 1991-92, respectively. Length frequency distribution illustrates that adult beaked redfish are almost absent from the area at present (Fig. 7). Juvenile redfish (Sebastes spec., <15cm) dominated abundance and biomass of species summarized under category "others". Both length distributions in 1991 and 1992 showed pronounced peaks at 6.5-7.5 cm and 9.5-13,5 cm (Fig. 8).

Abundance indices of Atlantic and spotted wolffish (*A. lupus* and *A. minor*) remained relatively unchanged since 1983 and varied among 10-13 million and 628,000-1,052,000 individuals, respectively. During 1982-85, trends of biomass estimates were negative for both species (Fig. 2 and 3, Tab. 4 and 5). Since 1989, these indices decreased again to 2,229 and 1,227 tonnes in 1991. For spotted wolffish last year's declines in abundance and biomass amounted to -57% and -90%. Dominance of juvenile spotted wolffish (13,5 and 28,5cm in 1991, 16,5 and 25,5 cm in 1992) was remarkable (Fig. 9). Contrarily, Atlantic wolffish was collected more frequently. Increases in abundance (34%) and biomass (33%) were particularily recorded in length groups between 17,5-35,5 cm (Fig. 10).

Juvenile Atlantic wolffish had abundance peaks at lengths 7.5-10.5 cm in 1991 and 12.5-15.5 cm in 1992.

The only elasmobranch species taken into consideration is starry skate *(Raja radiata)*. In 1982-84, occurrence of starry skate diminished (Fig. 2 and 3, Tab. 4 and 5). Subsequently to high abundance and biomass estimates in 1989, both indices decreased from 20 million to 5 million and from 4,081 tonnes to 908 tonnes in 1991. Last year's estimates showed the highest increase in abundance of all species by 122% due to the occurrence of juveniles (Fig 11). Therefore, biomass estimate increased only by 16%.

Correlation and regression analyses were applied to annual changes in abundance and biomass of cod and aggregate indices (production) as dependent and temperature and fishing effort as independent variables. Significant results ($p<=0.05$) were calculated for the relation between annual change in aggregate abundance, biomass and effort. p-levels, significant coefficients of correlation and regression functions are given in Table 7 and illustrated in Figure 12.

Discussion

During 1982-84 and in recent years (1988-92), ecologically important fish species cod (*G. morhua*), American plaice (*H. platessoides*), golden and beaked redfish (*S. marinus*, *S. mentella*), Atlantic and spotted wolffish (*A. lupus*, *A. minor*) and starry skate (*R. radiata*) inhabiting the shelf and the continental slope off West Greenland (0-400m) contributed to the dramatic decline in total fish abundance and biomass (Tab. 4 and 5, Fig. 2 and 3). Since 1987 overall decrease in aggregate abundance and biomass amounted to -85% and -98%, respectively. Comparing last year's (1992) and preceding year's estimates (1991), these values decreased by -29% and -41%. Although sampling effort of groundfish survey varies both in coverage of survey area and time and precision of resulting abundance and biomass indices is low (Rätz, 1991 b), these trends must be regarded as significant.

Length distributions revealed that at present very small individuals dominate demersal stocks (Fig. 4-11). Pronounced peaks of length distributions of juvenile redfish at 6.5-7.5 cm and 9.5-13.5 cm might correspond to age groups 0 and 1 year as smallest individuals were still silvery coloured without any red gleam (Fig. 8). Mean lengths of age groups 1-2 of juvenile spotted (13,5-16,5 cm, 25,5-28,5 cm, Fig. 9) and 0-1 of Atlantic wolffish (7,5-10,5 cm and 12,5-15,5 cm, Fig. 10) might also be indicated by peaks, respectively.

Mean temperature in November at Station 4 (0-200m) of the Fyllas Bank oceanograpic standard section was taken as representative of hydrographic conditions off West Greenland. Stein and Buch (1991) tested the hypothesis that subsurface ocean temperatures are predictable from air temperature data sampled at Nuuk. It appeared that late summer air temperature conditions steer upper ocean layer temperatures that are observed in November. Especially anomalous cold conditions in climate during early-1980s are thus reflected by mean temperature at Fyllas Bank.

No significant correlations between annual change in cod and aggregate abundance and biomass indices and temperature were found (Tab. 6 and 7). The very cold anomaly observed from 1981 until 1984 possibly contributed to the negative trend in fish abundance and biomass, especially as the following increase of indices coincided with higher temperature in 1985-87. Hansen (1949) described periodical occurrence of cod in Greenland waters. The ichthyofauna was found to be mainly composed of boreal species (Rätz, 1991 a). Therefore, a correlation between fish abundance and temperature might be expected. However, the second period of decreasing fish abundance and biomass estimates from

1987 until 1991 was lacking any distinct indication of cooling as respective temperatures returned to normal.

Exploitation of fish stocks off West Greenland is mainly directed to cod and redfish. Other fish species are taken more or less as by-catches. Unfortunately, no statistic of fishing effort by depth is documented. To obtain reliable figures, annual fishing effort (hours fished) directed to groundfish (Greenland halibut and shrimp excluded) for otter-trawls>500 GRT was summarized. The considerable shrimp fishery, which affects the demersal fish community by unknown by-catches (Carlsson and Kanneworff, 1992) is not considered due to lack of information.

Negative correlations between annual change in aggregate abundance, biomass indices (production) and fishing effort were found to be significant (Tab. 6 and 7, Fig 12). Years with high fishing activities are characterized by negative changes whereas periods of low effort conincide with steady conditions or positive values. Although the majority of fishing effort is directed to cod, relationships between change in cod abundance, biomass indices and fishing effort resulted in higher p-levels and were determined to be statistically insignificant. This might indicate multi species effects of fishing activities comprising a variety of species. Insignificance migth also be explained by loss of cod due to an emigration as postulated by Hovgård (1991). Following the assessment carried out by Schopka (1991), the contribution of migrating cod from Greenland to the Icelandic stock amounted to 100 million individuals during the last decade.

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Table 1 Specification of the strata.

64°15'N - 67°00'N		50°00'W - 57°00'W	
Stratum 1.1	depth 1-200m,	area	6,805 nm²
Stratum 1.2	depth 201-400m,	area	1,881 nm²
Stratum 1.3	depth 401-600m,	area	1,191 nm²
62°30'N - 64°15'N		50°00'W - 55°00'W	
Stratum 2.1	depth 1-200m,	area	2,350 nm²
Stratum 2.2	depth 201-400m,	area	1,018 nm²
Stratum 2.3	depth 401-600m,	area	259 nm²
60°45'N - 62°30'N		48°00'W - 53°00'W	
Stratum 3.1	depth 1-200m,	area	1,938 nm²
Stratum 3.2	depth 201-400m,	area	742 nm²
Stratum 3.3	depth 401-600m,	area	57 nm²
59°00'N - 60°45'N		44°00'W - 50°00'W	
Stratum 4.1	depth 1-200m,	area	2,568 nm²
Stratum 4.2	depth 201-400m,	area	971 nm²
Stratum 4.3	depth 401-600m,	area	353 nm²

Table 2 Number of valid hauls per stratum, 1982-92

Stratum Year	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	4.3	total
1982	20	11	4	16	7	2	9	6	0	13	2	0	90
1983	26	11	4	25	11	0	17	5	0	18	4	0	121
1984	25	13	13	26	8	2	18	6	1	21	4	1	138
1985	10	8	3	26	10	1	17	5	0	21	4	0	105
1986	27	9	7	21	9	3	16	7	1	18	3	0	121
1987	25	11	8	21	4	1	18	3	0	21	3	2	117
1988	34	21	9	28	5	1	18	5	2	18	2	1	144
1989	26	14	5	30	9	1	8	3	0	25	3	0	124
1990	19	7	7	23	8	0	16	3	0	21	6	1	111
1991	19	11	0	23	7	0	12	6	0	14	5	0	97
1992	6	6	0	6	5	0	6	6	0	7	5	0	47
total	237	122	60	245	83	11	155	55	4	197	41	5	1,215

Table 3 Trawl parameters of the survey.

Gear	140-feet bottom trawl
Horizontal net opening	22 m
Standard trawling speed	4.5 kn
Towing time	30 minutes
Coefficient of catchability	1.0

Table 4 Survey abundance indices (* 1,000) for listed fish species, others and total, 1982-1992. Confidence intervals (CI) are given at the 95% level of significance in per cent of the stratified mean.

Year	G.morhua	CI	H.plates.	CI	S.marinus	CI	S.mentella	CI	A.lupus	CI	A.minor	CI	R.radiata	CI	Others	Total
1982	92,276	30	77,970	32	133,598	110	3,115	106	23,068	25	1,508	33	9,697	39	10,949	352,181
1983	50,203	29	115,415	54	33,340	34	8,927	67	15,427	28	872	42	6,999	88	13,078	244,261
1984	16,694	38	86,700	47	31,506	37	12,010	50	11,050	24	804	26	6,455	44	22,683	187,902
1985	59,343	39	62,397	30	59,636	44	3,934	96	12,741	33	628	51	7,878	46	32,779	239,336
1986	145,706	35	111,851	45	58,203	38	21,131	46	12,116	31	1,052	30	6,859	47	262,470	619,388
1987	786,453	62	56,961	33	14,622	52	152,101	105	9,607	27	957	41	3,387	32	294,650	1,318,738
1988	626,558	50	33,973	25	64,873	53	33,645	55	10,532	31	940	35	7,247	39	124,383	902,151
1989	359,011	73	39,152	34	32,886	44	16,453	40	10,560	33	843	42	19,820	38	26,084	504,809
1990	34,658	71	29,360	36	6,036	30	33,369	45	10,414	27	641	35	13,643	52	115,308	243,429
1991	4,805	52	23,758	25	3,725	61	2,425	107	9,849	31	721	34	4,832	27	225,288	275,403
1992	2,042	61	24,106	29	2,194	43	157	95	13,164	29	313	55	10,710	51	142,067	194,753

Table 5 Survey biomass indices (t) for listed fish species, others and total, 1982-92. Confidence intervals (CI) are given at the 95% level of significance in per cent of the stratified mean.

Year	G.morhua	CI	H.plates.	CI	S.marinus	CI	S.mentella	CI	A.lupus	CI	A.minor	CI	R.radiata	CI	Others	Total
1982	128,490	26	17,394	34	55,704	101	1,109	117	26,002	33	7,950	47	6,090	37	23,367	266,106
1983	82,375	32	22,246	48	14,310	37	4,273	78	12,788	36	5,693	45	2,413	34	16,233	160,331
1984	25,575	39	13,378	51	11,646	45	3,023	56	7,026	26	4,022	32	1,986	36	9,992	76,648
1985	35,672	73	8,354	30	19,726	59	687	78	5,959	26	1,822	44	2,166	24	12,386	86,772
1986	86,778	35	14,806	41	18,647	45	3,224	50	6,774	25	3,536	38	1,864	31	16,605	152,234
1987	638,622	68	9,894	40	6,794	61	10,521	89	4,967	26	4,182	41	1,100	33	15,408	691,488
1988	608,028	50	4,956	29	7,420	37	3,793	66	4,512	21	4,766	59	1,767	30	19,425	654,667
1989	333,989	66	5,128	54	3,947	59	975	34	4,563	25	2,841	50	4,081	31	6,599	362,123
1990	34,499	70	3,087	35	2,500	45	1,956	45	3,130	23	2,262	49	2,295	47	5,190	54,919
1991	5,150	76	2,246	28	1,779	75	598	104	2,229	31	1,227	69	908	31	4,632	18,769
1992	607	64	1,991	28	946	49	32	107	2,969	23	126	87	1,054	31	3,426	11,151

Tab. 6 Annual fishing effort (hours fished) directed to groundfish (Greenland halibut and shrimp excluded) for otter-trawls>500GRT, mean water temperature at Fyllas Bank Station 4 (63°48'N, 53°56'W; 0-200m) and annual change in cod and aggregate abundance and biomass indices (production), 1983-92. Values of effort and temperature in 1992 are speculative or missing (s. text).

Year	Effort (h)	Temp. (°C)	Cod Abundance (1,000)	Cod Biomass (t)	Aggregate Abundance (1,000)	Aggregate Biomass (t)
1983	21,419	0.68	-42,072.4	-46,114.6	-107,920	-105,775
1984	12,862	2.01	-33,509.4	-56,800.4	-56,359	-83,683
1985	3,712	3.14	42,649.0	10,096.9	51,434	10,124
1986	1,714	3.34	86,362.8	51,106.2	380,052	65,462
1987	1,334	3.26	640,747.0	551,843.8	699,350	539,254
1988	12,012	2.53	-159,894.9	-30,593.1	-416,587	-36,821
1989	14,178	2.20	-267,546.8	-274,039.6	-397,342	-292,544
1990	16,637	2.60	-324,353.1	-299,490.3	-261,380	-307,204
1991	1,909	2.99	-29,853.0	-29,348.5	31,974	-36,150
1992	1,000		-2,762.8	-4,543.0	-80,650	-7,618

Table 7 Single correlation and regression functions between annual change in cod and aggregate abundance and biomass indices and fishing effort and temperature as listed in Table 6.

Variable Dependent	Indepedent	Coeff. Corr.	p	n	Const. a(x/y)	Slope b(x/y)
aggr.abun.	/effort	-0.638	0.047	10	234646.7	-28.8544
aggr.biom.	/effort	-0.631	0.050	10	143179.3	-19.4377
aggr.abun.	/temp.		0.172	9		
aggr.biom.	/temp.		0.220	9		
cod abun.	/effort		0.074	10		
cod biom.	/effort		0.081	10		
cod abun.	/temp.		0.312	9		
cod biom.	/temp.		0.312	9		

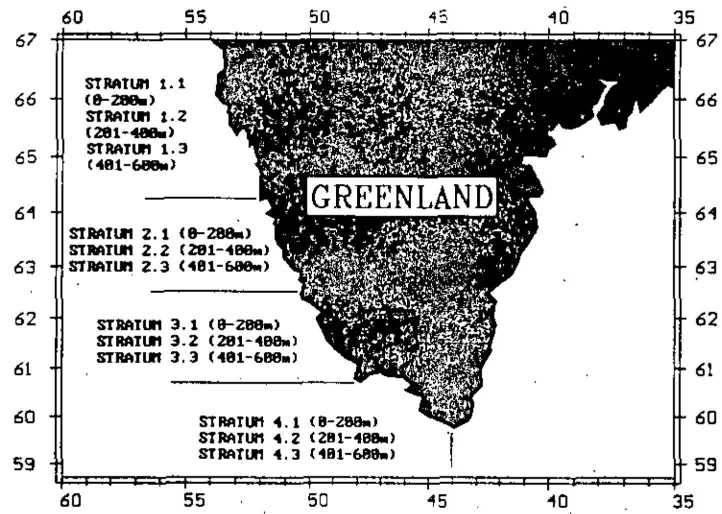

Figure 1 Survey area and stratification scheme as specified in Table 1.

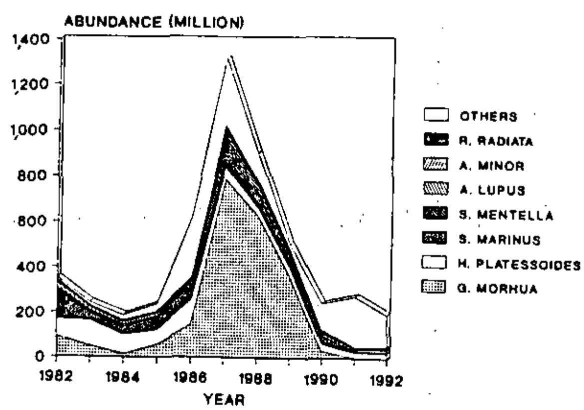

Figure 2 Aggregate fish abundance indices as listed in Table 4, 1982-92.

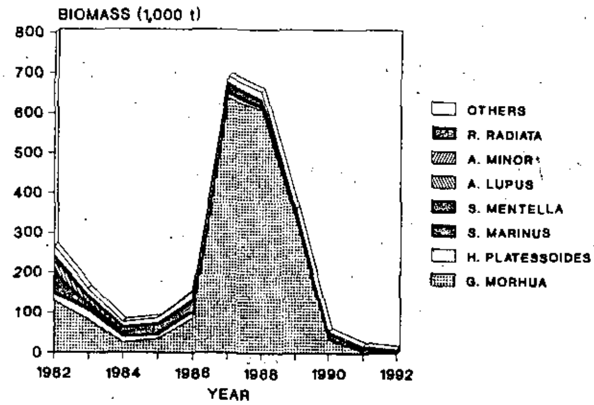

Figure 3 Aggregate fish biomass indices as listed in Table 5, 1982-92.

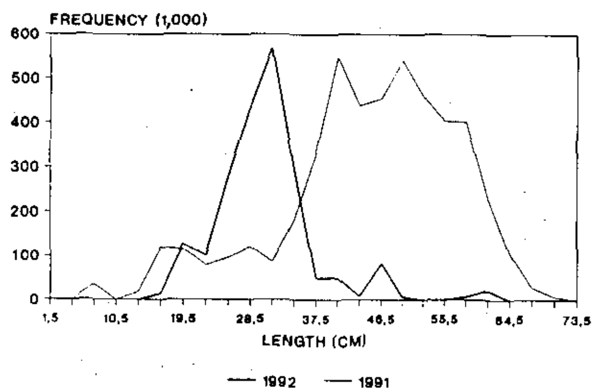

Figure 4 Cod (*Gadus morhua*), length structure of the stock off West Greenland in 1991 (4,805,000) and 1992 (2,042,000).

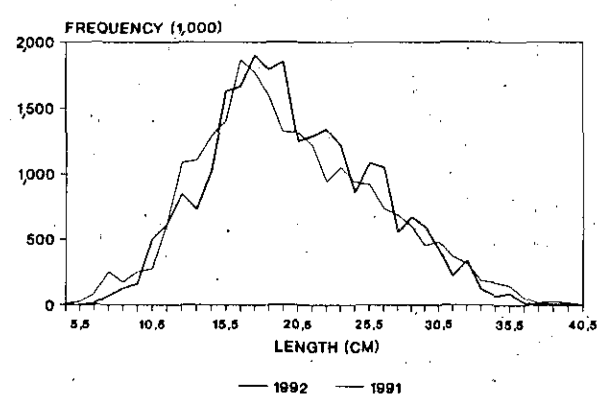

Figure 5 American plaice (*Hippoglossoides platessoides*), length structure of the stock off West Greenland in 1991 (23,758,000) and 1992 (24,106,000).

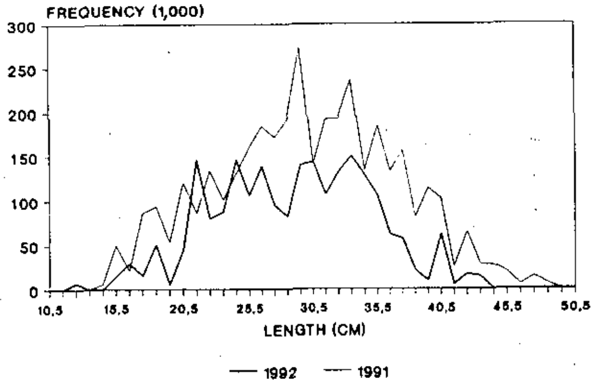

Figure 6 Golden redfish (*Sebastes marinus*), length structure of the stock off West Greenland in 1991 (3,725,000) and 1992 (2,194,000).

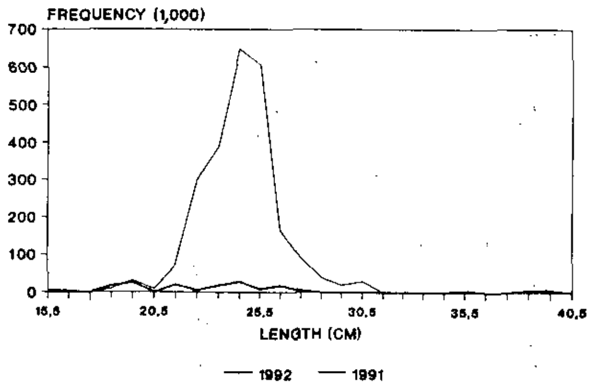

Figure 7 Beaked redfish (*Sebastes mentella*), length structure of the stock off West Greenland in 1991 (2,425,000) and 1992 (157,000).

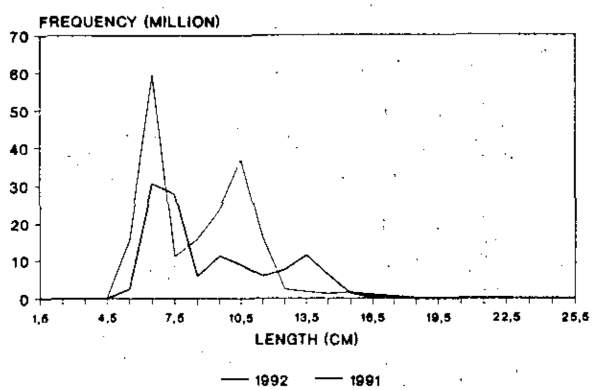

Figure 8 Juvenile redfish (Sebastes spec.), length structure of the stock off West Greenland in 1991 (187,955,000) and 1992 (119,960,000).

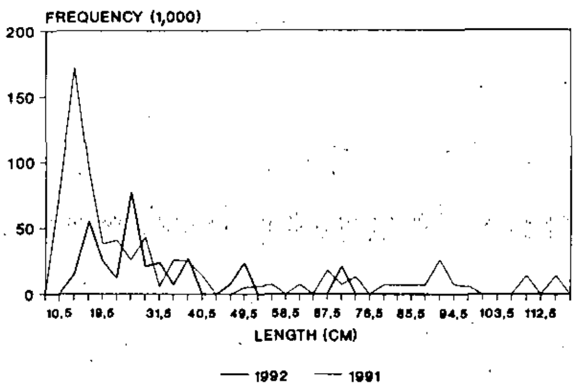

Figure 9 Spotted wolffish (*Anarhichas minor*), length structure of the stock off West Greenland in 1991 (721,000) and 1992 (313,000).

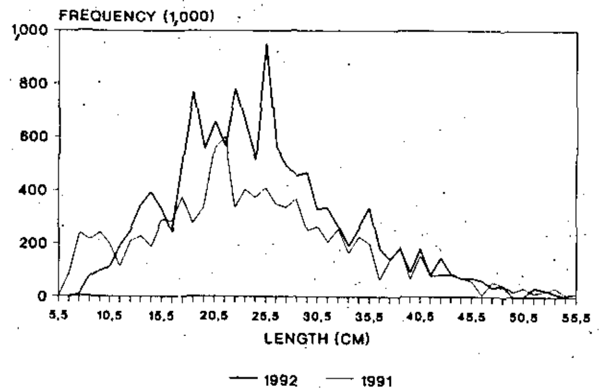

Figure 10 Atlantic wolffish (*Anarhichas lupus*), length structure of the stock off West Greenland in 1991 (9,849,000) and 1992 (13,164,000).

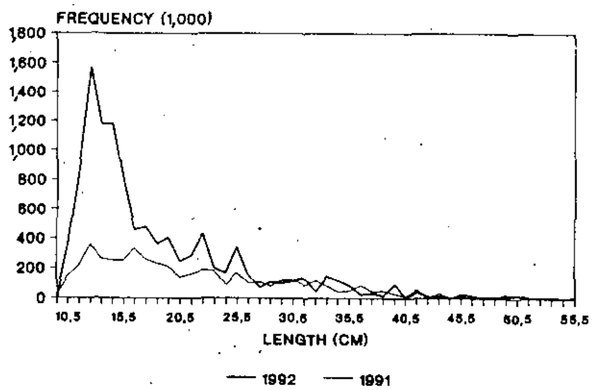

Figure 11 Starry skate (*Raja radiata*), length structure of the stock off West Greenland in 1991 (4,832,000) and 1992 (10,710,000).

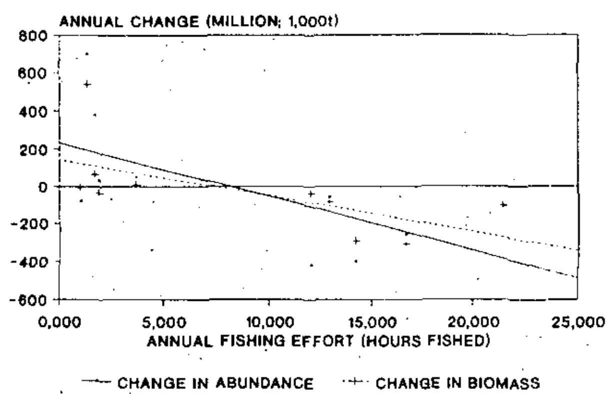

Figure 12 Regressions between annual change in aggregate abundance and biomass indices and annual fishing effort as listed in Table 6 and 7.