FISHERIES TRAINING PROGRAMME

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COMPARISON AMONG COMMERCIAL CATCHES OF GREENLAND HALIBUT USING TRAWL, LONGLINE AND GILLNET

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ABSTRACT

At present, Greenland halibut in the ICES subares I and II is caught by three types of fishing gears: trawls, longlines and gillnets. This study helps to understand and estimate differences in catches using these different types of fishing gears, as well as the influence of these fisheries on the exploited stock. The material for this investigation is fishing data on the Greenland halibut which was collected by the Marine Research Institute of Iceland during the period 1970-2005. Selectivity parameters of trawl and longline are accepted from previous experimental work. Selectivity parameters for gillnet are estimated from data from the Marine Research Institute of Iceland. This study estimates the difference in mean length and sex composition for catches from trawls, longlines and gillnets. The mean length (62.5 ± 1.55) and female share (0.58 ± 0.04) of the annual catches from trawls are less than the mean lengths and female shares from gillnet and longline catches. The selectivity patterns, the length distributions of stock and the annual catches are used to estimate discard from various fishing gears. Discards from the trawl and gillnet fisheries are similar to or less than those from longline. It was determined that there was a good correlation between the mean length of catch of Greenland halibut and the sea depth. The difference between the mean lengths of industrial trawl catches and stock assessment survey catches demonstrated good selectivity of the commercial fishery.

Keywords: Greenland halibut, selectivity, trawl, longline, gillnet, distribution, mean length, depth, catch, discard.

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1 INTRODUCTION

1.1 Biological and fishing background

The target species explored is Greenland halibut (Reinhardtius hippoglossoides, Walbaum).

Greenland halibut is a valuable round fish related to the group of wide-mouthed flounder family halibuts (Pleuronectidae order of flatfish Pleuronectiformes).

Thanks to its physiological, morphologic and functional characteristics, Greenland halibut is one of the most widespread amphiboreal species that live in moderate - cold water in the Atlantic and Pacific Oceans (PINRO 2006).

The Greenland halibut can be found everywhere in the Atlantic Ocean and contiguous areas of the Arctic Ocean. From the coast of Canada and the United States of America to the coast of Europe. On the west border of the range it is located from the Strait of Smith (between Canada and Greenland, 78° north latitude) down to the coast of New Jersey (USA, 40° north latitude) (Figure 1) (PINRO 2006).

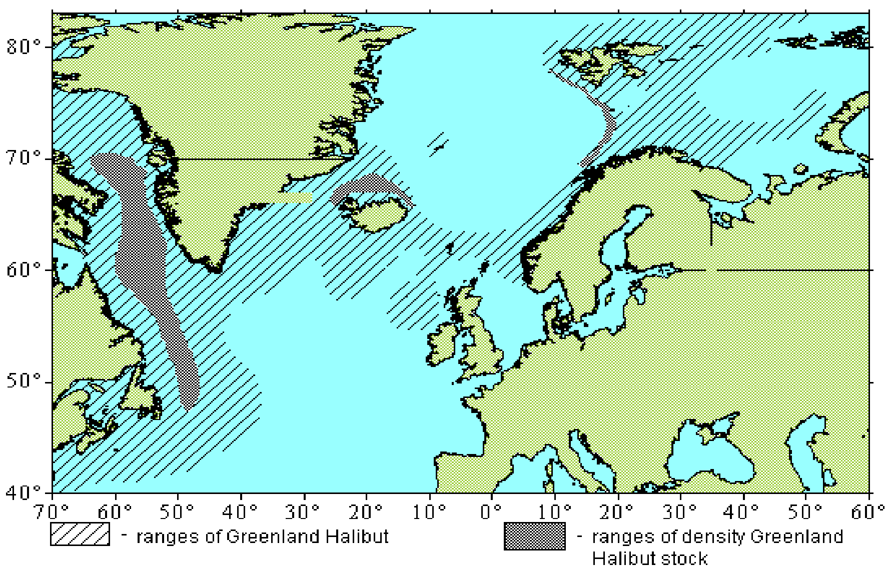

Figure 1: Greenland halibut ranges in the North Atlantic (PINRO 2006).

The Russian Polar Marine Research Institute (PINRO) is increasingly focusing on researching the Norwegian-Barents Sea population of Greenland halibut, which is an

important native fishery in the Barents Sea and allied water in the Norwegian and Greenland Sea (PINRO 2006).
In the Barents Sea, Greenland halibut clings predominantly in depths of 200-500 m. However, during migration can be found at other depths (PINRO 2006). Mass spawning of Greenland halibut takes place in the autumn and winter period in allied water Barents, Norwegian and Greenland Sea (PINRO 2006). The basic breeding ground is situated in deepwater (500-800 m) on the continental rise in the west part of the Norwegian and Barents Sea (between 71° and 75° north latitude) in reach of the warm Atlantic stream (PINRO 2006).

For a long time the main catch targets in the Barents Sea have been cod (Gadus morhua Linne) and haddock (Melanogrammus aeglefinus Linne) and Greenland halibut was only as insignificant by-catch of these species (PINRO 2006). In the post-war years Soviet fishing fleets increased catches of Greenland halibut to 2-4 thousand tons when developing the bottom trawl for fishing the cod in the Spitsbergen zone and then deepwater redfish (Sebastes mentella) in the westward Barents Sea (PINRO 2006). However its catches as before lacked independent meaning (PINRO 2006).

In the year 1964 at the west slope of the Spitsbergen zone during a trial of deep-sea trawl equipment, Soviet fishermen discovered compact spawning accumulation of Greenland halibut (PINRO 2006). This was the cause of the start of unregulated international longline and trawl fishing of Greenland halibut. Henceforth Greenland halibut became an objective of particularised longline and trawl fishing in the Barents Sea. The maximum catch was reached in 1970 (about 90 thousand tons). Since 1978, fishing has been settled by way of total allowable catches (TAC), thanks to which catching was stabilised in the 1980s at about 20 thousand tons, out of which 9-15 thousand tons are caught by vessels of the USSR (PINRO 2006).

A decrease in the spawning stock of Greenland halibut below the biological safety level led Norway and Russia to institute a prohibition in 1992 on specialised trawl fishing for this species (PINRO 2006). This prohibition is still in place at the present time.

In Russia this prohibition led to insignificant catch of Greenland halibut (1-2 thousand tons) in 1992-1995 as by-catch when targeting other species. Since 1996, the Russian catch began to grow because of increased by-catch of Greenland halibut and as a result additional catch has since been carried out on research trips (PINRO 2006). These trips are carried out in accordance with the programme of joint Russia-Norwegian investigation.

By-catch of Greenland halibut is found in practically all fishing areas of the Barents Sea (PINRO 2006). In addition, in order to accomplish the joint scientific programs, Russia receives several thousand tons of Greenland halibut annually. The total declared Russian catch in 2002 was about 5.6 thousand tons (ICES 2006).

Norway continues direct fishing of Greenland halibut by passive fishing gear (longline and gillnet). In addition, the Norwegian fleet gets by-catch of Greenland halibut and from time to time during research surveys where trawling is used for fishing. From 1992-2001, the annual Norwegian catch was 8-15 thousand tons (ICES 2006).

According to data from an ICES working group from 1970-1990 the Greenland halibut fishing stock of the Norwegian-Barents Sea population decreased from 312.3-77.4 thousand tons. Spawning stock biomass decreased from 139.6-21.0 thousand tons (ICES 2006). When the prohibition on trawl fishing of this fish was introduced in 1992, its biomass stock was estimated at 44.5 thousand tons. Spawning stock biomass was estimated at 16.0 thousand tons (Figure 2) (ICES 2006). Thanks to limitations on catching in consequence of the prohibition on specialised trawl fishing of Greenland halibut the stock gradually increased up to 80.0 thousand tons in 2003. Spawning stock biomass grew to 29.6 thousand tons (ICES 2006).

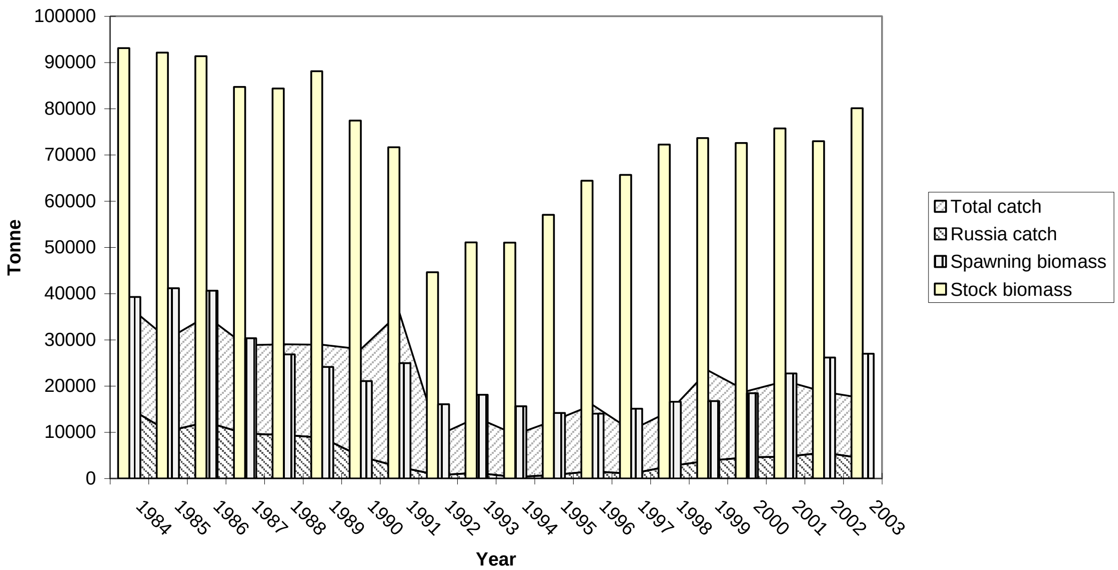

Figure 2: Conditions of the Greenland halibut stock in the ICES subares I and II, catch per year.

1.2 Fishing structure

Fisheries of Greenland halibut in the ICES subares I and II are conducted using trawl, longline and gillnet (ICES 2006). Their proportions of the total catch for the period 1980-2003 are next fellow for trawl from 42-92%, for longline from 2-42% and for gillnet from 4-18% (Figure 3) (ICES 2006). Since 1990, the longline share of the total catch began to grow gradually while the trawl share decreased. The level of gillnet catch has been stable during this period. So catches of trawl and longline equalised in 2003 and consisted of about 42% for each gear. The share of gillnet catch was about 16% in 2003 (ICES 2006).

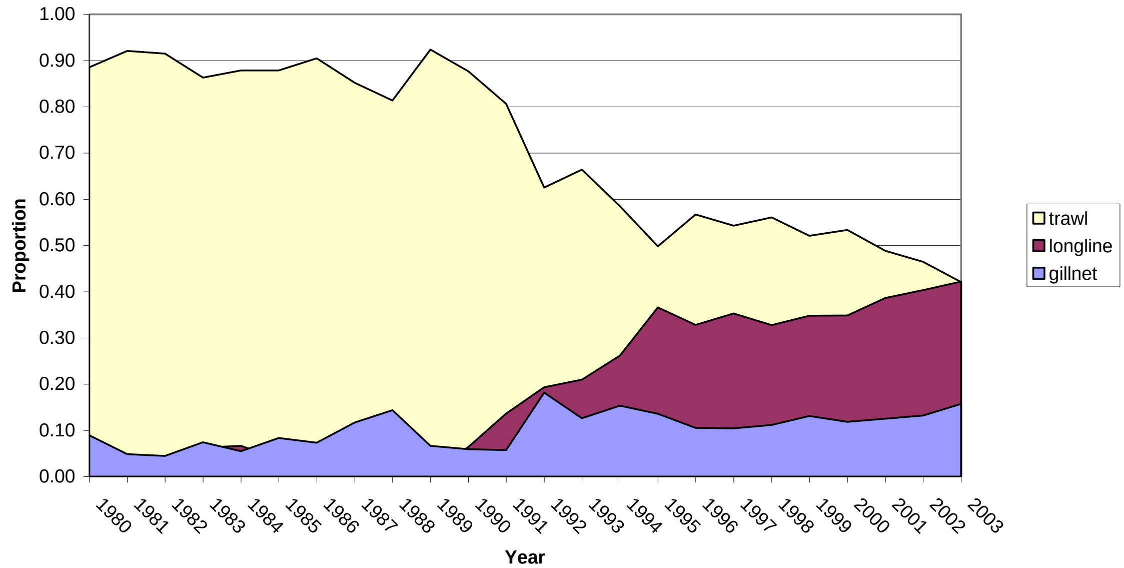

Figure 3: Proportion of Greenland halibut catches by trawl, longline and gillnet in the ICES subares I and II for the period 1980-2003.

1.3 Capture principles and selectivity of the different types of gears

The selectivity of trawl and longline (Woll et al. 1998) for Greenland halibut is different. Greenland halibut is normally hooked in the outer part of the mouth and sometimes the hook is not swallowed. This causes loss of Greenland halibut, mostly of large specimens in longline fishing in rough weather (Woll et al. 1998).

Catches from various fishing gears have different characteristics such as length and sex distribution, total weight etc. (Huse et al. 1999). Fish behaviour is explored by trawl, gillnet and longline in different ways for attracting and catching it and thus the catch samples are different. This is because the catch probability and selectivity of the gear depends on maturity status, feeding behaviour and conditions of the fisheries (Huse et al. 1999). Noise from the fishing vessels stimulates a startle recruiting in the fish, while the trawl has visual and auditory stimuli which guide the fish in front of the trawl.

Several studies of fish hearing have been carried out (Hawkins 1981) for different species but there are no data for hearing of Greenland halibut, it is possible to suppose that the fish react to sounds when they hear gears (Myrberg 1981). Some experimental results show that sight of the headline with its floats can keep large fish swimming in front of the trawl without entering the net (Hemmings 1973). Studies on actual reaction thresholds to low light levels are few (Hawkins 1981), but it is known that the feeding activity of Greenland halibut peaks around October at depths of 1100–1500 m. This fact lets us suggest that the fish is able to see the trawl gear at depths of 500–700 m at this time of year, even if the feeding activity includes vertical migrations that will reduce the probability of capture of halibut for ground gears for parts of the 24 hour day (Junquera 1995).

The trawl selection curve shows the proportion of fish retained in the codend but this also includes a process of selection of fish ahead of the trawl. It is necessary to take into account that small fish might be lost under the sweeps if they are unable to keep up with the narrowing wires, and large Greenland halibut are able of avoiding the trawl opening. Thus, the size and condition of individual fish may determine whether or not they are caught by the trawl. For large fish, there is a higher probability of already having seen and escaped a trawl and this may also influence the proportion of large fish in trawl catches (Pyanov 1993).

The behaviour of the target fish in searching for food is utilised by longlines. The selectivity process in longline fishing is composed of a two steps behavioural procedure. The basic assumption is that larger fish utilise extensive feeding grounds due to their higher swimming capacity (Hart 1993). There is a directional response against the current after the attractants have been detected (Pawson 1977, Lokkeborg 1998) and competition for the food after it has been found (Godo et al. 1997) where big fish do better. This will tend to lead to larger fish being overrepresented in the catches.

This selection assumption in longline is adaptive if both large and small fish are represented in the area, larger fish will dominate the catches. However, if longlines are set in areas with homogeneous length distributions dominated by small fish, there are only very weak mechanisms leading to selectivity (Huse et al. 1999). It is also necessary to take into account that the hooks and swivels are easily strong enough for the largest fish and the bait is small enough for the smallest Greenland halibut.

The catching process of gillnet depends on two main factors: firstly, the activity level of the fish which leads to its encounter with the mesh net; and secondly, the probability of the fish being retained in that mesh. Also the ways of attachment, which include gilling, wedging and tangling (Olsen and Tjemsland 1963, Hamley 1975) can affect the calculated selectivity parameters.

2 STATEMENT OF THE PROBLEM AND OBJECTIVES OF THE PROJECT

At present, Greenland halibut in the ICES subares I and II is caught by three types fishing gears: trawl, longline and gillnet. In previous experiments differences in catches of these fishing gears have been determined. These differences are essentially explained by different selectivity and catchability capacity.

It is important to understand and estimate these differences in case of a future reopening of the fishery. Usage of these differences assists to estimate the fishing process as well as the influence of fishing on the exploited stock.

For example longline fisheries provide indices that are accepted as linear estimates of stock abundance (Murphy 1960). Therefore, catch data from longlines are used for relative stock assessment of several stocks (e.g., Pacific halibut, Hippoglossus stenolepis; sablefish, Anoplopoma fimbria) and have a potential use in absolute stock assessment (Fernö and Olsen 1994).

The general idea of this study is to determine primary differences between the catches of different fishing gears.

The main research questions are:
Is there any difference in sex composition and length distribution between catches from trawl, longline and gillnet?
Is there correlation between the length distribution of catches and the sea depth of fishing?
Is it possible to estimate discards from various gears if the selectivity patterns and the length distributions of stock and the annual catch is known?
Is there correlation between the discards of different fishing gears and the mean length of stock?
What is the difference in the discards of different fishing gears?

3 MATERIALS AND METHODS

3.1 Data

The material for the investigation is primarily fishing data on Greenland halibut which was collected by the Marine Research Institute of Iceland.

This database consists of two parts. The first part is catching data collected by captains of fishing vessels and the second part is research data taken by fishing inspectors. The first part contains data about:
the number of vessel,
the fishing area,
the date (time, day, month, year) of fishing operation,
the type of fishing gear,
the parameters of the fishing gear (mesh size, horizontal distance between doors and vertical of trawl mouth, quantity of hooks etc.),
the total catch for one fishing operation and its structure per species.

The second part contains data about:
the number of vessel,
the fishing area,
the date (time, day, month, year) of fishing operation,
the type of fishing gear,
the length and sex composition of each catch

These databases are used for estimating fish length frequency from the catch of different gears in the period 1996-2005. Length distribution from trawl catches is separated into two databases, one from a stock assessment survey where the codend has 40+mm mesh sizes and a second database from the commercial fishing fleet where the trawlers are using a 135 mm mesh size in the codends for fishing Greenland halibut.

3.2 Selectivity

Selectivity parameters of trawl and longline are accepted from previous experimental work. The selectivity parameters for trawl with a 135 mm inner bag mesh size were taken from the selectivity experimental work of Lisovsky and Pavlenko (2003).

Selectivity parameters for longline are taken from the original (not published) experimental work of PINRO which was carried out in II subarea of ICES (PINRO, not published) (Figure 4).

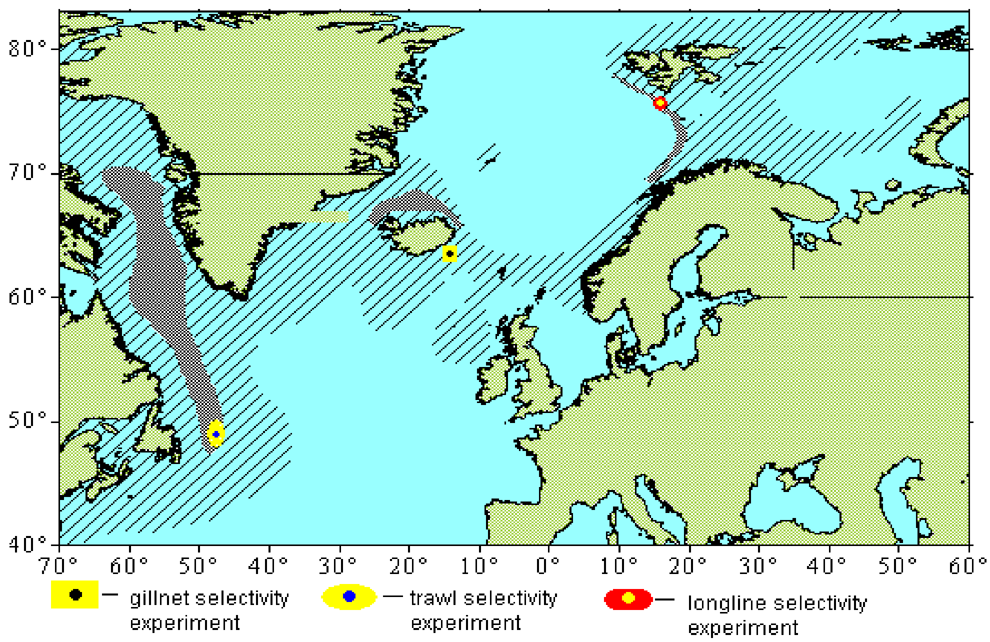

Figure 4: Regions of conducting selectivity experiments for trawl, longline and gillnet (PINRO 2006).

This experiment estimated the selectivity parameters of longline with hooks EZ 13 (Figure 5). The selectivity of longline was similar to the catch of trawls with small bag mesh.

Fishing operations of trawl and longline were made in same area and at similar times (Figure 4).

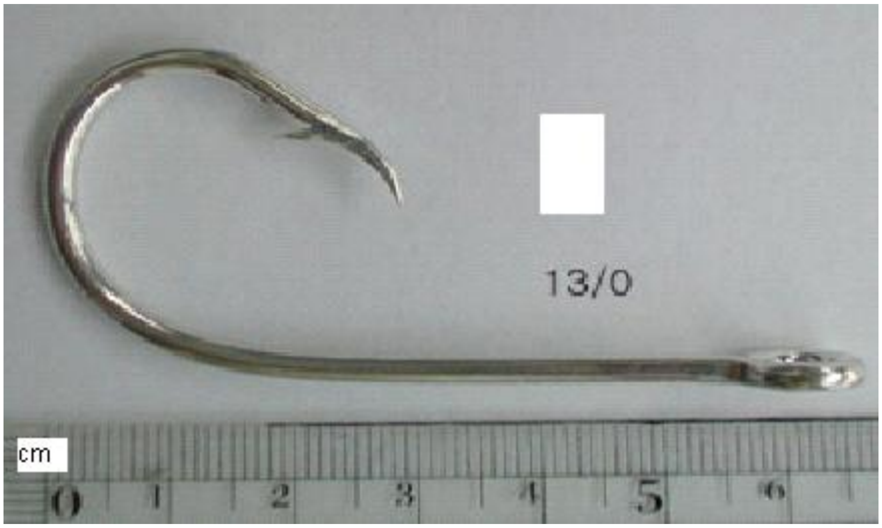

Figure 5: Hook EZ 13.

The data were analysed using the “Solver-sel”, “SELECT model” and “Estimated split model” computer programs (Tadashi Tokai 1997; Tadashi Tokai Tadashi Tokai and Takahisa Mitsuhashi, 1998, allowing us to estimate the parameters of trawl selectivity by a generalised logistic function of investigated fish retention likelihood depending on their length and by a split logistic function to estimate longline selectivity.

The equation of generalised logistic Richard’s function is described by the expression:

$$r(l)=\left(\frac{\exp(a+bl)}{1+\exp(a+bl)}\right)^{\frac{1}{\delta}} \qquad (1)$$

and the split logistic function is described by the expression:

$$r(l)=\left(\frac{p\exp(a+bl)}{1-p+p\exp(a+bl)}\right) \qquad (2)$$

where r(l) - the likelihood of fish retention by length l;
a, b, δ - parameters of the function;
l - retained fish length;
p - split parameter.

Fish length corresponding to 50% retention by the bag with B-mesh was calculated by the equation:

$$L_{50\%}=-\frac{a}{b} \qquad (3)$$

The selectivity range was calculated by the formula:

$$SR = \frac{2 \times \ln(3)}{b} \qquad (4)$$

where L75% and L25% - fish length, corresponding to 75% and 25% retention.

The research to estimate the selectivity of the trawl codend with the normative 135 mm mesh size was conducted at 850-1000 m depth, in Div. 3L of NAFO (Figure 6) regulation zone. Halibut made up 70-90% of the catches. The catches in codend varied from 0.30 to 80.0 tons amounting to 0.56 tons on average and in the cover from 0.5 to 1.0 tons with the mean of 0.75 tons.

The logistic function of investigated fish retention by 135.2 mm inner mesh size is shown in the next table (Table 1).

Table 1: Parameters of the logistic function for determining trawl selectivity (135.2 mm inner mesh size) (Lisovsky and Pavlenko 2003).

Parameter of function	Value
a	-10.06
b	0.22

Results of calculations to estimate the selectivity of the trawl bag with a 135.2 mm mesh size for Greenland halibut is present below in the Table and Graph (Table 2, Figure 4).

Table 2 : Selectivity parameters of trawl with a 135.2 mm inner bag mesh size (Lisovsky and Pavlenko 2003).

	Calculation	**Standard error**
$L_{25\%}$	**39.0**	**0.3**
$L_{50\%}$	**43.8**	**0.5**
$L_{75\%}$	**49.0**	**0.9**
S.R.	**10.0**	**N/A**
Ks.	**2.9**	**N/A**

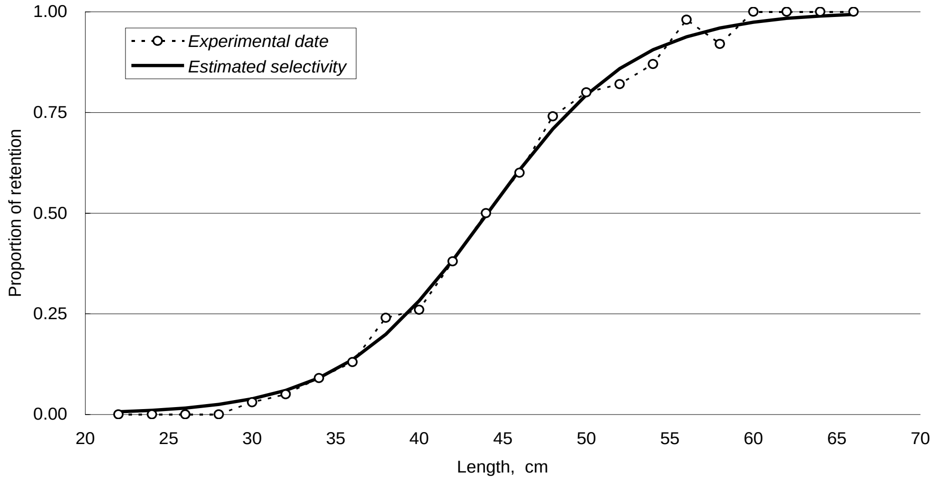

Figure 6: Selectivity of the trawl bag with a mesh size of 135.2 mm estimated by the generalised logistic function in relation to Greenland halibut in Div. 3L of NAFO regulation zone (Lisovsky and Pavlenko 2003).

Selectivity of longline determined relatively catch of trawl with a small bag mesh. The split logistic function of investigated fish retention by hook EZ 13 is shown in Table 3.

Table 3: Parameters of the logistic function for determining longline (hook type EZ 13) selectivity (PINRO, not published).

Parameter of function	Value
a	-5.35
b	0.80
split parameter p	0.74

The results of the estimated selectivity of hook EZ 13 for Greenland halibut are presented below in the table and graph (Table 4, Figure 6). These results were obtained in October – November of 2003 in II subarea of ICES zone (PINRO, not published).

Table 4: Selectivity parameters of longline with EZ 13 type hook (PINRO, not published).

	Calculation parameter	Standard error
$L_{25\%}$	39.9	8.3
$L_{50\%}$	56.3	8.2
$L_{70\%}$	87.0	8.2
S.R.	6.80	N/A

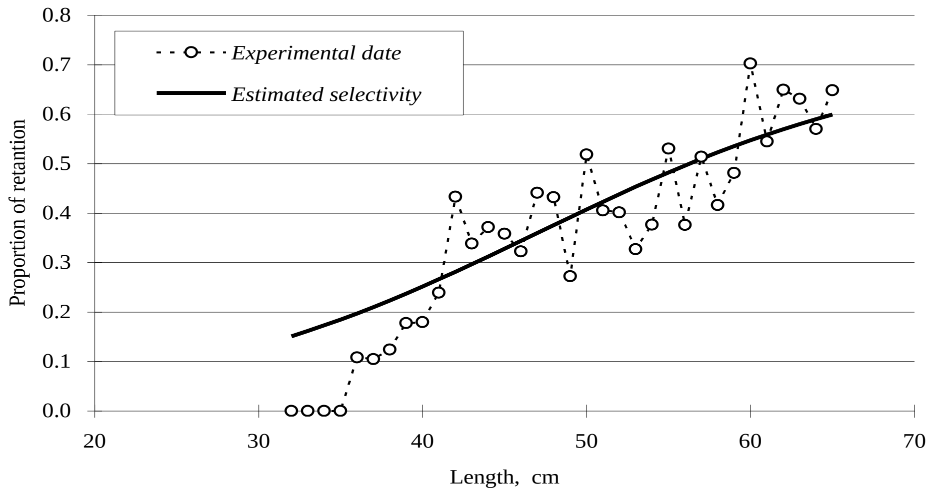

Figure 7: Selectivity of longline with EZ 13 hooks estimated by the Split logistic function in relation to Greenland halibut in subarea II of the ICES zone.

The selectivity parameters for gillnet are estimated using data from the Marine Research Institute of Iceland which were obtained in the Icelandic economic zone (Figure 4). It shows the date of catch and length frequency for 200 mm inner mesh size of gillnet for 2003-2005. The data were analysed using the general liner model that is described by the expression:

$$r(l)=\exp\left(\frac{-1(l-(k\times m))^2}{2\sigma^2}\right) \qquad (5)$$

where $r(l)$ - the likelihood of fish retention by length l;
k - parameters of the function;
l - retained fish length;
m – mesh size;
σ - standard deviation of the distribution.

3.3 Effects of depth on the distribution of Greenland halibut

In order to determine the effects of sea depth on the distribution Greenland halibut it is necessary to estimate the correlation between the catching depth and the mean length of fish in the catch. For calculation take dates from the survey stock database (1996-2005) for catches of bottom trawls with a bag mesh size of 45 mm and the commercial database for trawls with a 135 mm mesh size (1970-2005). Then separate catches per depth with a 50 m range and determine the mean length of fish in the catches at each depth.

The effects of sea depth on the mean length of fish in each catch are examined by using the equation for determining the correlation coefficient ρ_{xy} :

$$\rho_{xy} = \frac{Cov(X,Y)}{\sigma_x \sigma_y} \qquad (6)$$

where X – mean length of catch, cm;
Y – sea depth of fishing place, m;
σ - standard deviation of the distribution of mean length and depth of sea;
$Cov(X,Y)$ - covariance of mean length of catch and sea depth.

3.4 Value of difference between longline, trawl and gillnet catches

In order to determine the difference between catches of longline, trawl and gillnet, it is necessary to compare catches per mean fish length, sex composition and discards. These characteristics are estimated and compared according to fishing gear.

3.4.1 Average fish length of catches from different gear types

From the database choose all fishing operations per year and the type of fishing gears. Then estimate the mean fish length of the catches for trawl, longline and gillnet per year. Obtain and compare the mean fish length of catches from the different fishing gears for each year.

3.4.2 Determining the sex compositions of trawl, gillnet and longline catches

From the database, choose all fishing operations for which sex measures of the catch were made. Then separate the data into years and calculate the female share per catch like an average value corresponding to each fishing year:

$$Fshare = \frac{F}{M+F} \qquad (7)$$

where $Fshare$ - female share;
M - quantity of male
F - quantity of female

3.5 Fishing discards

Discards are defined as caught fish that are returned to sea for various reasons (Gjert 2001).

For estimating discard value for different fishing gears, compare the real length distribution of the catch with the estimated catch (Gjert 2001).

The estimated length proportion of the catch is obtained like a selectivity coefficient of each length of fish and the length distribution of each length fish in the stock (Gjert 2001). Length distribution of stock is taken from the database of survey trips.

$$r_{est.}(l_i) = s(l_i) \times f(l_i) \qquad (8)$$

where $r_{est.}(l_i)$ - proportion of retained fish *i* length in a cod-end, i.e. estimated catch;
$s(l_i)$ - selectivity coefficient of *i* length, i.e. retention probability;
$f(l_i)$ - length distribution of fish *i* length in the stock.

Denote length proportion of fish *r* (*l*) for annual catch. Then adjust estimated catch for cases where the estimated length proportions were bigger than in real catch r (*l*) by:

$$C_{est.\,i} = r_{est.}(l_i) \times C_{an.}, \qquad (9)$$

where $C_{est.i}$ – estimated total catch fish of *i* length for definite fishing gear, kg;
$C_{an.}$ – annual total catch for definite fishing gear, kg.

Further obtain the percentage of discards for each fish length of catch by:

$$D_i = \frac{C_{est.i} - C_{an.i}}{C_{an.i}} \times 100, \qquad (10)$$

where D_i - percent discarded fish of *i* length;
$C_{an.i}$ – annual total catch fish of *i* length for definite fishing gear, kg;
$C_{est.i}$ – estimated total catch fish of *i* length for definite fishing gear, kg.

Then determine the average discards for all fish lengths of annual catch per fishing gear and year.

$$D = \frac{\sum_{i}^{n} C_{est.i} - C_{an.i}}{\sum_{i}^{n} C_{an.i}} \times 100, \qquad (11)$$

where *D* - percent of discarded fish for total length.

4 RESULTS

4.1 Selectivity of the gillnet for Greenland halibut

Selectivity parameters for the gillnet are estimated from data from the Marine Research Institute of Iceland. The selectivity is determined for 200 mm inner mesh size gillnets for the period 2003-2005.

Table 5 : Gillnet selectivity

Parameter of function	Value			
	2003	2004	2005	total
k	0.32	0.32	0.32	0.32
Sigma (standard deviation)	41.12	21.25	39.65	47.82
Optimal length	64.69	64.69	64.69	64.69

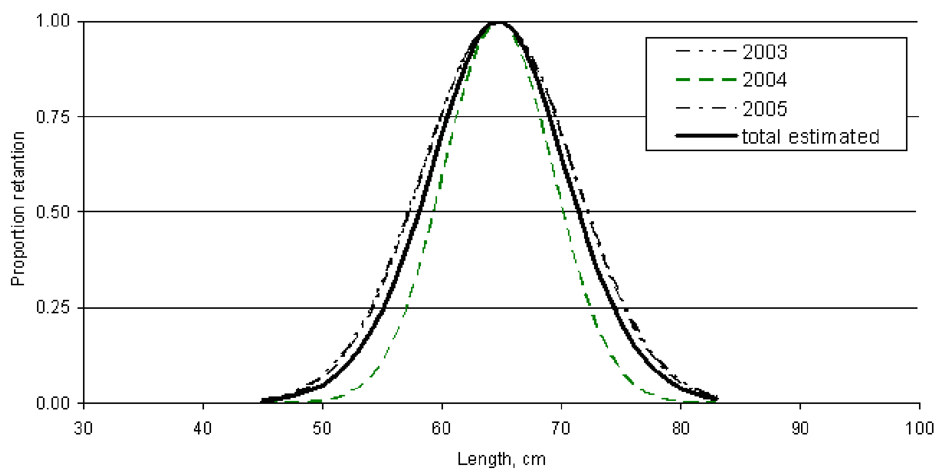

Figure 8: Selectivity of gillnets with a mesh size of 200 mm estimated using the general linear model in relation to Greenland halibut in the Icelandic economic zone.

4.2 Differences in mean fish lengths and sex composition of longline, trawl and gillnet catches

It was determined that the calculations for longline, trawl and gillnet catches were completed with a confidence level of 95.0% for each value. This data is presented for the period 1971-2005 in the table and graph below. Fisheries data were analysed for trawl fishing with 135 mm inner codends, for gillnet with a 200 mm inner mesh size and for longline with hook type EZ 13.

Table 6: Mean fish lengths and sex proportions of catches for each fishing gear for the period 1971 – 2005.

Fishing gear	Fish length of catch		Female share in catch	
	Mean length, cm	Confidence level (95.0%)	Mean share	Confidence level (95.0%)
Trawl	62.16	1.55	0.58	0.04
Gillnet	68.29	1.70	0.82	0.05
Longline	67.06	8.68	0.80	0.05

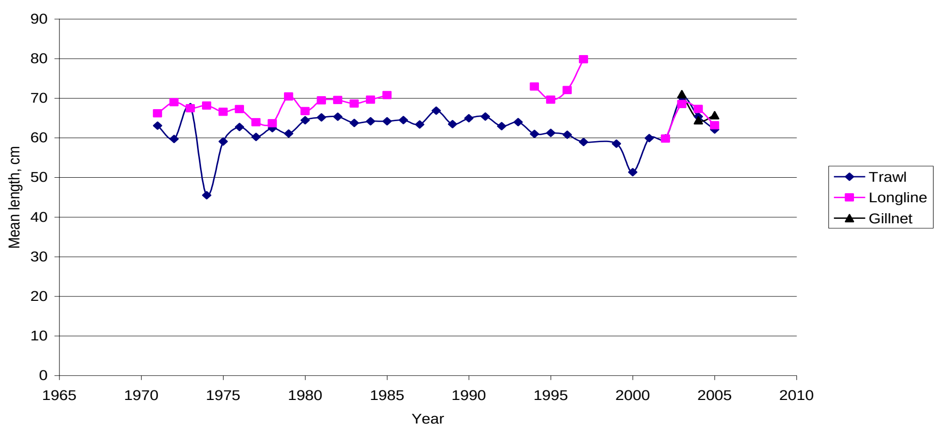

Figure 9: Mean fish lengths of trawl, longline and gillnet catches per year.

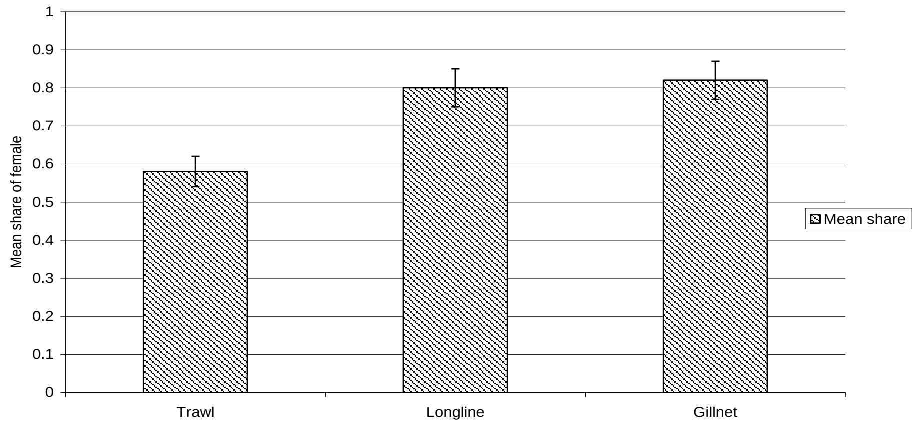

Figure 10: Female shares in trawl, longline and gillnet catches.

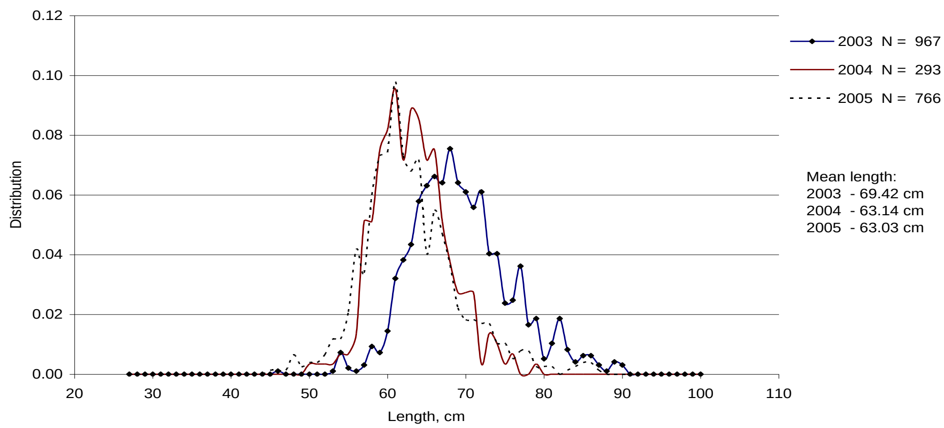

Figure 11: Length distribution of the gillnet catch in 2003-2004.

4.3 Fishing discards

The fish length proportions of estimated and real catches are presented in graphs like accumulation curves (Figure 12a). Accumulation length proportions of the stock are also presented in the graphs. Another graph presents fish discards per length (Figure 13b).

a b

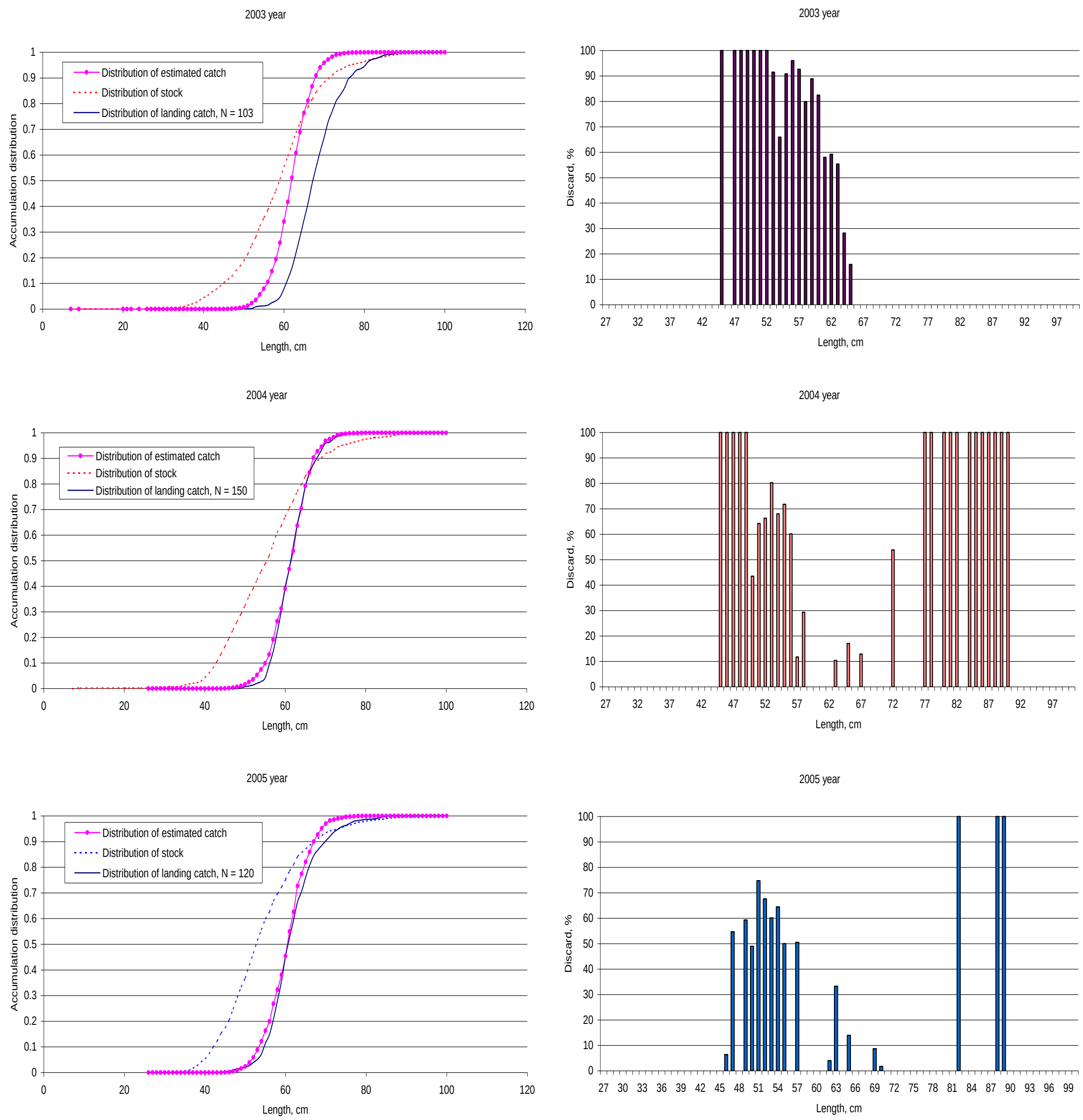

Figure 12: Accumulation distribution of (a) fish length of stock, estimated and landing catch of gillnets (200 mm mesh size), (b) discarded fish per length in the period 2003-2005.

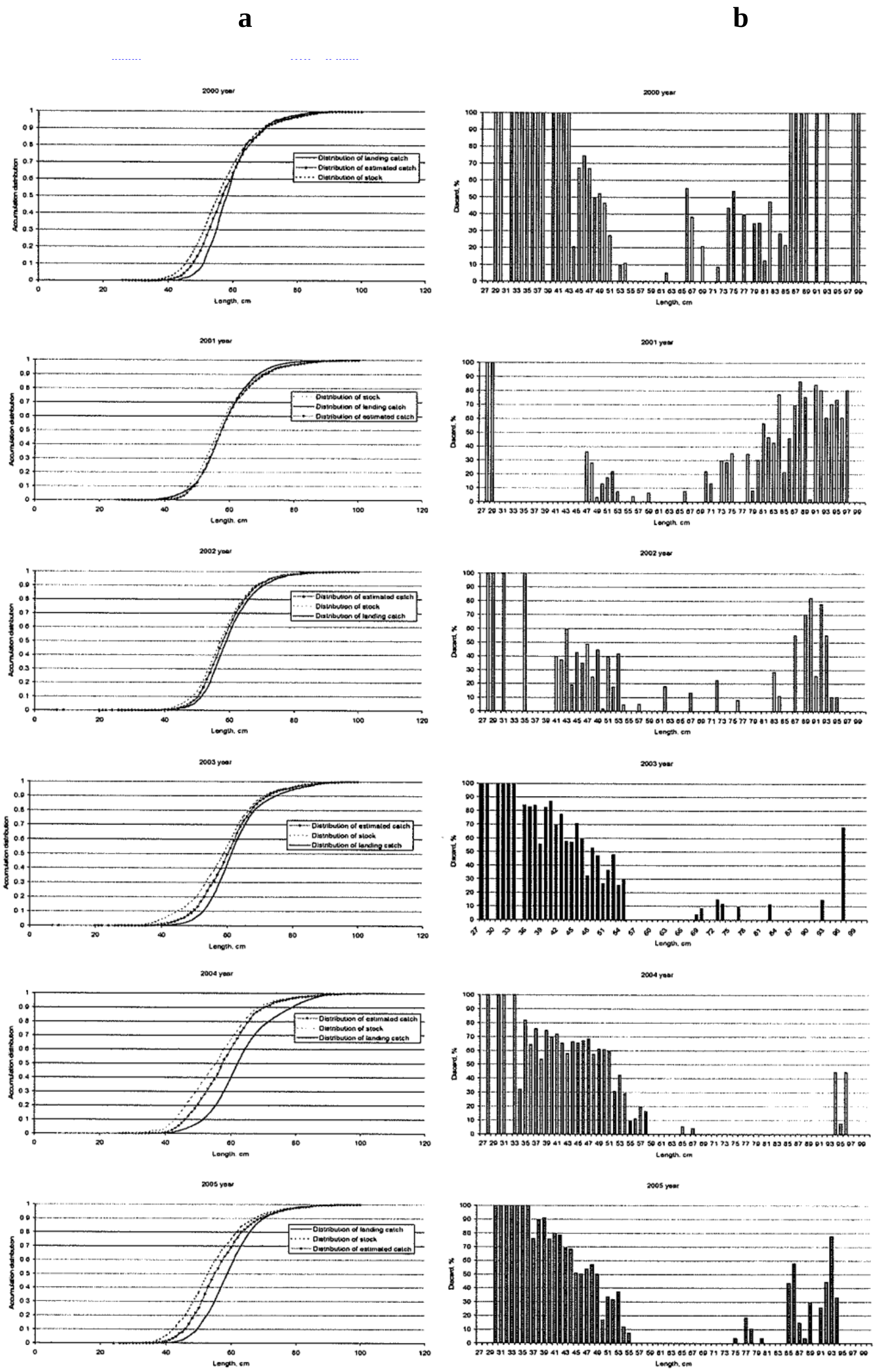

Figure 13: Accumulation distribution of (a) fish length of stock, estimated and landing catch of trawls (135 mm mesh size), (b) discarded fish per length in the period 2000 - 2005.

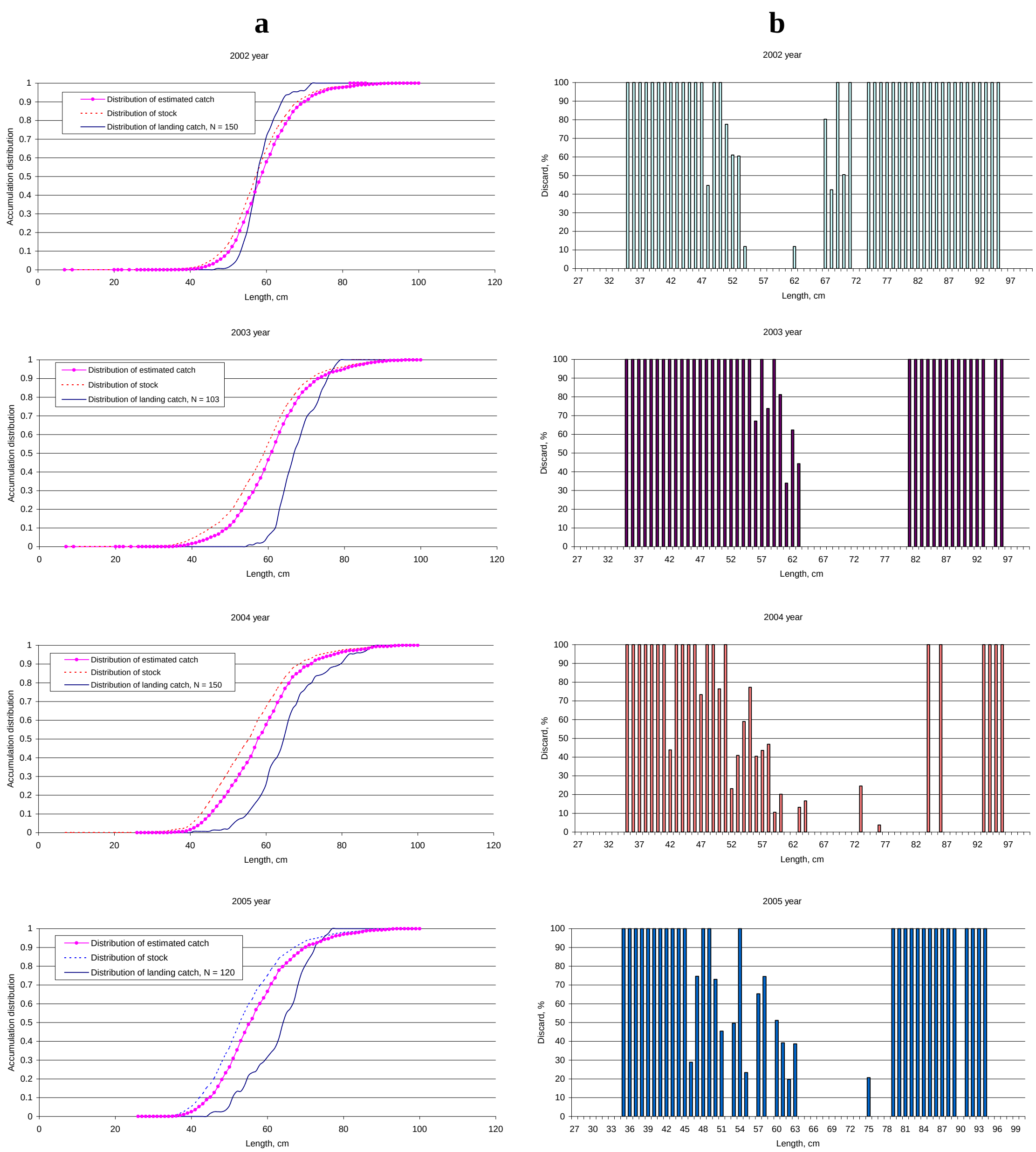

Figure 14: Accumulation distribution of (a) fish length of stock, estimated and landing catch of longlines (hook type EZ 13), (b) discarded fish per length in the periods of 1996-1997 and 2002-2005.

The effects of discard on different fishing gears are estimated by correlation between stock mean length and percentage of discards. The coefficient of correlation of mean length fish of stock. For Greenland halibut the percentage of discards of the trawl catch is ρ = - 0.86, 0.06 for longline and ρ = -1.00 for gillnet (Table 7).

Table 7: Correlation between the mean length of stock and percentage of discards.

Year	Stock mean fish length, cm	Discards, %		
		longline	gillnet	trawl
2000	57.07	N/A	N/A	18.12
2001	58.39	N/A	N/A	8.57
2002	58.42	30.68	N/A	9.93
2003	59.15	55.45	N/A	11.45
2004	56.18	38.96	15.82	22.59
2005	54.55	48.06	17.49	20.95
Correlation		0.06	-1.00	-0.87

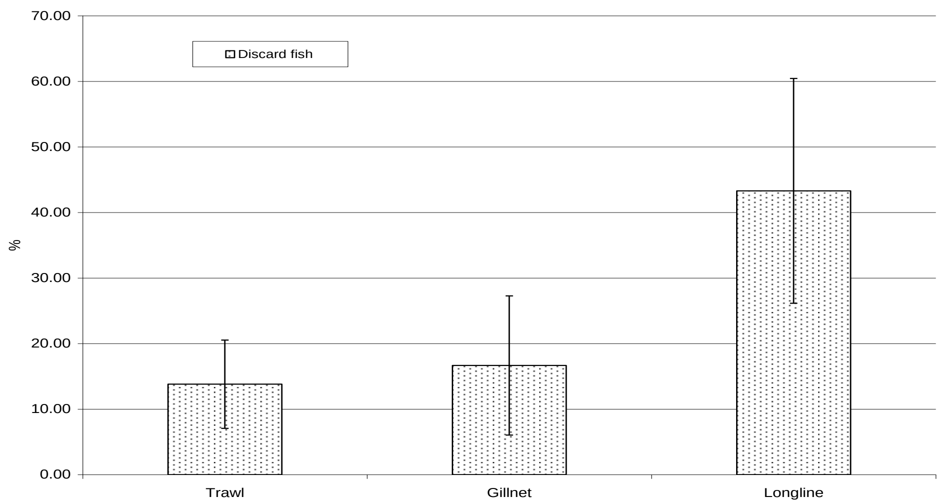

Figure 15: Discarded fish of trawls for the years 2000 – 2005, gillnet for the years 2004 – 2005 and longline for the years 2002 – 2005.

4.4 Effects of depth on the distribution of Greenland halibut

The effects of sea depth on the distribution Greenland halibut are estimated by correlation between the catching depth and the mean length of fish in the catch. The mean length of fish in the catch according to depth is presented below in the graph (Figure 16). The coefficient of correlation of sea depth and the mean fish length for the trawl catch stock assessment survey where the codend is with 40+mm mesh sizes is ρ = 0.92 and for commercial fishing where the trawlers are using 135 mm mesh size in the codends is ρ = 0.92.

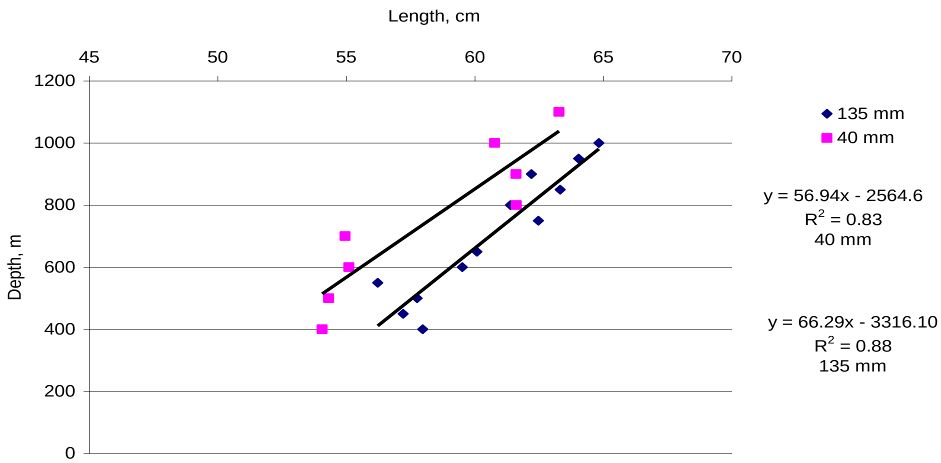

Figure 16: Distribution of mean lengths of Greenland halibut in the survey (mesh 40+ mm) and commercial (mesh 135 mm) trawl catches according to sea depth.

5 DISCUSSION

5.1 Selectivity

Selectivity experiments of trawl, longline and gillnet were conducted in different parts of the North Atlantic Ocean (Figure 4). These parts are located in range of Greenland halibut which means that there is similar biometric data in all parts of its range. In spite of this, it is possible apply the results of these selectivity experiments to analyse fisheries data for Greenland halibut in the Icelandic economic zone because selectivity depends of fish size and hook and mesh sizes (Kadilnikov 2001). This assumption is correct if we suppose that the environmental conditions of fishing one species and the type of fishing gear for catching that species are the same. For other cases, it is necessary to estimate selectivity patterns for each fisheries condition. In view of this, the results of this work are approximate.

5.2 Differences in mean fish length and sex composition of longline, trawl and gillnet catches

The average mean lengths and female shares of annual catches of different fishing gears for the period 1971 – 2005 are presented in Table 6. Mean fish lengths and female shares (Figure 10) of annual catches from trawls are less than those of gillnets and longlines. This can be explained by different length sizes per sex of Greenland halibut; the female is bigger than the male (Bjornsson 1994) and different selectivity patterns of different fishing gears which depend on the fish size (Kadilnikov 2001). Thus selectivity of gillnets with a mesh size of 200 mm and longlines with the hook type EZ 13 led to more catch of bigger fish than from trawls and mostly this fish is female.

It is necessary to take into account a distinction in fish behaviour depending on different fishing gears. For trawls, experimental results have shown that sight of the headline with its floats can keep large fish swimming in front of the trawl without entering the net (Hemmings 1973). Small fish might be lost under the sweeps if they are unable to keep up with the narrowing wires.

For longlines, larger fish utilise extensive feeding grounds due to their higher swimming capacity (Hart 1993) and they do better in the competition for food after it is found (Godo *et al*. 1997). This tends to lead to larger fish being overrepresented in the catches if both large and small fish are represented in the area. If longlines are set in areas with homogeneous length distributions small fish will dominate and baits are small enough for the smallest Greenland halibut in the area to get hooked (Huse *et al.* 1999).

For gillnets, the main selectivity factors are mesh size and the activity level of the fish in the fishing area. Usually the fish activity is an uncontrolled value and mesh size is chosen in accordance with selectivity patterns for best biological parameters of species (author’s private opinion). Therefore, the total of these factors predetermines selectivity results for different fishing gears.

5.3 Discards

Discards were calculated for trawl, longline and gillnet fishing for the period 2003-2005 because fishing by gillnet only began in 2003. In that period different fishing gears were used together which means that they fished in similar conditions and caught fishes of the same stocks. This circumference allows us to compare results of estimated discards from the different gears.

Data for gillnet fishing in 2003 is excluded from calculations of discards because in that year catch from gillnets consisted of bigger fishes than catches from the next years (Figure 10). This signifies that in 2003 gillnet fishing used a larger mesh size than in the years 2004-2005. Thus it is impossible to determine selectivity and discards for gillnets in 2003 because the mesh size is not known.

Discard is when fishes are dropped from the catch for different reasons. For example, it is maybe due to the low market price for small size fish, a large share of fish below the legal minimum landing size, poor quality of fish (Gjert 2001), dropped fish from hooks of the longline (Woll *et al.* 1998). The amount of discards depends on the market situation, the discarding policy of the fishermen and size and age composition of the stock (Gjert 2001). The last observation is confirmed by the results of this study that show a good correlation value between the mean length of the stock and the percentage of discards (Table 7). This correlation has a good value for trawls and gillnets but not for longlines. The value for longlines is bad because its percentage of discards also depends on weather conditions (Gundersen *et al.* 1998a, Woll *et al.* 1998).

Values of the average percentage for different fishing gears have wide confidence levels. The value of longline is bigger (Figure 13). In spite of rough values it is possible to compare discards of the trawl, longline and gillnet fisheries among themselves for approximate valuation. Discards of the trawl and longline fisheries are similar but the discards of longline may be bigger. Large discards of longline may also be explained by dropped fishes from hooks in rough weather because hooks often are not swallowed by halibut and normally it is hooked on the outer part of the mouth (Gundersen *et al.* 1998a, Woll *et al.* 1998). It is necessary to take this into account to make allowance for discard values that the selectivity experiment was conducted in alcyon weather but the fishing process is often not stopped in rough seas (author’s private opinion). As for small fish, they are usually taken off hooks during the whale process and are not taken on the board by the fishermen. This happens because of the quota system, as fishermen will lose benefits unless they release their quota of small fish which has a low market price (author’s private opinion).

5.4 The effects of depth on the distribution Greenland halibut

There is a good correlation value between trawl fishing in deep waters and the mean length of catch which demonstrates that stability depends on the mean length of Greenland halibut and the sea depth (Figure 14). This conclusion agrees with the results obtained by Nedreaas *et al.* (1996).

The stability difference between the mean lengths of the industrial trawl catches and the stock assessment survey catches where the codend has a 40+mm mesh size proves the stability selectivity of Icelandic commercial fisheries (Figure 14).

Because correlation between the mean length of the catch and the sea depth is strong, it is possible to adjust the value of fishery discards in view of fishing depth.

6 CONCLUSION

Catches of Greenland halibut by trawl, longline and gillnet are different. These catches differ in terms of mean length and sex composition. The mean length of the trawl catch is lower and it has a smaller share of female fish than the catches of longlines and gillnets. This can be explained by the different selectivity of bottom trawl with a 135 mm inner mesh size of codend, gillnets with a 200 mm inner mesh size and longlines with hook type EZ 13.

There are differences in the discard values of the trawl, gillnet and longline fisheries. Discards of trawls and gillnets are similar and much smaller than the discards of the longline fishery.

There is a correlation between the mean length of Greenland halibut and sea depth.
The stability difference between the mean fish length of the industrial trawl catch and the stock assessment survey which demonstrates good selectivity of the commercial fishery.

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