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CATCH RATES AND HOOK AND BAIT SELECTIVITY IN LONGLINE FISHERY FOR GREENLAND HALIBUT AT EAST GREENLAND

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Abstract

A joint Norwegian-Greenland longline survey was conducted in East Greenland August 1997, using different hook types. The Norwegian longline fleet uses most commonly hook type EZ 12/0 hook. This hook was compared to three different versions of circle 14/0 hooks. Catches from a total of 66 040 hooks composing 3 845 Greenland halibut were used in the analyses. In average the CPUE was 281 kg/1000 hook for the EZ hook. The CPUE for the circular hooks was somewhat higher making an overall significant difference in CPUE between the EZ hook and the circle hooks. The bait used during the survey was squid apart from a few settings where squid and grenadier was used in combination. The CPUE of Greenland halibut was 25 % higher when using grenadier bait probably due to a higher average size of Greenland halibut. The grenadier bait gave very little bycatch

Catches by EZ 12/0 hook and a circle 14/0 hook were compared in order to examine size selectivity. Using the SELECT approach expected proportions were fitted to the observed proportions for five different models of selectivity. All models resulted in almost identical fits. The absence of non-selective data requires the choice of selectivity curve to be based on specific knowledge on the capture process. Since the selectivity curves cannot be determined unambiguously, none of the applied curves can be preferred.

KEY WORDS
Greenland halibut – longline – hook selectivity – bait – East-Greenland

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INTRODUCTION

Greenland halibut (*Reinhardtius hippoglossoides*, WALBAUM) is an important fishery resource in the East Greenland – Iceland area, where it peaked at about 60 000 t in the early 1990s. Since then the fishery has declined to about 25 000 t in recent years. Most fisheries were formerly conducted as trawl fisheries, but in recent years gillnet and longline fisheries have also developed. The Greenland halibut stock in the area is presently declining, probably due a very high exploitation rate and utilisation of the resource is characterised by growth overfishing (Anon. 1997). Therefore a change in exploitation pattern are suggested in order to exploit larger size components of the stock allowing more fish to grow older and enter the spawning stock.

Since 1992 Greenland-Norwegian exploratory longline fisheries have been conducted at East Greenland to explore possibilities for a commercial longline fishery for Greenland halibut as well as other deep-sea species. In connection with these trials, a part of the fishery in 1997 took place as a fishery testing different hooks. The trials were designed to test whether hook shape and type of bait affected catch rates.

In this paper is presented analyses of the catch rates for the different hook types and an estimated size selectivity of the different hook sizes.

MATERIALS AND METHODS

Fishing trials and gear
From 29 July to 5 August 1997 a fishery was carried out by the vessel «M/S Loran», a Norwegian longline boat. Fishing depths were from 750-1080 meters in the East Greenland area from 64°05' – 64°45' N, 34°55' – 36°10' W (Fig. 1). Each setting consisted of a sequence of 4 different hooks tested with an equal number of each types of hook. From one setting to the next, the sequence of the 4 types of hooks changed randomly. 4 different hook types were used: the standard hook EZ size 12/0 and three types of circular hook size 14/0 hereafter named hook B, hook C and hook D. A detailed description of the hooks and other gear specifications are given in Table 1. All hooks were hand baited during the trial, which ensured a homogenous baiting percent (100) and no or minimal loss of bait when setting (no difference observed between hook types). Soaking time varied between 5 and 14 hours.

A total of 66 040 hooks were set and 3 845 Greenland halibut were caught. All fish caught were length measured to the cm below. Trials on hook and bait selectivity were conducted. In the hook analyses (45 760 hooks, 2 899 Greenland halibut) squid was used as bait on all hooks. In the analyses of bait selectivity (6630 hooks, 526 Greenland halibut), squid and grenadier were used as bait in ratio 2:1. The mean weight for the squid bait was 27g and for the grenadier bait 50g.

The catch rates (CPUE) of Greenland halibut is expressed in weight (kg) per 1000 hooks. The number of fish occupying the hooks is expressed as percent of the total number of hooks. The number of fish reflects catch saturation in the gear, as only a certain number of hooks are available. The catch saturation is found for the Greenland halibut and for the bycatch.

An analysis for normality of CPUE values by hooktype did show that only logtransformed values were normal distributed (90% significance level). In order to take account of depth, soaktime and waveheight when exploring effects of hook type on the overall CPUE, an analysis of variance was carried out using CPUE as dependant variable and type of hook, waveheight, depth and soaktime as independent variables. A posteriori mean range test (Tukey's studentized range test (HSD)) (SAS 1996) was carried out in order to compare mean cpue values of the four different hooks.

For assessing the size selective properties only EZ 12/0 hook and the Circle 14/0 hook type B, the one with the thinnest wire diameter 2.64mm, were included in the analyses. In the analyses mid-point estimates of fish lengths were used (adding ½ cm).

Statistical analysis for assessing the size selectivity curve

Catch data from hook selectivity experiments are counts and thus modelled similarly to catch data from gillnet experiments. Taking the SELECT approach (Millar, 1992) the number of length ℓ fish caught on the j'th hook size is assumed Poisson distributed, with a rate depending on the relative population size λ_ℓ and the relative selectivity $r_j(\ell)$:

$$N_{j\ell} \sim \text{Po}\left(\lambda_\ell \cdot r_j(\ell)\right)$$

With only two different hook sizes, this corresponds to assume a binomial sampling distribution for the catches on the larger hook **(Feller, W. 1968)**

$$N_{2\ell} \sim \text{bi}\left(n_{+\ell}, \Phi(\ell)\right)$$

where $\Phi(\ell)$ is the probability for a length ℓ fish to get caught on the larger hook, given that it has be caught on one of the two types. The selectivity curves for hook size 12/0 and 14/0 are denoted $r_1(\ell;\theta)$ and $r_2(\ell;\theta)$ respectively, where θ is a parameter vector. The expected proportion of length ℓ fish caught on the larger hook is then given by

$$\Phi(\ell;\theta) = \frac{r_2(\ell;\theta)}{r_1(\ell;\theta) + r_2(\ell;\theta)}$$

Here it is assumed that the two hooks have the same efficiency and that they are fished with the same effort.

$$\begin{aligned} L(\theta) &= \sum_\ell n_{1\ell} \cdot \log\left(1 - \Phi(\ell;\theta)\right) + n_{2\ell} \cdot \log\left(\Phi(\ell;\theta)\right) \\ &= \sum_\ell n_{1\ell} \cdot \log\left(\frac{r_1(\ell;\theta)}{r_1(\ell;\theta) + r_2(\ell;\theta)}\right) + n_{2\ell} \cdot \log\left(\frac{r_2(\ell;\theta)}{r_1(\ell;\theta) + r_2(\ell;\theta)}\right) \end{aligned}$$

After the model has been fitted, estimates of the relative population size λ_ℓ can be derived by

$$\hat{\lambda}_\ell = \frac{n_{1\ell} + n_{2\ell}}{r_1(\ell;\hat{\theta}) + r_2(\ell;\hat{\theta})}$$

As part of the statistical analysis, the appropriateness of the selectivity curve is assessed by goodness of fit statistics and residual plots. Statistics based on the fit can be used to judge if a candidate provided a good description of the data.

RESULTS

CPUE and hook type

Catch rates (CPUE) for Greenland halibut varied for the stations. The standard hook, EZ 12/0, had a lower catch rate than the circle hooks for most of the stations (Table 2, Fig. 2). The mean CPUE for the catches from EZ was 281 kg / 1000 hook while CPUE for the circular hooks was 36% higher. Comparing the different circular hook types, the one with Mustad blue gangion gave the highest catch rate (435 kg / 1000 hook) which is 55% higher than for the EZ hook (Table 2).

Assessing different effects on CPUE showed that both hooktype and depth had a significant effect (99% confidence level) on overall CPUE, while soaktime and wave height had no significant effect. The weather condition during the survey was calm and wave height varied from 0.8-4.0 m. Only for 6 of the 41 stations the wave height was more than 2 m. CPUE showed a decreasing trend with increasing wave height for both the EZ hook and the circular hooks although not statistical significant (Fig. 3). A posteriori mean range test revealed significant differences between the EZ 12/0 hook and the 3 types of circle hooks (Table 3). The frequency distribution of the CPUE values from the four different hook types is shown in Fig 2.

For Greenland halibut catch saturation was 5.2% for the EZ hook and 6.7% for the circular hooks. The highest catch saturation was obtained with the circular hook C with Mustad blue gangion which had a catch saturation of 7.5% (Table 2).

Among bycatch fish occupied 13.5% for the EZ hook and 13.3% for the circular hooks (Table 2). The circular hook with Mustad blue gangion gave the smallest catch saturation of bycatch (11.3%). The total catch saturation for all fish was 18.7% for the EZ hook and 20.0% for the circular hooks.

Length frequencies of the Greenland halibut caught by the different hooks were almost equal, ranging from 43 cm to 115 cm (Table 4). Catches from all hook types had a distinct peak in the length range 80 – 84 cm. The EZ hook caught more fish in the range 60 – 70 cm and less in the range 80 –95 cm than the bigger circle hooks (Fig. 4a). The length frequencies for the three different circle hooks were very similar (Fig. 4b).

CPUE and type of bait

On the settings baited with squid and grenadier, CPUE for Greenland halibut was slightly higher for hooks baited with squid on two of the stations and considerable higher for grenadier on three of the stations (Fig. 5). The mean CPUE for all hook types baited with squid was 386 kg / 1000 hook, for grenadier 34% higher. The higher CPUE for grenadier bait seems to be related to bigger fish caught by this bait as shown in Table 5.

The occupation of bycatch on the line was different for the two types of bait. The hooks baited with grenadier gave only 1.6% catch saturation while the hooks baited with squid gave 18.9% saturation for the bycatch.

Selectivity for different hooks

In the analysis for the selectivity curves the EZ hook and the circular hook B was compared. Catches of both hook types had a distinct peak about 80 cm, however, the small size hook, EZ, caught smaller fish in the length range 60-70 cm.

The expected catch proportions on the larger hook were fitted to the data, using five different selectivity curves. Four of these were uni-modal, determined by two parameters. The fifth was a gamma curve augmented with a constant to the right of the modal length. The constant allows for a relatively high level of selectivity above the modal length and fading to a constant level. The idea of adding a constant level of selectivity above a certain length is due to Wileman (Anon b. 1997), who used it for modelling gillnet selectivity. Longline catches often show a skew distribution; i.e. more fish are caught above the length of highest retention than below.

All five selectivity curves provided equally good fits with deviances from 47.4 to 48.6 on 59-60 degrees of freedom (Table 6 and Fig. 7). When the deviance's are referred to a Chi-square distribution these corresponds p-values about 85-87%. Hence none of the models can be rejected based on the current data set, but they cannot be distinguished either. Residual plots are almost identical and therefore provide no help in the evaluation (Boje et al. 1998). However, it should be noted that they indicate tendencies of under estimation in a broad range of mid length classes.

DISCUSSION

CPUE and hook type

The standard hook, EZ 12/0, had the lowest CPUE among the hook types in the trial. This result was due to lower catch saturation and a lower mean length for Greenland halibut caught with this hook type.

Observations during the survey showed that approximately 100% of the Greenland halibut were hooked in the mouth. Halibut, hake and haddock are usually hooked in the mouth (Løkkeborg 1991), and previous work indicates that the effect of improved hook design is most significant for such species. In fishing trials with an experimental hook designed to improve hooking efficiency by penetrating the inside of the mouth, no significant catch increase was obtained for cod when the proportion of swallowed hooks were high. In trials with a low proportion of swallowed hooks the experimental hook had higher catch rates than the normal J-hook (Huse and Fernö, 1990).

Three processes must be considered when assessing catch rates: attraction of the fish by bait and hook, the hooking and hauling of the gear. Hook shape is considered primarily to affect the hooking and hauling process and might be an important factor determining the higher catch rates of Greenland halibut by the circle 14/0 hooks. Efficient hooking will result in both a higher catch rate (as observed at bottom) and less loss during hauling. The circle hook is also larger than the EZ hook, which is considered to affect the attraction of the hook, also resulting in higher catch rates. The circle hook with Mustad blue gangion had a significant better CPUE than the other circle hook types suggesting that the blue gangion make either the hooking or the attraction better. The size of the fish caught with the circle hook was larger than the size of fish caught with the EZ hook; i.e. size selective processes acting either during the attraction or the hooking are possibly responsible.

Wave height during the trial was relatively constant. Just a few settings were registrated with wave height more than 2 meters. The calm weather conditions during the trials makes it necessary to conduct further trials in rough weather to test the difference in catch rates for the different hook types in a broader range of weather conditions.

CPUE and type of bait

On the settings baited with squid and grenadier, CPUE was higher for hooks baited with grenadier while the catch saturation was higher for hooks baited with squid. The higher catch rate was due to a higher mean length for the fish caught with grenadier bait. Both bait types are on the same line and thus both available to Greenland halibut at the same time. The result indicates that the larger size Greenland halibut prefer the grenadier bait either because of the shape, the size or the smell of the bait. Larger fish are assumed to swim faster than small fish thereby covering a larger area and will consequently have a higher probability in getting the preferable bait (Hart 1993). Allen (1963) has showed that registration of length frequencies indicates that the biggest individuals are most successful in the competition on the bait. Intra- and interspecific competition on the bait has been observed by Fernö *et al.* (1986).

The bycatch in the trial fishery was mostly roughhead grenadier. For hooks baited with grenadier the bycatch was approximately zero. The result indicates that the grenadier bait gave no response for the roughhead grenadier. For catches off Southeast Greenland the main prey item in the stomach is prawn (pers. observations). This indicates that the grenadier prefer small prey in accordance with its small mouth. Previous results have shown that bait size may also have a species – selective effect (Løkkeborg *et al.*, 1989).

Selectivity of different hooks

After the first fish has been caught on a hook the gear is literally saturated. Effort in terms of fishing time therefor plays a different role for hook selectivity experiments compared to that of other types of gears. At the time of hauling the long lines, only the total fishing time is known, not the time at which a fish got caught and the single hook became saturated. Hence fishing with different efficiencies cannot be accommodated for in the analysis in the same way it is done for other types of gears. It is therefore important to design the experiments with equal effort on all hook sizes.

The choice of selectivity curve is less obvious for hook selectivity than it is for gillnets and trawl experiments. Trawl experiments, in particular, are often conducted with two codends, one of which is virtually (or assumed) non-selective. Besides the physical arguments for choosing sigmoid shaped curves, the observed catch proportions for the test codend provide a visual guideline for the shape of the selectivity curve. In the absence of non-selective data, which is the case for experiments with gillnets, hooks and other passive gears, any conclusive form of selectivity curve cannot be determined (Millar 1995), and best choice of curvature will be dependent on knowledge on the mechanism in the capture process. For gillnet selectivity it has been commonly accepted that the selectivity curves are bell shaped or variants of this (bi- or multi-modal). Millar and Holst (1997) demonstrates how appropriate fits to gillnet selectivity data can be obtained by four different uni-modal curves. The same curves can be applied to hook data, but only little is known about the capture process of fish on longlines. It does, however, seems reasonable to draw similarities between gillnets and hooks, only that hooks catch all fish in the mouth whereas fish can be caught in number of different ways in gillnets. If the mouth of fish is too small compared to the size of a hook, the fish has only little risk of getting caught by that hook size. Similarly if the fish is big compared to the size of the hook the fish may be able to free itself from the hook. It is thus natural to assume some optimum size of a fish length for given hook size and that this length is proportional to the size of the hook. Likewise we can assume that the spread of the selectivity curve is proportional to the hook size. These two assumptions on the modal length and the spread of the selectivity curves are essentially the Baranov conjecture (Baranov, 1948).

Present analyses demonstrate that although it is not possible to determine the exact shape of the selectivity curve for hooks, modal lengths for a given hook size are very constant between all models and model lengths between different hook sizes are different.

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Table 1. Specification of gear used in the trial fishery

Gear	Specifications
Main line:	9 mm Mustad line
Hook distance:	1.3 m
1 setting:	1560 hooks
Hook A:	EZ 12/0, No 39975, wire-diameter 2.34 mm
Hook B:	Circle 14/0, No 39957D, wire-diameter 2.64 mm
Hook C:	Circle 14/0, No 39961D, wire-diameter 2.94 mm
Hook D:	Circle 14/0, No 39961D, wire-diameter 2.94 mm
Gangion (hook A, B, D):	length 23', no 16
Gangion (hook C):	Mustad blue gangion

Table 2. CPUE (kg / 1000 hook) for Greenland halibut and catch saturation for Greenland halibut and bycatch caught on EZ 12/0 hook and three different type of circle 14/0 (hook B, C and D).

Hook type		Species	no. of stations	no. of hooks	no. of fish	CPUE			Occupation of hooks %
						kg/1000 hook	std	ratio	
EZ 12/0		Greenland halibut	29	11 440	599	281	180	1	5.2
		Bycatch	10	3 900	526				13.5
Circle 14/0		Greenland halibut	29	34 320	2 300	382	126	1.36	6.7
		Bycatch	10	11 799	1 572				13.3
	hook B	Greenland halibut	29	11 440	691	344	168	1.22	6.0
		Bycatch	10	3 999	591				14.8
	hook C	Greenland halibut	29	11 440	862	435	211	1.55	7.5
		Bycatch	10	3 900	442				11.3
	hook D	Greenland halibut	29	11 440	747	368	195	1.31	6.5
		Bycatch	10	3 900	539				13.8

Table 3. Results of Tukey's mean range test. Means with the same underscore are not significantly different.

	EZ 12/0	Circle B	Circle D	Circle C
Mean ln(CPUE)	5.37	5.68	5.75	5.90
Grouping 1	___	___	___	
Grouping 2		___	___	___

Table 4. Mean length of Greenland halibut caught on EZ 12/0 and circle 14/0 hook for longline baited with squid

Hook type	No of G. halibut	Total length (cm)			
		Average	std dev	min	max
EZ 12/0	599	75.5	11.5	45	106
Circle 14/0	2 300	77.0	11.4	43	115
hook B	691	77.0	11.4	47	108
hook C	862	77.3	11.5	45	115
hook D	747	76.8	11.4	43	108
All hooktypes	2 899	76.7	11.5	43	115

Table 5. Mean length of Greenland halibut caught on EZ 12/0 and circle 14/0 hook for longline baited with squid and grenadier in ratio 2:1.

Hook type	Bait	No of G. halibut	Total length (cm)			
			Average	std dev	min	max
EZ 12/0 & circle 14/0	squid	365	72.4	11.5	103	45
	grenadier	161	82.3	10.8	112	59
	squid+grenadier	526	75.5	12.2	112	45

Table 6. Selectivity parameters for 12/0 and 14/0 hook using 5 different model approaches.

Selection Curve	Modal Length		Spread		Goodness of Fit	
	12/0	14/0	12/0	14/0	Deviance	dof
Normal Scale	78.6 cm	91.7 cm	34.1 cm	39.7 cm	48.6	60
Normal Location	76.9 cm	89.7 cm	38.6 cm	38.6 cm	48.0	60
Gamma	77.2 cm	90.1 cm	35.8 cm	41.8 cm	48.0	60
Log Normal	76.7 cm	89.4 cm	37.2 cm	38.5 cm	47.9	60
Gamma-Wileman	75.3 cm	87.9 cm	(31.9 cm)*	(37.3 cm)*	47.4	59

* The Gamma-Wileman spread is based on the gamma part of the curve

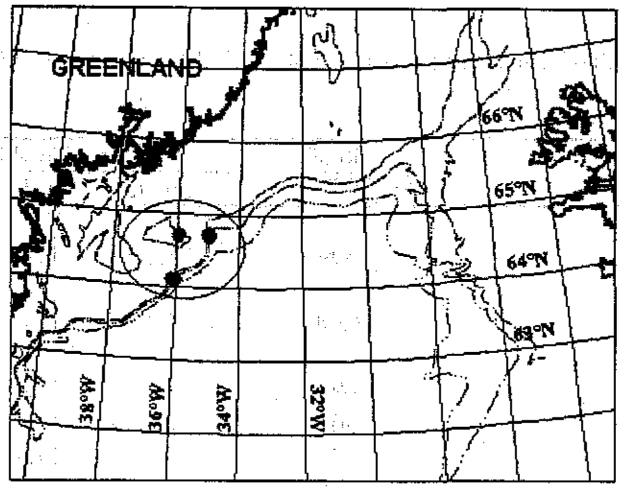

Fig. 1. Map of the study area and locations of settings. 500 m, 1000 m and 1500 m's depth contours are indicated.

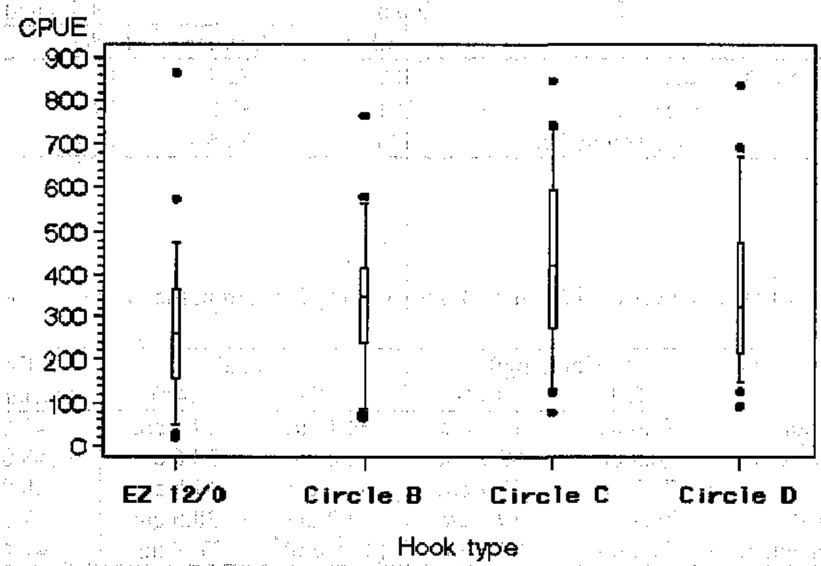

Fig. 2. Box plot of CPUE frequencies for each type of hook. The bottom and top edges of the box are located at the sample 25th and 75th percentiles. The center horizontal line is drawn at the 50th percentile (median). The vertical lines extend from the box as far as the data extend, to a distance of at most 1.5 inter- quartile ranges

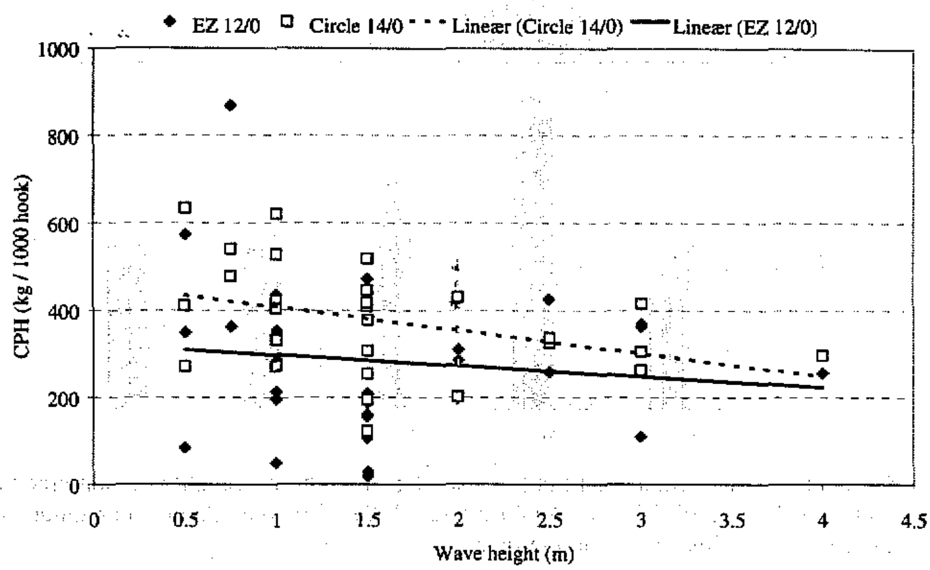

Fig. 3. Catch rates for Greenland halibut (CPUE = kg / 1000 hook) for station with different wave height caught on EZ 12/0 hook and circle 14/0 hook. ICES–Division XIVb. August 1997.

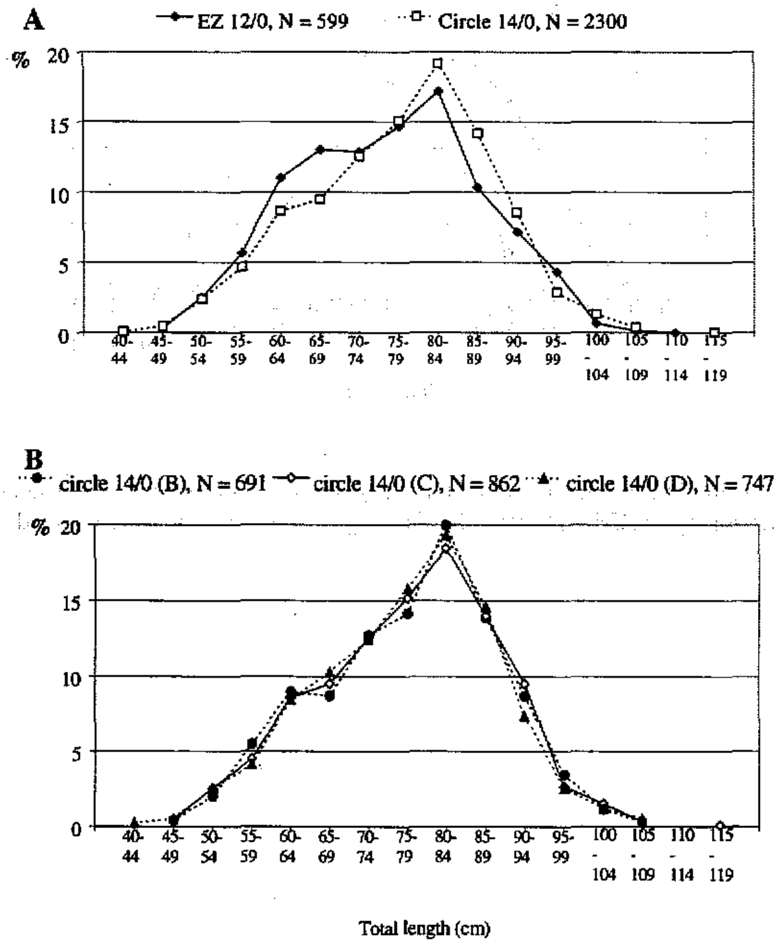

Fig. 4. Length distribution for Greenland halibut caught on: a) EZ 12/0 hook and circle 14/0 hook. b) Three different types of the circle 14/0 hook (B, C and D).

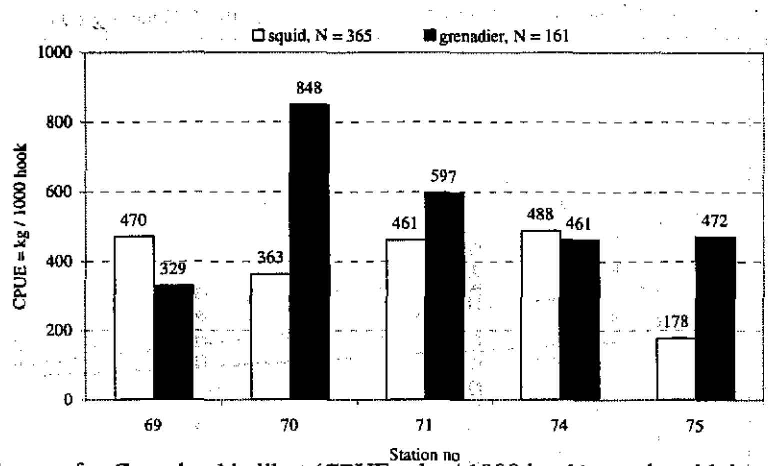

Fig. 5. Catch rates for Greenland halibut (CPUE = kg / 1000 hook) caught with longline baited with squid and grenadier. ICES–Division XIVb. August 1997. N = no of Greenland halibut caught with the different baits. Nos above column refer to nos of hooks.

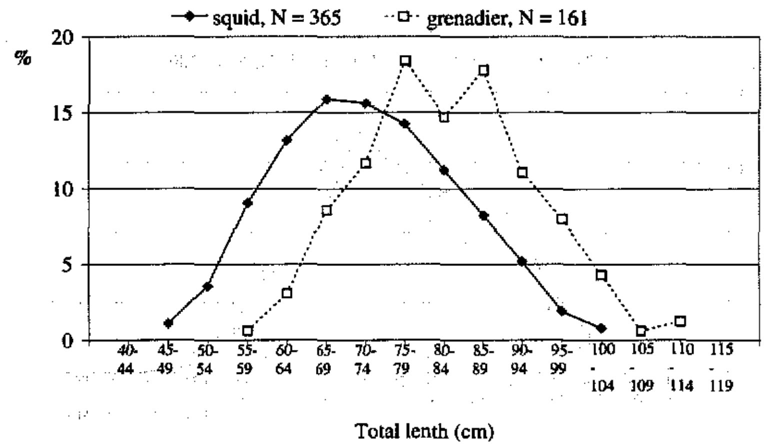

Fig. 6. Length distribution for Greenland halibut caught with longline baited with squid and grenadier on a longline survey in ICES–Division XIVb. August 1997. N = no of Greenland halibut.

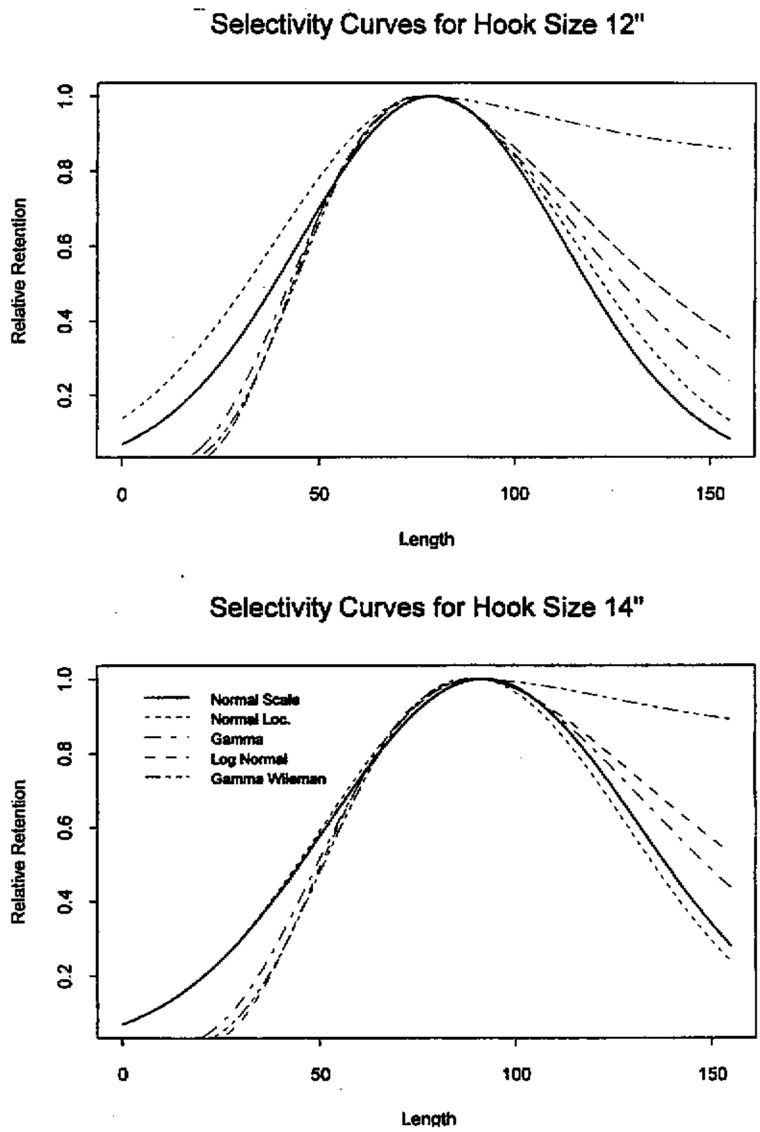

Fig. 7. Selectivity curves for five different models