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C.M.1979/G:8
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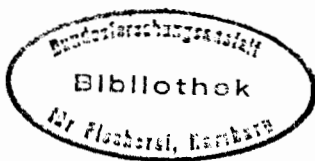
REPORT OF THE WORKING GROUP ON GREENLAND HALIBUT

IN REGION 1

Charlottenlund, 7 - 10 May 1979

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REPORT OF THE WORKING GROUP ON GREENLAND HALIBUT IN REGION 1

1. ## PARTICIPANTS

W R Bowering	Canada
C J Rørvik	Norway
A Sigurdsson	Iceland
B Vaske (Chairman)	German Democratic Republic

V M Nikolaev, ICES Statistician, also attended the meeting.

No representatives were present from Poland and USSR, but the Working Group received relevant data of these countries for 1978.

2. ## TERMS OF REFERENCE

At the 66th Statutory Meeting of ICES it was decided (C.Res.1978/2:41)

> "that the Working Group on Greenland Halibut in Region 1 should meet at ICES headquarters to assess TACs for 1980. To facilitate this, participants are urged to bring to the meeting of the Working Group all relevant data".

3. ## GREENLAND HALIBUT IN SUB-AREAS I AND II

3.1 ### Nominal Catches

The total nominal catches for the main fishing areas are included in Table 1 for the period 1967-78. Nominal catches by country for each fishing area are given in Tables 2, 3 and 4. In Table 5 the catches are summarised for Sub-areas I and II.

For the period under consideration the total catch of Greenland halibut in Sub-areas I and II increased from a catch of 26 168 tonnes in 1968 to a maximum catch of 89 484 tonnes in 1970. The catches decreased to a level of 29 938 tonnes in 1973. In the period 1974-76 total catches have been relatively constant in a range between 36 074 tonnes and 38 172 tonnes.

The preliminary catch for 1978 in Sub-areas I and II of 24 448 tonnes is the lowest catch since 1978, representing a drop of 4 439 tonnes from the amount taken in 1977.

3.2 ### Catch per Unit Effort and Effort Data

Catch figures per hour trawling were available from the USSR fishery from the period 1965 to 1978 (Table 6). Using the catch per unit effort values in the USSR trawl fishery as a standard, the effort for the total fishery was calculated (Table 6).

Data from the USSR trawl fishery show a considerable decrease in the catch per unit effort in 1977 and 1978 compared with the period before 1970-76.

Catch per unit effort values were also calculated for the German Democratic Republic freezing trawlers in Division IIb in October as catch per day for the period 1973-78 (Table 6). Unfortunately, the data are only available as the catch of Greenland halibut related to the total effort exerted on all species caught during the month. These data also show a downward trend similar to that of the USSR c.p.u.e. data. For further information the proportion of Greenland halibut to the total monthly catch is included in Table 6.

3.3 Virtual Population Analysis (VPA)

3.3.1 Age composition of landings

The age compositions in 1977 were adjusted according to changes in the catch statistics. For 1978, age compositions were available for the trawl catches of the German Democratic Republic, the USSR and Norway. These were raised to the total landings in the trawl fishery.

Furthermore, age compositions were presented for the Norwegian long-line and gill-net fishery. All age compositions available in 1978 represented 95% of the total landings in Sub-areas I and II.

The total age compositions for 1970-78 are given in Table 7.

3.3.2 Estimation of the input fishing mortalities for 1978

The fishing pattern in 1978 was iteratively estimated equal to the average fishing pattern in 1975-77.

The fishing mortalities on the oldest age group (16) in 1970-77 were set equal or close to the unweighted average fishing mortality on 8 to 13 year old fish in the same year.

In estimating the actual fishing mortality in 1978 on the fully recruited age groups, the Group considered two alternatives.

Alternative 1

The input fishing mortalities in 1978 were chosen so that the total effort and the corresponding F_{8-13} in 1978 fitted with the regression line between the same set of values for 1970-74 (Figure 1a). The consequences of this alternative is that as the total effort in 1978 has the same relation with F_{8-13} as the relation for 1970-74, this relationship breaks down, however, for the years 1975-77. This alternative is parallel to Alternative 2 in the last year's report (Doc. C.M.1978/G:4), where the total effort in 1975 and 1976 were assumed to be under-estimated.

The results of the VPA based on the present Alternative 1 are given in Tables 8 and 9.

Alternative 2

The calculated total effort in 1978 was 18% higher than the average total effort in 1975-77. For this Alternative the fishing mortality on the fully recruited age groups was

adjusted so that the unweighted F_{8-13} in 1978 becomes 18% higher than the mean F_{8-13} in 1975-77. This is shown in Figure 1.b. The results of the VPA based on this alternative are given in Tables 10 and 11. The change of F_{8-13} in 1978 from 0.42 in Alternative 1 to 0.75 in Alternative 2 resulted in little change of the total effort F_{8-13} relationship for 1970-74. The corresponding relationship for the years 1975-77, however, is much more sensitive to F_{8-13} in 1978 (Figure 1.a and Figure 1.b).

If Alternative 2 is correct, Figure 1.b indicates that the relation between the total effort and the fishing mortality has changed from the periods 1970-74 to 1976-78, 1975 being an intermediate year. A possible reason for this change could be errors in the estimation of the effort.

Another reason could be that the areas where Greenland halibut concentrate have changed. This could be a reaction to changes in hydrographic conditions, since the colder Arctic waters have had wider distribution in the Barents Sea during recent years. This corresponds to increased catches in Division IIa and decreased catches in Division IIb in 1977 and 1978 compared with previous years (Tables 3 and 4).

If the area of distribution has been reduced, one would expect the same effort to generate higher fishing mortality. This hypothesis could also explain why the c.p.u.e. in the USSR trawl fishery remained fairly stable in 1971-76 (Table 6), while the stock size decreased (Figure 2).

3.4   Mean Weight at Age

Mean weights at age used in the biomass calculations and catch predictions were increased by 5% compared with the data used by the Working Group in 1976 and 1977. The new mean weights per age group correspond with the average values in the USSR fishery in the period 1970-76. The adjustment was necessary to get a correspondence between the observed catches and the sum of products of the mean weights and estimated numbers per age group for the period 1970-78. The mean weight at age data used in the calculations are given in Table 12.

3.5   Yield and Spawning Stock per Recruit

The yield and spawning stock per recruit curves were calculated for the 1978 exploitation pattern (Figure 3 and Table 12).

Compared with the previous assessment (Doc. C.M.1978/G:4), there are only slight changes in the exploitation pattern. For the present exploitation pattern, the $F_{0.1}$ and F_{max} values correspond to 0.12 and 0.20, respectively, therefore,

the 1978 fishing mortality under both alternatives (0.42 or 0.75) is far above the level corresponding to F_{max}.

For the 1978 fishing mortality, $F_{0.1}$ and F_{max}, the corresponding sustainable yield and equilibrium spawning stock biomass were calculated assuming average recruitment corresponding to the different alternatives:

$$R_{1970-74} = 36 \times 10^6 \quad \text{(Alternative 1)}$$

$$R_{1970-74} = 31 \times 10^6 \quad \text{(Alternative 2)}.$$

R	F	Y/R (kg)	Sustainable yield (tonnes)	Y/R (kg)	Spawning stock biomass (tonnes)
36×10^6	$F_{78}= 0.42$	.62	22 320	0.8	28 800
	$F_{0.1}= 0.12$	.60	21 600	4.5	162 000
	$F_{max}= 0.20$	.66	23 760	2.6	93 600
31×10^6	$F_{78}= 0.75$	.56	17 360	0.2	6 200
	$F_{0.1}= 0.12$	.60	18 600	4.5	139 500
	$F_{max}= 0.20$	.66	20 460	2.6	80 600

Under both alternatives it appears that the present high F values have no important effect on the yield per recruit. The spawning stock biomass per recruit, however, could be increased quite considerably by reducing the present F towards F_{max}. Unfortunately, the data set is too short to construct a relationship between parental stock and recruitment to indicate an optimal spawning stock biomass.

3.6 **Catch Prediction and the State of the Stock**

Catches were projected for 1980 using the 1978 exploitation pattern and average recruitment from VPA for 1970-74 at age 3 (Table 12). Furthermore, it was assumed that the TAC of 25 000 tonnes will be taken in 1979.

These calculations were performed based upon four options of fishing mortality in 1980 for each of the alternatives. The resultant total stock biomass and spawning stock biomass for the beginning of 1981 were also calculated for each option.

The four options of F are as follows:

Option A: Fishing at an F level in 1980 equal to the level of F required to take the TAC of 25 000 tonnes in 1979

Option B: Fishing at an F level in 1980 corresponding to the midpoint between the required F level to take the TAC of 25 000 tonnes in 1979 and F_{max}

Option C: Fishing at F_{max} in 1980

Option D: Fishing at $F_{0.1}$ in 1980.

Alternative 1 - Under Alternative 1 the catch projections for 1980 ranged from 9 800 tonnes for Option D to 29 500 tonnes for Option A with projected catches of 22 600 tonnes and 15 700 tonnes for Options B and C, respectively (Table 13). The resultant stock size under this alternative will appear to stabilise in 1981 at Option A and show increases under the three other options. If this alternative is correct, it would appear to halt the dramatic decreases in stock size which have been occurring over the years up to 1977 (Figure 2), fishing under any of the four options. The estimates of stock biomass derived from VPA under this alternative appear to have also been stable over the past three years even though the catch per unit effort seems to have decreased (Figure 4).

Alternative 2 - Under Alternative 2 the catch projections for 1980 ranged from 3 300 tonnes for Option D to 20 700 tonnes for Option A with projected catches of 14 200 tonnes and 5 400 tonnes for Options B and C, respectively. Under this alternative the required F to catch the TAC in 1979 would have to be very high (F = 1.05). The stock size would indicate a continuing decrease under Option A. However, for the three other options the stock would appear to slowly rebuild. The stock size under this alternative has been on a decreasing trend over the past 9 years (Figure 2) and would continue to do so until at least 1981 at the 1979 assumed fishing level. The catch per unit effort for the past three years has decreased which is in accordance with stock size (Figure 5). If Alternative 2 is correct, then this would be an expected occurrence, unlike the relationship apparent in Alternative 1.

4. GREENLAND HALIBUT IN SUB-AREAS V AND XIV

4.1 Nominal Catch

The nominal catches for Divisions Va and Vb and Sub-area XIV are given in Tables 14 to 17 for the period 1968-78. The tables present the nominal catches by country for each fishing area.

In the period 1968-75 total nominal catches in all the areas were in the range of 21 872 tonnes to 36 280 tonnes. In 1976 the total catch decreased to 6 045 tonnes, but increased again to 16 578 tonnes and 14 208 tonnes in 1977 and 1978, respectively.

4.2   Virtual Population Analysis (VPA)

4.2.1   Age composition of landings

The fishery for Greenland halibut in this area is conducted by two types of gear, that of otter trawl and longline. Therefore, in order to assess this fishery adequately, commercial samples for length and age from both gears is a basic requirement. For 1976-78 age and length distributions were obtained from both gears as supplied by Iceland and were used to estimate total catches in numbers at age for these three years. There were essentially no catches by longline in 1975, therefore the trawl catches were considered representative of the total fishery for that year. Length compositions of trawl catches from the German Democratic Republic were broken down by an Icelandic age/length key and numbers at age adjusted up to the total catch for 1975.

Length and age data were available from the Icelandic longline fishery from 1972 to 1974, however, no samples were available from the trawl fishery during this period with the exception of a small sample in 1972. Considering the vast difference in size composition between catches from the two gears (Figure 6) and the fact that during this period the trawl catches comprised the major portion of the landings, it was considered impossible to calculate reliable estimates of the total numbers caught at age for these years.

An attempt was made by the Working Group to derive a relationship between the relative age distribution of the two gears for the years when samples were available from both gears, and use this relationship to break down trawl catches for 1973 and 1974. The variability in this relationship between years was so large that the Working Group felt that to use such data would be inappropriate and completely unrealistic. The Working Group, therefore, had to perform a virtual population analysis based only upon the last four years (1975-78) in which minimum, however reliable, data were available (Table 18).

4.2.2   Estimation of input fishing mortalities for 1978

Due to the lack of catch per unit effort data a definitive value for the present level of fishing mortality was impossible to obtain. A catch curve (Figure 7) was, however, constructed by combining the 1975-78 data in order to give some indication of the average fishing mortality over the past 10 years. A value of $F = 0.35$ (assuming $M = 0.15$) was derived with a correlation coefficient on the regression of $r = 0.99$. This F value represents average removals of about 23 000 tonnes annually over the past 10 years. This value was considered high for terminal F and an arbitrary value somewhat lower of 0.25 was used to initiate the calculations. This value was considered to possibly be in the neighbourhood of the true value, since the weighted F over the fully recruited age groups for 1975 was close to the value derived from the catch curve and the catch in 1975 was the same as the long-term average of 23 000 tonnes. The results of the VPA are presented in Tables 19 and 20.

In view of the uncertainty connected with the estimation of terminal F, the Working Group agreed that future catch predictions based upon this analysis would be considered very unreliable.

The results of the VPA were used, however, to derive estimates of exploitation pattern for 1978 (Table 21) in order to produce an up-to-date yield per recruit curve and a spawning stock per recruit curve. This was done by assigning such fishing mortality values to the younger ages in 1978 that would reflect reliable recruitment estimates in 1975 and 1976.

4.3 Yield and Spawning Stock per Recruit

Yield and spawning stock per recruit curves (Figure 8) were constructed using the exploitation pattern for 1978 as derived from the VPA. The mean weights per age group (Table 21) were taken from the commercial catch composition for 1978. The age at entry into the commercial fishery was considered to be age 5.

For the 1978 exploitation pattern the $F_{0.1}$ and F_{max} values correspond to 0.125 and 0.45, respectively. The F value of 0.25 as selected for 1978 falls between $F_{0.1}$ and F_{max}.

4.4 Total Allowable Catch (TAC)

With the many assumptions and uncertainties connected with the data, the Working Group considered it impossible to make predictions on catch levels for 1980 or beyond. It also agreed that the yield per recruit analysis is reasonable and is probably a fair estimation of the 1978 fishing pattern.

The 1978 estimated fishing mortality, even with a fairly large degree of probable error, would still appear to occur within the range between $F_{0.1}$ and F_{max}. It was therefore agreed that the TAC for 1979 of 15 000 tonnes is an acceptable catch level and should be continued for 1980.

Therefore, the Working Group recommends a TAC for Greenland halibut in Sub-areas V and XIV for 1980 of 15 000 tonnes.

5. CONSIDERATION OF THE SCIENTIFIC QUESTIONS RAISED BY ACFM

Question 1: Can independent estimates of stock be developed in Sub-areas I and II?

Answer: No. No data are available for swept area calculations. The taggings are not usable for this purpose as the tagging mortality and the shedding of tags are unknown. Acoustic surveys are not possible.

Question 2: Can catch per unit effort be used to estimate total mortality in Sub-areas I and II?

Answer: The fisheries in Sub-areas I and II are comprised of three different gears, gill net, longline and otter trawl, with varying levels of fishing by years. It was indicated that the catch at age was radically different between trawl and the other two gears; therefore, mortality levels based on the c.p.u.e. data for the same year classes between consecutive years would be biased. However, during the first meeting of the Working Group in 1977, c.p.u.e. data for individual age groups were used to estimate M by relating Z to total effort. The Z values showed a poor correlation with the total effort, and the method was, at that time, evaluated as unreliable for giving an estimate of M in this particular case.

Question 3: What additional information is required for more reliable estimates of stock size in Sub-areas V and XIV?

Answer: Any age/length compositions if available from trawl for the period prior to 1975 would be useful to create a longer series of data for the total fishery and consequently a more reliable VPA. For the present data, it is considered necessary to have at least two more years of age/length data from the total fishery in order to place a higher degree of confidence on VPA results.

One basic requirement that is necessary for proper assessment is that of catch per unit effort data from all sectors of the fishing fleet. Without these data, it is almost impossible to determine a value of terminal F required to initiate the calculations of virtual population and cohort analyses.

Table 1. Greenland halibut. Total nominal catch by main fishing areas (tonnes).

Year	Sub-area I	Div. IIb	Div. IIa	Div. Va	Div. Vb	Sub-area XIV	Total catch
1967	2 198	6 712	15 357	30 657	442	200	55 566
1968	2 488	8 935	14 745	21 036	647	189	48 040
1969	8 393	25 010	10 386	23 141	906	280	68 116
1970	4 011	70 523	14 950	30 001	-	3 822	123 307
1971	5 413	62 764	10 857	15 049	11	13 913	108 007
1972	8 549	18 873	15 633	10 666	417	15 389	69 527
1973	5 667	16 081	8 190	7 386	358	12 719	50 401
1974	5 251	24 660	7 852	7 866	325	28 089	74 043
1975	6 495	28 511	3 166	3 308	560	19 627	61 667
1976	2 479	29 610	3 985	5 448	324	273	42 119
1977	2 164	15 492	11 231	15 679	658	241	45 465
1978*	1 280	10 090	13 078	11 452	596	2 160	38 656

* Preliminary

Table 2. Greenland halibut. Nominal catch (tonnes) in Sub-area I.

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
German Dem.Rep.	23[1]	256[1]	-[1]	14[1]	1[1]	-	-	5	-	-	-
Germany,Fed.Rep.	-	-	-	-	-	25	22	6	2	1	-
Norway	1 488	689	1 675	1 951	3 116	2 947	2 167	2 160	1 203	1 262	942
Poland	-	5 314	-	7	117	-	1	-	9	-	-
UK(Engl.&Wales)	-	-	-	-	949	995	732	550	665	541	127[2]
USSR	977[1]	2 134	2 336	3 441	4 366	1 700	2 329	3 774	600	360	211
Total	2 488	8 393	4 011	5 413	8 549	5 667	5 251	6 495	2 479	2 164	1 280

* Preliminary.

1) From national statistics.

2) December catch estimated.

Table 3. Greenland halibut. Nominal catch (tonnes) in Division IIa.

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
Faroe Islands	-	-	44	-	-	-	-	-	2	21	-
German Dem.Rep.	1[1]	501[1]	2 131[1]	353[1]	1 069[1]	52	656	172	354	1 641	1 398
Germany,Fed.Rep.	+	+	-	3	3	+	49	41	17	22	321
Norway	14 744	9 885	6 408	4 974	11 715	7 861	6 593	2 265	3 490	2 281[1]	2 283
Poland	-	-	6 291	5 036	2 643	137	499	66	31	95	197[1]
UK(Engl.&Wales)	-	-	-	-	182	118	55	107	48	211	70[2]
USSR	-	-	76	491	21	22	-	515	43	6 960	8 809
Total	14 745	10 386	14 950	10 857	15 633	8 190	7 852	3 166	3 985	11 231	13 078

* Preliminary.
1) From national statistics.
2) December catch estimated.

Table 4. Greenland halibut. Nominal catch (tonnes) in Division IIb.

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
German Dem.Rep.	233[1]	3 031[1]	16 598[1]	2 582[1]	563[1]	3 902	5 258	8 295	8 601	6 535	3 213
Germany,Fed.Rep.	-	71	-	-	-	34	17	47	12	125	-
Norway	6 282	4 282	7 788	2 541	1 152	3 181	31	433	1 312	671[1]	855[1]
Poland	-	-	12 971	7 234	5 221	2 003	4 646	3 579	3 526	129	347[1]
UK(Engl.&Wales)	-	-	-	-	131	122	79	74	222	307	44[2]
USSR	2 420[1]	17 626	33 166	50 407	11 806	6 839	14 629	16 083	15 937	7 725	5 631[1]
Total	8 935	25 010	70 523	62 764	18 873	16 081	24 660	28 511	29 610	15 492	10 090

* Preliminary.
1) From national statistics.
2) December catch estimated.

Table 5. Greenland halibut. Nominal catch (tonnes) in Sub-areas I and II, 1968-78.
(Data for 1968-77 from Bulletin Statistique)

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
Faroe Islands	-	-	44	-	-	-	-	-	2	21	-
German Dem.Rep.	257[1]	3 788[1]	18 729[1]	2 949[1]	1 633[1]	3 954	5 914	8 472	8 955	8 176	4 611
Germany,Fed.Rep.	-	71	-	3	3	59	88	94	31	148	321
Norway: trawl catch[1]:	-	-	1 638	2 309	9 656	10 217	4 656	1 686	4 030	2 526	2 300
long-line catch and gill net[1]:	22 514	14 856	14 233	7 157	6 327	3 772	4 135	3 172	1 975	1 688	1 780
Poland	-	5 314	19 262	12 277	7 981	2 140	5 146	3 645	3 566	224	544
UK(Engl.&Wales)	-	-	-	-	1 262	1 235	866	731	935	1 059	241
USSR	3 397[1]	19 760	35 578	54 339	16 193	8 561	16 958	20 372	16 580	15 045	14 651
Total	26 168	43 789	89 484	79 034	43 055	29 938	37 763	38 172	36 074	28 887	24 448

* Preliminary.
1) From national statistics.

Table 6. Greenland halibut in Sub-areas I and II.
Catch per unit effort and total effort.

Year	USSR catch/hour trawling (tonnes)	Hours trawling (USSR effort)	Total effort	German Dem.Rep. catch/day trawling (tonnes)	Proportion of Greenland halibut (%)
1965	.80	20 853	43 558		
1966	.77	12 587	34 084		
1967	.70	8 196	34 667		
1968	.65	5 226	40 258		
1969	.53	37 283	82 621		
1970	.53	67 128	168 838		
1971	.46	118 128	171 813		
1972	.37	43 765	116 365		
1973	.39	21 951	76 764	10.7	98
1974	.40	42 395	94 408	9.6	96
1975	.39	52 236	97 877	8.5	81
1976	.40	41 458	90 185	6.9	90
1977	.27	55 722	106 989	4.3	84
1978	.21	69 767	116 419	4.7	82

Table 7.   Greenland halibut in Sub-areas I and II.
            Input data - catch in numbers by year
            and by age (thousands).

AGE	1970	1971	1972	1973	1974	1975
3	1	1	1	1	1	22
4	34	1	461	19	276	334
5	526	80	1109	212	917	840
6	2792	4486	3521	1117	2519	2337
7	10464	12712	9605	3923	6204	6520
8	18562	12283	6438	3515	3838	4118
9	10034	6130	2775	2551	1834	2265
10	6671	4339	1734	1919	1942	1654
11	2517	2703	1368	1536	1622	1857
12	1250	1660	1234	1127	1338	1536
13	616	1044	675	716	734	1122
14	1104	300	200	251	531	600
15	266	123	40	70	137	270
16	15	20	40	56	79	98
TOTAL	54852	45882	29201	17013	21972	23573

AGE	1976	1977	1978
3	1	62	78
4	98	755	528
5	830	2037	1883
6	2982	3255	3563
7	5824	4202	4088
8	5002	2529	2349
9	3000	1617	1499
10	1350	1109	939
11	915	1066	730
12	1212	860	435
13	698	596	347
14	526	385	146
15	254	93	83
16	104	87	28
TOTAL	22796	18653	16696

Table 8. Greenland halibut in Sub-areas I and II.
Fishing mortalities by year and by age
(Alternative 1).

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978
3	.000	.000	.000	.000	.000	.001	.000	.001	.002
4	.001	.000	.014	.001	.011	.014	.003	.013	.010
5	.014	.003	.037	.008	.040	.042	.041	.066	.040
6	.066	.145	.155	.046	.110	.129	.192	.212	.150
7	.293	.446	.491	.243	.357	.426	.506	.424	.420
8	.693	.620	.402	.315	.375	.402	.639	.404	.420
9	.588	.486	.257	.259	.254	..374	.542	.411	.420
10	.601	.515	.231	.268	.303	.361	.377	.371	.420
11	.489	.491	.285	.311	.359	.498	.328	.544	.420
12	.473	.658	.411	.378	.459	.641	.671	.548	.420
13	.621	.879	.581	.419	.427	.833	.643	.788	.420
14	1.480	.666	.379	.417	.594	.702	1.221	.859	.420
15	1.817	.587	.160	.208	.398	.651	.694	.682	.420
16	.580	.610	.360	.330	.360	.520	.530	.510	.420

MEAN F FOR AGES >= 8 AND <= 13 (NOT WEIGHTED BY STOCK IN NUMBERS)
```
      .578    .608    .361    .325    .363    .518    .533    .511    .420
```

AGE-NATURAL MORTALITY

3	4	5	6	7	8	9	10	11	12	13
.150	.150	.150	.150	.150	.150	.150	.150	.150	.150	.150

14	15	16
.150	.150	.150

Table 9. Greenland halibut in Sub-areas I and II.
          Stock in numbers (thousands) at beginning
          of year (Alternative 1).

AGE	1970	1971	1972	1973	1974	1975
3	43820	41816	33907	30326	30375	46224
4	35815	37715	35991	29183	26101	26143
5	41941	30794	32461	30550	25101	22210
6	46945	35612	26431	26912	26098	20755
7	44238	37820	26501	19492	22129	20132
8	39628	28413	20835	13961	13152	13322
9	24118	17051	13158	11995	8771	7779
10	15789	11526	9028	8761	7968	5855
11	6965	7453	5925	6168	5768	5064
12	3548	3676	3925	3836	3891	3468
13	1424	1902	1638	2240	2262	2116
14	1512	659	680	789	1268	1270
15	335	296	291	401	447	603
16	36	47	142	214	280	259
TOTAL						
	306115	254780	210911	184827	173610	175198
SPAWNING STOCK (AGE >= 9)						
	53728	42610	34786	34403	30654	26413

AGE	1976	1977	1978
3	70718	66450	42039
4	39765	60867	57137
5	22192	34135	51689
6	18338	18332	27494
7	15701	13026	12769
8	11316	8150	7337
9	7668	5140	4682
10	4606	3838	2933
11	3513	2719	2280
12	2648	2179	1359
13	1572	1165	1084
14	792	711	456
15	542	201	259
16	270	233	87
TOTAL			
	199642	217147	211607
SPAWNING STOCK (AGE >= 9)			
	21612	16187	13141

Table 10. Greenland halibut in Sub-areas I and II.
Fishing mortalities by year and by age
(Alternative 2).

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978
3	.000	.000	.000	.000	.000	.001	.000	.002	.003
4	.001	.000	.015	.001	.014	.019	.004	.026	.020
5	.014	.003	.040	.008	.046	.051	.057	.110	.080
6	.067	.151	.162	.049	.119	.149	.243	.310	.270
7	.295	.453	.515	.259	.389	.474	.621	.595	.750
8	.696	.628	.412	.338	.408	.456	.773	.570	.750
9	.593	.489	.262	.268	.280	.424	.668	.579	.750
10	.605	.523	.233	.275	.317	.412	.455	.526	.750
11	.492	.497	.291	.315	.372	.533	.397	.748	.750
12	.477	.665	.419	.390	.468	.681	.761	.754	.750
13	.626	.893	.592	.432	.447	.865	.724	1.046	.750
14	1.490	.677	.390	.430	.623	.761	1.364	1.130	.750
15	1.827	.597	.163	.216	.417	.715	.822	.918	.750
16	.580	.620	.370	.340	.380	.560	.630	.710	.750

MEAN F FOR AGES >= 8 AND <= 13 (NOT WEIGHTED BY STOCK IN NUMBERS)

| | .582 | .616 | .368 | .336 | .382 | .562 | .630 | .704 | .750 |

AGE-NATURAL MORTALITY

3	4	5	6	7	8	9	10	11	12	13
.150	.150	.150	.150	.150	.150	.150	.150	.150	.150	.150

14	15	16
.150	.150	.150

Table 11. Greenland halibut in Sub-areas I and II.
Stock in numbers (thousands) at
beginning of year (Alternative 2).

AGE	1970	1971	1972	1973	1974	1975
3	41121	38826	29817	24828	22163	28449
4	34204	35392	33417	25663	21369	19075
5	40654	29408	30461	28335	22071	18136
6	46396	34504	25238	25191	24191	18147
7	43925	37348	25547	18465	20647	18490
8	39520	28143	20429	13143	12269	12049
9	23971	16958	12926	11647	8068	7021
10	15707	11400	8949	8562	7668	5250
11	6934	7382	5816	6100	5597	4807
12	3525	3650	3864	3743	3832	3321
13	1415	1883	1615	2188	2182	2065
14	1508	652	663	769	1223	1201
15	334	293	285	386	431	564
16	36	46	139	208	268	244
TOTAL	299251	245884	199168	169229	151979	138821
SPAWNING STOCK (AGE >= 9)	53431	42263	34258	33604	29269	24474

AGE	1976	1977	1978
3	36511	33420	28040
4	24466	31425	28708
5	16109	20967	26348
6	14832	13096	16161
7	13457	10010	8267
8	9907	6226	4750
9	6575	3935	3031
10	3954	2902	1899
11	2994	2159	1476
12	2428	1733	880
13	1447	977	702
14	749	604	295
15	483	165	168
16	238	183	57
TOTAL	134149	127801	120780
SPAWNING STOCK (AGE >= 9)	18867	12657	8507

Table 12. Greenland halibut in Sub-areas I and II.
Input parameters used in the catch prediction.

Age	Exploitation pattern	Mean weights (kg)	Stock size 1979 ('000)	
			Alternative 1	Alternative 2
3	0.006	.200	36 000	31 000
4	0.025	.441	36 126	24 062
5	0.10	.567	48 708	24 189
6	0.36	.737	42 762	20 928
7	1.00	1.079	20 371	10 619
8	1.00	1.421	7 221	3 361
9	1.00	1.848	4 150	1 931
10	1.00	2.281	2 648	1 232
11	1.00	2.887	1 659	772
12	1.00	3.247	1 290	600
13	1.00	4.303	768	358
14	1.00	4.931	613	285
15	1.00	5.765	258	120
16	1.00	6.308	147	68
Average recruitment			36 000	31 000

Table 13. Greenland halibut in Sub-areas I and II.
Catch predictions for 1980 according to Alternatives 1 and 2.

	Alternative 1				Alternative 2			
	a	b	c	d	a	b	c	d
1978								
$\overline{F}_{8-13}$	0.42	0.42	0.42	0.42	0.75	0.75	0.75	0.75
Catch (tonnes)	24 448	24 448	24 448	24 448	24 448	24 448	24 448	24 448
Stock biomass (tonnes)	134 000	134 000	134 000	134 000	78 000	78 000	78 000	78 000
Spawning stock (tonnes)	35 000	35 000	35 000	35 000	23 000	23 000	23 000	23 000
1979								
$\overline{F}_{8-13}$	0.41	0.41	0.41	0.41	1.05	1.05	1.05	1.05
Catch (tonnes)	25 000	25 000	25 000	25 000	25 000	25 000	25 000	25 000
Stock biomass (t)	138 000	138 000	138 000	138 000	71 000	71 000	71 000	71 000
Spawning stock (t)	31 000	31 000	31 000	31 000	15 000	15 000	15 000	15 000
1980	(F_{1979})	$(\frac{F_{1979}+F_{max}}{2})$	(F_{max})	$(F_{0.1})$	(F_{1979})	$(\frac{F_{1979}+F_{max}}{2})$	(F_{max})	$(F_{0.1})$
$\overline{F}_{8-13}$	0.41	0.30	0.20	0.12	1.05	0.62	0.20	0.12
Catch (t)	29 500	22 600	15 700	9 800	20 700	14 200	5 400	3 300
Stock biomass (t)	190 000	140 000	140 000	140 000	62 000	62 000	62 000	62 000
Spawning stock (t)	29 000	29 000	29 000	29 000	7 100	7 100	7 100	7 100
1981								
Stock biomass (t)	137 000	145 000	153 000	160 000	57 000	65 000	76 000	78 000
Spawning stock (t)	31 000	35 000	39 000	42 000	4 300	6 600	10 000	10 800

Table 14. Greenland halibut. Nominal catch (tonnes) in Division Va.

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
Faroe Islands	-	-	4 122	1 316	1 180	188	41	2	373	947	251
German Dem.Rep.	6 247[1]	7 768[1]	14 958[1]	3 317[1]	159[1]	320	388	-	-	-	-
Germany,Fed.Rep.of	1 253	1 488	-	882	1 119	826	1 786	887	1 719	4 642	-
Iceland	1	5 856	7 343	5 020	4 640	2 115	2 842	1 212	1 687	10 090	11 187
Norway	-	54	338	369	186	-	-	-	-	+	14
Poland	-	-	1 127	899	31	-	485	-	-	-	-
UK(Eng.&Wales)	-	-	-	-	2 223	3 648	2 314	1 207	1 669	-	-
USSR	13 535[1]	7 975[1]	2 113	3 246	1 128	289	10	-	-	-	-
Total	21 036	23 141	30 001	15 049	10 666	7 386	7 866	3 308	5 448	15 679	11 452

*Preliminary.   1) From national statistics.

Table 15. Greenland halibut. Nominal catch (tonnes) in Division Vb.

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
Faroe Islands	-	-	-	-	-	-	7	6	2	304	1
German Dem.Rep.	68[1]	855[1]	-	-	-	-	147	91	-	-	-
Germany,Fed.Rep.of	579	51	-	11	405	287	163	437	309	341	571
Norway	-	-	-	-	-	-	-	7	7	5[1]	3
Poland	-	-	-	-	-	9	-	18	-	-	-
UK(Eng.&Wales)	-	-	-	-	12	61	8	+	6	8	21[2]
USSR	-	-	-	-	-	1	-	-	-	-	-
Total	647	906	-	11	417	358	325	559	324	658	596

* Preliminary.   1) From national statistics.   2) December catch estimated.

Table 16. Greenland halibut. Nominal catch (tonnes) in Sub-area XIV.

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
German Dem.Rep.	-	42[1]	2 981[1]	3 491[1]	7 328[1]	8 806	25 266	16 872	-	-	-
Germany.Fed.Rep.of	187	183	-	270	5	7	+	64	191	224	2 156
Greenland	2	+	-	2	3	4	2	1	1	4	...
Iceland	-	24	2	+	-	3	1	+	2	-	-
Norway	-	-	-	-	-	-	-	-	-	2[1]	3
Poland	-	-	732	7 910	7 847	3 122	1 057	1 054	-	-	-
UK(Eng.&Wales)	-	-	-	-	1	1	1	2	5	11	1[2]
USSR	-	31	107	2 240	205	776	1 762	1 634	74	-	-
Total	189	280	3 822	13 913	15 389	12 719	28 089	19 627	273	241	2 160

* Preliminary.   1) From national statistics.   2) December catch estimated.

Table 17. Greenland halibut. Nominal catch (tonnes) in Sub-areas V and XIV, 1968-78.
(Data for 1968-77 from Bulletin Statistique)

Country	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*
Faroe Islands	-	-	4 122	1 316	1 180	188	48	8	375	1 251	252
German Dem.Rep.	6 315[1]	8 665[1]	17 939[1]	6 808[1]	7 487[1]	9 126	25 801	16 963	-	-	-
Germany,Fed.Rep.of	2 019	1 686	-	1 163	1 529	1 120	1 949	1 388	2 219	5 207	2 727
Greenland	2	+	-	2	3	4	2	1	1	4	...
Iceland	1	5 880	7 345	5 020	4 640	2 118	2 843	1 212	1 689	10 090	11 187
Norway	-	-	338	369	186	-	-	7	7	7	20
Poland	-	-	1 859	8 809	7 878	3 131	1 542	1 072	-	-	-
UK(Eng.&Wales)	-	-	-	-	2 236	3 710	2 323	1 209	1 680	19	22
USSR	13 535[1]	8 006[1]	2 220	5 486	1 333	1 066	1 772	1 634	74	-	-
Total	21 872	24 237	33 823	28 973	26 473	20 463	36 280	23 494	6 045	16 578	14 208

* Preliminary.   1) From national statistics.

Table 18. Greenland halibut in Sub-areas V and XIV.
Input data - catch in numbers by year
and by age (thousands).

AGE	1975	1976	1977	1978
4	1	1	1	1
5	120	43	1	23
6	800	296	34	90
7	1775	584	671	340
8	1782	621	1727	1019
9	1259	431	2289	1193
10	926	240	834	835
11	464	121	420	557
12	459	86	423	306
13	279	37	174	228
14	193	32	120	214
15	137	14	28	112
16	39	6	86	110
17	2	1	41	63
18	2	1	8	18
19	18	1	6	6
20	24	1	1	4
TOTAL	8280	2516	6864	5119

Table 19. Greenland halibut in Sub-areas V and XIV.
Fishing mortalities by year and by age.

AGE	1975	1976	1977	1978
4	.00	.00	.00	.00
5	.01	.00	.00	.00
6	.07	.03	.00	.01
7	.17	.06	.09	.04
8	.28	.08	.24	.18
9	.35	.09	.42	.25
10	.33	.10	.25	.25
11	.22	.06	.23	.25
12	.38	.06	.30	.25
13	.28	.04	.14	.25
14	.29	.04	.19	.25
15	.54	.03	.05	.25
16	.54	.04	.23	.25
17	.05	.02	.36	.25
18	.24	.03	.23	.25
19	1.48	.17	.25	.25
20	.25	.25	.25	.25

MEAN F FOR AGES >= 9 AND <= 20 (WEIGHTED BY STOCK IN NUMBERS)

	.32	.08	.30	.25

AGE-NATURAL MORTALITY

4	5	6	7	8	9	10	11	12	13	14	15	16	17
.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15

18	19	20
.15	.15	.15

Table 20. Greenland halibut in Sub-areas V and XIV.
Stock in numbers (thousands) at beginning
of year.

AGE	1975	1976	1977	1978
4	14741	13149	19199	10769
5	11897	12687	11316	16524
6	13174	10129	10880	9739
7	12349	10598	8444	9333
8	7899	8987	8581	6646
9	4588	5153	7160	5790
10	3492	2787	4036	4052
11	2487	2151	2176	2703
12	1565	1712	1739	1485
13	1217	923	1394	1107
14	829	790	760	1039
15	350	535	650	544
16	100	175	448	534
17	43	50	145	306
18	10	35	42	87
19	25	7	29	29
20	116	5	5	19
TOTAL	74883	69873	77007	70707
SPAWNING STOCK (AGE >= 9)	14822	14323	18586	17695

Table 21. Greenland halibut in Sub-areas V and XIV.
Parameters used in yield and spawning
stock per recruit calculations.

Age	Mean weights (g)	Exploitation pattern
5	968	0.0003
6	1 199	0.04
7	1 423	0.17
8	1 854	0.71
9	2 256	1.00
10	2 607	1.00
11	3 081	1.00
12	3 591	1.00
13	4 604	1.00
14	4 695	1.00
15	5 151	1.00
16	5 893	1.00
17	6 511	1.00
18	7 474	1.00
19	8 538	1.00
20	8 476	1.00

Figure 1. Greenland halibut in Sub-areas I and II. The relation between the mean fishing mortalities on age groups 8-13 and total effort.

Figure 1.a

Alternative 1

Lin.regr.1970-74

$y = 6.80 \times 10^{-2} + 3.02 \times 10^{-3} x$

$r^2 = 0.93$
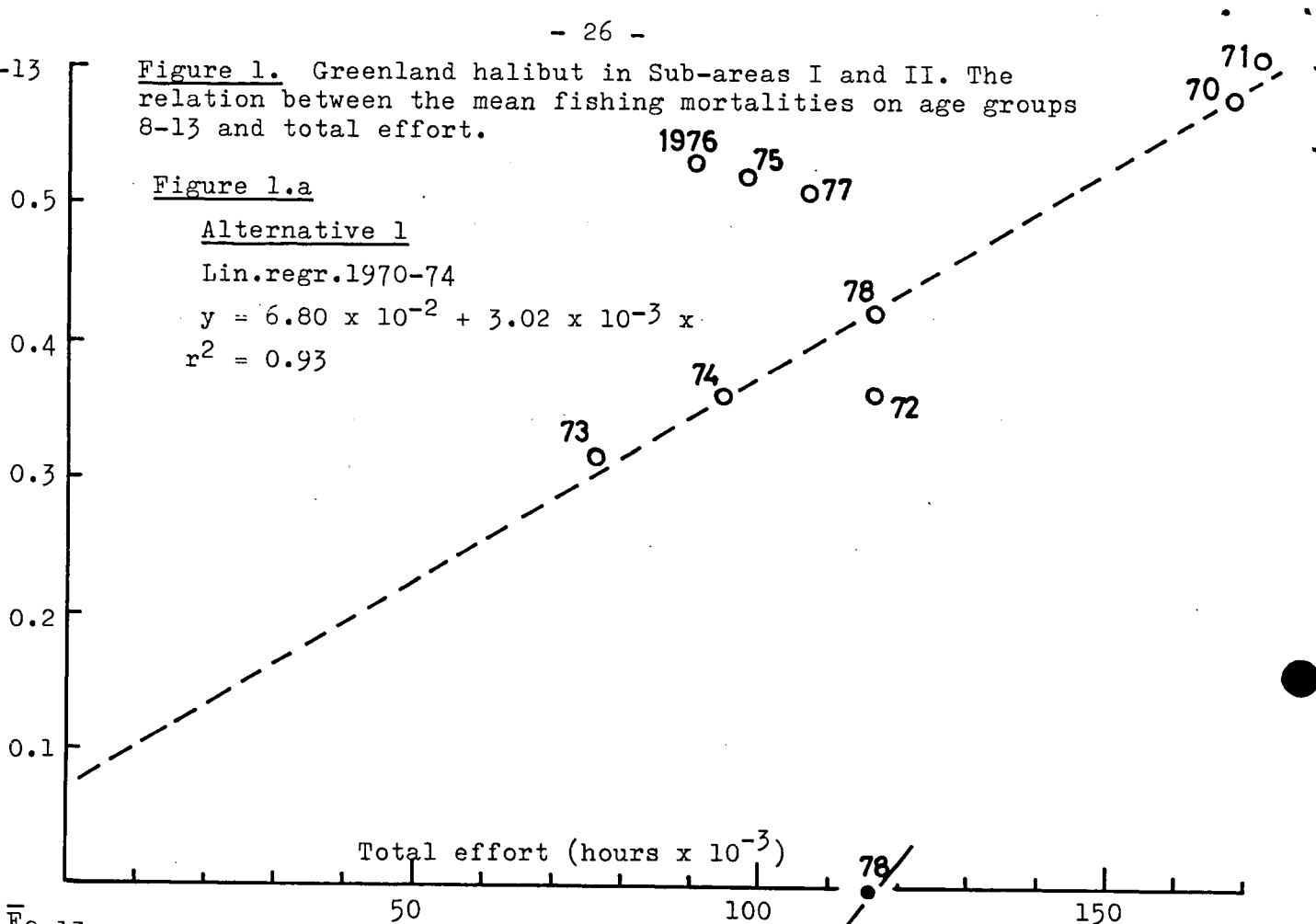
Figure 1.b

Alternative 2

Broken line:
Lin.regr. 1970-74

$y = 9.06 \times 10^{-2} + 2.92 \times 10^{-3} x$

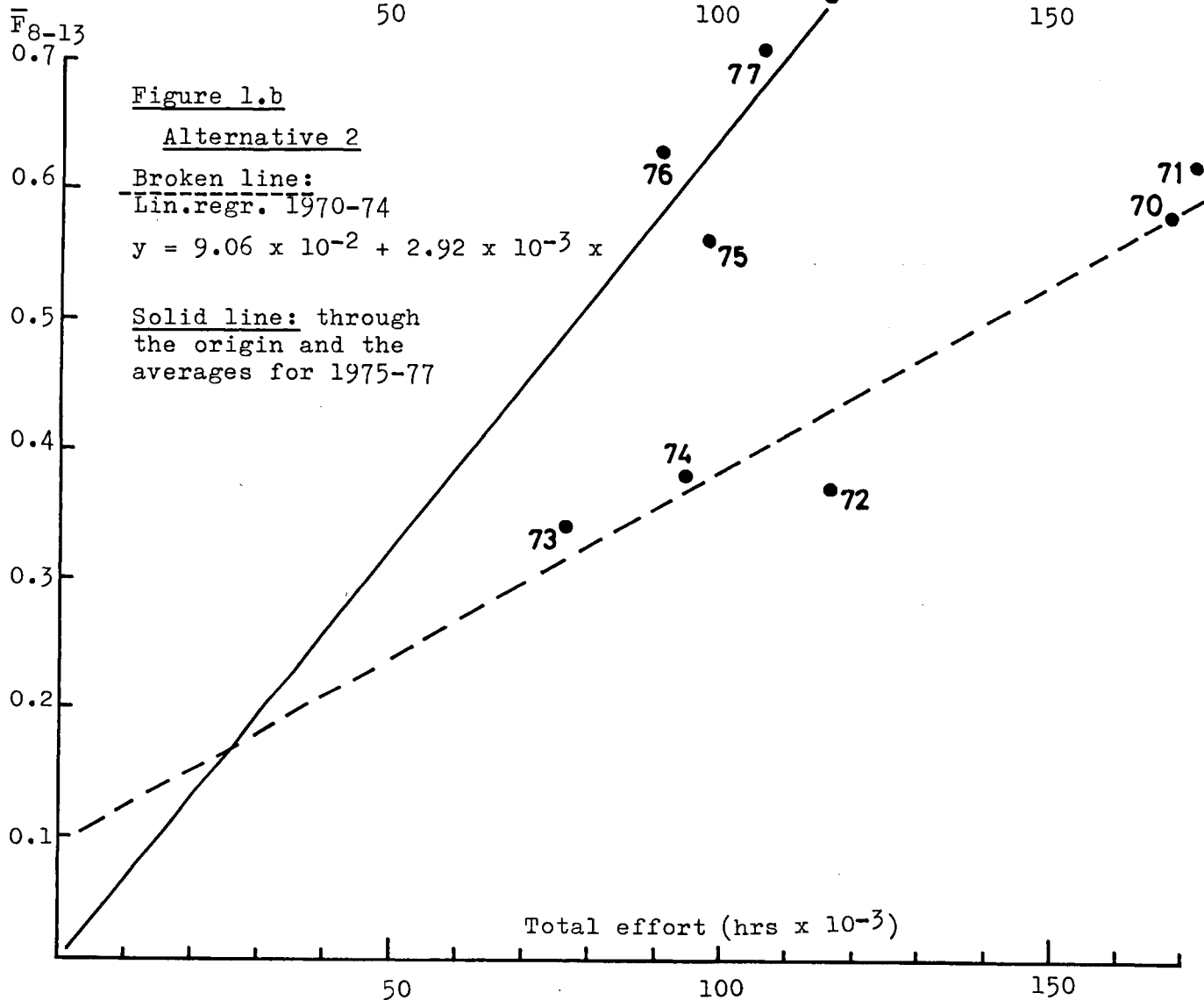Solid line: through the origin and the averages for 1975-77

Figure 2. Greenland halibut in Sub-areas I and II. The stock size (4 years and older) and the spawning stock (9 years and older) 1970-78.
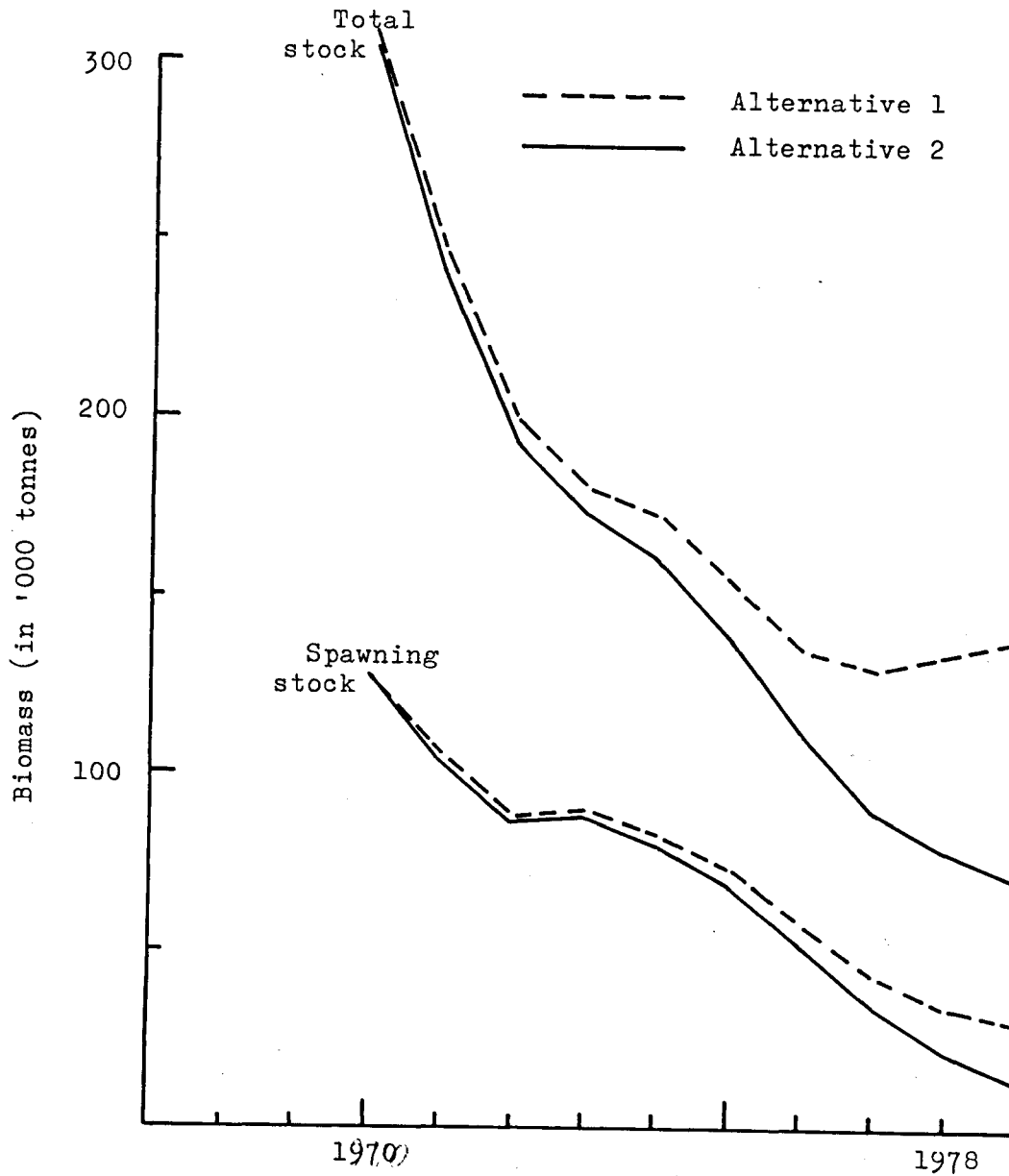
Figure 3. Greenland halibut in Sub-areas I and II.
Yield and spawning stock per recruit curve.
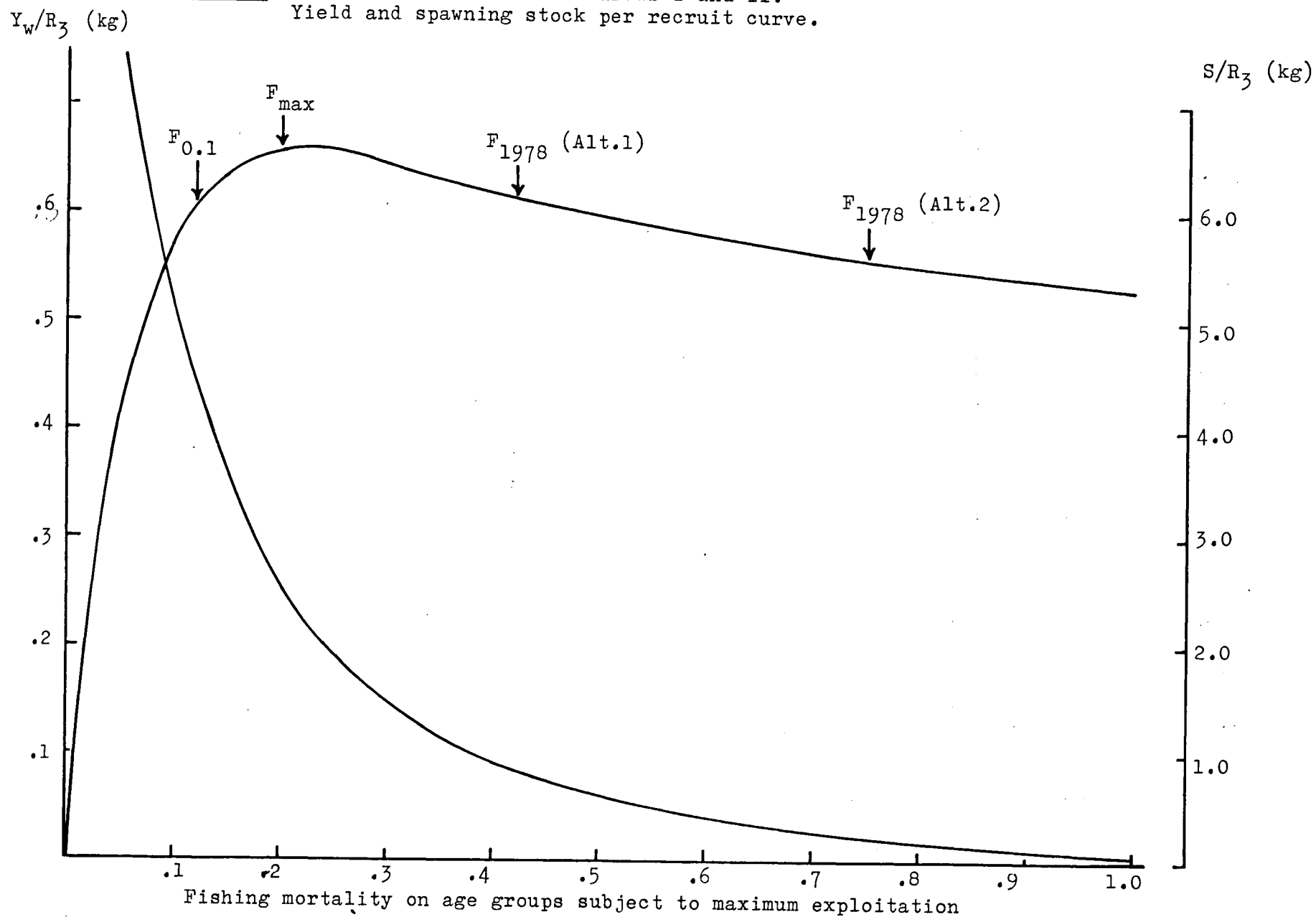
Figure 4. Greenland halibut in Sub-areas I and II.
The relation between catch per hour trawling
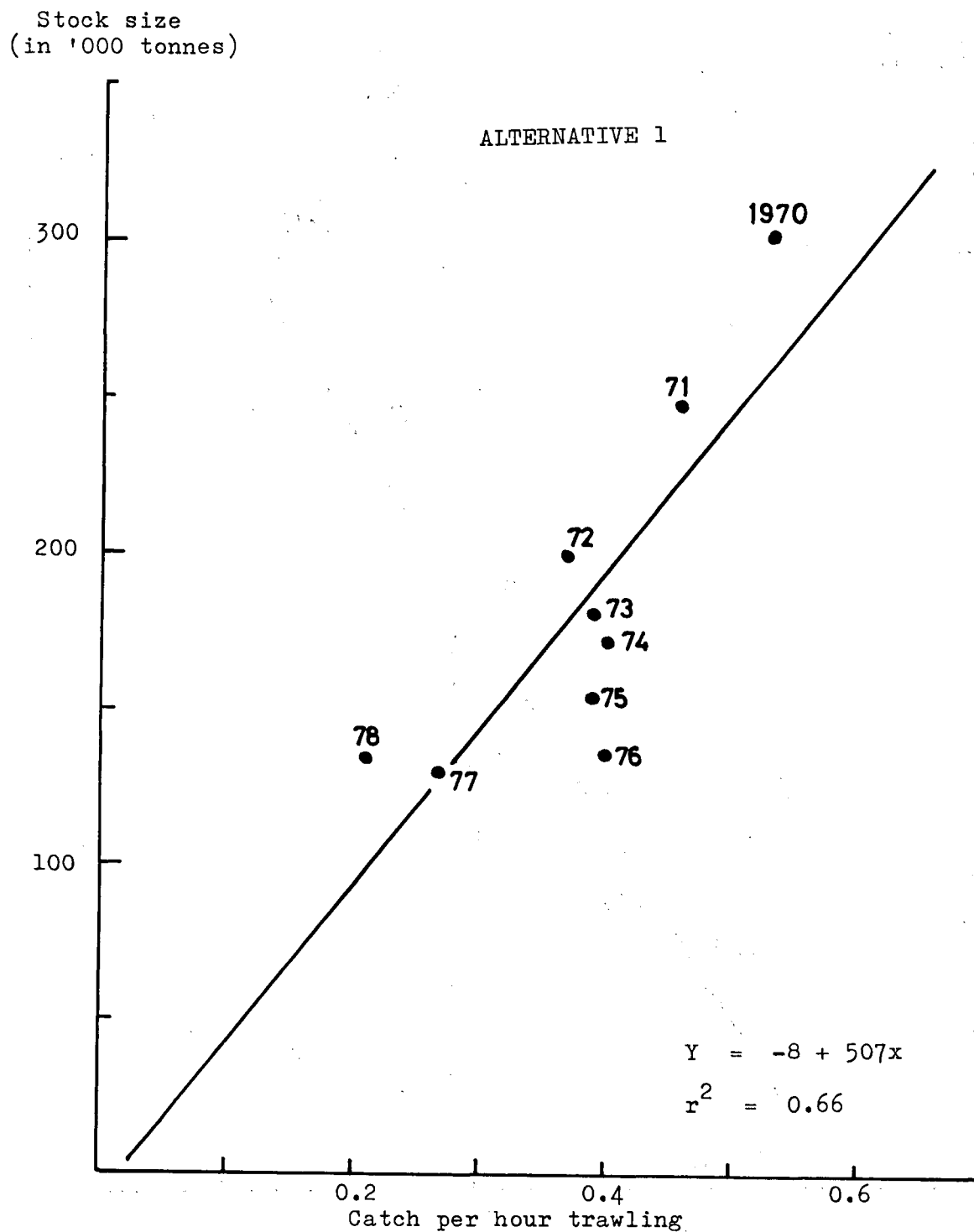in the USSR fishery and the estimated stock
size under Alternative 1.

Figure 5. Greenland halibut in Sub-areas I and II.
The relation between catch per hour trawling in
the USSR fishery and the estimated stock size
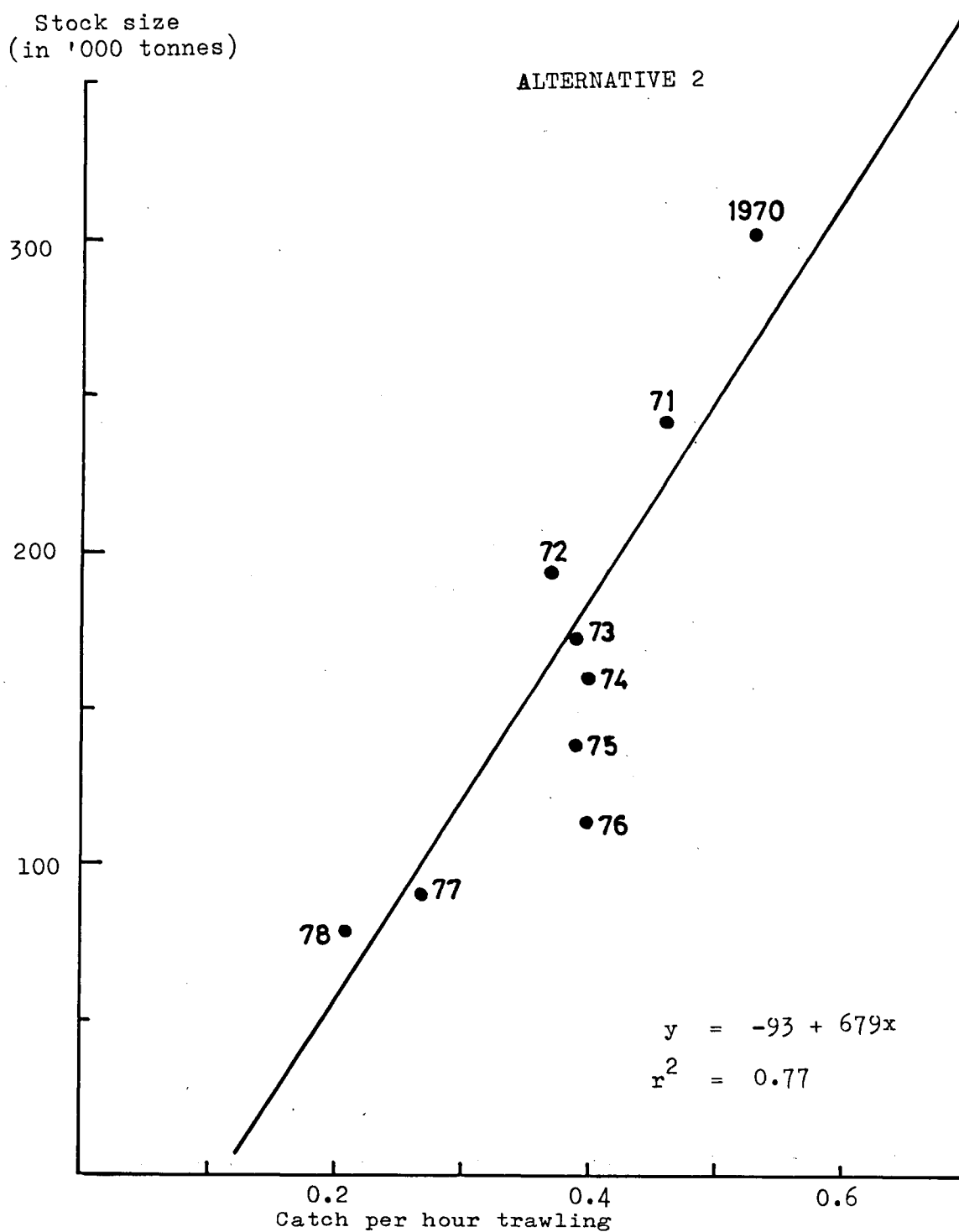under Alternative 2.

Stock size
(in '000 tonnes)

ALTERNATIVE 2

$y = -93 + 679x$

$r^2 = 0.77$

Catch per hour trawling

Figure 6. Greenland halibut in Sub-areas V and XIV.
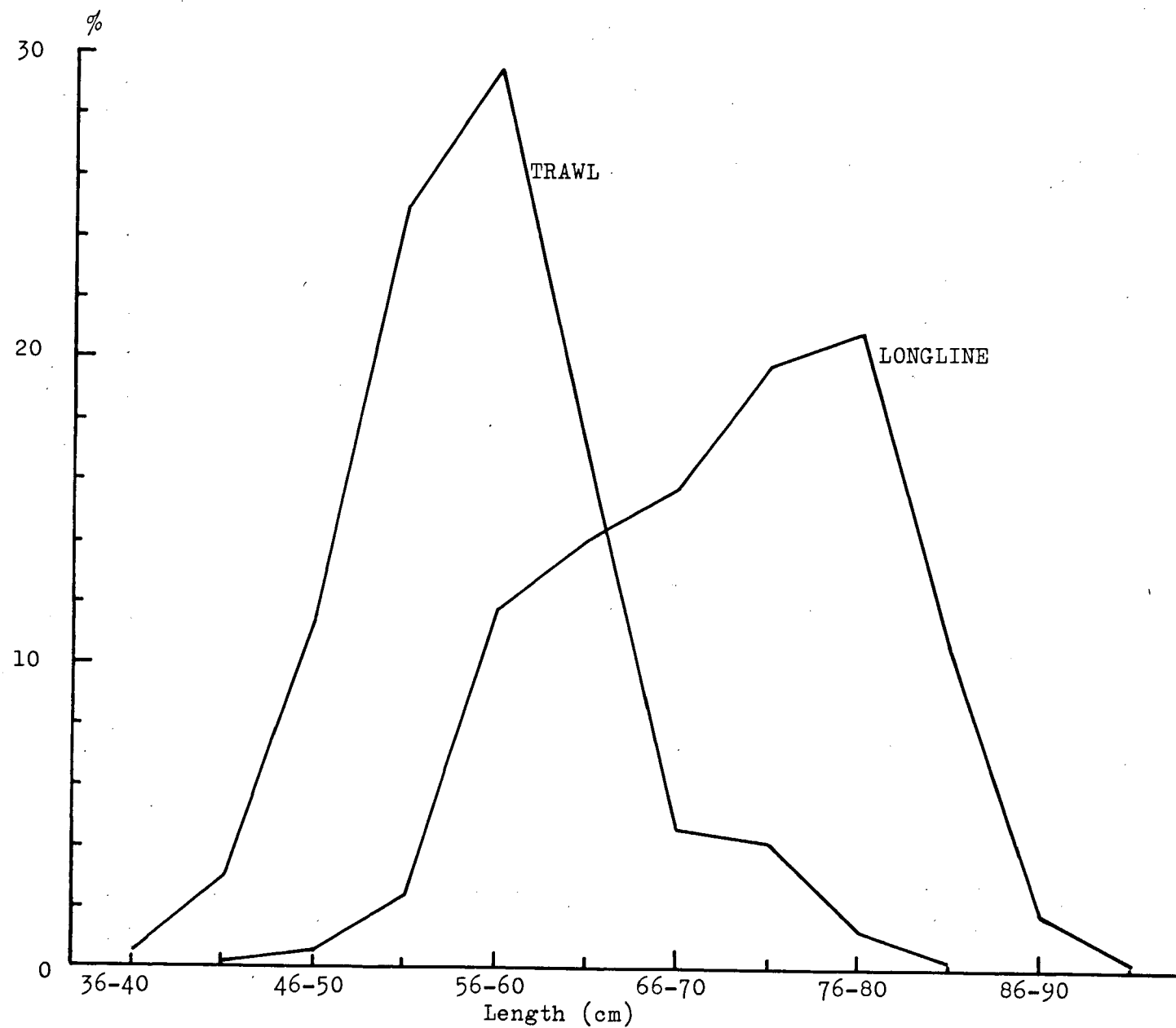Length composition of commercial trawl and longline catches for 1978.

Figure 7. Greenland halibut in Sub-areas V and XIV.
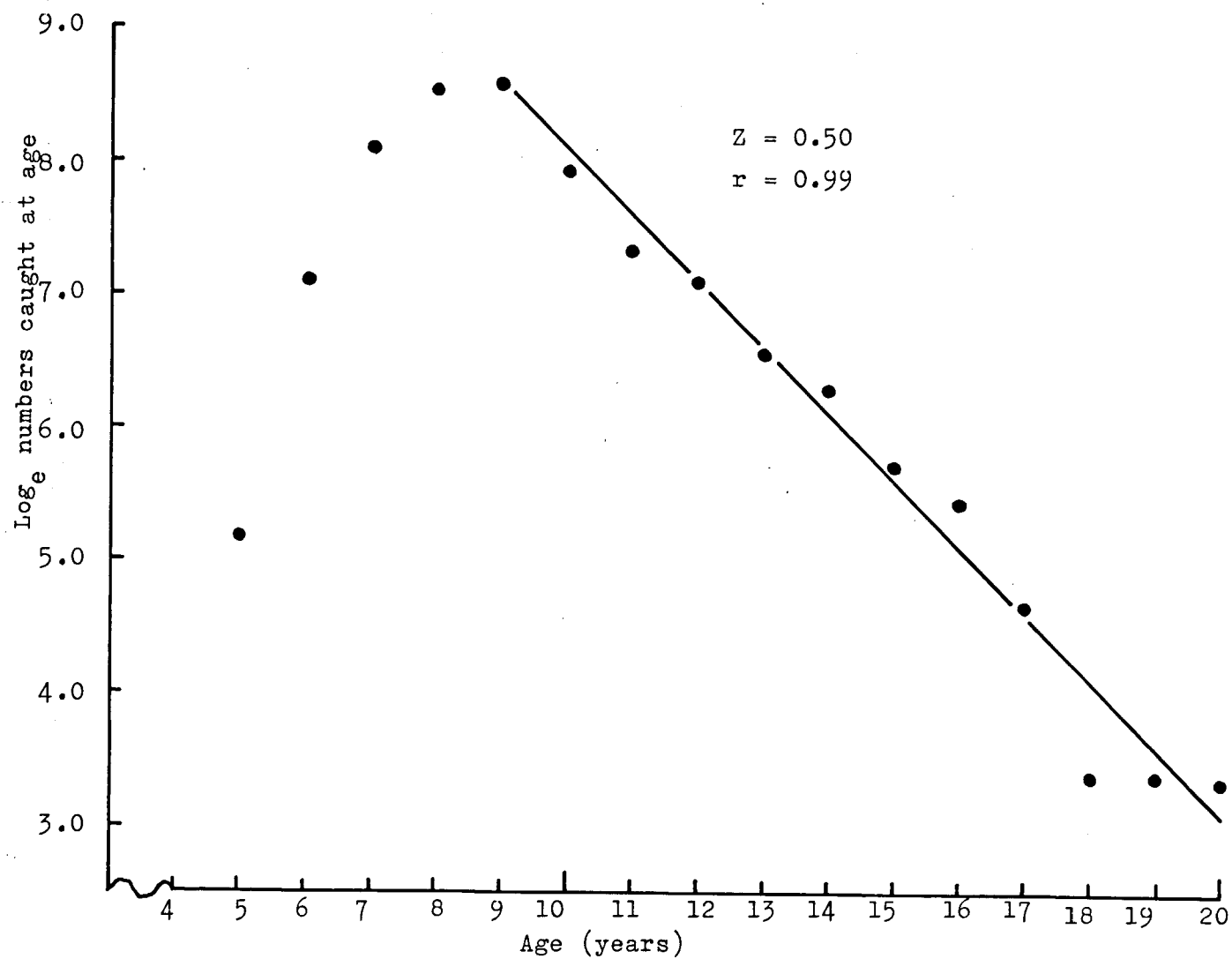Catch curve for 1975-78.

Figure 8. Greenland halibut in Sub-areas V and XIV.
Yield and spawning stock per recruit curves.