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The Analysis of the Results from the Investigation into Selectivity of Trawl Codends with 120-150 mm Mesh Size in the Fishery of Greenland Halibut in the NAFO Regulatory Area

by

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Abstract

The paper describes the results of selectivity tests for codends with 130.8, 145.2 and 150.2 mm mesh size in Greenland halibut fishery in the NAFO Regulatory Area.

Selectivity parameters for males and females were not found to differ significantly; therefore, the results were analyzed regardless of sex.

The calculations were made by the generalized logistic (Richard's) and logistic functions of dependence of fish retention on length. Estimating the likelihood by both models through minimizing Akaike's Information Criterion (AIC) showed that Richard's function more precisely described fish retention.

In a series of experiments the length of fish corresponding to 50% retention ranged from 41.7 cm for 130.8 mm mesh to 45.2 and 46.7 cm for, respectively, 145.2 and 150.2 mm meshes.

Selectivity range was 6.1- 8.4 cm and selectivity coefficient varied from 3.1 to 3.2.

Calculated fish length corresponding to 25% retention ranged from 38.2 for 130.2 mm mesh to 41.8 cm for that one with 150.2 mm size.

Processing the data obtained indicated that an increase of trawl mesh size from 130 mm and over would not be profitable in the long term. Trawl fishery for Greenland halibut would be economically inexpedient owing to a significant reduction in the efficiency of trawls with larger mesh.

The commercial size of Greenland halibut for trawls with 130 mm mesh can be increased to 34 cm. In this case, the by-catch of undersized fish will not exceed 10% in numbers, as adopted by the NAFO Fisheries Commission.

Introduction

The total of 0.28 x 10^6 tons of Greenland halibut have been caught over the last decade (1991-2000) in Div. 3LMNO. By the 1A STATLANT database, the annual catch varied from 51 800 tons in 1992 to 12 800 tons in 1995. Until 1995, this fishery had been regulated only by the minimum mesh size of 130 mm in codends. Since 1995 the NAFO Fisheries Commission has been also setting an annual TAC, which is further divided into national allocations. Besides these measures on regulation, the Fisheries Commission of NAFO adopted a minimum

commercial size of 30 cm for trawl fishery on Greenland halibut. This size is based on selectivity calculations and corresponds to 25% retention.

Maximum allowable by-catch of undersized (below 30 cm) fish – 10% (Anon., 2001).

These regulations have already caused positive trends in stock dynamics. Both the TAC and the total catch started to grow. The catch of Greenland halibut in 1996 was 14 300 tons. TACs for 2001 and 2002 were, respectively, 40 000 and 44 000 tons.

It remains essential to reduce catches of immature Greenland halibut, both as a target species and as by-catch in other fisheries (Anon., 2000; Anon., 2001). The selectivity of fishing gears in directed Greenland halibut fishery, as well as its by-catches, should be, therefore, accurately estimated for all fisheries, especially by trawl. This paper describes the selectivity tests on trawls with different mesh size during Greenland halibut fishery in the NAFO Regulatory Area.

Material and Methods

Experimental works to determine selectivity when fishing Greenland halibut were conducted aboard the Russian trawler "Remøifjord" in NAFO Div.3L in December 2001. The vessel length was 63.25 m, the width – 12.50 m; the tonnage – 1538.0 gross tons, main engine – 3180 horsepowers.

When conducting investigations the bottom 45.8 m trawl "Turbot" (Fig.1) with 26 m horizontal and 5 m vertical opening was used. The trawl was equipped with a rockhopper along the bottom headline with 500 mm diameter bobbins, the doors of "Kwin topp" type with the area of 8.6 m^2, the weight equaled to 2 600 kg. The length of cables was 245 m each. The tow speed amounted to 3.0-3.2 knots, the duration of experimental fishery corresponded to that one when fishing (from 2 hours 10 minutes to 5 hours).

The trawl codends with actual 130 mm; 145 mm and 150 mm mesh size, made of polyamid cord with 7.0 mm diameter, folded in two were tested. The length of the cylindrical part of the trawl codend was 10 m, the perimeter – 80 meshes. The length of the cylindrical part was measured in the upper panel of the codend. The measurement was executed in the row of meshes, which was parallel with the longitudinal axis of the trawl codend, at the distance of 10 meshes from the longitudinal seams and of 5 meshes – from the codline loops. In all, 20 meshes were measured each time. The measurement was performed immediately after the trawl having been lifted with the aid of the probe – the wedge-shaped plate in 2 mm thickness of ICNAF type - thrown into mesh with the effort of 50 N. The measurements were made at the beginning and at the end of every experimental series.

The selectivity of the trawl codends was determined applying the method of small-meshed bag-shaped cover with 90 mm mesh size mounted on the conical part of the trawl codend at the distance of 4-5 m from the site of its joining the cylindrical part of the trawl codend. The perimeter of cover edge was 30-90% larger than that one of the cylindrical part in the trawl codend and 2-3 m projecting behind it.

All the fish from codend and cover were emptied out to the different bunkers and measured separately with dividing by sex. Every 200-300 individuals from all the catches by the trawl codend and cover were measured. When the catches were large, the rest of fish was counted and the length frequencies were corrected in the proper way.

The data were collected and processed according to the ICES Recommendations on studying trawl selectivity (Anon., 1996). The data analysis was performed using computer programs "Solver-sel.xls" and "Select model" (Tadashi Tokai, 1997; Tadashi Tokai and Takahisa Mitsuhashi, 1998) allowing the selectivity parameters to be estimated using generalized Richard curve or the logistic ogive of the probability of the examined fish retention depending on their length.

The equation of Richard curve function is discribed by the expression:

$$r(l) = \{\exp(a + bl) / [1 + \exp(a + bl)]\}^{1/d}, \qquad (1)$$

where: $r(l)$ – probability of retention of fish with length l;

a,b,d – parameters of Richard curve;
l – length of fish retained.

The length of fish corresponding to 50% retention in the codend with mesh B was calculated using the formula:

$$L_{50\%} = \frac{\log it(0.5)^d - a}{b}. \quad (2)$$

The selectivity range was calculated by the formula:

$$SR = L_{75\%} - L_{25\%} = \frac{\log it(0.75^d) - \log it(0.25^d)}{b}, \quad (3)$$

where: $L_{75\%}$ and $L_{25\%}$ - fish lengths, corresponding to 75% and 25% retention.

The selectivity coefficient was calculated by the formula:

$$K_S = \frac{L_{50\%}}{B}, \quad (4)$$

where: B – the inner size of the codend mesh.

The selectivity was also calculated using ligistic ogive:

$$r(1) = \frac{\exp(a + bl)}{l + \exp(a + bl)}. \quad (5)$$

Fish length corresponding to 50% retention was calculated by this formula from the expression:

$$L_{50\%} = \frac{a}{b}. \quad (6)$$

Selectivity range was calculated by the formula:

$$SR = L_{75\%} - L_{50\%} = \frac{2\log_e(3)}{b} = \frac{2.197}{b}. \quad (7)$$

The likelihood in the both models (Richard curve and logistic ogive) was calculated by minimizing the logarithmic function of likelihood (Akaike's Information Criterion (AIC)). The calculations were executed with dividing fish by sex.

Standard errors were estimated by every calculation model using computer program Tokai Tadashi (Tokai Tadashi, 1997).

The change of possible efficiency of fishing Greenland halibut by trawls with the mesh size different than 130.8 mm was evaluated by means of comparing the experimental data on catches, as well as through calculating possible decrease in catch by the trawl with larger mesh size as a result of selectivity increase. The catch of every length group by trawl with a new mesh was estimated proceeding from the length composition of catch by the trawl with 130.8 mm mesh size, the difference in the selectivity of 130.8 mm mesh and the new one.

The weight of catches was calculated using mean long-term PINRO's data on the dependence of the weight of each Greenland halibut individual on length and number of fish in the catches by every mesh.

$$\sum_{l}^{n} P_{2i} = \sum_{i=1}^{n} N_{li} \frac{S_{2i}}{S_{li}} M_i, \qquad (8)$$

where: P_{2i} - weight of catch of i-length group by a new mesh;
N_{li}, N_{2i} - the catch of i-length group by the old and new meshes, respectively;
M_i - the weight of one individual of fish from i-length group;
S_{2i} and S_{li} – the selectivity of trawls with new and old meshes relative to fish from i-length group.

In the paper the results from the investigations into selectivity of trawl codends, which had been obtained by the other scientists and the authors of this paper before were also used.

Results

The data on tows and catches are presented in Table 1. Table 2 gives the results from mesh measurements in the trawl codends with different mesh size. During the trials the average sizes of meshes in trawl codends were equal to 130.8 mm, 145.2 mm and 150.2 mm. The summarized data on catches in trawl codends with different mesh size and in the cover are shown in Table 3.

When testing trawl codends with 130.8 mm mesh size the catches in trawl codend amounted to 1.6-0.5 t, in the cover – to 0.2-0.5 t. The portion of Greenland halibut in the catches was 94-99% (Table 1). The Greenland halibut 26-62 cm in length was fished (Table 3, Fig. 2). The mean lengths of males in a catch equaled to 45.8 cm, in the cover – to 39.8 cm, those ones of females were 46.6 cm and 40.8 cm, respectively. The mean length of caught fish without dividing by sex equaled to 44.2 cm and in the catch – to 46.2 cm and in the cover – to 40.0 cm.

The lengths of males and females retained by trawl codend with 130.8 mm mesh size corresponding to 50% retention $L_{50\%}$ differed insignificantly – 41.6 cm and 41.8 cm, respectively, and the selectivity ranges (SR) were 5.6 cm and 6.4 cm, correspondingly. The selectivity coefficients for males and females were not different and equaled to K_S=3.2.

When testing the trawl codends with 145.2 mm mesh size the catches varied from 0.3 t to 0.8 t per a trawling in the trawl codend and within the limits of 0.3 t-0.9 t per a haul in the cover (Table 1). The Greenland halibut prevailed (79-97%). Fish having the length from 28 cm to 82 cm and the mean length of 43.5 cm were fished out. The ratio of males and females in the aggregations fished out was 2:3 (Table 2, Fig. 3a). In the catches females were predominant (2:1). Their length varied from 34 cm to 82 cm and the mean length amounted to 46.7 cm. The length of males in the catches ranged from 34 cm to 64 cm, the mean one was 45.7 cm. Fish as long as 28 cm – 54 cm and with the average length of 41.4 cm escaped through the trawl codend.

The length of 50% retained fish, the selectivity range and the coefficient of selectivity were the same for both males and females and equaled to $L_{50\%}$ = 45.2 cm; SR = 7.1 cm and K_S = 3.1, respectively (Fig. 3b).

The catches by trawl with 150.2 mm mesh size were 0.5-0.7 t and the escapement of fish to the cover – 0.7-0.9 t per a tow (Table 1).

The Greenland halibut 28 cm - 80 cm in length and with the average length of 43.7 cm (Table 2, Fig. 4) were fished out. In the catches the mean length of males was 45.4 cm, that one of females – 46.8 cm. The halibut having the length of 28 cm – 54 cm and the mean one of 42.1 cm escaped through the meshes of the trawl codend. The average length of males escaped was 41.6 cm, that one of females – 42.4 cm.

The selectivity coefficients for males and females slightly differed and amounted to 3.1 and 3.2, respectively.

The selectivity curves of the trawl codends with different mesh size relative to the Greenland halibut without dividing by sex, calculated by Richard and logistic functions are shown in Fig.5, 6. Table 4 presents the calculating parameters of selectivity with the estimations of standard errors and optimizing AICs.

The example of calculating parameters of Richard function to estimate selectivity of trawl codends with 150.2 mm mesh size relative to Greenland halibut without dividing by sex is shown in Table 5.

Possible change calculating estimations of Greenland halibut fishing efficiency as a result of enlarging the permitted minimum mesh size, which exceeded 130.8 mm are given in Table 6.

While testing the selectivity of trawl codends with the mesh size from 130.8 mm to 150.2 mm the length composition of both males and females fished out and caught differed insignificantly (Fig. 2a, 3a, 4a). The selectivity parameters were also slightly different. That allowed the results of investigations to be used without dividing by sex.

In our experiments the length composition of Greenland halibut fished out without dividing by sex differed a little (Fig.8). The average length of fish varied from 44.2 cm to 43.7 cm.

Comparing the values of AICs when calculating selectivity it may be noticed that Richard function describes the probability of fish retention in the trawl codends with different mesh size more precisely. Indeed, while calculating by Richard function AIC was 10.1-1.7% lower than by the logistic one for all tested trawl codends with the mesh size of 130.8 mm, 145.2 mm, 150.2 mm. Therefore, when further analyzing the selectivity model calculated by Richard function was only used.

Discussion

As our investigations and the other scientists' papers (Chumakov *et al*., 1981; Nikeshin *et al*., 1983; Gardenus *et al*., 1995; Huse and Nedreaas, 1995; Walsh and Hickey, 2000; Lisovski *et al*., 2001) showed, the selectivity coefficient of trawl codends with 121mm-150 mm mesh size varied from 2.8 to 3.3 and the selectivity range – from 6.1 cm to 11.8 cm (Table 7). Higher parameters of selectivity were obtained by the method of using the bag-shaped cover and the two codend trawl. The analysis of data available indicated that the commercial size of 30 cm having been adopted at present and allowed for landing did not correspond to 25% retention of the trawl codend with 130 mm mesh size. This length must be enlarged up to 34-36 cm. For this, the by-catch of individuals with the length below the limits which have been adopted again – less than 34 cm and 36 cm - will amount to 0.4-5.2% and 1.1-12.8%, respectively.

Thus, the minimum length of Greenland halibut allowed for fishing might be increased to 34 cm. For this, the by-catch of fish with the length of less than the adopted one would be below 10% of the value approved by the NAFO Fisheries Commission at present.

The calculations of possible change of fishing efficiency as a result of selectivity caused by increasing mesh size in trawl codends showed that when enlarging the mesh size from 130 mm to 145 mm the efficiency would be reduced by 27% and from 130 mm to 150 mm – by 43% (Fig. 7). The similar change of efficiency was also corroborated by the lower presented experimental parameters of catch by trawls with enlarged mesh size. For this, the trawl fishing of Greenland halibut by trawls with the mesh size increased up to both 145 mm and 150 mm will be economically inexpedient.

The calculations of long-term profits as a result of enlarging the mesh size from 130 mm to 145 mm made by Darby (Darby, 2001) also corroborate our opinion concerning the inexpediency of enlarging the mesh size. The effect would be slight.

Conclusions

When fishing the Greenland halibut in NAFO Div. 3LMNO using 130 mm mesh the least length of fish permitted for catch and corresponding to 25% retention may be enlarged up to 34 cm. For this, the allowable by-catch of Greenland halibut to 10% in numbers will be provided.

Such an increase will diminish the press on fish juveniles.

Enlarging mesh size from 130 mm to 150 mm in trawls in Div.3LMNO will not give the essential long-term profits and under the existing length composition of Greenland halibut fished out will lead to the cessation of its fishing by trawls as a consequence of economical inexpediency.

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Table 1. Main characteristics of tows when determining selectivity of trawl codends with different mesh size for Greenland halibut, December 2001, NAFO Regulatory Area.

NO	DATE	TIME START	START POSITION		COURSE, DEG	TOW DURATION, H/MIN	DEPTH, M	SPEED, KN	CATCH, KG		CREENLAND HALIBUT, %
			N DEG, MIN	W DEG, MIN					CODEND	COVER	
MESH SIZE 130,8 MM											
1	25.12	21:40	48.08.8N	47.29.1W	90	5:00	1069	3,2	598	214	96
2	26.12	12:30	48.08.8N	47.27.1W	87	5:00	1059	3,1	548	327	94
3	26.12	20:00	48.09.2N	47.07.5W	270	5:00	1081	3,2	854	476	95
4	27.12	10:10	48.08.1N	47.07.9W	270	4:50	1060	3,1	728	332	94
5	27.12	16:40	48.08.7N	47.28.3W	90	4:50	1060	3,2	453	212	90
6	28.12	11:30	48.07N	47.04W	270	5:00	860	3,1	1534	421	97
7	28.12	18:40	48.07N	47.29W	90	4:50	875	3,3	1599	387	97
8	29.12	7:50	48.07N	47.28W	90	2:10	900	3,1	781	239	96
9	30.12	13:40	48.07N	47.06W	270	4:50	850	3,2	1508	402	99
10	31.12	9:20	48.07N	47.26W	90	4:10	880	3,1	1223	473	95
MESH SIZE 145,2 MM											
11	19.12	15:50	48.06N	47.24W	90	4:10	770	3	747	938	88
12	20.12	4:20	48.06N	47.32W	90	4:00	770	3,1	824	812	89
13	21.12	21:40	48.05.2N	47.09.1W	270	4:10	700	3	843	963	81
14	21.12	9:20	48.05.2N	47.09.1W	270	3:20	700	3	714	812	79
15	21.12	21:50	48.06.3N	47.08.4W	270	4:10	768	3,2	731	809	80
16	22.12	12:20	48.06N	47.24W	270	4:00	770	3,1	641	759	92
17	23.12	11:10	48.08N	47.28W	90	4:10	970	3,1	537	303	90
18	23.12	17:20	48.09.7N	47.10.7W	270	4:00	1100	3,1	506	300	93
19	24.12	21:30	48.09.9N	47.07.2W	265	4:30	1136	3,2	263	297	97
20	25.12	4:00	48.09.2N	47.31.4W	90	4:20	1140	3	311	354	97
MESH SIZE 150,2 MM											
21	16.12	19:40	48.07.ON	47.10.1W	270	3:50	910	3	598	837	99
22	17.12	7:30	48.07.1N	47.06.3W	275	4:10	970	3,1	733	912	98
23	18.12	7:40	48.07.6N	47.07.2W	270	4:20	925	3,2	680	720	93
24	18.12	20:00	48.06N	47.08W	95	4:00	760	3	491	789	90

Table 2. Results from the measurements of meshes in trawl codends with the normative 130 mm (a), 145 mm (b) and 150 mm (c) mesh size when testing the selectivity for Greenland halibut in NAFO Regulatory Area (Div. 3L,), December 2001.

No	Mesh size, mm		No	Mesh size, mm	
	At the beginning of tests	At the end of tests		At the beginning of tests	At the end of tests
			?		
1	129	129	11	129	131
2	130	131	12	129	129
3	132	130	13	131	129
4	129	132	14	132	130
5	132	130	15	130	130
6	133	131	16	130	131
7	131	132	17	130	130
8	133	130	18	132	131
9	132	132	19	131	132
10	133	132	20	130	132
	Average mesh size			*130,9*	*130,7*
				130,8	
			b		
1	146	147	11	147	147
2	145	147	12	138	138
3	145	146	13	147	147
4	144	146	14	144	146
5	145	145	15	145	143
6	144	145	16	152	160
7	147	145	17	144	143
8	145	145	18	142	142
9	146	145	19	145	145
10	147	144	20	144	142
	Average mesh size			*145,1*	*145,4*
				140,2	
			?		
1	150	151	11	150	151
2	152	151	12	156	150
3	151	148	13	146	152
4	146	147	14	148	150
5	148	147	15	154	150
6	150	151	16	147	150
7	150	150	17	147	149
8	156	150	18	153	152
9	148	147	19	151	150
10	151	148	20	155	155
	Average mesh size			*150,4*	*150,0*
				150,2	

TABLE 3. Length composition of Greenland halibut caught and escaped by th trawl codends with 130.8, 145.2 and 150.2 mm mesh size in NAFO Regulatory Area Div. 3L, December 2001.

Length, cm	Mesh size 130,8 mm				Mesh size 145,2 mm				Mesh size 150,2 mm			
	Caught, number		Escaped, number		Caught, number		Escaped, number		Caught, number		Escaped, number	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
24	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	2	0	0	0	0	0	0	0	0	0
28	0	0	10	4	0	0	24	6	0	0	3	0
30	0	0	49	32	0	0	38	36	0	0	15	12
32	0	0	76	69	0	0	59	54	3	3	31	44
34	15	0	186	251	13	16	163	189	11	3	96	79
36	50	61	166	179	31	24	236	217	11	8	76	81
38	116	110	359	389	105	85	533	629	26	45	250	234
40	452	577	691	958	241	362	961	1254	113	131	419	484
42	267	408	321	360	175	282	499	741	69	122	269	383
44	934	1276	351	453	506	755	695	1215	183	297	323	535
46	774	1112	138	135	324	721	283	505	124	277	226	291
48	732	1394	25	47	480	853	150	293	153	406	143	246
50	465	934	6	14	314	584	52	121	126	280	49	92
52	128	288	0	0	75	212	8	6	34	75	0	17
54	79	357	0	0	81	213	1	8	33	85	3	3
56	31	90	0	0	13	79	0	0	3	39	0	5
58	14	55	0	0	9	45	0	0	0	16	0	0
60	9	24	0	0	5	15	0	0	0	8	0	0
62	0	4	0	0	3	0	0	0	0	3	0	0
64	0	0	0	0	1	0	0	0	0	3	0	0
66	0	0	0	0	0	0	0	0	0	2	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	2	0	0	0	0	0	0
74	0	0	0	0	0	2	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	2	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	2	0	0
82	0	0	0	0	0	2	0	0	0	0	0	0
Total	**4066**	**6690**	**2380**	**2891**	**2376**	**4254**	**3702**	**5274**	**890**	**1805**	**1902**	**2506**

TABLE 4. Sele?tivity parameters of trawl codends with different mesh size for Greenland halibut in NAFO Div. 3L, calculated usiing logistic and Richard curves, December 2001.

Parameters	Richard curve		Logistic curve	
	Calculation	Standard error	Calculation	Standard error
		Mesh size of codend 130,8 mm		
$L_{25\%}$, *cm*	38.2	0.08	38.5	0.07
$L_{75\%}$, *cm*	44.3	0.09	44.0	0.14
$L_{50\%}$, *cm*	41.7	0.05	41.3	0.10
S.R., cm	6.1	0.09	5.5	0.11
$?_s$, *cm*	3.2		3.2	
Value of AIC	56.99		63.18	
		Mesh size of codend 145,2 mm		
$L_{25\%}$, *cm*	41.2	0.08	41.0	0.06
$L_{75\%}$, *cm*	48.3	0.10	48.5	0.15
$L_{50\%}$, *cm*	45.2	0.05	44.8	0.10
S.R., cm	7.1	0.09	7.4	0.13
$?_s$, *cm*	3.1		3.1	
Value of AIC	62.03		68.14	
		Mesh size of codend 150,2 mm		
$L_{25\%}$, *cm*	41.8	0.18	43.0	0.11
$L_{75\%}$, *cm*	50.2	0.15	51.3	0.28
$L_{50\%}$, *cm*	46.7	0.08	46.3	0.16
S.R., cm	8.4	0.16	9.3	0.26
$?_s$, *cm*	3.1		3.1	
Value of AIC	65.94		67.05	

Table. 5 **Maximum log-likelihood estimates of Richard curve parameters with Solver on MS-EXCEL.**

Richard curve equation $r(l) = \{ \exp(a + bl) / [1+\exp(a + bl)] \}^{1/d}$

Mesh size 150.2 ??; Div. 3L

Selectivity from Richard	Length(cm)	Standard errors
0.25	41.8	0.18
0.75	50.2	0.15
S.R. =	8.43	

$?_s$ = 3.1

Parameters		Standard errors
a =	-24.11	0.77
b =	0.47	0.02
d =	3.17	
Changing cells		
$L_{50\%}$ =	46.7	0.08
S.R. =	8.4	0.16

Sum of log-likelihood: -29.97

Initial value	Parameters estimated by eye
-12.36	$L_{50\%}$ =
0.27	S.R. =

Akaike's Information Criterion
Value of AIC: 65.94

Target cell should be maximized

Length(cm)	Catch number of Codend	Cover	Total	Propotion retained in codend	Selectivity from Richard	Likelihood of each length class	log(likelihood)	Deviance residual
24	0	0	0	0.00	0.02	1.00	0.00	0.00
26	0	0	0	0.00	0.02	1.00	0.00	0.00
28	0	3	3	0.00	0.03	0.91	-0.10	-0.44
30	0	26	26	0.00	0.04	0.32	-1.15	-1.52
32	6	75	82	0.08	0.06	0.04	-3.27	0.77
34	14	175	189	0.08	0.08	0.05	-2.95	-0.14
36	19	157	176	0.11	0.11	0.09	-2.46	0.11
38	71	484	556	0.13	0.14	0.01	-4.41	-0.92
40	244	904	1148	0.21	0.19	0.00	-5.46	1.82
42	191	652	843	0.23	0.26	0.00	-6.87	-2.05
44	480	858	1338	0.36	0.34	0.05	-3.09	1.13
46	402	517	919	0.44	0.46	0.01	-4.96	-1.16
48	560	389	949	0.59	0.59	0.02	-4.04	-0.07
50	407	141	547	0.74	0.73	0.04	-3.21	0.50
52	108	17	125	0.87	0.85	0.11	-2.18	0.36
54	119	5	124	0.96	0.93	0.03	-3.58	1.20
56	43	5	48	0.89	0.97	0.01	-4.94	-2.46
58	15	0	15	1.00	0.99	0.83	-0.18	0.60
60	7	0	7	1.00	1.00	0.97	-0.03	0.26
62	3	0	3	1.00	1.00	0.99	-0.01	0.11
64	2	0	2	1.00	1.00	1.00	0.00	0.05
66	2	0	2	1.00	1.00	1.00	0.00	0.03
68	0	0	0	0.00	1.00	1.00	0.00	0.00
70	0	0	0	0.00	1.00	1.00	0.00	0.00
72	0	0	0	0.00	1.00	1.00	0.00	0.00
74	0	0	0	0.00	1.00	1.00	0.00	0.00
76	0	0	0	0.00	1.00	1.00	0.00	0.00
78	0	0	0	0.00	1.00	1.00	0.00	0.00
80	2	0	2	1.00	1.00	1.00	0.00	0.00
82	0	0	0	0.00	1.00	1.00	0.00	0.00
84	0	0	0	0.00	1.00	1.00	0.00	0.00
86	0	0	0	0.00	1.00	1.00	0.00	0.00
88	0	0	0	0.00	1.00	1.00	0.00	0.00
90	0	0	0	0.00	1.00	1.00	0.00	0.00
92	0	0	0	0.00	1.00	1.00	0.00	0.00
94	0	0	0	0.00	1.00	1.00	0.00	0.00
96	0	0	0	0.00	1.00	1.00	0.00	0.00
98	0	0	0	0.00	1.00	1.00	0.00	0.00
100	0	0	0	0.00	1.00	1.00	0.00	0.00

Table 6 Greenland halibut (without dividing by sex).Calculatin of length-weight composition in the codend with mesh size of 145.2 and 150.2 mm in relation to that one with 130.8 mm mesh size.

Lenth group, cm	Mesh size codend 130,8 mm			Mesh size codend 145,2 mm			Mesh size codend 150,2 mm		
	Length friquencies	Mean weight,(g)	Catch weight,(kg)	Retention rate 145,2/130,8 mm	Catch namber	Catch weight,(kg)	Retention rate 150,2/130,8 mm	Catch namber	Catch weight,(kg)
24	0	217	0.0	1.19	0	0.0	1.09	0	0.0
26	0	271	0.0	1.08	0	0.0	0.96	0	0.0
28	0	322	0.0	0.97	0	0.0	0.84	0	0.0
30	0	372	0.0	0.88	0	0.0	0.73	0	0.0
32	0	423	0.0	0.80	0	0.0	0.64	0	0.0
34	1	474	0.7	0.72	1	0.5	0.56	1	0.4
36	10	529	5.5	0.65	7	3.6	0.49	5	2.7
38	21	587	12.4	0.60	13	7.4	0.43	9	5.4
40	96	650	62.2	0.56	53	34.6	0.39	37	24.4
42	63	720	45.2	0.54	34	24.5	0.37	23	16.8
44	205	797	163.7	0.57	117	93.5	0.39	80	63.5
46	175	883	154.8	0.65	115	101.2	0.45	79	70.0
48	198	979	193.5	0.77	152	149.1	0.57	112	109.7
50	130	1086	141.2	0.88	114	123.7	0.71	93	100.5
52	39	1206	46.7	0.94	36	44.0	0.85	33	39.4
54	40	1340	54.3	0.98	40	53.0	0.93	38	50.6
56	11	1489	16.8	0.99	11	16.6	0.97	11	16.3
58	6	1654	10.6	1.00	6	10.6	0.99	6	10.5
60	3	1837	5.5	1.00	3	5.5	1.00	3	5.5
62	1	2039	0.8	1.00	0	0.8	1.00	0	0.8
TOTAL	1000		913.7			668.3			516.3
Yeld rate						0.73			0.57

Table 7 Selectivity parameters of trawl bags with different mesh size in Greenland halibut fishery in NAFO RA as provided by various reserchers

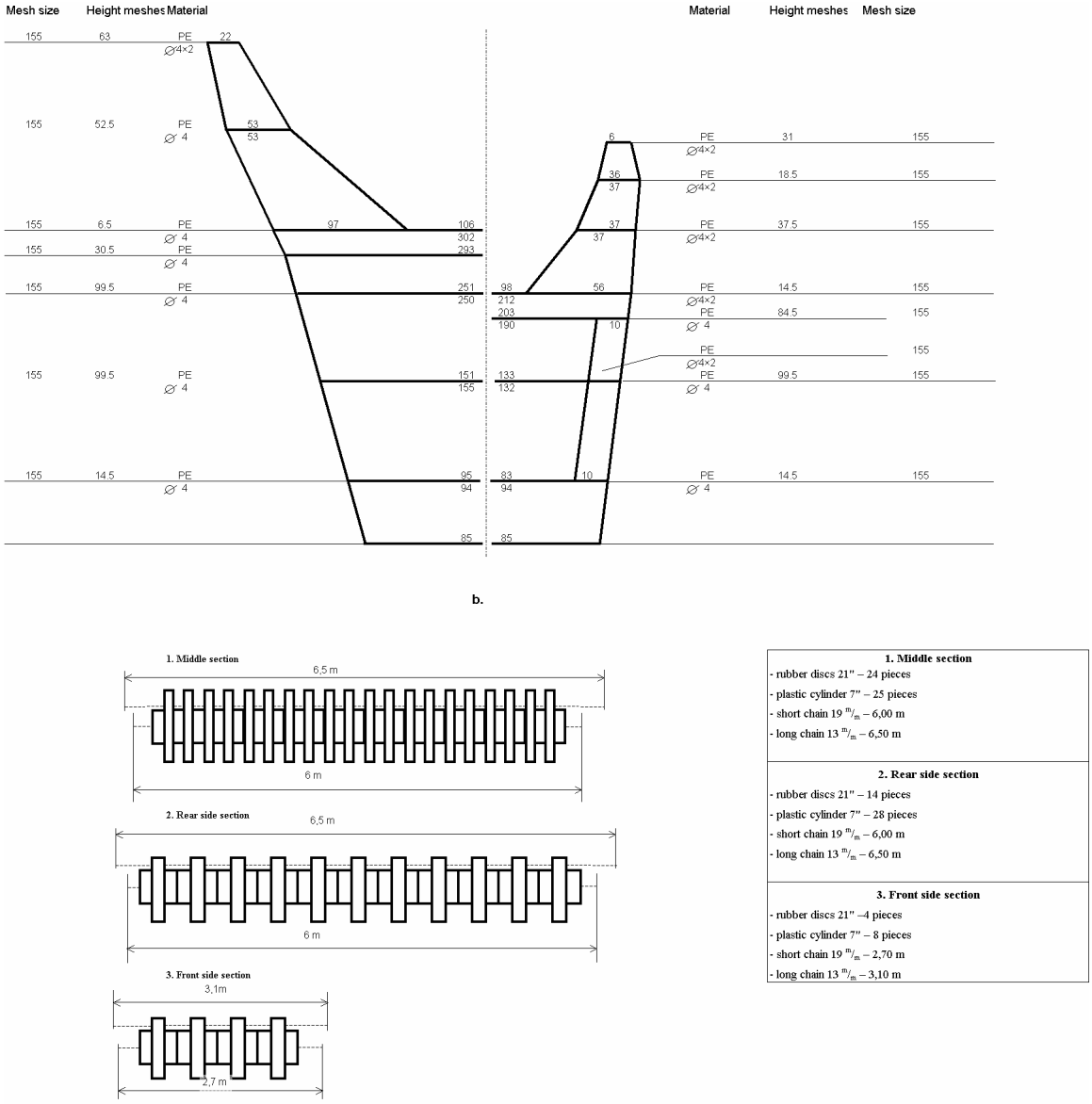
Mesh size, mm	Quantity hauls	Duration hauls, h	L_{50}, cm	K_S	SR,cm	L_{25}, cm	Notes
121[1]	7	5	33.5	2.77	7.3	30.2	Lisovsky et al., 2001
121[1]	7	5	35.5	2.93	6.5	33	Lisovsky et al., 2001
130[1]	7	5	38.5	2.96	7.1	31.8	Lisovsky et al., 2001
132[1]	9	5	40	3.03	10.5	34	Lisovsky et al., 2001
127[2]	7	1.5	37	2.91	?	?	Chumakov et al.,1981 Nikeshin et al., 1983
130[1]	4	1	38.7	2.99	7.5	34.5	de Cardenas et al., 1995
130[1]	2	4	37.7	2.91	11.8	30.5	de Cardenas et al., 1995
133[2]	7	?	40.5	3.08	?	?	Chumakov et al., 1981 Nikeshin et al., 1983
135[3]	14	4	42,0	3.1	9.6	37.2	Huse and Nedreaas,1995
145[3]	14	4	47.7	3.29	7.4	44	Walsh et al., 2000
145[3]	14	4	47,2	3,3	7,0	43,2	Walsh and Hickey, 2000
131[1]	10	4-5	41,7	3,2	6,1	38,2	This document
145[1]	10	4	45,2	3,1	7,1	41,2	This document
150[2]	4	4	46,7	3,1	8,4	41,8	This document

Method used to determine selectivity:

[1] - bag-shaped;

[2] - ICES type cover;

[3] - throuser bag.



b.

1. Middle section
- rubber discs 21" – 24 pieces
- plastic cylinder 7" – 25 pieces
- short chain 19 $^{m}/_{m}$ – 6,00 m
- long chain 13 $^{m}/_{m}$ – 6,50 m
2. Rear side section
- rubber discs 21" – 14 pieces
- plastic cylinder 7" – 28 pieces
- short chain 19 $^{m}/_{m}$ – 6,00 m
- long chain 13 $^{m}/_{m}$ – 6,50 m
3. Front side section
- rubber discs 21" –4 pieces
- plastic cylinder 7" – 8 pieces
- short chain 19 $^{m}/_{m}$ – 2,70 m
- long chain 13 $^{m}/_{m}$ – 3,10 m

Fig.1. Plan of the bottom trawl "Turbot" (a) and its groundrope gear (b)

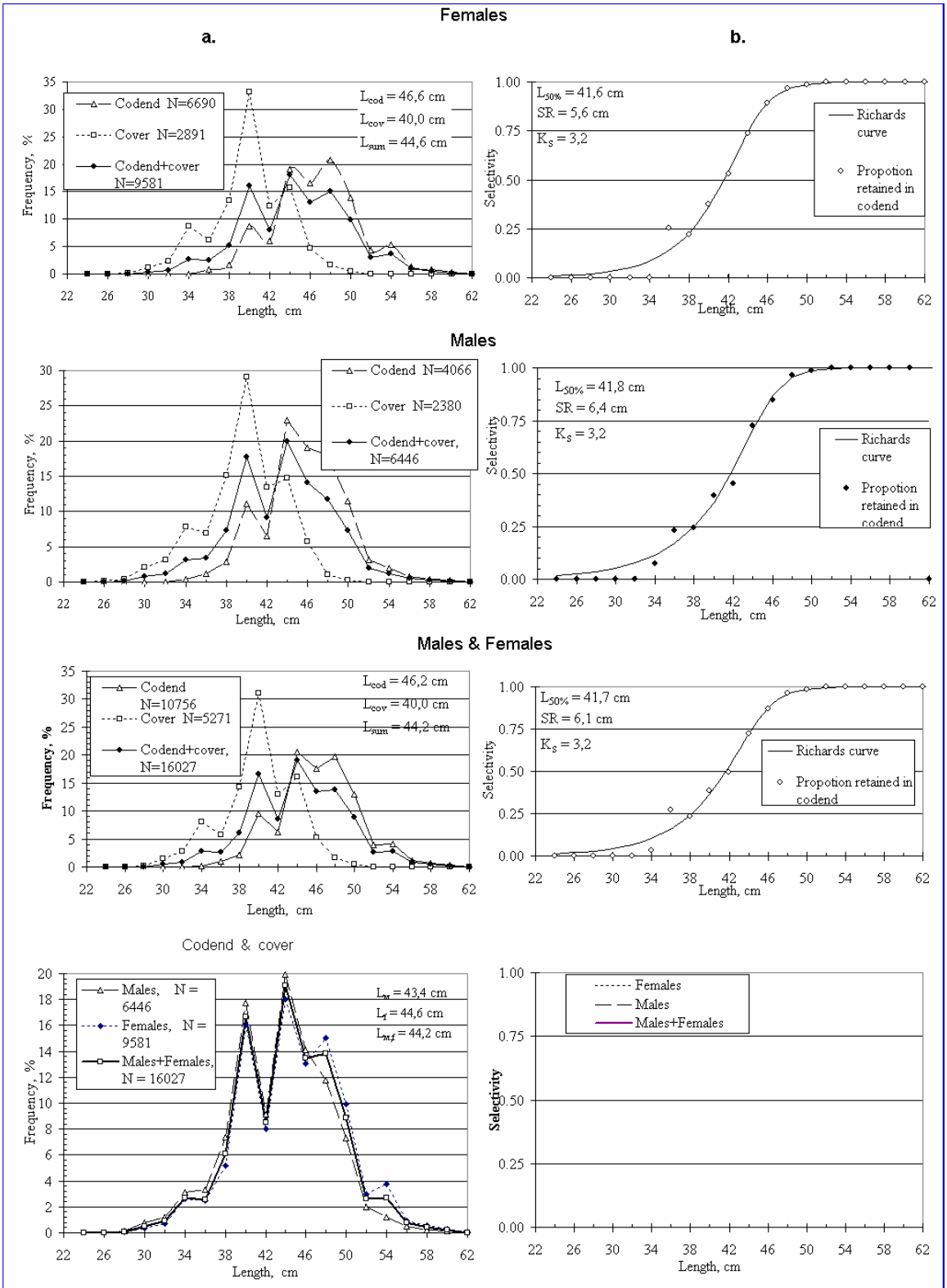


Fig. 2. Length composition of fish caught and escaped (**a**) and selectivity of trawl codend with 130.8 mm mesh size (**b**) calculated using Richard's curve for Greenland halibut with and without dividing by sex, December 2001, Div. 3L.

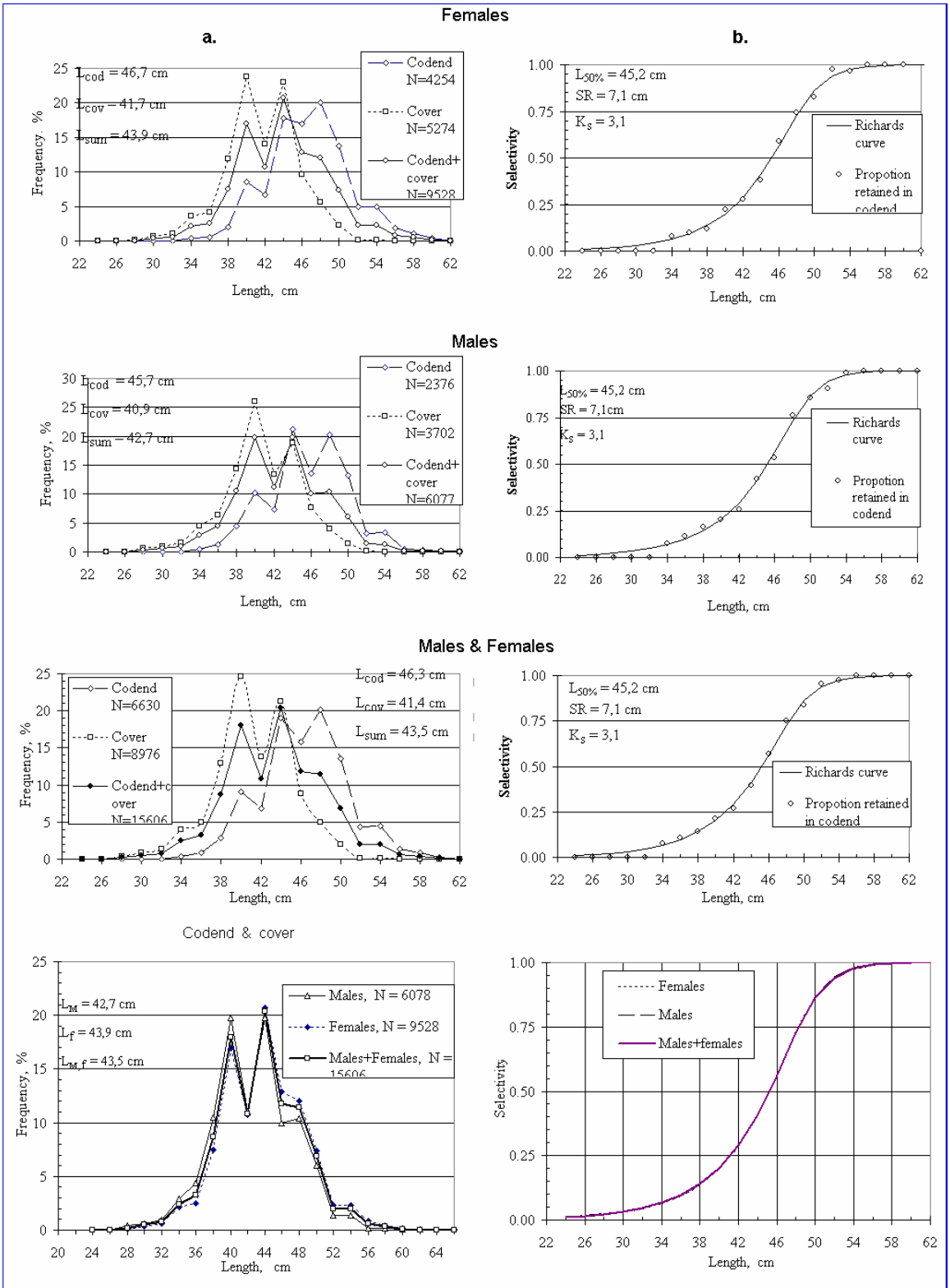


Fig. 3. Length composition of fish caught and escaped (**a**) and selectivity of trawl codend with 145.2 mm mesh size (**b**) calculated using Richard's curve for Greenland halibut with and without dividing by sex, December 2001, Div. 3L.

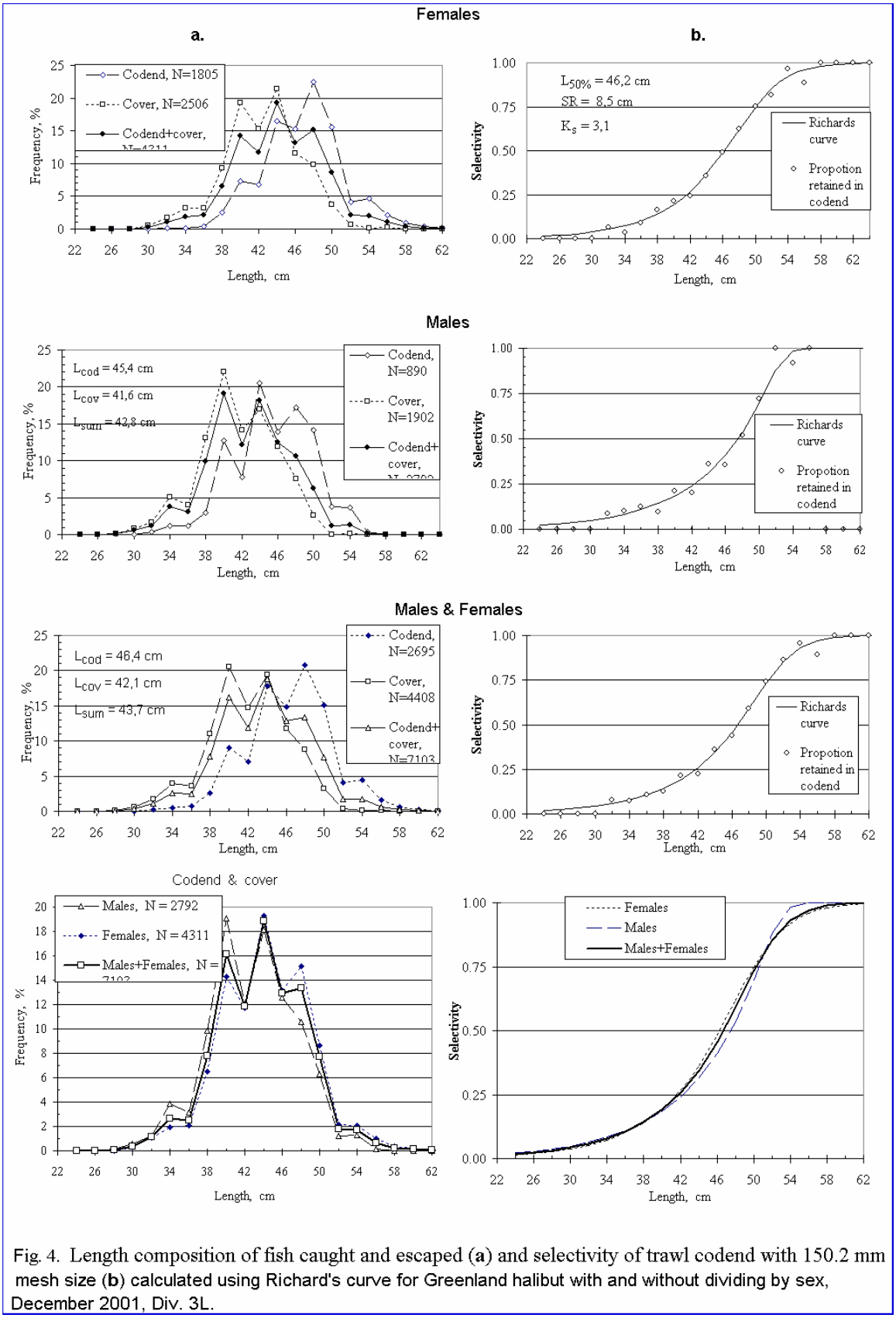


Fig. 4. Length composition of fish caught and escaped (**a**) and selectivity of trawl codend with 150.2 mm mesh size (**b**) calculated using Richard's curve for Greenland halibut with and without dividing by sex, December 2001, Div. 3L.

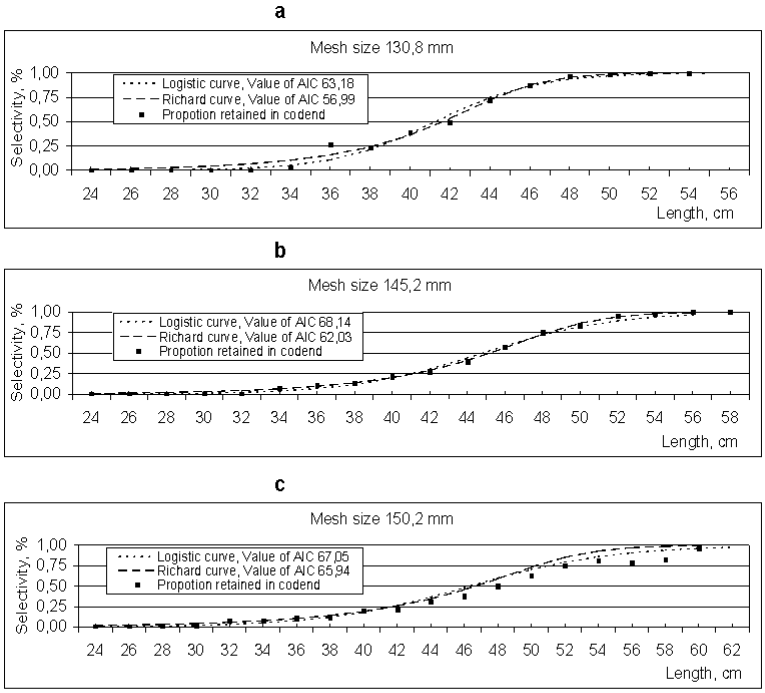


Fig.5 Selektivity of trawl codends with 130,8 mm (a), 145,8 mm (b), 150,2 mm (c) mesh size for Greenland halibut (without dividing by sex) in NAFO Div. 3L, calculated using logistic and Richard curves.

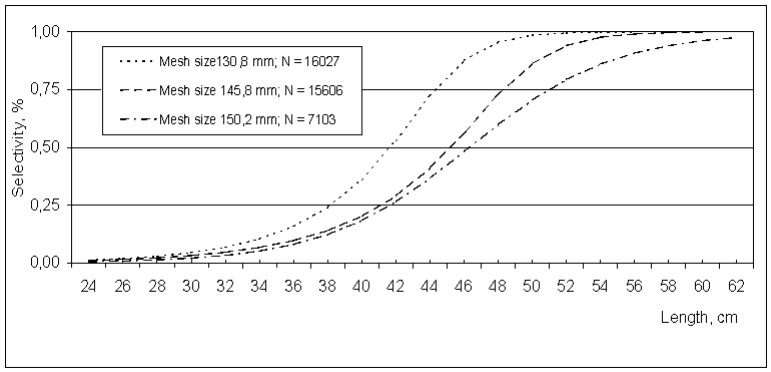


Fig. 6. Selectivity of trawl codends with different mesh size for Greenland halibut (without dividing by sex) in NAFO Div. 3L, calculated using Richard curves.

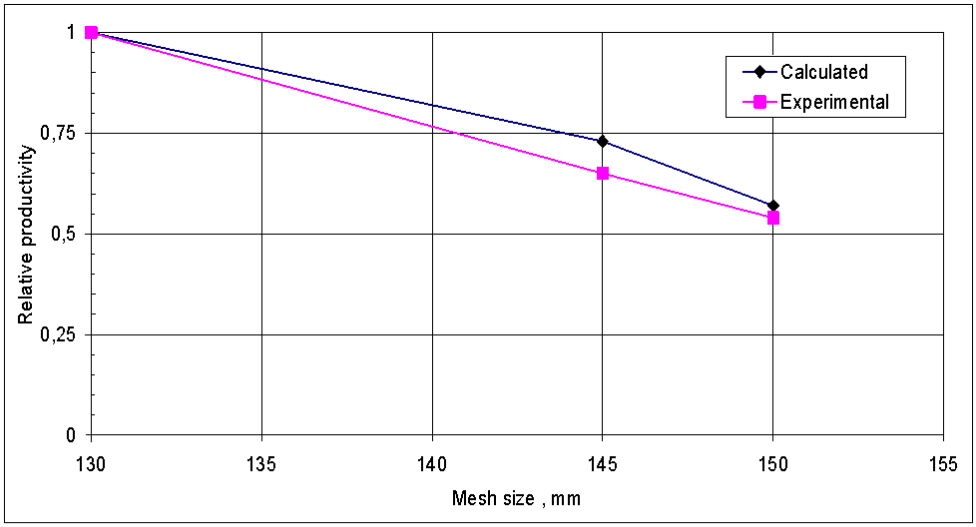


Fig. 7. Calculated and converted experimental variation of productivity when fishing the Greenland halibut by trawls with 130.8; 140.2 and 150.2 mm mesh size.

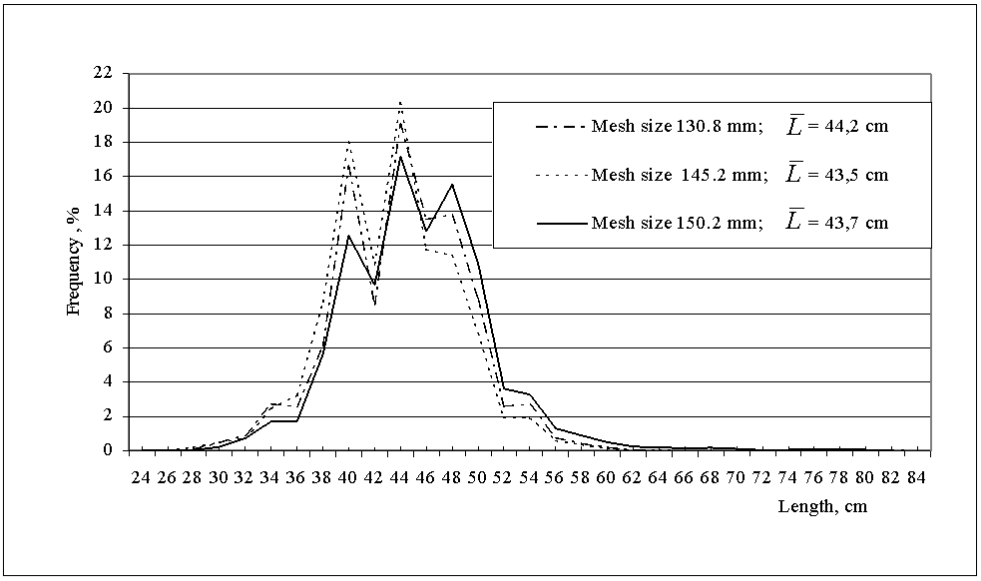


Fig.8 Length frequency of Greenland halibut (without dividing by sex) fished by trawls with different mesh size,in NAFO Div.3L., December 2001.