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A Long-line Estimate of Swept Area Abundance of Cod in Inshore Areas off West Greenland

by

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1. Introduction

Assessment of the West Greenland cod stock has since the mid eighties been based on swept area estimates of trawlable biomass. Surveys has been carried out annually by the Fed. Republic of Germany in the areas outside the 3 nm. line in NAFO divisions 1B to 1F down to 600 meters depths(fig. 1). Only insignificant numbers of cod have been found north of 64.30 deg. and at the western bank slopes below 300 meters. The surveys therefore give a good coverage of the offshore stock distribution. However catches have been high close to the shore, and a significant proportion of the stock might therefore be expected to be found in the coastal and fiord areas not covered by the surveys.

The inshore areas of West Greenland are not suitable for trawling and other types of gears must therefore be used when estimating stock size. Initial trials showed that long-lines were superior to gill-nets and a pilot long-line survey in inshore areas were carried out in 1986. The length distribution obtained was very different from that of offshore trawlings (Nygård & Hovgård, 1987) indicating a considerable difference in selection between long-line and trawl.

The purpose of the present paper is to describe long-line selectivity relative to the research trawl and subsequently to convert long-line CPUE to trawl units to estimate inshore cod abundance.

2. Material and methods

Long-line survey

The long-line survey were carried out by R/V Misiliisoq and R/V Adolf Jensen in October-November 1987-1989. Simultaneous coverage of inshore and offshore areas was attempted but bad weather conditions in 1989 prevented any offshore coverage in that year.

Fishing was carried out with 7 mm polypropylene long-lines anchored at both ends and with minor loads attached at 200 m intervals. Each line carried 400 hooks (traditional 'J-hooks' with a gap size of 23 mm.) mounted on 50 cm snoods by 2 m intervals and baited with capelin. Fishing was restricted to the daylight period with an average fishing time of 4.5 hours.

Stations were distributed in groups of 3 to 5; each group covered in one day of fishing. Stations were distributed according to a stratified scheme based on NAFO divisions, habitats (fiords, coast and banks) and three depth zones (< 100 m, 100-200 m, 200-300 m). The number of successful settings by strata are shown in table 1.

Trawl survey

Since 1982 random stratified trawl surveys have been carried out in the offshore areas of West Greenland in October-November by the German research vessels Walther Herwig. The number of stations has been between 100 and 150 per year.

The research gear used was a 140' bottom trawl equiped with a small mesh (30 mm) liner inside the codend. Wing spread and vertical net opening are given as 22 m and 3.5 m, respectively, Anon. (1986). Mean towing speed has been 4.5 knots and a standard towing time of 30 min. has been attempted. Fishing has been restricted to daylight hours.

Stratification is based on NAFO divisions and 100 m depth zones (0 - 600 m). About half the effort is allocated on an area basis, the rest being allocated to high density areas (upper 200 m in division 1D-1F).

Strata sizes

The size of the offshore areas was estimated by planimeter measurements on high resolution depth contour maps prepared by the Greenland Geological Research Institute. No maps with reliable depth informations were available for the inshore areas. For some areas strata sizes could be estimated and the depth distribution from these areas were then raised to cover total area by NAFO divisions (see Hovgård *et al*, 1988). The strata sizes are listed in tabel 2.

3. Results

3.1 Length distribution in long-line and trawl catches

Length distributions of cod catches by the offshore trawl survey and by long-line surveys in offshore and inshore areas are shown in fig. 2.

The trawl survey shows unimodal length distributions, mainly composed of cod from the very large 1984 year-class although supplemented with a proportion of cod of the 1985 year-class in 1989. No other year-classes are of any importance. This age distribution is similar to what is seen in the commercial fisheries.

The length distribution of the long-line surveys differs markedly as catches predominantly consist of larger cod. In 1987 and 1988 a bimodal length distribution was observed, with one peak occurring at the size of the 1984 year-class and another peak for cod at a size of 65-70 cm.

Little difference is seen between inshore and offshore long-line catches and little differences should hence be expected in the size and age structure of cod in these areas.

3.2 Long-line selection relative to the research trawl

The relative selection (RS) of long-lines as compared to the research trawl was derived by comparing CPUE of the two gears in concurrent fisheries in offshore areas, i.e. as :

$$RS = \frac{\text{Line CPUE}}{\text{Trawl CPUE}} \quad \frac{\text{(nos. caught/100 hooks)}}{\text{(nos. caught/ 30 min. tow)}}$$

where the calculations was done by 6-cm groups. Only data from concurrent fisheries in five stratas where cod were abundant were used. Catches, effort, CPUE and relative selection for these stratas are given in table 3.

Scrutinizing the RS values indicated multiplicative errors and the RS's where therefore log-transformed. The log(RS) increases up to the size group of 66-71 cm (fig. 3) showing that only cod of this size and above are fully recruited to the long-line as compared to the research trawl.

The relative selection of the long line as compared to the research trawl was then described by a one-sided ANOVA, i.e.

$$\log(RS) = \beta \text{ (length group)} + \text{noise}$$

where length group are the 6-cm groups given in table 3 except for cod above 66 cm which has been pooled. Cod below the 36 cm were to few to allow analysis. The statistics and the estimates from the ANOVA are presented in table 4. When transforming the RS from the logaritmic scale back to the required arithmetic, the RS's has been corrected by $\exp(s^2/2)$. This factor amounts to 1.42 (table 4).

This gives a serie of equations by which long-line catch per 100 hooks are translated to trawl catch per 30 min tow for separate size groups of cod.

Cod length	Equation
< 36 cm	no estimate
36-41 cm	T= 1924 x L
42-47	T= 493.2 x L
48-53	T= 250.1 x L
54-59	T= 76.36 x L
60-65	T= 8.562 x L
> 65	T= 2.034 x L

These equations relate rather uncomparable units i.e. a 30 min tow covering a distance of about 4 km opposed to the length of a 100-hook line of 0.2 km. If instead comparing the catches of a 4 km long-line to a 30 min tow, i.e. comparing equivalent 'path lengths' then a measure of effeciency of the lines relative to trawl is computed as :

Cod size	36-41	42-47	48-53	54-59	60-65	> 65
Rel. Eff.	0.01	0.04	0.08	0.26	2.34	9.83

Using the terminology of Dickson (1986) the effective pathwidth of the long-lines relative to trawls varies from a factor of 0.01 for the smallest cod to 10 for the largest cod.

3.3 Cod distribution in the inshore area

The observed CPUE in the long-line survey supplies information on relative densities of cod within the inshore areas. A presentation of data by strata, year and size is spacious and only CPUE by NAFO division and by coastal/fiord zones are therefore given. The CPUE values presented are strata means weighted by area. CPUE of cod above and below 54 cm is given separately thereby roughly seperating the abundant 1984 and 1985 year-classess from the scarce, although more effeciently caught, older fish.

The highest densities of smaller cod (<54 cm) was observed in Div. 1C in 1987 and 1988 (table 5). This is in contrast to the findings in the trawl survey where densities were highest in Div. 1DEF. For 1988 there is reasons to believe that lines hit a high local concentration in Div. 1C and that the survey consequently overestimates the true densitiy (Anon., 1989). For 1989 the trend in offshore and inshore densities are comparable with an increase in densities to the south. From table 6 it is seen that for both small and large cod density is higher in the coast region as compared to the fiords. Further the highest densities is found in the upper 100 m.

3.4 Estimation of abundance

Offshore stock abundance was calculated by raising the number caught in the trawl survey by the ratio of total area to swept area for all stratas. Long-line CPUE was converted to swepth area units by the equations given in section 3.2 and these were then raised by strata areas.

A simple check of the long-line convertion was made by comparing the trawl abundance in Div. 1D in 1987 and 1988 with the concurrent estimate based on the long-line catches. In both years the long-line estimate comes out somewhat below the trawl estimate (8% in 1987 and 24% in 1988).

The offshore trawl estimates and inshore long-line based estimates for the years 1987-1989 are given by NAFO Div. in table 7 and the distribution of the inshore abundance is presented by coastal zone in table 8.

4. Discussion

The use of long-lines in research work is not common and a few remarks on the virtues and limitations of this gear is therefore necessary. The biggest asset is of cource that long-lines can be used on rocky and very sloping bottom. For areas like the Greenland coast and fiords it is probably the only gear which can be freely used. Another asset is that it can be operated from small and technologically outdated wessels. However, the limitations are equally clear. As a fixed gear restrictions are placed on the distributions of stations i.e. stations to be covered in one day must be situated rather closely and this enhances the chance of hitting local high or low concentrations of fish. Long-lines are also saturable as hooks are occupied or bait are lost. This effect has however been ignored in the present analysis as averagage catch per 100 hooks is less than 10 fish of all species.

Relative to the research trawl the long-lines selected the larger cod with full selection taking place for fish above 65 cm. Long-line CPUE was therefore converted to trawl units on a size dependent basis. The conversion factors varies with a factor of 1000 and this implies that a single small fish will influence an abundance estimate as much as the catch of 1000 large ones. Long-line estimates are thus sensitive to chance variations in the catch of small fish. This should not adversively affect a total abundance estimate achieved by adding 20 independent strata estimates but it might influence values for single stratas. Further, the convertion of long-line data to trawl units adds extra uncertainties to the estimate of the abundance. The magnitude of this has yet to been evaluated.

In spite of the problems connected with the convertion of long-line CPUE to trawl units the surveys give a first-time imperical estimate of inshore cod abundance off West Greenland. The line surveys have not covered the entire West Greenland area but if comparing the inshore and offshore abundance in NAFO divisions covered by both the long-line and the trawl survey (table 7) the fraction of the inshore stock component amounts to 20% (1987) 37% (1988) and 21% (1989). The high level in 1988 was due to large catches in Div. 1C and, as mentioned, this might be caused by the lines hitting a high, but local concentration of cod. Placing limited reliance on the 1988 value an average proportion of roughly 20-25% of the total stock seems to be found inshore.

Within the inshore area the density of cod is significantly higher in the coastal area compared to the fiords (table 6). The coastal area is also much larger than the fiord area and about 85% of the inshore cod population is thus found between the coast/mouth of the fiords and 3 nm. off the base line (table 8). Analysis of tag return data from 1920 to 1965 have shown that fiord tagged cod only rarely leves the fiords and these cod are therefore assumed to belong to local stationary populations (Hansen, 1949 ; Hovgård and Christensen, 1990). If this patterns still remains the size of the local fiord populations should at present be very small compared to the bank population.

5. References

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Table 1: Number of long line settings by strata at West Greenland, 1987-1989.

Year	Area Depth[1] Div.	Off shore 50	150	250	Coast 50	150	250	Fiord 50	150	250
1987	1C	3	7	3	7	7	2	2	2	-
	1D	12	6	5	9	4	4	5	3	6
	1E	1	7	2	7	7	1	2	2	2
1988	1C	4	5	1	10	7	3	3	3	2
	1D	7	8	4	10	11	3	2	4	2
	1E	1	-	2	1	2	1	1	1	-
1989	1B	-	-	-	9	9	2	6	6	3
	1C	-	-	-	5	6	2	8	4	2
	1D	-	-	-	17	8	3	6	4	3
	1E	-	-	-	6	3	3	2	3	3

[1] 50 indicate dept zone 0-100m etc.

Table 2 : Strata areas by NAFO divisions (sq. naut. miles).

NAFO div.	Depth Area	0-100 m	100-200 m	200-300 m	Total
1B	Fiord	78	50	43	171
	Coast	380	176	40	596
	Bank	865	1256	297	2418
1C	Fiord	269	131	121	521
	Coast	962	135	34	1131
	Bank	1191	3493	996	5680
1D	Fiord	381	185	134	700
	Coast	1093	85	86	1264
	Bank	1475	875	628	2978
1E	Fiord	258	102	63	423
	Coast	963	184	21	1168
	Bank	276	1662	464	2402
1F	Fiord	485	291	255	1031
	Coast	844	742	52	1638
	Bank	366	2202	607	3175

Tabel 3 : Catch, effort, CPUE and relative selection of long-lines to trawl by length group of cod for offshore trawl and long-line research fisheries at West Greenland, in 1987 and 1988.

Area / effort	Length (cm)	Trawl Catch	Trawl CPUE	Long-line Catch	Long-line CPUE	Rel. Selec.
1987	24-29	162	18.0	1	0.023	.00128
	30-35	1267	140.8	6	0.138	.00098
Div. 1D	36-41	8494	943.8	39	0.900	.00095
	42-47	11242	1249.1	128	2.953	.00236
0-100 m.	48-53	3859	428.8	45	1.038	.00242
	54-59	522	58.0	39	0.900	.01552
9 trawl hauls	60-65	145	16.1	86	1.984	.12316
	66-71	227	25.2	115	2.653	.10520
4334 hooks	72-77	134	14.9	74	1.707	.11468
	78-83	10	1.1	20	0.461	.41532
	84-89	-	-	5	0.115	-
1987	24-29	1071	82.4	-	-	-
	30-35	3224	248.0	-	-	-
Div. 1D	36-41	11730	902.3	2	0.086	.00010
	42-47	12482	960.2	18	0.780	.00081
100-200 m.	48-53	3786	291.2	12	0.520	.00179
	54-59	665	51.2	14	0.606	.01185
13 trawl hauls	60-65	68	5.2	39	1.689	.32291
	66-71	212	16.3	51	2.209	.13544
2309 hooks	72-77	32	2.5	44	1.906	.77415
	78-83	40	3.1	13	0.563	.18298
	84-89	3	0.2	3	0.130	.56301
1987	24-29	1764	92.8	1	0.037	.00040
	30-35	3882	204.3	-	-	-
Div. 1E	36-41	13309	700.5	2	0.074	.00011
	42-47	10726	564.5	17	0.631	.00112
100-200 m.	48-53	2306	121.4	20	0.742	.00612
	54-59	378	19.9	14	0.519	.02611
19 trawl hauls	60-65	299	15.7	70	2.597	.16505
	66-71	115	6.1	133	4.935	.81536
2695 hooks	72-77	84	4.4	95	3.525	.79732
	78-83	58	3.1	31	1.150	.37682
	84-89	14	0.7	5	0.186	.25179
1988	24-29	17	1.3	-	-	-
	30-35	435	33.5	2	0.084	.00250
Div. 1D	36-41	2537	195.2	8	0.334	.00171
	42-47	11329	871.5	41	1.713	.00197
0-100 m.	48-53	13696	1053.5	64	2.673	.00254
	54-59	4257	327.5	33	1.378	.00421
13 trawl hauls	60-65	565	43.5	35	1.462	.03364
	66-71	36	2.8	38	1.587	.57319
2394 hooks	72-77	9	0.7	15	0.627	.90504
	78-83	7	0.5	5	0.209	.38787
	84-89	-	-	1	0.042	-
1988	24-29	73	4.6	-	-	-
	30-35	5406	337.9	7	0.239	.00071
Div. 1D	36-41	13967	872.9	10	0.342	.00039
	42-47	27881	1742.6	71	2.425	.00139
100-200 m.	48-53	21579	1348.7	103	3.518	.00261
	54-59	5491	343.2	27	0.922	.00269
16 trawl hauls	60-65	749	46.8	23	0.786	.01678
	66-71	55	3.4	31	1.058	.30800
2928 hooks	72-77	50	3.1	29	0.990	.31694
	78-83	58	3.6	23	0.786	.21670
	84-89	-	-	3	0.102	-

Table 4 : ANOVA of log(Rel. selec) vs. cod length group

Statistics

Source	Df	SS	MS	F	R^2
Model	5	283.8	56.778	80.4	0.918
Noise	36	25.2	0.706		

Estimates

Length group	Estimate log-scale	95% conf.[1] interval	Retrans.[2] estimate
36-41	-7.915	± 0.9662	0.00052
42-47	-6.554	± 0.9662	0.0020
48-53	-5.875	± 0.9962	0.004
54-59	-4.727	± 0.9962	0.013
60-65	-2.501	± 0.9962	0.117
>66	-1.063	± 0.4300	0.492

[1] 95 % c.i = $t_{.975,n} \cdot s_{\mu}$, where s_{μ} = sqrt(MS/n) and n= number of observations

[2] Retransformed estimate = exp(log-estimate) · exp(MS/2)

Table 5 : Cod densities by NAFO div. expressed by CPUE in the long-line surveys (nos. per 100 hooks) given separately for two size groups of cod. Division values are strata means weighted by area.

Area / Year	Cod size	inshore 1B	1C	1D	1E	offshore 1D
1987	<54 cm	-	1.35	0.70	0.36	2.86
	≥54 cm	-	0.55	3.80	3.99	6.07
1988	<54 cm	-	5.29	1.72	0.35	4.58
	≥54 cm	-	1.00	2.45	0.45	4.29
1989	<54 cm	0.30	0.47	0.55	0.87	-
	≥54 cm	0.05	0.12	0.34	0.78	-

Table 6 : Cod densities by inshore zone expressed by CPUE in the long-line survey given for two size groups of cod. Values for the different zones are strata means weighted by areas.

Area Depth[1] m.		Coast 50	Coast 150	Coast 250	Fiord 50	Fiord 150	Fiord 250	1D-bank 50	1D-bank 150	1D-bank 250
Year	size (cm)									
1987	<54	1.07	0.49	0.38	0.56	0.00	0.06	4.68	1.38	0.63
	≥54	4.41	1.25	1.36	0.62	0.08	0.14	7.28	7.03	1.85
1988	<54	3.57	1.50	1.29	0.96	0.48	0.16	4.69	1.38	1.78
	≥54	2.06	0.63	0.43	0.60	0.16	0.00	5.23	4.65	1.59
1989	<54	0.69	0.42	0.36	0.58	0.31	0.17	-	-	-
	≥54	0.36	0.43	0.22	0.49	0.19	0.06	-	-	-

[1] 50 m indicates the depth zone 0-100 etc.

Table 7 : Estimates of swept area abundance of cod above 36 cm., West Greenland, 1987-1989. Offshore estimates are derived from trawl surveys conducted by the Fed. Repub. of Germany and inshore estimates from Greenlandic long-line surveys converted to swept area units. The abundance is given in millions of fish.

Year	1987		1988		1989	
Div.	insh.	offsh.	insh.	offsh.	insh.	offsh.
1B	-	+	-	+	8	+
1C	67	135	198	1	18	1
1D	32	221	68	435	22	24
1E	17	107	16	38	31	240
1F	-	33	-	47	-	94

- : No coverage in area + : estimate less than 0.5 mill.

Table 8 : Long-line estimates converted to swept area abundance of inshore cod above 36 cm by area and depth, West Greenland, 1987-1989. Abundance in millions.

Area Depth[1]	Coast 50	Coast 150	Coast 250	Fiord 50	Fiord 150	Fiord 250
1987	96	7	1	12	+	+
1988	234	12	3	29	3	+
1989	54	6	1	14	3	1

+ : less than 0.5 mill. cod

[1] depth 50 m indicates depth zone 0-100 m etc.

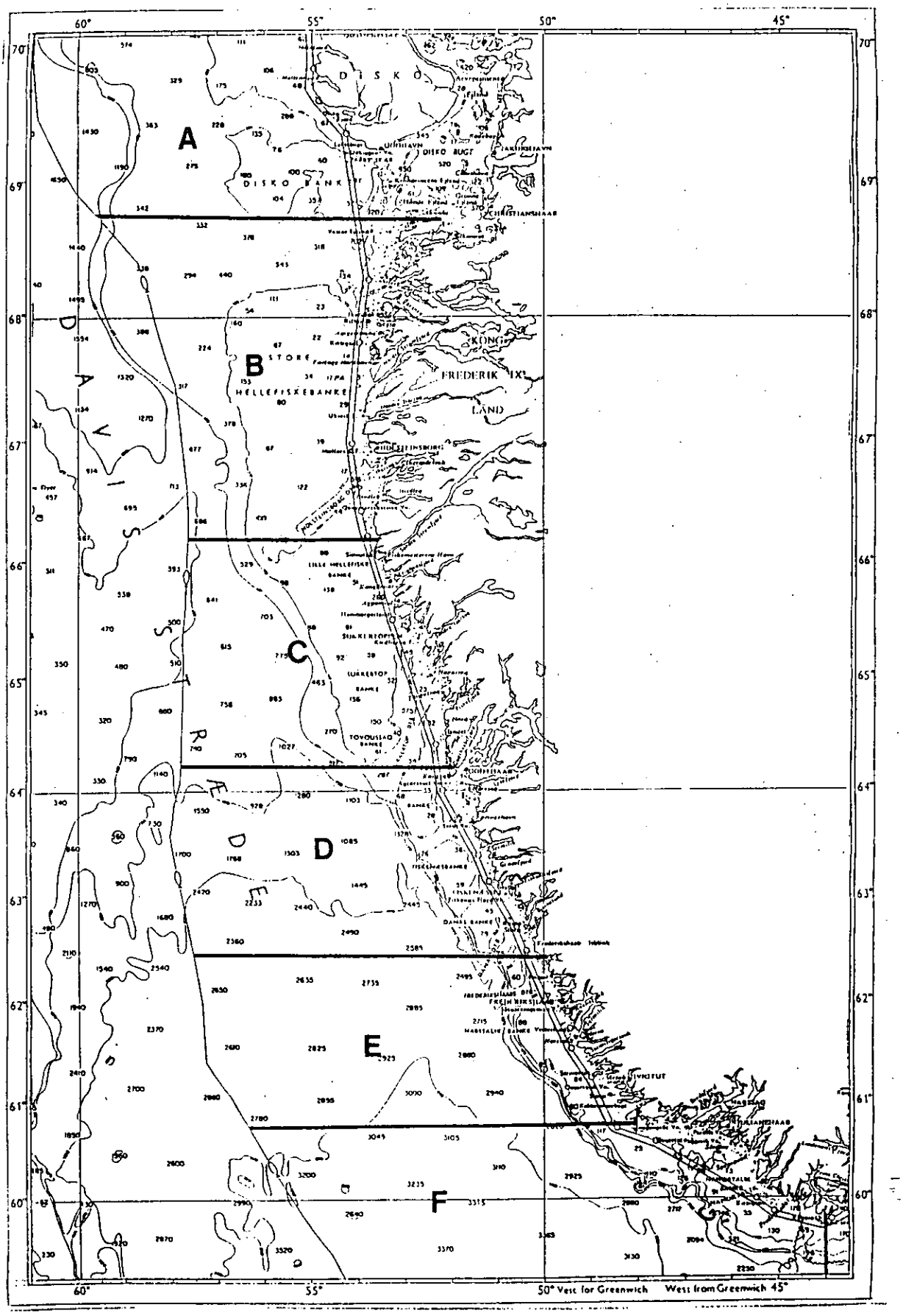

Fig 1 : Map of West Greenland showing NAFO divisions (A-F), the baseline and the 3 nm. line.

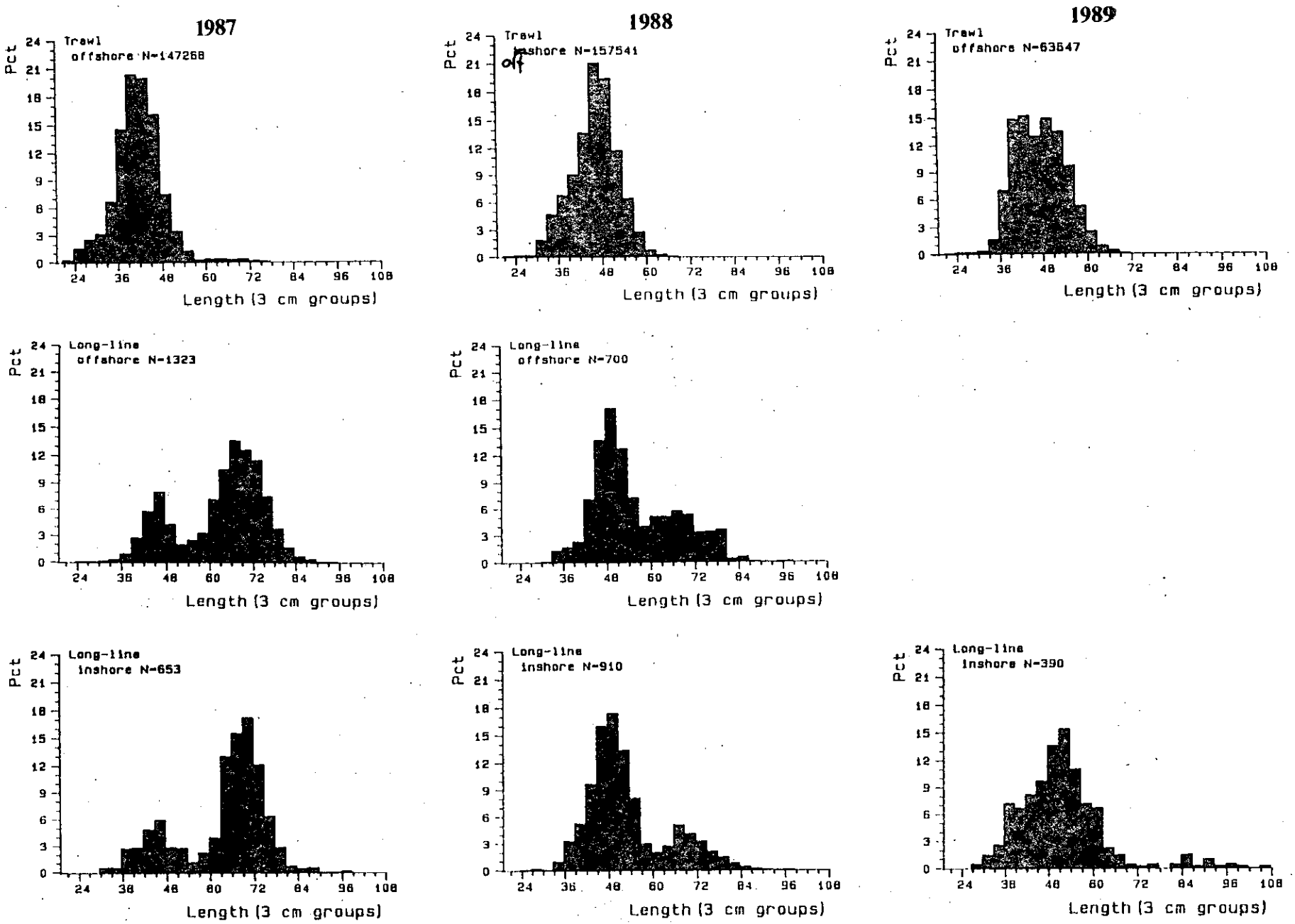

Fig 2 : Length distributions of cod taken in research trawl and research long-line in West Greenland, 1987-1989.

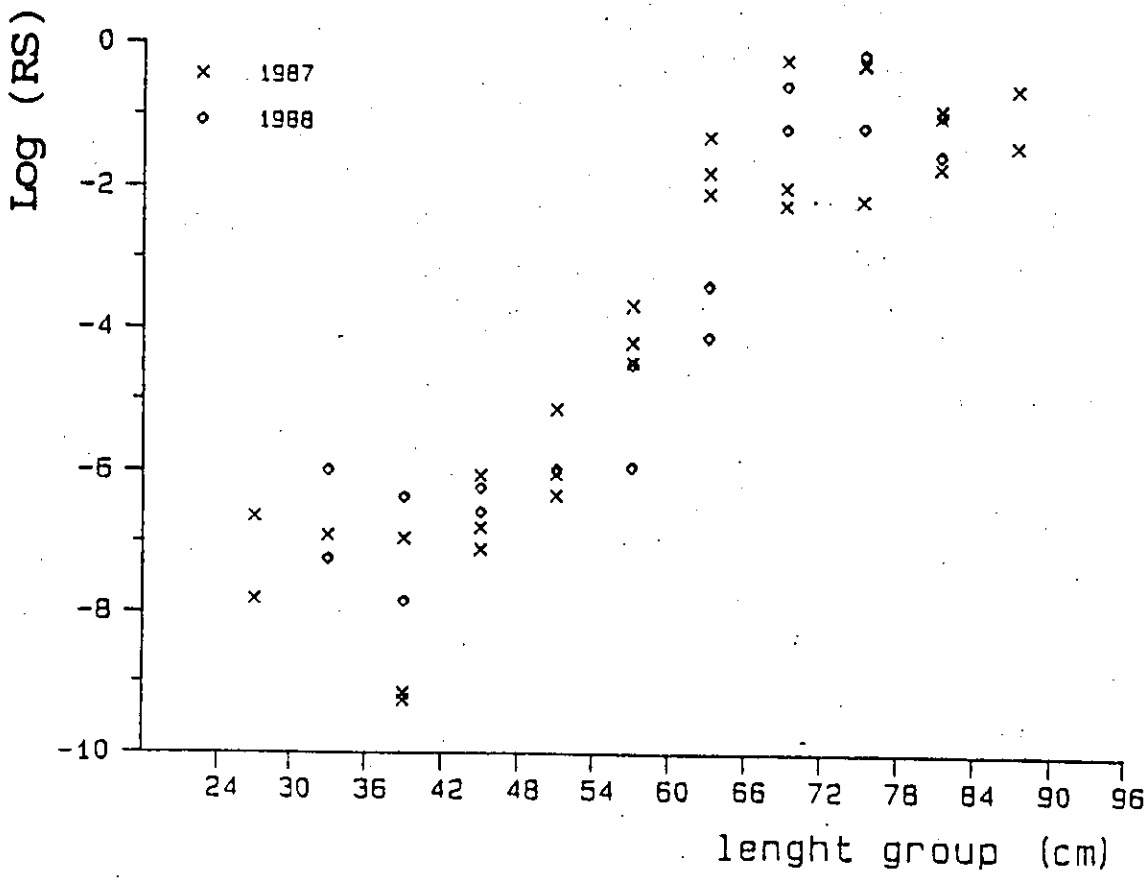

Fig 3 : Relative selection of long-line to trawl vs. size of cod.