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On the Minimal Trawl Codend Mesh Size in the Fishery of Redfish Species in Division 3O of the NAFO Regulation Area

by

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Abstract

The results from research of selectivity of the trawl codends with mesh size of 95, 100 and 105 mm in the redfish harvesting in Div. 3O are presented. Selectivity coefficients were 2.7 for 95 mm mesh size, 2.6 for 100 mm mesh size and 2.6 for 105 mm mesh size. Selectivity range was 5.0 ± 0.2, 4.1 ± 0.2 and 5.4 ± 0.2, respectively. Trawl codends sorted out from 55 to 48% of fish got into them. The calculations of long-term profits as a result of enlarging mesh size from 100 to 130 mm showed that using 130 mm mesh size wouldn't lead to a positive effect. Fishing losses would not be compensated during the nearest 15-20 years. With the same fishing efforts the catch will decrease in almost 4 times. Fishing with the use of 130 mm mesh size is not to the purpose.

Introduction

One of the technical measures of fishery regulation with the purpose of rational using commercial fish stocks is limiting minimal mesh size in trawl codends that allows us to minimize catch of immature fish and avoid the excessive escape of commercial size fish.

In Div. 3O of NAFO Regulation Area, in the international waters, the trawl fishery of redfish is limited by mesh size and TAC (Anon., 2005). A commercial size has not been established for them. According to STATLANT 21A Fisheries Statistics, in the last 40 year period, in Div. 3O, the catch of redfish varied from 2.8 x 10^3t (1995) to 22.1 x 10^3t (2001). In 2003, the catch was estimated at 21.6 x 10^3t.

In the mid-1990s, participating countries executed the decision on the establishment of 130 mm mesh size in trawls in the fishery of demersal fish all over NAFO Regulation Area including the redfish from Div. 3O.

Since the selectivity of the trawls with such a mesh is very different for different species having appeared was the necessity to estimate short-term and long-term profits and losses for fishery as a result of its use in the fishery of redfish in Div. 3O of NAFO Regulation Area, as well as to determine the optimal mesh size.

This paper summarizes the data on the results of estimating codend selectivity for redfish from the North Atlantic which were collected by PINRO's and other scientists and published in ICES and NAFO before. Moreover, the results from study of selectivity obtained in 2003 and 2004 are given.

Material and Methods

Presented data are based on the results from trials of codend selectivity in the redfish fishery by the research and fishing vessels.

The researches of selectivity were conducted aboard M-0035 trawler "*Vladimir Gavrilov*" in Div. 3O of NAFO Regulation Area, in December 2003 and February 2004. The main vessel details were: overall length – 83.9 m; width – 14 m; draught – 5.6 m; load displacement – 3 800 t; tonnage – 729 t; main engine power – 1 470 kWt.

During the trials a standard fishing mid-water 57/300 m "Makrurus" trawl made of polyamide netting (Fig. 1) was used. With a trawling speed of 3.3-3.6 knots the vertical opening of the trawl was 50 m and the horizontal one – 45 m.

Along the upper headline the trawl was rigged by hydrodynamic canvas cover with 10 m length and 0.5 m width. The lower headline was equipped by 22 mm caliber chain with the weight of 150 kg. In addition, false headline made of 29 mm caliber chain weighting 350 kg was applied. The trawl was equipped by cables and bare ends with 50 m length each, 5m regulation ends, loads-depressors weighting 900 kg each. Trawl horizontal opening was provided by pelagic wing-shape trawl boards with the area of 5.5 m^2 and weighting 1 500 kg.

Four panel trawl codends were produced from polyethylene rope folded in two with 7.5 mm diameter. Codend mesh size varied in the upper panel. The measurement was made in the row disposed parallel to longitudinal axis of the trawl codend being at the distance of 10 meshes from longitudinal seams and 5 meshes from codline loops. For this purpose, the wedge-shaped panel of ICNAF-type with 2 mm thickness was inserted into mesh with 50°N effort after trawl having been lifted at once. During the trials, the selective characteristics of mid-water trawl codends with the actual mesh size of 95, 100 and 105 mm were determined.

Codend selectivity was estimated according to ICES recommendations for study of trawl selectivity (Anon., 1996 a) by method of small-mesh cover with the use of bag-shaped covers having the mesh size of 80 mm. Their construction provided a free escapement of fish from codend and excluded their repeated capture by trawl. To provide it the cover was installed in the conic part of the codend at the distance of 5-7 m in front of the place where it is jointed to the cylindrical part. The cover perimeter was 50-60% more than that one in the codend cylindrical part. After having been mounted in the codend the cover was 3-4 m projecting outside it.

All the fish from the codend and cover were separately run out and measured with dividing by species and sex. By 300-400 individuals from codend and cover were measured. The rest having not been measured were completely counted and the length distribution was corrected in the proper way.

When analyzing catches a number of caught fish escaping from trawl through mesh was assessed. The effect of cover on the escapement of fish from the codend was estimated by comparing length distribution and ratios of fish length groups in the tows with cover and codends with cover.

The data derived were analysed using a computer programme on the basis of SELECT model and solving the problem was improved by method of successive approximations with the aid of Solver-sel (Tadashi Tokai, 1997; Tadashi Tokai and Takahisa Mitsuhashi, 1998) by the logistic and generalized logistic functions of retention probability of studied fish depending on their length.

The equation of generalized logistic (Richard's) function is described as follows (1):

$$r(l) = \{\exp(a + b*l) / [l + \exp(a + b*l)]\}^{1/d}, \quad (1)$$

where $r(l)$ – probability of retention of fish with length l;
a, b, d – function parameters;
l – retained fish length.

Fish length corresponding to 50% retention of fish was determined by the formula (2)

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

Selectivity range was calculated by formula (3)

$$SR = L_{75\%}\text{-}L_{25\%} = \frac{\text{logit}(0,75^{d}) - \text{logit}(0,25^{d})}{b} \qquad (3)$$

where $L_{75\%}$ and $L_{25\%}$ are fish length corresponding to 75% and 25% retention.

The required estimates were obtained by minimizing likelihood function (AIC). Further, all the calculations were made using parameters obtained for generalized logistic and logistic functions having less (by value) estimate function criterion (AIC).

Selectivity coefficient K_S was calculated by the formula (4)

$$Ks = \frac{L_{50\%}}{B}, \qquad (4)$$

where B – the inner size of trawl codend mesh.

Standard errors of selectivity parameters were determined applying computer programme "STATISTICA", by methods used in mathematical statistics.

The weight of catch was calculated by PINRO's mean long-term data on the dependence of each redfish individual on length and the number of fish caught by each codend with different mesh by the formula (5):

$$\sum_{1}^{n} P_{2i} = \sum_{i=1}^{n} N_{1i} \frac{S_{2i}}{S_{1i}} M_i, \qquad (5)$$

where P_{2i} - catch weight of i-size group by a new mesh;
N_{1i}, N_{2i} - catch of i-size group by old and new mesh, respectively;
M_i - weight of one fish from i-size group;
S_{2i} and S_{1i} - selectivity of trawls with new and old mesh for fish from i-size group.

Selectivity parameters of trawl codend with 100 mm mesh were taken starting from the results of considered investigations and with 130 mm mesh –from the published data on selectivity research in Div. 3N (Lisovsky *et al*., 1995). The comparison of data on 130 mm mesh selectivity in Div. 3L and 100 mm mesh in Div. 3O, in our opinion, is rightful, since the average length of fish in harvested aggregations was the same and made up 24.8 cm; 25.2 cm, respectively.

The catch corresponding to new 130 mm mesh size was calculated by the ratio of selectivity coefficients for this mesh size and 100 mm mesh for each size group of fish.

To estimate the long-term effect from the new mesh introduction ASC (analysis of selective cohorts) method was used (Blinov, 1981).

Structural and age (length composition) composition of catch by trawl with 100 mm mesh was obtained as a result of Russian experimental works to estimate selectivity and given as 100 000 individuals. In calculations used was a length-age key for redfish from Div. 3O (Vaskov, 2004).

Taking into consideration that the occurrence frequency of fish from every age group in the catch corresponds to the probability of catching it by trawl with given mesh, to some rate of certainty, it was conditionally taken as corresponding to fishing mortality F. In our case, the bulk of catch with 100 mm mesh and, respectively, fishing mortality relates to fish aged 7-10 amounts to $F_{7\text{-}10} = 0.2152$.

The initial fishing mortality F for each size group when fishing it by a new 130 mm mesh was estimated by ratio of its and 100 mm mesh selectivity coefficients. In further calculations of the long-term effect from introduction of a new mesh, the derived initial fishing mortality F, under the new 130 mm mesh, was gradually increased to its value equaled to F under 100 mm mesh.

When calculating the abundance of fish caught in each age group the modified equation (6) of Beverton-Holt (Blinov, 1981) was used:

$$Ci = Ni_{\text{nat bal}} (1 - e^{-F}) , \qquad (6)$$

Where $Ni_{\text{nat bal}}$ - number of fish from i-age group in the previous fishing period.

The abundance of fish having escaped through mesh in the first year of fishery was calculated using the equation (7) (Blinov, 1981)

$$N(i)_{\text{nat bal}} = e^{-M} Nir , \qquad (7)$$

where M – natural mortality taken to be equal to 0.1 for fish from every age group;
Nir - number of fish having escaped through mesh after the first year of fishing with a new mesh.

In the following years of fishery, the abundance of fish having escaped through mesh was calculated by the formula (8):

$$N(i+1)_{\text{bal}} = Nir\, e^{-(M+Fi)} , \qquad (8)$$

where Fi - fishing mortality of i-age group in fishing with a new mesh size.

Losses of the first year were calculated by the formula (9)

$$\mathbf{W}_{\text{los}} = \sum_{i=i0}^{i=i} WiNir , \qquad (9)$$

where Wi - weight of one individual of i-age group calculated by Bertalanfy equation. Equation parameters were chosen using the length-age key for redfish species from Div.3O in NAFO Regulation Area (Vaskov, 2004).

A relative effect from new mesh introduction was determined by the formula (10), by means of calculating the ratio of difference between the sum of catches, fish having escaped through it in the first year of fishery, in the following years and annual losses for catch by trawl with an old mesh (Blinov, 1981).

$$P = \frac{\sum_{i=2}^{i=18} Ci - Wlos}{Vst} , \qquad (10)$$

Where P – a relative effect from new mesh introduction;
Vst - catch by trawls with an old mesh.

Results

Research on selectivity of trawl codends with 100 mm mesh size were conducted at 500-600 m depths, in February 2004. The data on tows are given in Table 1 and the results of mesh inner size measurements – in Table 2. The average mesh size of codend was equal to 99.7 mm. The duration of tows amounted to 1.0-6.7 h; and speed – to 3.0-3.2 knots. The catch by trawl codend changed from 0.1t to 0.8 t, by cover – from 0.1t to 0.5 t. By-catch of the other fish species did not exceed 1-3%.

During researches, the redfishes 16-42 cm in length with the mean length of 25.2 cm were fished. The mean length of males was 24.1 cm; of females – 26.3 cm (Fig.2a).

The catch by codend was represented by individuals with the average length of 26.9 cm including males 25.5 cm in length and females as long as 28.0 cm. In the catcher, fish were somewhat smaller, than in the codend: mean length was 23.8 cm, under 23.3 cm for males and 24.4 cm for females. Sex ratio in catches by codend was 7:10 and in concentrations – 14:10.

Selectivity plots calculated by logistic and generalized logistic functions with dividing by sex are shown in Fig. 26 and selectivity parameters – in Table 3. Selectivity of males is more reliably characterized by Richard's function and that one of females – by the logistic function. As the given data show, the male length corresponding to 50%-retention $L_{50\%}$ and selectivity coefficient K_S are less, than for females. So, the length of males was 25.8 ± 0.2 and of females – 26.5 ± 0.1 cm and the selectivity – 2.6 and 2.7, respectively. Without dividing by sex it was 26.1 ± 0.1 cm and selectivity coefficient – 2.6. Selectivity ranges S.R. for males and females did not reliably differ and amounted to 3.6 ± 0.2 cm.

The analysis of the results from experimental tows indicated that the trawl codend with 100 mm mesh size only retains 44% of redfish by abundance.

Investigations into selectivity of codend with 105 mm mesh size were carried out at 480-550 m depths, in February 2004. The trawl towing speed was from 2.8 to 3.2 knots. The tows lasted from 1.7 to 3.5 hours. The average size of codend mesh was 105.8 mm.

Table 1 presents the main data on trawlings and the results of codend mesh inner size measurement are given in Table 2.

In the period of research, fished were redfish 18-42 cm in length with the average one of 26.1 cm including males with mode 20-25 cm group, average length of 24.6 cm and females with 25-30 cm mode group and the average length of 27.3 cm (Fig. 3a). The catches by the cover varied from 0.3 to 0.5 t and by the codend – from 0.2 to 1.1 t. Codend retained 51.4% of redfish catch by abundance. Sex ratio was, approximately, 13:10. By-catch of regulated fish species did not exceed 1-3%.

Mean size of redfish males in the catch by codend was 26.1 cm, that one of females – 28.6 cm; by cover – 23.5 cm and 25.3 cm, respectively and without dividing by sex: in the codend – 27.8 cm; in the catcher – 24.3 cm (Fig. 3a). Sex ratio in catches by trawl codend was, approximately, 2:1.

Selectivity indices for males and females of redfish insignificantly differed (Fig. 36 and Table 3).

Indeed, the length of redfish males retained by 50% amounted to 25.8 ± 0.2 cm and of females – to 26.5 ± 0.2 cm. Selectivity range did not differ reliably and was within the values conditioned by 0.95 confidence probability. So, it was 5.4 ± 0.5 cm for males and 4.9 ± 0.3 cm for females.

Selectivity coefficients for males and females were insignificantly different and made up 2.4 and 2.5, respectively.

Research on selectivity of codends with the mesh size of 95 mm were carried out at 400-460 m depths, in December 2003. The mean mesh size of codend equaled to 96.1 mm (Table 2). In the codend catch by weight fluctuated from 2.5 to 3.1 t; in the cover – from 1.3 to 1.7 t. In all, 2 check tows were made.

In the period of investigations, redfish 17-42 cm in length were fished. The mean length of caught males was 24.8 cm, of females – 26.8 cm and without dividing by sex – 26.3 cm (Fig.4a). The results of selectivity estimation, parameters characterizing it, standard error and estimation criteria of function type (logistic or generalized logistic) are presented in Fig. 4 and Table 3.

The analysis of data obtained shows that the trawl codend selectivity in relation to redfish males and females is different. The analysis of estimation criterion value for both functions (logistic and Richard's) indicated that for redfish (without dividing by sex) it was optimal for Richard's function in all the cases.

Selectivity coefficient (for males and females) by Richard's function for codend with 96.1 mm mesh size was 2.7; fish length corresponding to 50% retention – 26.6 cm, selectivity range – 5.4 ± 0.3 cm.

Since only 2 valid tows were made the obtained data should be considered as preliminary.

The calculations of possible instantaneous losses of catch when changing the mesh size from 100 to 130 mm show that catch may decrease in almost 4 times (Table 4).

Also, according to calculations, with changing the mesh size from 100 mm to 130 mm there will be no long-term profits for fishery. With the primary (instantaneous) losses, as a result of mesh enlargement, 75% of catch will be lost, and in the nearest 9-18 years the losses will change from 66 to 42% under fishing mortality of 0.04-0.22 (Fig. 5).

Discussion

In Div.3O, the fishing of, primarily, two redfish species *S. mentella* and *S. fasciatus* was carried out. *S. fasciatus* made up the bulk of catch (to 85%) (Vaskov, 2004). This species is characterized by less length and earlier maturation, than *S .mentella* (Vaskov, 2005).

The analysis of obtained data shows that trawl codend selectivity in relation to males and females insignificantly differs. Actually, when using the mesh size of 100 mm selectivity coefficients amounted to 2.6 and 2.7; in applying that one of 105 mm they were 2.4 and 2.5 for males and females, respectively. Selectivity ranges were not different for certain. With 100 mm mesh they equaled to 3.6 ± 0.2 for males and females; with 105 mm mesh size they were 5.4 ± 0.5 and 4.9 ± 0.3 for males and females, respectively. The length of males and females retained by 50% insignificantly differed. So, under 100 mm mesh it was 25.8 ± 0.2 cm for males and 26.5 ± 0.2 cm for females; under that one of 105 mm the length was 25.8 ±0.2 cm and 26.5 ± 0.2 cm, respectively, that allows us to use data on selectivity of trawl codends in relation to redfish species from Div. 3O without dividing by sex.

As it was noticed before (Lisovsky, 2001), the most reliable results may be obtained when estimating selectivity with the use of the bag-shaped cover. The analysis of the results from selectivity research by this method in NAFO Regulation Area showed that our data insignificantly differed from those ones having obtained before (Table 5). Indeed, according to our data, the selectivity coefficient amounted to 2.6 and, in compliance with the others it varied from 2.4 to 3.1. Selectivity range 4.1-5.5 cm is also within the values obtained by different scientists (Table 5). Fish length corresponding to 50% retention was 26.1 ± 0.1 cm for 100 mm mesh and 34.6 cm for 130 mm mesh.

Fish escape from the trawl codend with 100-105 mm mesh was, according to our data, 48-55% and from that one with the mesh size of 120-132 mm, in accordance with the data of the other scientists, reached 72-90% (Table 5). Fish with the same length as those ones retained by the trawl codend escaped from the trawl codends with 88-132 mm mesh size.

The calculations of fishery profits and losses made in the present paper (Fig. 5) and by the other authors (1983; Lisovsky *et al*., 1995; Lisovsky, 1997, 2001) show that the enlargement of mesh from 100 to 130 mm in the harvesting of redfish has not led to a positive result. The annual catches taken during 15-20 years and more after 130 mm mesh put into effect have been remaining to be lower than those obtained by 100 mm mesh and do not compensate the losses appeared as a result of mesh size increase.

The change-over to fishing of redfish in Div. 3O using the mesh size, at least, of more than 100 mm died in result in the diminution of fishing efficiency in almost 4 times. Realizing TAC will require considerable increase in fishing effort that will lead to their repeated many times fishing and, consequently, the escapement through mesh and possible traumatic death of fish having escaped from the trawl codend when lifting trawl as a result of abrupt change of hydrostatic pressure (Konstantinov, 1981; Konstantinov *et al*., 1983; Lisovsky, 1997 and 2001). Russian research in the Barents Sea conducted earlier (SCR Doc. 95/25) showed that 18-30% of the redfish died in result in this reason only (Lisovsky *et al*., 1995).

Therefore, having arrived at a decision on the change-over to redfish harvesting by trawls with 130 mm mesh was unjustified.

As it was mentioned above, redfish *S. fasciatus* predominated in Div. 3O. In Divs. 3LMN, its percentage in the catches reduces and here the redfish *S. mentella* prevail. And so, redfish harvesting by trawls with 100 mm mesh will not have a significant influence on structure of other commercial stocks of redfish in NAFO Regulation Area.

In 1996 at NAFO Scientific Council meeting the recommendation on diminishing mesh size in redfish fishery in Div. 3LN was already adopted (ANON., 1997). The Joint Fisheries Commission agreed with it as well as approved the proposal on experimental fishing of redfish by trawls with minimal 90 mm mesh size (ANON., 1996b). However the decision on experimental fishing has not been realized.

Conclusion

In Div. 3O, where *S. fasciatus* prevails (to 85%) redfish species are harvested.

In the fishery of redfish species in Div. 3O it is expedient to decrease the mesh size, at least, to 100 mm. Actual catch losses entailed by the use of 130 mm mesh size cannot be compensated by potential long-time benefits for the fishery due to larger sizes of the redfish caught Fishing by trawls with 130 mm mesh does not lead to the long-term profits.
Diminishing mesh size, at least, to 100 mm in Div. 3O will have no influence on the stock status of other redfish species, since here *S. fasciatus* predominates in the catches.

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TABLE 1. Main characteristics of tows when determining selectivity of trawl codends with different mesh size for Redfish in Div.3O, NAFO Regulatory Area, 2003-04

NO	DATE	TIME START	START POSITION		COURSE, DEG.	TOW DURATION, H:MIN	DEPTH M	SPEED KN.	CATCH, KG		RED FISH %
			N DEG, MIN	W DEG, MIN					CODEND	COVER	
MESH SIZE 99,7 mm											
1	04.02	05:10	43°23′1	51°44′7	120	4:10	600	3,0	114	140	98
2	05.02	18:30	43°10′7	51°23′3	110	5:30	550	3,0	106	96	97
3	06.02	07:40	43°11′5	51°24′6	170	3:50	540	3,2	297	416	98
4	07.02	05:10	43°19′1	51°39′0	130	4:50	550	3,2	119	167	98
5	08.02	10:30	43°07′5	51°23′7	100	4:30	550	3,0	528	288	99
6	09.02	00:00	43°08′8	51°22′2	100	1:00	550	3,0	96	256	99
7	10.02	20:20	43°14′7	51°27′2	140	3:40	500	3,1	373	436	98
8	11.02	01:10	43°04′5	51°18′5	330	3:20	530	3,3	330	404	98
9	13.02	07:30	43°07′1	51°22′0	150	6:40	530	3,0	482	736	99
10	14.02	07:20	43°09′1	51°21′8	330	2:00	520	3,0	297	482	99
MESH SIZE 105,8 mm											
1	19.02	12:50	43°08′0	51°12′0	280	1:40	550	3,2	532	436	99
2	20.02	20:30	43°06′7	51°17′4	110	3:30	480	2,8	330	198	98
3	21.02	01:20	43°07′1	51°07′5	260	2:40	500	2,8	272	172	97
4	21.02	05:20	43°06′6	51°22′0	90	3:10	510	3,2	520	1157	99
5	21.02	11:20	43°06′5	51°20′6	90	2:40	530	3,3	396	664	99
MESH SIZE 96,1 mm											
1	01,12	09-00	43°23′0	51°43′0	120	4-00	400	3,4	1354	3081	99
2	02.12	09-00	43°22′9	51°43′7	136	5-00	460	3,3	1680	2520	99

TABLE 2. Results of mesh measurement in codends with 95-105 mm normative mesh size in the research on Redfish selectivity in Div. 3O of NAFO Regulatory area, 2003- 04

NO.	AT THE BEGINNING OF TRIALS	AT THE END OF TRIALS	NO.	AT THE BEGINNING OF TRIALS	AT THE END OF TRIALS
normative mesh size 100 MM					
1	102	101	11	100	104
2	104	98	12	100	94
3	97	100	13	99	102
4	94	99	14	99	100
5	96	100	15	97	100
6	106	98	16	100	98
7	96	100	17	100	100
8	100	102	18	98	102
9	101	102	19	102	102
10	97	96	20	101	100
				99,5	*99,9*
	AVERAGE MESH SIZE			**99,7**	
normative mesh size 105 MM					
1	105	105	11	104	104
2	104	103	12	104	104
3	110	109	13	110	111
4	103	104	14	103	105
5	104	101	15	105	101
6	110	111	16	109	111
7	104	111	17	106	110
8	104	107	18	105	108
9	106	101	19	104	103
10	109	101	20	110	101
				105,6	*106,0*
	AVERAGE MESH SIZE			**105,8**	
normative mesh size 95 MM					
1	94		11	94	
2	94		12	96	
3	102		13	94	
4	94		14	94	
5	98		15	102	
6	96		16	92	
7	98		17	100	
8	96		18	98	
9	94		19	94	
10	94		20	98	
				96,1	
	AVERAGE MESH SIZE			**96,1**	

TABLE 3. Selectivity parameters of codends with different mesh size for Redfish calculated by logistic and generalized (Richard's) functions, Div. 3O, NAFO, 2003-2004

FUNCTION	PARAMETER	MALES		FEMALES		MALES+FEMALES	
		CALCULATION	STANDARD ERROR	CALCULATION	STANDARD ERROR	CALCULATION	STANDARD ERROR
				MESH SIZE 100 mm			
Logistic	$L_{50\%}$ *(cm)*	25.7	0.1	***26.5***	***0.1***	***26.1***	***0.1***
	SR (cm)	4.0	0.3	***3.6***	***0.2***	***4.1***	***0.2***
	KS (cm)	2.6		***2.7***		***2.6***	
	Value of AIC:	40.1		***46.5***		***54.2***	
Richard's	$L_{50\%}$ *(cm)*	***25.8***	***0.2***	26.5	0.1	26.2	0.1
	SR (cm)	***3.6***	***0.2***	3.6	0.2	4.1	0.2
	KS (cm)	***2.6***		2.7		2.6	
	Value of AIC:	***39.6***		48.5		55.4	
				MESH SIZE 105 mm			
Logistic	$L_{50\%}$ *(cm)*	***25.8***	***0.2***	***26.5***	***0.2***	26.2	0.1
	SR (cm)	***5.4***	***0.5***	***4.9***	***0.3***	5.4	0.3
	KS (cm)	***2.4***		***2.5***		2.6	
	Value of AIC:	***41.1***		***64.0***		72.9	
Richard's	$L_{50\%}$ *(cm)*	25.9	0.2	26.5	0.2	***26.3***	***0.1***
	SR (cm)	5.5	0.5	5.0	0.3	***5.5***	***0.2***
	KS (cm)	2.6		2.5		***2.6***	
	Value of AIC:	42.6		65.3		***71.1***	
				MESH SIZE 95 mm			
Logistic	$L_{50\%}$ *(cm)*					26.2	0.1
	SR (cm)					5.0	0.2
	KS (cm)					2.7	
	Value of AIC:					94.0	
Richard's	$L_{50\%}$ *(cm)*					***26.6***	***0.5***
	SR (cm)					***5.4***	***0.3***
	KS (cm)					***2.7***	
	Value of AIC:					***35.2***	

TABLE 4. Calculation of Redfish catch by trawls rigged with codends with 100 mm and 130 mm mesh size in relation to that one by codend with 100 mm mesh.

Length of fish, cm	Mesh size 100 mm			Mesh size 130 mm		
	Frequency of occurrence	Mean weight of one fish, g	Weight of catch, kg	Retention ratio 130/100 mm	Number of fish in catch, ind.	Weight of catch, kg
16	4	52.2	0.2	1.667	6	0
18	602	80.1	48.2	0.714	430	34
20	3513	105.6	370.8	0.365	1284	136
22	10273	140.5	1442.8	0.262	2695	378
24	31120	185.5	5771.2	0.217	6738	1250
26	26893	239.9	6450.3	0.180	4837	1160
28	16535	288.1	4763.7	0.211	3481	1003
30	6098	350.0	2134.4	0.264	1610	564
32	2188	423.7	926.8	0.342	749	317
34	1523	505.9	770.3	0.483	735	372
36	568	612.6	348.1	0.579	329	202
38	390	733.7	286.1	0.668	260	191
40	241	802.9	193.8	0.805	194	156
42	52	901.0	46.8	0.853	44	40
Total	100000		23554		23393	5803
Catch ratio						0.25

TABLE 5. Results from investigations into determination of selectivity of mid-water trawls with different mesh size in relation to Redfish, carried out in the Northwest Atlantic Method – bag type cover)

Parameters		Name of vessel										
		Menze-linsk[1]	Vladimir Gavrilov[5]			Vilnus[2]		Vaigach[3]			R. Bayamo, R. la Palma[4]	
Inner mesh size in codend, mm		124	96	100	106	126	137	88	118	132	90	120
Divisions		3M, 3N	3O	3O	3O	3M	3M	3N	3N	3N	3M	3M
Number of fish in the catch, spec	in codend	46974	-	11953	10709	2948	557	12767	2144	2119	6609	11657
	in cover,	117937	-	14972	10127	20222	17133	11412	6794	18073		
	total	154911	-	26925	20836	23170	17690	24179	8920	20192		
Length range of fish, (cm)	retained	22-47	-	20-43	20-41	21-43	24-46	17-45	17-47	16-45	23-47	23-44
	escaped	22-40	-	16-42	18-42	14-38	14-40	15-34	16-39	16-43	20-45	20-44
	in water	22-47	17-42	16-43	18-42	14-43	14-46	15-45	16-47	16-45	20-47	20-44
Mean weight of one spec., kg	retained	0,350	-	0,284	0,261	0,437	0,497	0,294	0,328	0,351		
	escaped	0,190	-	0,180	0,207	0,294	0,282	0,149	0,189	0,205		
	in water	0,230	46705	0,227	0,235	0,312	0,289	0,224	0,225	0,220		
Size series mode in water fish, cm		30; 35	17-42; 26-30	24-29	25-29	23-26; 29-32	24-30	18-20; 23-29	18-20; 23-29	18-20; 23-29	26-29; 33-35	26-29; 33-35
Retention by number, %		28,5		44,4	51,4	12,7	3,1	52,8	24,0	10,0		
Selectivity coefficient		2,4	2,6	2,6	2,6	2,9	2,9	2,8	2,5	2,6	3,1	2,6
Selectivity range, cm		8,4	5,4	4,1	5,5	5,6	4,3	4,4	6,6	9,0	5,0	8,2

[1] Konstantinov *et. al.*, 1981.
[2] Gorchinsky *et. al.,* 1993.
[3] Lisovsky *et. al.,* 1995.
[4] Valdes and Fraxedas, 1981
[5] This report.

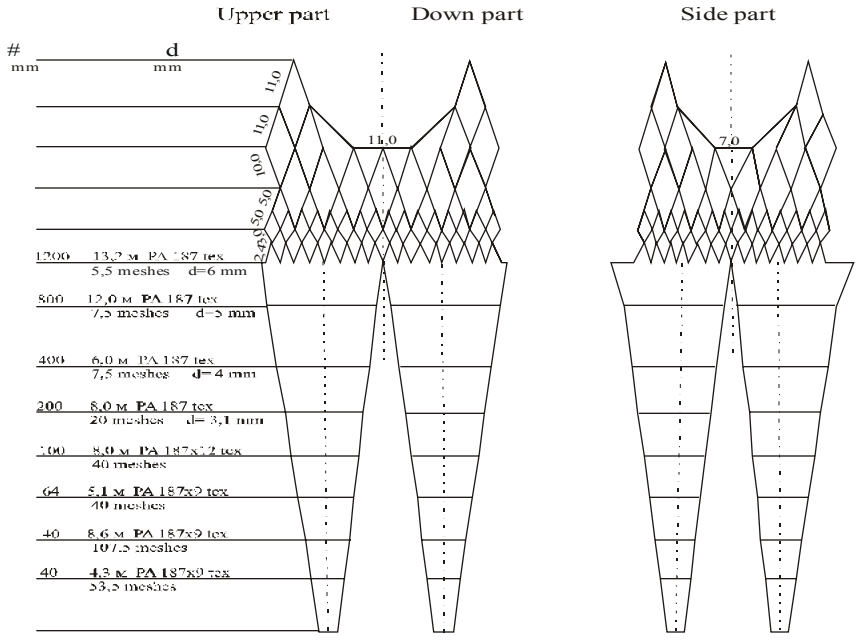

Fig. 1. Midwater 57/300 m "Makrurus" trawl

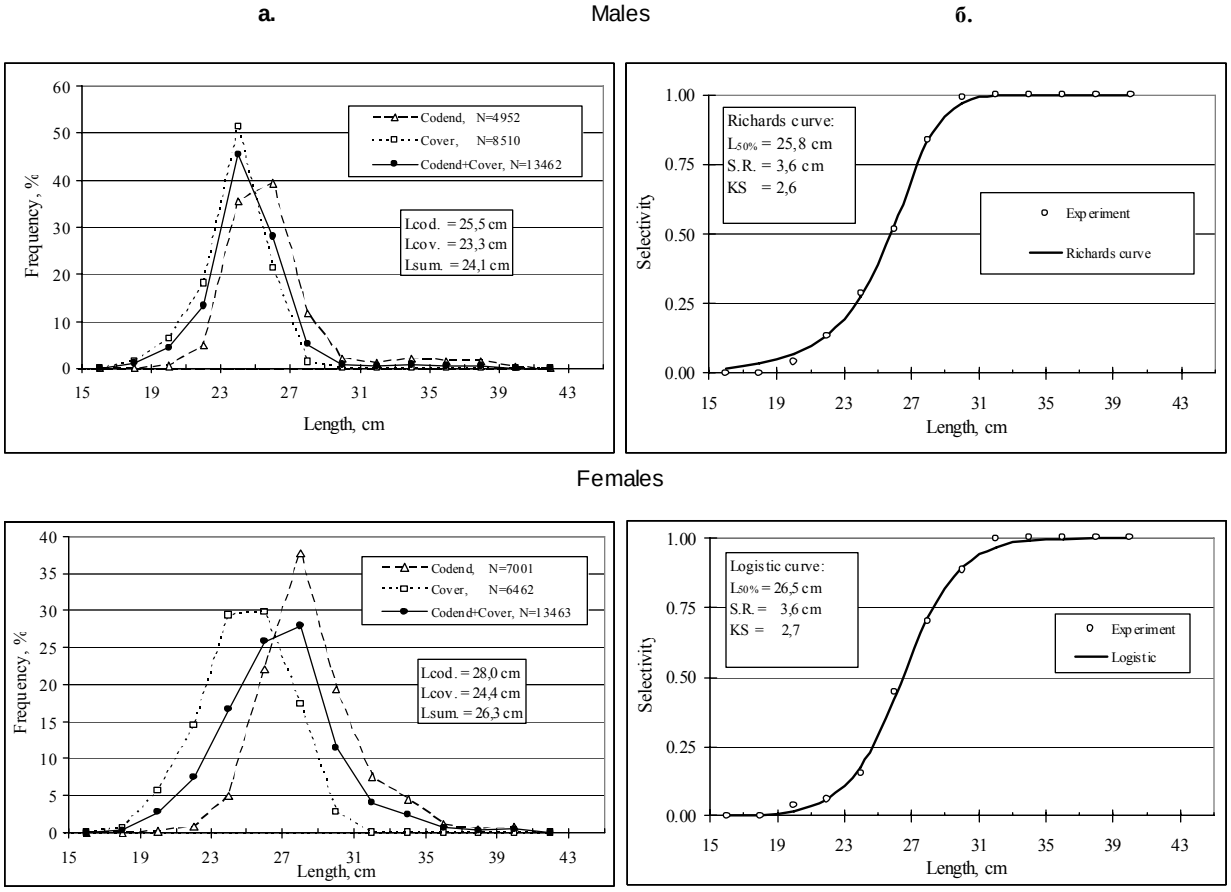

Fig. 2. Length composition of caught fish and escaped (**a**) and selectivity of trawl codend with 100 mm mesh size (**b**) for Redfish with dividing by sex, February 2004, Div. 3O.

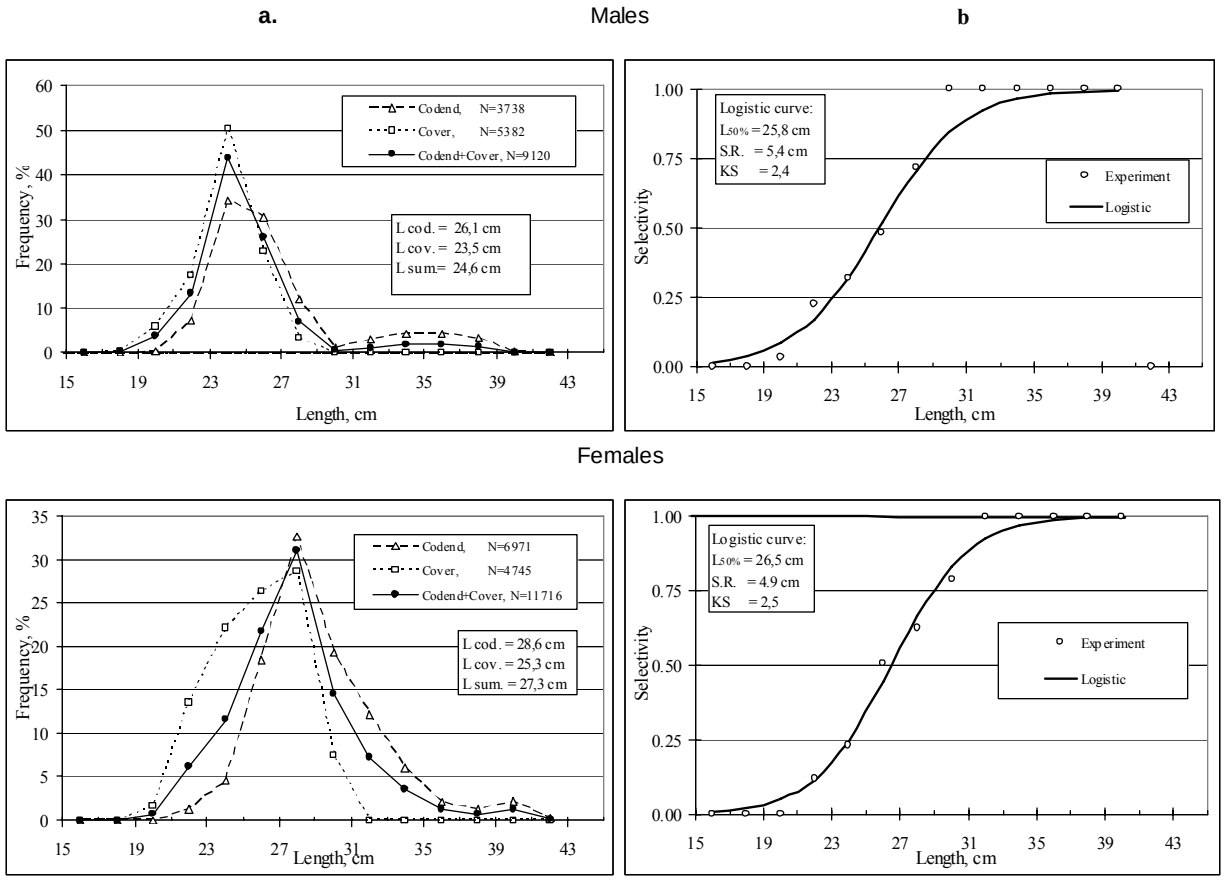

Fig. 3. Length composition of caught fish and escaped (a) and selectivity of trawl codend with 105 mm mesh size (b) for Redfish with dividing by sex, February 2004, Div. 3O.

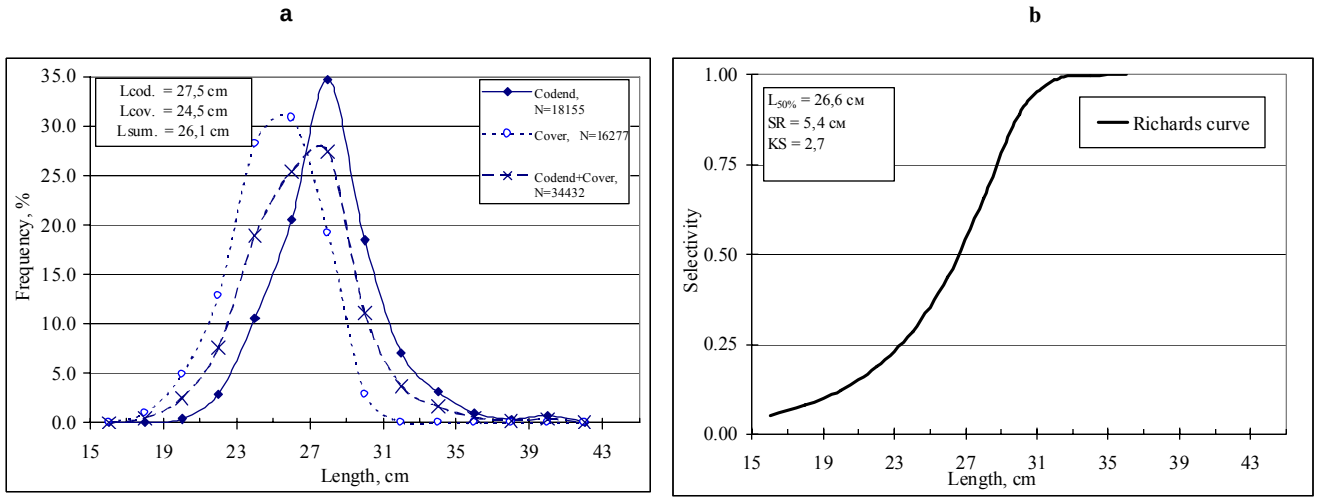

Fig. 4. Length composition of caught fish and escaped (a) and selectivity of trawl codend with 95 mm mesh size (b) for Redfish without dividing by sex, December 2003, Div. 3O.

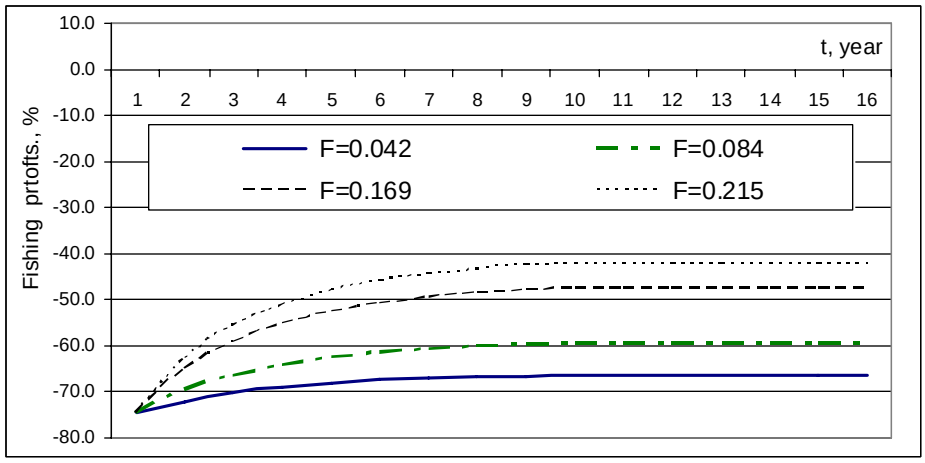

Fig. 5. Long-term profits of fishery when changing mesh size (from 100 to 130 mm) in Div 3O with different fishing mortality F_{bar} 7-10