Working Document
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Minimum legal length of Greenland halibut (*Reinhardtius hippoglossoides*) in ICES Sub-areas I and II, and suggested criteria for legal bycatch of shorter specimens.

by

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INTRODUCTION

This is a slightly modified version of the Working Document put forward to the Arctic Fisheries Working Group in Copenhagen, 10-19 September 1991.

ICES Advisory Committee on Fishery Management (ACFM) concluded in 1989 that the stock of Greenland halibut appears to be small compared to historic levels and that a strategy for rebuilding the stock should be adopted. In 1990 ACFM further recommended that technical measures to improve the exploitation pattern should be considered. On behalf of the Norwegian-Soviet Fisheries Commission, a request has been put forward to ICES for advice on the consequences in terms of yield (and SSB) per recruit of introducing a minimum length for Greenland halibut allowed to be caught in Sub-areas I and II.

The purpose having rules about minimum legal size is to make sure that the spawning stock will be large enough to produce, at least with greater possibility, constantly good yearclasses, and to take advantage of the growth potential inherited within the species. The fish should have reached a minimum length before it is allowed to be fished. From a biological point of view, without looking at how the fishery is conducted, it should be, in theory, possible through calculations and analyses to arrive at a preferrable minimum size of Greenland halibut before the fish is caught.

If we knew how big it was possible for the North-east Arctic stock of Greenland halibut to become, the strength of future yearclasses, and the exact magnitude of natural mortality, then it would have been possible to define a concrete stock size to aim at. Different kinds of regulations, e.g., quotas and minimum legal length, could then have been used to reach this goal. On the other hand, only biologically based regulations without considering the practice of the fishery will undoubtly have a huge influence upon the fishery as it is conducted today.

In order to find the most correct minimum legal length for Greenland halibut, biological data have been analysed as well as the structure and practice of the fishery. In theory, a minimum legal size is knife-edged, but to make this held in practice a small bycatch of shorter specimens has to be tolerated. This is done by legalizing a percentage of the total catch in numbers of the species to be shorter than the minimum legal length.

BIOLOGICAL MATERIAL AND RESULTS

The growth of males and females Greenland halibut is different (e.g. Kovtsova and Nizovtsev 1985). Growth of females exceeds that of males from about age 5 (≈42 cm) onwards. Lahn-Johannessen (1965) calculated growth and growth parameters for both sexes. These results, which are listed in Table 1, make up the basis for the biological calculations and evaluations in this document. Before these data from the nineteen-sixties were used, they were compared with newer data (e.g., Bowering and Stansbury 1984, Kovtsova and Nizovtsev 1985, Godø and Haug 1989, ICES 1990).

In the calculations of yield-per-recruit for each sex the following relation between length and weight was used (Lahn-Johannessen 1965):

Males: $W(\text{gram})=0.00719 \times L^3 (\text{cm})$
Females: $W(\text{gram})=0.00793 \times L^3 (\text{cm})$

About 50% of North-east Arctic Greenland halibut become sexual mature at age 6-7 (Table 2), males earlier than females (e.g. Kovtsova and Nizovtsev 1985). Although the sexes show different growth, different age at first maturity, and probably also different natural mortality and longevity, a common minimum legal length for both sexes is necessary. Different rules for the sexes would be too difficult and resource demanding to control.

Beverton and Holt's yield-per-recruit model estimates the gain in yield when the age at entry to the exploited phase (t_c) is increased (Beverton and Holt 1957). The results of these yield-per-recruit calculations for males and females are shown in Figure 1 and 2, respectively. Increasing the age at entry to the fishery will produce a gain in kilogram per recruit of around 30% (average for both sexes) for each age the entry to the fishery is postponed (at least within the age range 3-7 years). If, e.g., t_c is increased from age 4 to age 5, the yield-per-recruit will increase by around 30 %. In addition, by increasing t_c from e.g. age 3 to age 6, F-max will also increase (Figure 1 and 2). The same gain will be the result if data from more recent years (Table 3) were used. Although these recent data, not splitted on sex, give a higher condition factor, and consequently higher yield-per-recruit than the data from Lahn-Johannessen (1965), the percentage gain by increasing the age at entry to the fishery will be the same.

Stock biomass-per-recruit will also increase if the age at entry to the fishery is postponed. This is demonstrated for males and females in Figure 3 and 4, respectively. The gain for females is higher than for males. For a fishing mortality of 0.40 (F=0.40) the gain will be 42% and 48% if the entry is postponed from age 3 to age 4 for males and females, respectively. The gain will then slightly decrease to 27% and 32% when starting fishing at age 6 instead of at age 5. For F=0.25 the gain between age 3 and 4 and between age 5 and 6 will be 33-37% and 22-27%, respectively. Even for F=0.05 the gain will be 14-19% for each age the entry to the fishery is postponed.

The net gain in yield and biomass by postponing the entry to the fishery can also be biologically substantiated by comparing the relative increase in fish weight during one year with the loss from natural mortality during the same period of time. Table 4 shows the increase in fish weight for a Greenland halibut growing from age 3 to age 4, from age 4 to age 5, and so on. The constant natural mortality of 0.15 used by ICES in the assessment (e.g., ICES 1990) corresponds to a 14% decrease in numbers during one year relative to the number at the beginning of the year. Table 4 shows that even for males up to 14 years the gain in weight during one year is greater than the 14% loss due to natural mortality.

THE FISHERY

North-east Arctic Greenland halibut is fished in a conventional fishery by gill nets and long lines and in a directed trawl fishery using the same trawls as those used for cod. Greenland halibut is also taken as bycatch when using cod trawls for other species, and as bycatch in the shrimp fishery. Specimens caught by gill nets and long lines are generally bigger than those caught by trawl, and a minimum legal length should therefore only have a positve influence on these fisheries, also in the short run.

The selection curve for cod trawl is shown in Figure 5. The 50% and 25% retention lengths for Greenland halibut are 43 cm and 37 cm, respectively. The length distribution of Greenland halibut in the directed Norwegian trawl fishery using 135 mm cod trawl, and before any minimum legal size was introduced, is shown in Table 5. About 20%, on average, of all fish caught are shorter than 45 cm.

Due to smaller mesh size in shrimp trawls, specimens of Greenland halibut caught by this gear are much smaller, even shorter than 10 cm (Table 5). In 1988, 1989 and 1990 the Norwegian landings of Greenland halibut in the shrimp trawl fishery amounted to 112 t, 320 t and 105 t, respectively, a relatively small part of the total Greenland halibut catch. However, surveillance and inspections have revealed that huge bycatches of small Greenland halibut specimens in the international shrimp fishery have been discarded, up to 30 million specimens in one year (1985), which is equal to an average year class at age 3. (Institute of Marine Research, internal document).

A grid sorting system (Isaksen *et al*. 1990) has been introduced and prescribed in the Norwegian coastal and fjord shrimp fishery since 1 February 1990. Since 30 September 1991 this system is prescribed in all shrimp fishery within the Norwegian Economic Zone north of 62°N. The USSR are also doing experiments with this grid sorting system, and the system will therefore probably be prescribed for all shrimp fishery in the North-east Arctic in near future.

Figure 6 shows the percentage of Greenland halibut that is sorted out when using the grid sorting system. The figure shows that e.g. 50% of all 14 cm, 75% of all 20 cm and nearly all 30 cm Greenland halibut are sorted out by this system. Although bycatches of Greenland halibut larger than 20 cm will be reduced to a minimum by using the grid, bycatches of the smallest fish will still be a problem, which can only be solved by closing geographical areas.

From surveillance and controls of the commercial shrimp fishery conducted by the Directorate of Fishery, data on bycatch are available (Table 6). The material in Table 6 is taken from the surveillance during 1988, only including the stations with the largest bycatches (more than 100 specimens independant of length). The table shows how many Greenland halibut this would amount to per 10 kilograms shrimp, (A) independant of fish length and if the grid sorting system was used, (B) without the grid sorting system and of fish less than 40 cm, and (C) without the grid sorting system and of fish less than 45 cm.

By evaluating all data on bycatch of Greenland halibut in the shrimp fishery (Table 6), it is reasonable to suggest, and it should also be acceptable for the shrimp fishery itself, that legal bycatch of fish shorter than the minimum length is limited to maximum 3 Greenland halibut per 10 kilo shrimp. Exactly where within the range 40-45 cm the minimum legal length will be placed will not affect the above suggested legal bycatch numbers.

CONCLUSION

For each age (t_c) the entry of young Greenland halibut to the fishery is postponed (at least within the age range 3-7 years), the gain in yield-per-recruit will be about 30%. A gain of same magnitude will also be achieved in stock biomass-per-recruit.

By increasing t_c from e.g. age 3 to age 6, F-max will also increase.

Considering the gain in biomass, yield and exploitation, and without interfering unacceptably with the directed trawl fishery, it is suggested that the minimum legal total length of North-east Arctic Greenland halibut is set to 45 cm which corresponds to age 5-6. This is also close to the 50% maturity age.

It is suggested that rules regarding legal bycatch of specimens shorter than 45 cm in the directed trawl fishery should follow the same rules existing in the cod and haddock fishery. This means that legal bycatch of Greenland halibut shorter than 45 cm in the directed trawl fishery with cod trawl should not exceed 15% in numbers of the total catch of this species per haul.

Legal bycatch in the shrimp fishery of Greenland halibut shorter than 45 cm should be limited to maximum 3 specimens per 10 kilo shrimp.

The Greenland halibut fishery will then be regulated by quotas and closing geographical areas.

LITERATURE:

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Table 1. Von Bertalanffy growth parameters for males and females Greenland halibut (Lahn-Johannessen 1965). The maximum age (t_λ) is an approximal value based on samples from the USSR and Norway. Natural mortality (M) is same used by the Arctic Fisheries Working Group (ICES 1990).

PARAMETERS	MALES	FEMALES
L_∞ (cm)	86	108
W_∞ (gram)	4573	9990
t_0 (year)	0.04	0.47
t_λ (year)	25	25
K	0.13	0.105
M	0.15	0.15

Table 2. Percentage of mature Greenland halibut by age. Sexes combined. Data from the USSR for the years 1983-1990 (ICES 1992).

Age years	Average 1983-1987	1984	1985	1986	1987	1988	1989	1990
3	-	-	-	-	-	-	-	-
4	0.05	-	-	0.04	0.06	-	0.01	0.09
5	0.23	0.28	0.18	0.23	0.20	0.04	0.10	0.29
6	0.49	0.68	0.43	0.49	0.46	0.40	0.66	0.52
7	0.66	0.70	0.64	0.52	0.70	0.57	0.74	0.66
8	0.78	0.76	0.77	0.62	0.74	0.63	0.68	0.75
9	0.89	0.80	0.92	0.80	0.91	0.67	0.81	0.71
10	0.95	0.89	0.97	0.88	0.96	0.89	0.92	0.77
11	0.99	0.96	0.99	1.00	1.00	1.00	0.94	0.93
12	0.99	0.96	1.00	1.00	1.00	1.00	1.00	1.00
13	0.99	0.96	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Mean total length (cm) and weight (round weight in grams) by age. Males and females together. (A) Lahn-Johannessen (1965), (B) Average over the years 1971-1984 (Kovtsova and Nizovtsev (1985), (C) Norwegian bottom trawl survey, Svalbard 1989, (D) Norwegian bottom trawl survey, Svalbard 1990, (E) An average of the USSR and Norwegian material ($W \approx 0.0091 x L^3$).

	A		B		C		D		E	
AGE	LENG	WEIG	LENG	WEIG	LENG	WEIG	LENG	WEIG	LENG	WEIG
1	-	-	-	-	15	40	12	20	14	30
2	18	42	-	-	22	90	19	60	20	80
3	-	-	35	393	30	240	30	240	30	240
4	34	297	38	453	36	440	37	450	36	450
5	-	-	41	610	42	690	43	720	42	690
6	47	784	45	810	47	990	48	1050	47	900
7	52	1092	49	1120	53	1360	54	1450	52	1150

Table 4. Percentage length- and weight increment from one age to another from surveys and commercial catches. (A) from Kovtsova and Nizovtsev (1985) and for the years 1971-1975. (B) from Kovtsova and Nizovtsev (1985) and for the years 1981-1984. (C), from the Norwegian Svalbard survey 1990, sexes combined. (D), from the USSR commercial catches in 1990, and presented to the Arctic Fisheries Working Group in 1991, sexes combined. (E), from the Norwegian commercial catches in 1990, and presented to the Arctic Fisheries Working Group in 1991, sexes combined. M=males, F=females, L=length-increment(%), W=weight-increment(%).

Age range	(A)				(B)				(C)		(D)	(E)
	M		F		M		F					
	L	W	L	W	L	W	L	W	L	W	W	W
3- 4					9	63	6	26	23	88	14	73
4- 5	9	33	6	75	7	5	12	14	16	60	52	26
5- 6	9	44	13	23	11	34	10	45	13	46	42	54
6- 7	12	49	13	58	9	29	9	22	11	38	19	22
7- 8	9	26	10	30	8	24	11	39	7	26	28	33
8- 9	8	40	5	25	8	22	11	43	15	65	47	17
9-10	2	7	7	18	4	15	8	28			25	24
10-11	7	20	5	26	5	29	5	19			36	6
11-12	3	18	3	7	8	3	6	19			21	24
12-13	9	30	7	26	7	39	5	20			2	1
13-14			5	23	3	31	6	27			27	15
14-15			9	18			5	21			21	
15-16			4	16			9	25				
16-17			9	16			4	6				
17-18			0	1								

Table 5. Length distribution (%) of Greenland halibut (A) as bycatch in the Norwegian commercial shrimp fishery (without the grid sorting system), and (B) in the directed Norwegian trawl fishery with cod trawl. Data from the Directorate of Fisheries surveillance in 1988.

Length (cm)	A	B
5- 9	0.7	
10-14	17.7	
15-19	10.0	
20-24	9.6	
25-29	5.6	+
30-34	8.4	1.0
35-39	13.9	5.7
40-44	15.9	15.6
45-49	9.8	27.7
50-54	4.1	17.5
55-59	1.5	11.5
60-64	1.5	8.0
65-69	0.5	6.4
70-74	0.4	3.9
75-79	0.2	1.5
80-84	+	0.7
85-89		0.3
Mean length	31.3	51.7
St.deviation	14.2	9.9
Nos. measured	3371	4501

Table 6. Bycatch of Greenland halibut in the shrimp fishery. Data from the Norwegian Directorate of Fisheries surveillance of shrimp fields in 1988. Only stations with more than 100 Greenland halibut are presented. The table shows how many Greenland halibut this would amount to per 10 kilograms shrimp, (A) independant of fish length and if the grid sorting system was used, (B) without the grid sorting system and of fish less than 40 cm, and (C) without the grid sorting system and of fish less than 45 cm.

Station	Total bycatch Greenl.halibut (numbers)	Shrimp catch (kilo)	Nos. Greenland halibut per 10 kilo shrimp A	B_{40} 1)	C_{45} 2)
1	104	60	7	17	17
2	105	190	0.2	2	4
3	129	175	3	7	7
4	137	552	0.2	1	2
5	162	390	0.6	3	4
6	194	23	59	84	84
7	294	550	0.3	3	5
8	315	289	2	9	11
9	384	575	1	5	6
10	527	322	2	13	15
11	768	184	0.1	29	38
12	1650	115	96	143	143
13	1925	115	100	167	167

1) $$10 \times \frac{\text{(Total bycatch of Gr.halibut) - (Nos. Gr.halibut} \geq 40\text{ cm)}}{\text{Shrimp catch (kilo)}}$$

2) $$10 \times \frac{\text{(Total bycatch of Gr.halibut) - (Nos. Gr.halibut} \geq 45\text{ cm)}}{\text{Shrimp catch (kilo)}}$$

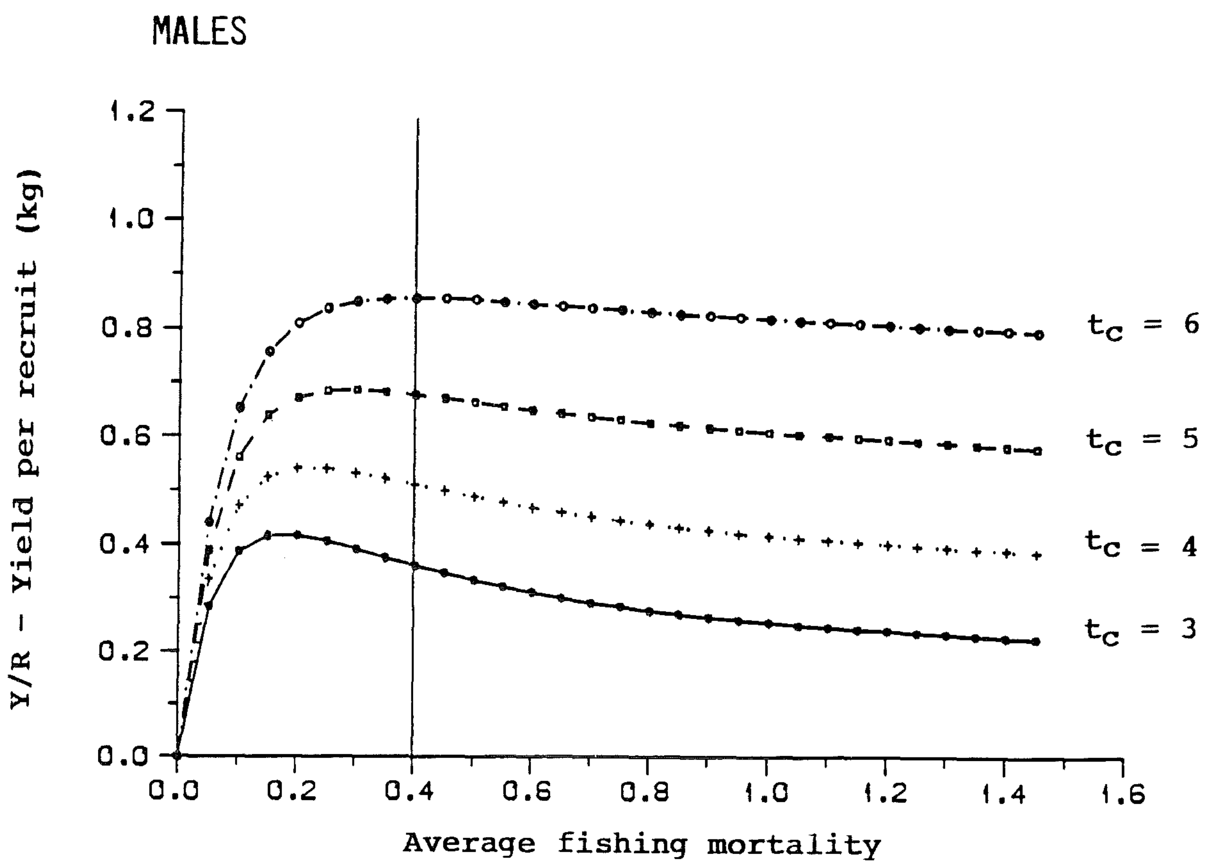

Figure 1. MALES. Yield-per-recruit curves for different ages (t_c) at entry to the fishery. Present (1988) average fishing mortality (age 7-11) is indicated.

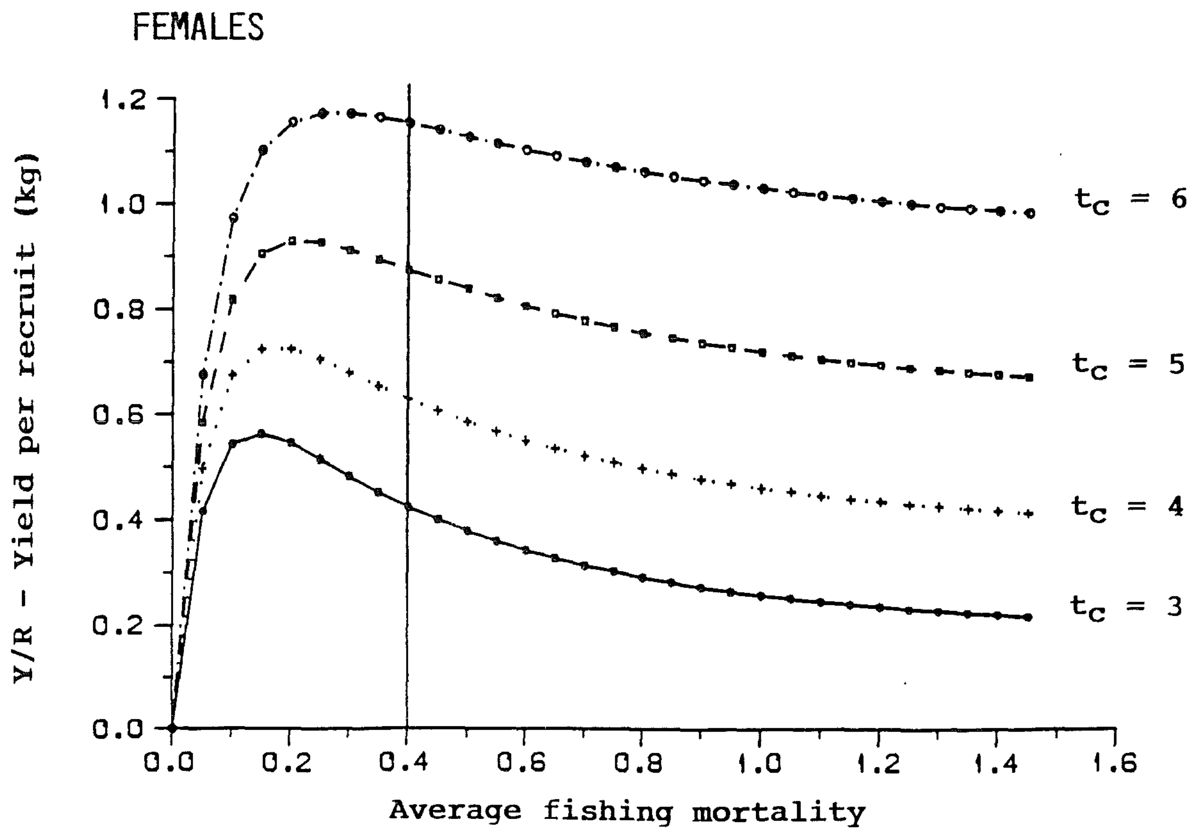

Figure 2. FEMALES. Yield-per-recruit curves for different ages (t_c) at entry to the fishery. Present (1988) average fishing mortality (age 7-11) is indicated.

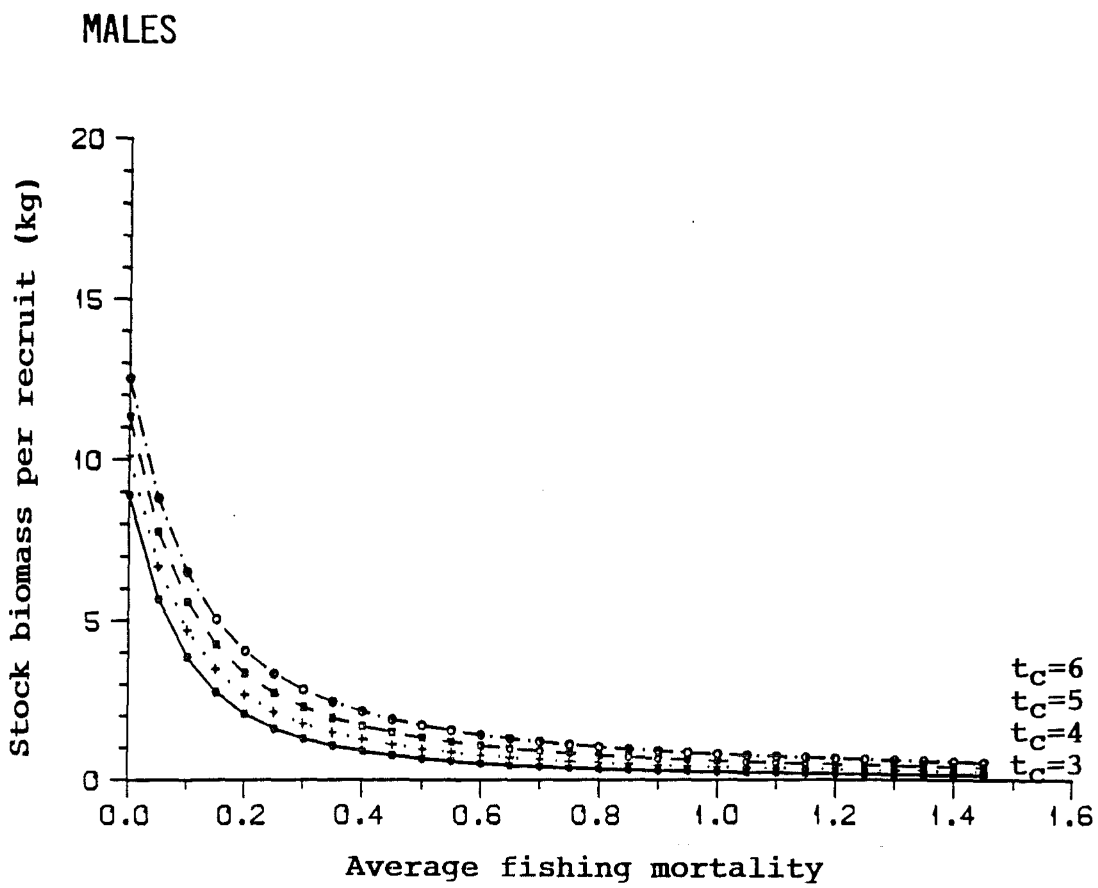

Figure 3. MALES. Stock biomass-per-recruit curves for different ages (t_c) at entry to the fishery.

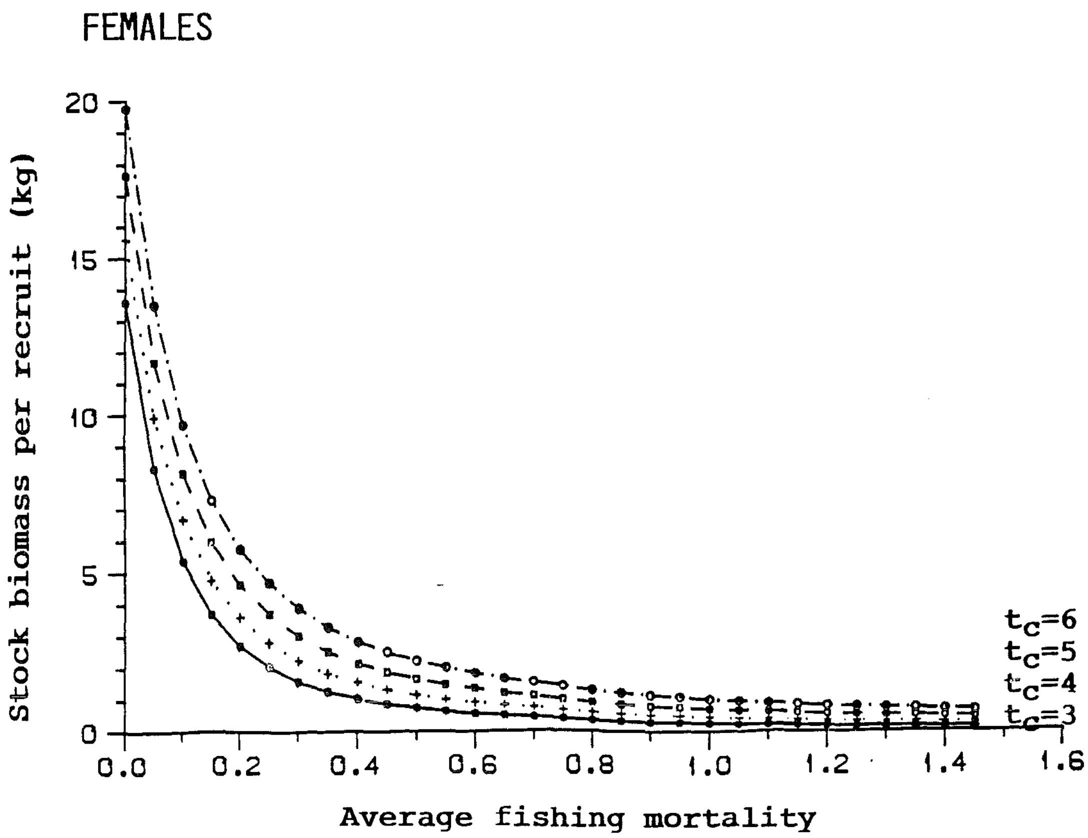

Figure 4. FEMALES. Stock biomass-per-recruit curves for different ages (t_c) at entry to the fishery.

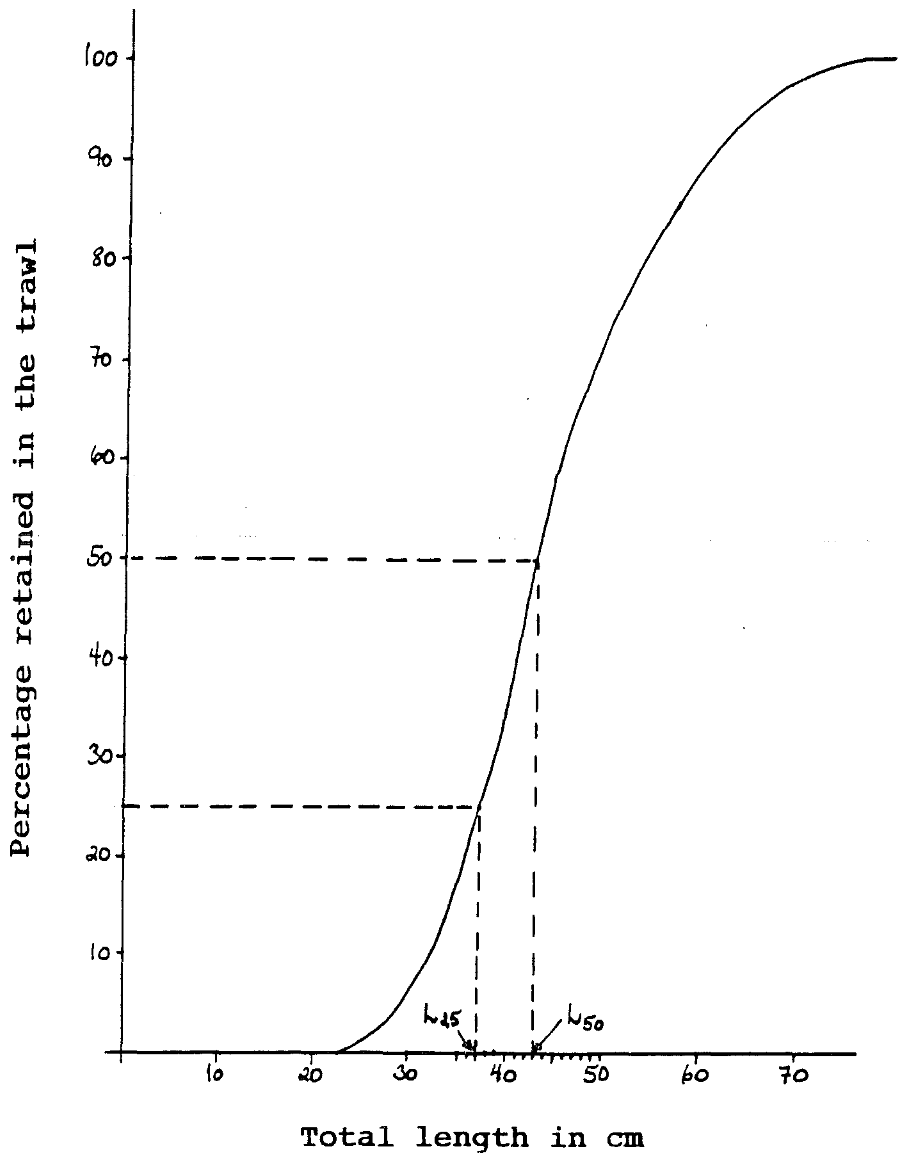

Figure 5. Selection curve for the Norwegian commercial cod trawl used in the directed trawl fishery for Greenland halibut. L_{25} and L_{50} are the lengths where 25% and 50%, respectively, of all specimens at that length are retained in the trawl.

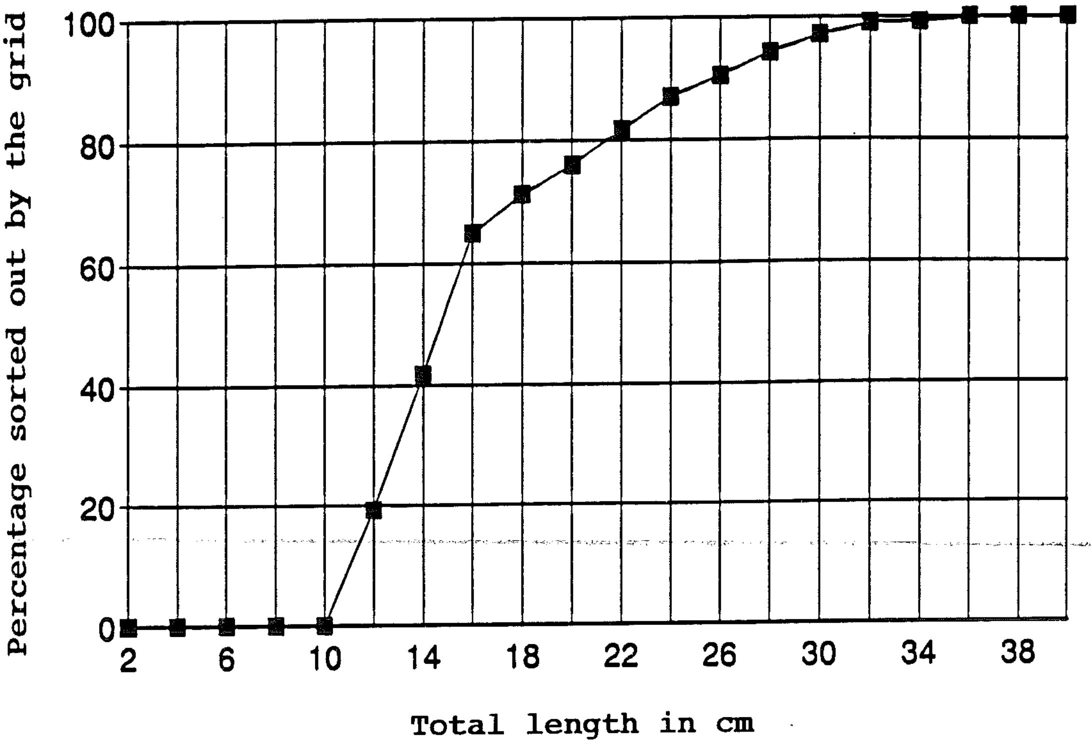

Figure 6. Selection curve for Greenland halibut using the fish/shrimp separator grid. The figure shows the percentage of specimens at each 2 cm length-group sorted out by the grid. (Source: Isaksen <u>et al</u>. 1990).