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Selectivity of the Codends with 130-150 mm Mesh Size in Specialized Trawl
Fishery for Greenland Halibut in Division 3L of NAFO Regulatory Area

by

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Abstract

Presented are the results of estimating the selectivity of the trawl codends with 130 mm, 135 mm, 136 mm, 145 mm and 150 mm mesh size for the Greenland halibut (*Reinhardtius hippoglossoides*) from the NAFO Regulatory Area and the objects of by-catch in its specialized fishery: roughhead grenadier (*Macrourus berglax*), redfishes (*Sebastes*) and American plaice (*Hippoglossodes plassetoides*).

The works were executed by two stages. Selectivity was estimated with the aid of the bag-shaped cover. The calculation was made applying generalized logistic Richard's function using the "SELECT model" and "Solver. sel." Programmes. The likelihood estimations were obtained by minimizing logarithmic likelihood function.

In experiments the selectivity coefficient for the trawl codends with 130-150 mm mesh size for Greenland halibut varied from 2.9 to 3.3, the selectivity range – from 6.0 to 10.0 cm and the fish length corresponding to 25% retention – from 35.9 to 45.1 cm.

The data analysis showed that 130-150 mm increase in the mesh size when fishing Greenland halibut led to the essential instantaneous losses and the long-term profits of the fishery were negligible.

The selectivity parameters of the trawl bags for roughhead grenadier, redfish and American plaice were the same as the results obtained before.

Introduction

In the recent decade (from 1992 to 2001), in Divs.3LMNO, 0.28×10^6 t of Greenland halibut were caught. According to the data in STATLANT 21A reports, the annual catch fluctuated from 51.8×10^3 t in 1992 to 12.8×10^3 t in 1995. Before 1995, the fishery was only regulated by minimal 130 mm mesh size in trawl codends. Since 1995, besides that, the Fisheries Commission annually establishes TAC divided into national quotas. In addition to the regulation measures, for the trawl fishing of Greenland halibut the Commission adopted a minimal 30 cm commercial size, which was derived using the selectivity calculations and corresponded to 25% level of fish retention. The maximum allowable by-catch of fish with the length of less than 30 cm is 10% by abundance (ANON., 2003).

Such regulation measures have already resulted in the positive trends of stock development. The annual catch, as well as TAC, have begun to increase. In 1996, the catch of Greenland halibut amounted to 14.3×10^3 t, the TAC for 2002 – to 44×10^3 t.

For this, the reduction in immature Greenland halibut catch has remained to be the urgent task. It concerns both its specialized fishery and by-catch in others (ANON., 2002). Therefore, the selectivity of fishing gears for Greenland halibut in each kind of fishery (by trawl, in the first turn), as well as its by-catch size while fishing the other fish species, should be estimated objectively. The present paper concerns the investigation into selectivity of trawls with the different mesh size in specialized fishing of Greenland halibut relating to the fish species in by-catch: roughhead grenadier, redfish and American plaice.

Material and Methods

Experimental works to estimate selectivity in Greenland halibut fishery were carried out aboard the Russian trawler “Remøyfjord” in Div. L of the NAFO Regulatory Area, in April-May (the 1st stage) and in June-September (the 2nd stage) 2002. The length of the vessel – 63.25 m; the width – 12.50 m, the gross tonnage – 1 538 t; the main engine – 3 180 h.p.

When investigating, the bottom 45.8m “Turbot” trawl with 26 m horizontal and 5 m vertical opening was used (Lisovsky *et al.*, 2001). At the first stage, along the lower headline, the trawl was equipped by the rockhopper weighting 2600 kg, with 500 mm diameter bobbins, the trawl doors of the “Kwin topp” type with the area of 8.6m². The length of each cable was 245m. At the second stage, applied were the trawl doors with the area of 7.4 m² and each cable was as long as 125 m. The tow speed equaled to 3.0-3.2 knots, the duration of fishing was as in the fishery (from 4 to 7 hours).

Tested were the trawl codends with the normative mesh size of 130, 135, 145, 150 mm made of polyamide twin cord with 7.0 mm diameter. The length of the codend cylindrical part was 10 m, the perimeter – 80 meshes. The trawl codend mesh size was measured in the upper panel. The measurement was made in the row disposed in parallel to the lengthwise axis of the trawl bag being 10 meshes distant from the lengthwise seams and 5 meshes – from the codline loops. In all, not less than 20 meshes were measured. The measurement was done at once after lifting the trawl with the aid of the probe – a wedge-shaped plate with 2mm thickness, of the ICNAF-type, inserted into the mesh with 50Hz effort. The measurements were made at the beginning and at the end of the experimental series.

Trawl bag selectivity was estimated by method of small-meshed bag-formed cover with 90 mm mesh size mounted on the conic part of the trawl codend at the distance of 4-5 m from the place of its sewing together with the cylindrical one.

All the fish from the codend and the cover were put into different tanks and measured separately being selected by species and sex. 200-300 individuals from every catch by the trawl codend and cover were measured. When the catches were great, the rest fish were counted and the length series were corrected. Processed were Greenland halibut, roughhead grenadier, American plaice and redfish species.

The results of investigations were collected and processed in compliance with the instructions approved in PINRO (Anon., 2001) and the ICES recommendations for the study of trawl selectivity (Anon., 1996). The data were analyzed using “Solver-sel” and “SELECT model” computer programs (Tadashi Tokai, 1997; Tadashi Tokai and Takahisa Mitsuhashi, 1998), allowing us to estimate the parameters of selectivity by generalized logistic function of investigated fish retention likelihood depending on their length.

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

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

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

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

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

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 length, corresponding to 75% and 25% retention.

The selectivity coefficient K_s was calculated by the formula:

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

where B – the inner mesh size.

Results

1. Selectivity of trawl codends with 130-150 mm mesh size for Greenland halibut

The researches to estimate selectivity of the trawl codend with normative 135 mm mesh size were conducted at 850-1000 m depth, in Div. 3L, in April (Table 1). In the catches halibut made up from 70% to 90%. The catches in codend varied from 0.30 to 80.0 t amounting to 0.56 t, on the average, and in the cover – from 0.5 to 1.0 t with the mean ones of 0.75 t. Redfish and American plaice predominated in by-catch. When testing the mean mesh size in the codend was 135.8 mm.

The length composition of halibut males and females taken by cover and codend and fish before trawl is presented in Fig. 1a, the selectivity curves are given in Fig. 1b.

The main characteristics of tows are shown in Table 1.

In the trawl codend the halibut size varied within the range of 28-66 cm, the mode was 46-48 cm. In the cover it was in the limits of 22-54 cm under the mode of 40-42 cm. In the series of tows, the mean size of halibut was: 45.4 cm in the codend, 39.7 cm in the cover, and 41.8 cm was the length of fish before trawl.

Table 2 shows the results of calculations to estimate the selectivity of the trawl bag with 135.8 mm mesh size for Greenland halibut.

Investigations to estimate selectivity of the trawl bag codend with normative 145 mm mesh size were conducted at 920-1050 m depth, in Div. 3L, in April-May. In those tows the portion of the Greenland halibut made up 79-97% of the catch. The catch in the codend fluctuated from 0.35 to 0.75 t and was 0.55 t, on the average, in the cover – from 0.5 to 1.35 t and equaled to 0.93 t, on the average. Redfish and roughhead grenadier predominated in the by-catch. In the codend the mesh size was 145.4 mm.

Fished out were the halibut with the length of 24-82 cm and 41.8 cm, on the average. In the catch by the codend, halibut length composition was 24-82 cm, the mode – 48 cm, the mean length – 46.2 cm. In that one by the cover the length ranged from 24 cm to 54 cm, the mode was 32 cm, the mean length – 40.2 cm.

Figure 2 presents the length composition of halibut (males and females) taken by cover, codend and fish before trawl and corresponding selectivity curves.

As Fig. 2b shows, in this case, the selectivity curves for Greenland halibut males and females completely coincide, therefore, further analysis of selectivity is made without selecting individuals by sex.

The main results of estimating selectivity of the trawl codend with 145.4 mm mesh size for the Greenland halibut are presented in Table 2.

At the second stage, the experimental works to estimate selectivity of the trawl codend with normative 130 mm mesh size were executed at 830-900 m depth, in Div. 3L, in August-September. In this period, in tows, the portion of Greenland halibut was 71-97% of the catch. In the codend the catch varied from 0.1 to 1.5 t, in the cover – from 0.05 to 0.80 t. The by-catch was, mainly, represented by roughhead grenadier (to 18%). When investigating, the mean mesh size equaled to 130.3 mm.

The length composition of halibut taken by the cover, the codend and before trawl is given in Fig. 3a, the selectivity curves are shown in Fig. 3b and the data on tows are presented in Table 3.

Fished out were the halibut with the length of 28-62 cm, 37-38 cm mode and the average size of 41.2 cm. In the catch by the codend, halibut length composition was 32-62 cm, the mode – 43-44 cm, the mean size – 42.9 cm, by the cover – 28-54 cm, the mode – 37-38 cm, the mean length was 38.4 cm.

At the second stage, the selectivity of the trawl codend with the normative 135 mm mesh size was estimated at 650-1050 m depth, in Div. 3L, in August. In that period, in tows, the portion of the Greenland halibut was equal to 73-94% of catch. The catch by codend varied from 0.31 to 0.94 t, by cover – from 0.16 to 0.81 t. In the by-catch the roughhead grenadier prevailed (to 10%). The average mesh size of the trawl codend was 135.2 mm.

Halibut as long as 26-66 cm with the mode of 37-38 cm and 40.8 cm mean length were fished out. In the catch by codend halibut length composition was 32-66 cm, the mode – 43-44 cm, the average length – 43.0 cm, in that one by the cover the length ranged from 26 to 56 cm, the mode was 35-36 cm, the mean size – 38.6 cm.

Figure 4a gives the length composition of halibut taken by cover, codend and before trawl, Fig. 4b – the selectivity curves.

At the combined Diagram 4b it is shown that selectivity curves of males and females completely coincide. Selectivity parameters and curves are given in Table 2.

At the second stage, the experimental tows to estimate selectivity of the trawl codend with normative 150 mm mesh size were carried out at 650-1130 m depth, in Div.3L, in June-July. In that period, in tows, the portion of Greenland halibut was 71-97% of catch. The catch in the codend varied from 0.24 to 0.56 t, in the cover – from 0.38 to 1.38 t. The by-catch was, primarily, represented by roughhead grenadier (to 14%) and red hake. The average mesh size amounted to 149.8 mm.

Halibut with the length of 26-58 cm, the mode of 43-44 cm and the average size of 41.2 cm were fished out. The length of fish caught by codend ranged from 38 to 58 cm, the mode was 47-48 cm, the average size – 43.0 cm. The halibut taken by cover were 26-52 cm in length, with the mode of 43-44 cm and the average size of 38.6 cm.

The length composition of halibut (females and males) in the cover, codend and before trawl is given in Fig. 5a, the selectivity curves are shown in Fig. 5b.

Combined Diagram 5b shows that the selectivity curves for Greenland halibut males and females completely coincide.

Calculation characteristics of selectivity curves and calculation indices of selectivity are presented in Table 2.

2. Selectivity of trawl bags with 130-150 mm mesh size for roughhead grenadier

The researches to estimate selectivity of the trawl codend with 130 mm mesh size for the roughhead grenadier were performed at 830-900 m depth, in Div. 3L, in August-September, simultaneously with the investigations for halibut. In that period, the by-catch of roughhead grenadier made up 18%. The trawl codend mean mesh size was 130.3 mm.

In the catch by trawl codend the weight of roughhead grenadier varied from 3 to 191 kg, by the cover – from 4 to 36 kg. In the codend the length composition of roughhead grenadier was 24-84 cm with the mode of 44 cm, in the cover it was from 24 to 56 cm under 40 cm mode, the fish before trawl were 24-84 cm having the mode of 40 cm. In the series of tows, the average length of roughhead grenadier was equaled to: 46.7 cm in the codend, 38.6 cm in the cover and 42.1 cm for fish before trawl.

Figure 6a gives the length composition of roughhead grenadier (females and males) in the cover, codend and for fish before trawl, Fig. 6b presents the selectivity curves. Here there is no coincidence of selectivity curves for roughhead grenadier males and females (Fig. 6b).

Calculation characteristics of selectivity curves and indices are given in Table 2.

For roughhead grenadier, the selectivity of the trawl codend with 135 mm mesh size was estimated simultaneously with the investigations of selectivity for halibut in August.

In that period, the by-catch of roughhead grenadier amounted to 10%. The average mesh size of the trawl codend was 135.2 mm.

In the codend, the weight of roughhead grenadier fluctuated from 7 to 56 kg, in the cover, – from 3 to 64 kg. In the codend the length composition of roughhead grenadier was 28-82 cm with the mode of 44 cm, in the cover the length ranged from 24 to 52 cm under the mode of 38-42 cm, the size of fish before trawl was 24-82 cm and the mode – 42 cm. In the series of tows, the average length of roughhead grenadier was: 45.8 cm in the codend, 38.8 cm – in the cover and 41.3 cm for fish before trawl.

Figure 7a gives the size composition of roughhead grenadier (females and males) in the cover, codend and fish before trawl. Fig. 7b presents the selectivity curves. The selectivity curves of the roughhead grenadier males and females slightly vary within the whole selectivity range. So, $L_{50\%}$ is 44.3 cm for males and 45.3 cm for females. The selectivity range SR is 10.2 cm and 9.4 cm, respectively.

Selectivity curves and indices are shown in Table 2.

Investigations to estimate selectivity of the trawl codend with 145 mm mesh size for roughhead grenadier in special fishery for halibut were carried out in Div. 3L, in April-May, simultaneously with the same research for Greenland halibut. Then, the roughhead grenadier made up to 10-30% of catch. The average size of trawl codend mesh was 145.4 mm.

In the codend, the weight of roughhead grenadier fluctuated from 30 to 500 kg, in the cover – from 20 to 150 kg. In the codend and in the cover the roughhead grenadier length composition was 27-42 cm with the mode of 42 cm and 15-48 cm under 39 cm mode, respectively. In the series of tows, the mean length of the roughhead grenadier was estimated at: 43.0 cm (41.4 cm of males and 44.6 cm of females) in the codend and 35.4 cm (35.8 cm of males and 34.5 cm of females) in the cover.

The roughhead length composition in the cover, codend and for fish before trawl is presented in Fig. 10a. The selectivity curves are shown in Fig. 10b.

The diagrams of roughhead selectivity for males and females slightly differ within the selectivity range.

Table 2 shows the parameters of the selectivity curves and selectivity indices.

The research to estimate selectivity of the trawl codend with 150 mm mesh size for roughhead grenadier were conducted in Div. 3L, in June-July, simultaneously with those ones for halibut. At the depth of over 900 m, the roughhead grenadier constituted to 10-14% of catch. The average size of the trawl codend was 149.8 mm.

In the codend and in the cover, the roughhead grenadier weight fluctuated from 20 to 80 kg and from 3 to 36 kg, respectively. The length composition of roughhead grenadier was 30-88 cm with the mode of 42 cm in the codend, 24-66 cm under the mode of 38 cm in the cover and 24-88 cm with the mode of 42 cm for fish before trawl. When

towing, the mean length of the fish was 47.1 cm in the codend, 38.6 cm in the cover and of fish before trawl – 41.6 cm.

The length composition of roughhead grenadier (females and males) in the cover, in the codend and for fish before trawl is presented in Fig. 8a, the curves of selectivity are shown in Fig. 8b. The selectivity curves of roughhead grenadier males and females differ within the whole range of selectivity.

The selectivity calculation indices and indices are given in Table 2.

3. Selectivity of 135-145 mm mesh codend for redfish

Selectivity studies for 135 mm mesh codend with regard to redfish were conducted in NAFO Subarea 3L in April simultaneously with selectivity experiments on Greenland halibut. The portion of redfish in test hauls was 25% of the catch. Mean mesh size in codend was 135.8 mm.

Weight of redfish in the codend ranged from 0.02 to 0.11 tons, that in the cover, from 0.04 to 0.25 tons. Length of redfish in the codend varied from 23 to 42 cm, with a 34 cm mode, that in the cover ranged from 21 to 37 cm, with a 25 cm mode. Mean length of redfish in this series of hauls was the following: 32.6 cm in the codend (32.0 cm for males, 33.6 cm for females), 28.5 cm in the cover (28.2 cm for males, 28.8 cm for females), 29.3 cm for fish before the trawl (28.9 cm for males, 29.9 cm for females).

Length composition of redfish catches in the cover, codend and fish before the trawl is shown in Fig. 9a. Selectivity curves are presented in Fig. 9b. The latter figure shows nearly coinciding selectivity curves, therefore in further selectivity studies fish were not divided by sex.

Calculated selectivity parameters and other indices are given in Table 4.

Selectivity studies of trawl codend with 145 mm mesh for redfish in Subarea 3L were conducted in April-May. The portion of redfish in these experiments reached 15-20%. Mean mesh size was 145.4 mm.

Weight of redfish in the codend ranged from 3 to 65 kg, that in the cover from 3 to 105 kg. Length of redfish in the codend varied from 23 to 40 cm, with a 33 cm mode, that in the cover ranged from 18 to 37 cm, with a 29 cm mode. Mean length of redfish in this series of hauls was the following: 32.8 cm in the codend (32.3 cm for males, 33.5 cm for females), 29.5 cm in the cover (29.6 cm for males, 29.7 cm for females).

Length composition of redfish (males and females) catches in the cover, codend and fish before the trawl is shown in Fig. 10a, selectivity curves are presented in Fig. 10b. The latter figure shows nearly coinciding selectivity curves, therefore in further selectivity studies fish were not divided by sex.

Selectivity parameters for codend with 145.4 mm mesh with regard to redfish are given in Table 4.

4. Selectivity of 135 mm mesh codend for American plaice

Selectivity studies for 135 mm mesh codend with regard to American plaice were conducted in Subarea 3L in April simultaneously with selectivity investigations on Greenland halibut. American plaice made up to 13% of the catch. Mean mesh size was 135.8 mm.

Weight of American plaice in the codend ranged from 30 to 115 kg, that in the cover, from 2 to 60 kg. Length of fish in the codend varied from 24 to 52 cm, with a 38 cm mode, that in the cover ranged from 20 to 38 cm, with a 30 cm mode. Mean length of American plaice in this series of hauls was the following: 37.3 cm in the codend, 32.5 cm in the cover, and 34.2 cm for fish before the trawl.

Length composition of American plaice (males and females) catches in the cover, codend and before the trawl is shown in Fig. 11a, selectivity curves are presented in Fig. 11b. Selectivity curves for males and females in Fig. 11b do not coincide, probably due to lacking amount of data on males.

Calculated selectivity parameters and other indices are given in Table 4.

Discussion

Selectivity of codends with 130-150 mm mesh for Greenland halibut was similar for both males and females. For codends with 130 and 136 mm mesh, selectivity was somewhat higher with regard to males. This was, however, observed only for males of more than 45 cm length.

Selectivity coefficient for different mesh size was found to vary from 2.9 to 3.4, which is in line with the results of our previous investigations and other researchers' data (Table 5).

Selectivity range for Greenland halibut also fell within the previously identified limits (Table 6). For 130.3 mm mesh, length of 25% retainment was found to be 35.1 cm, increasing to 45 cm for 150 mm mesh.

Our studies and other research (Chumakov *et al.*, 1981; De Cardenas *et al.*, 1995; Huse, Nedreaas, 1995; Lisovsky *et al.*, 2000; Lisovsky *et al.*, 2002; Nikeshin *et al.*, 1983; Walsh, Hickey, 2000; Walsh *et al.*, 2000) show that selectivity coefficient for codends with 121-150 mm mesh ranges from 2.8 to 3.3 and their selectivity range lies within 6.1-11.8 cm (Table 5). The analysis of the obtained results indicates that the current landing size of 30 cm for Greenland halibut (Anon., 2003) does not correspond to 25% retainment in a codend with 130 mm mesh. The landing size can be increased to 34-36 cm, which would correspond to 0.4-5.2% by-catch of undersized fish below 34 cm and 1.1-12.8% of fish below 36 cm.

Thus, the minimum landing size of Greenland halibut can be increased to 34-35 cm. In this case the by-catch of fish below the new landing size will not exceed 10%, which is the by-catch currently allowed by the Fisheries Commission (Anon., 2003).

Our previous estimation of possible effects of increased selectivity on fisheries efficiency due to the increase of mesh size from 135 to 150 mm (Lisovsky *et al.*, 2002) showed that this would result in the 43% efficiency reduction. Greenland halibut fishery with 150 mm mesh trawls will be economically unprofitable.

Long-term benefits resulting from the increase of mesh size from 130 to 145 mm (Darby, 2001) will be insignificant, which supports our opinion regarding the inexpediency of mesh increase.

Investigations indicated considerable changes in the selectivity coefficient and selectivity range depending on mesh size. For 145 mm mesh, K_S was 2.5, while that for 135 mm mesh, 3.5. Selectivity range for 135 mm mesh was 9.8 cm, that for 150 mm mesh, 13.5 cm. This was probably due to the fact that the studied object made up only a small, and highly variable, portion. To obtain more accurate data about the effects of mesh size on the selectivity for roughhead grenadier, further studies are required.

Regarding redfish, selectivity coefficients for codends with a bag-shaped cover was 2.6 for 135.8 mm mesh and 2.3 for 145.4 mm mesh, which was notably higher than those for the ICES cover (Lisovsky, 2000). Selectivity range for 135.8 mm mesh was 4.9 cm, for 145.4 mm mesh, 5.7 cm, while in most experiments with the ICES cover, the attempts to define selectivity range resulted in a failure.

Selectivity coefficients for codends with different mesh size were rather independent of the method of their calculation. In the experiments the ICES cover, the coefficient was found to range from 2.2 to 2.4, while for the bag-shaped cover, from 2.2 to 2.7. Studies of codend selectivity indicate a smaller selectivity range for similar or lower selectivity coefficient. These results are primarily due to fact that American plaice is usually a non-target species, being mainly taken as by-catch in the fishery for Greenland halibut and other species.

Conclusion

With the currently allowable minimum mesh size of 130 mm, the landing size of Greenland halibut within its fishery in the NAFO Subarea 3L can be increased to 34-35 cm.

The increase of mesh size from 130 to 145 and 150 mm in the fishery for Greenland halibut is not viable as it will not give any significant long-term benefits and can make this fishery stop because of economic unprofitability.

The results of selectivity studies for codends with different mesh size in the direct fishery for Greenland halibut with regard to such by-catch species as American plaice, roughhead grenadier and redfish are in line with the previous data.

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Table 1. Main characteristics of tows when determining selectivity of trawl codends with different mesh size for Greenland halibut fishery 2002, NAFO Regulatory Area, period 1.

Haus, no	Date	Position of start		Start time, h : min	Haus duration, h : min	Direction, degree	Depth, m	Catch, kg								
		N degree,min	W degree,min					Greenland halibut		Roughhead grenadier		Redfish		American place		Total
								codend	cover	codend	cover	codend	cover	codend	cover	
Mesh size 135,8 mm																
1	09.04.02	48°07'8	47°31'8	6:20	5:10	85	850	550	550			105	246	46	30	1527
2	10.04.02	48°07'3	48°08'0	12:30	5:00	270	870	637	953			70	188	48	32	1928
3	12.04.02	48°07'8	47°28'0	7:00	5:00	90	880	336	505			46	108	30	40	1065
4	14.04.02	48°16'0	46°34'0	8:40	5:00	240	860	304	566			65	195	38	14	1182
5	16.04.02	48°08'0	47°34'9	8:20	5:00	90	930	420	580			101	245	325	25	1385
6	17.04.02	48°08'1	47°37'0	16:20	4:30	95	940	450	676			65	218	55	21	1485
7	20.04.02	48°08'3	47°37'2	5:30	5:30	90	980	808	988			17	38	70	60	1981
8	22.04.02	48°08'7	47°36'0	7:20	6:00	90	1000	807	1027			63	163	66	55	2181
9	23.04.02	48°09'4	47°03'4	9:00	5:00	70	970	687	807			70	150	115	15	1844
10	24.04.02	48°16'5	46°34'0	8:30	6:00	180	850	602	767			66	197	65	2	1699
Mesh size 145,4 mm																
1	27.04.02	48°18'0	46°32'6	11:50	5:00	230	1010	450	675	36	200	65	85			1511
2	30.04.02	48°07'9	47°08'9	3:20	5:00	270	970	555	833	45	140	60	100			1733
3	03.05.02	48°09'0	47°09'0	9:20	6:00	270	1050	653	1113	30	80	10	10			1896
4	04.05.02	48°08'8	47°07'5	9:10	5:20	75	1050	684	1027	50	240	8	12			2021
5	06.05.02	48°16'1	46°38'9	16:20	5:40	250	1020	744	1116	20	30	5	8			1923
6	07.05.02	48°08'9	47°34'6	13:20	5:00	90	1050	500	1352	22	35	45	105			2059
7	09.05.02	48°15'0	46°40'0	12:50	5:00	250	1020	552	1025	68	140	50	100			1935
8	10.05.02	48°14'0	46°42'0	12:00	5:00	250	990	420	780	150	330	31	57			1768
9	12.05.02	47°41'0	46°50'0	18:40	4:00	20	920	600	900	57	245	42	78			1922
10	14.05.02	48°09'0	47°05'0	5:00	5:00	60	1050	347	520	130	500	3	3			1503

Table 2. Selectivity parameters of trawl codends with different mesh size for Greenland Halibut and Roughhead grenadier in NAFO Div 3L calculated using generalized logistic function, 2002.

Parameters	Greenland halibut		Roughhead grenadier	
	Calculation	Standard error	Calculation	Standard error
Mesh size 130,3 mm - period 2				
L_{25%} =	35,9	0,5	37,2	2,9
<i>L_{75%} =</i>	45,5	1,2	49,5	1,4
<i>L_{50%} =</i>	40,2	0,8	44,4	1,2
S.R. =	9,8	1,2	12,3	1,8
<i>Ks. =</i>	3,1		3,4	
Mesh size 135,2 mm - period 2				
<i>L_{25%} =</i>	39,0	0,3	40,4	1,5
<i>L_{75%} =</i>	49,0	0,9	48,9	1,1
<i>L_{50%} =</i>	43,8	0,5	45,4	0,6
S.R. =	10,0		8,5	1,1
<i>Ks. =</i>	2,9		3,5	
Mesh size 135,8 mm - period 1				
<i>L_{25%} =</i>	41,0	0,3		
<i>L_{75%} =</i>	48,9	0,4		
<i>L_{50%} =</i>	45,3	0,2		
S.R. =	7,9	0,8		
<i>Ks. =</i>	3,3			
Mesh size 145,4 mm - period 1				
L_{25%} =	42,9	0,1	31,6	0,7
<i>L_{75%} =</i>	49,1	0,4	41,4	0,7
<i>L_{50%} =</i>	46,2	0,2	37,0	0,4
S.R. =	6,3	0,3	9,8	0,8
<i>Ks. =</i>	3,2		2,5	
Mesh size 149,8 mm - period 2				
<i>L_{25%} =</i>	45,1	0,6	39,3	1,1
<i>L_{75%} =</i>	52,0	1,5	52,8	2,7
<i>L_{50%} =</i>	48,7	1,0	45,7	1,7
S.R. =	6,9		13,5	2,2
<i>Ks. =</i>	3,2		3,1	

Table 3. Main characteristics of tows when determining selectivity of trawl codends with different mesh size for Greenland halibut fishery 2002, NAFO Regulatory Area, period 2

Haus, no	Date	Position of start		Start time, h : min	Haus duration, h : min	Direction, degree	Depth, m	Catch, kg					
		Degree,min	Degree,min					Greenland halibut		Roughhead grenadier		Other fish specves	Total
								codend	cover	codend	cover		
1	24.08.02	48 ⁰ 14'0	46 ⁰ 33'6	8:50	5:00	200	850	354	285	24	30	77	771
2	26.08.02	48 ⁰ 06'0	47 ⁰ 06'9	4:40	7:20	270	870	475	515	7	4	49	1050
3	28.08.02	48 ⁰ 07'1	47 ⁰ 12'0	11:40	1:00	270	850	755	575	3	20	67	1420
4	30.08.02	48 ⁰ 07'1	47 ⁰ 13'0	8:30	5:00	270	850	1165	699	25	5	63	1956
5	01.09.02	48 ⁰ 07'1	47 ⁰ 11'3	4:40	6:00	270	850	1453	788	15	12	77	2345
6	02.09.02	48 ⁰ 08'0	47 ⁰ 39'6	6:00	6:00	90	850	795	550	16	14	54	1429
7	03.09.02	48 ⁰ 07'2	47 ⁰ 08'2	5:40	6:20	270	850	100	50	191	36	20	397
8	04.09.02	48 ⁰ 14'0	46 ⁰ 41'8	3:40	5:20	240	900	526	188	23	33	91	862
9	05.09.02	48 ⁰ 07'2	47 ⁰ 09'9	3:20	7:00	270	850	856	455	10	7	91	1419
10	07.09.02	48 ⁰ 07'0	47 ⁰ 09'7	10:20	4:05	270	830	498	358	7	8	128	998
Mesh size 135,2 mm													
1	09.08.02	48 ⁰ 17'0	46 ⁰ 33'0	11:40	5:00	250	950	454	374	13	10	70	921
2	11.08.02	48 ⁰ 11'4	46 ⁰ 37'5	7:30	5:00	200	850	710	613	7	4	66	1399
3	12.08.02	47 ⁰ 54'3	46 ⁰ 39'4	3:20	5:00	20	1050	312	162	23	10	64	571
4	13.08.02	48 ⁰ 07'2	47 ⁰ 33'1	5:50	5:00	90	798	338	216	21	40	64	679
5	15.08.02	48 ⁰ 07'1	47 ⁰ 10'3	10:30	5:00	270	850	400	213	14	33	127	787
6	16.08.02	48 ⁰ 07'6	47 ⁰ 33'4	7:00	5:00	100	950	545	235	22	64	86	952
7	17.08.02	48 ⁰ 07'2	47 ⁰ 07'9	2:30	5:00	270	850	405	420	56	31	90	1002
8	19.08.02	48 ⁰ 08'0	47 ⁰ 38'2	12:00	5:30	90	850	938	813	10	3	62	1824
9	21.08.02	48 ⁰ 05'9	47 ⁰ 32'0	7:00	5:00	90	650	325	550	15	3	48	940
10	22.08.02	48 ⁰ 05'5	47 ⁰ 29'5	11:10	5:00	90	750	628	423	23	9	104	1187
1	20.06.02	48 ⁰ 09'2	47 ⁰ 08'6	8:00	5:00	270	1040	300	1175	62	35	79	1651
2	22.06.02	48 ⁰ 08'6	47 ⁰ 30'7	8:10	5:00	90	265	425	907	57	14	4	1406
3	27.06.02	48 ⁰ 17'3	46 ⁰ 31'7	9:00	5:00	250	1030	488	639	24	3	38	1191
4	30.06.02	48 ⁰ 05'7	47 ⁰ 10'7	16:30	5:00	280	840	550	550	51	21	139	1311
5	03.07.02	48 ⁰ 07'0	47 ⁰ 32'5	7:00	5:00	180	820	313	550	78	25	68	1034
6	05.07.02	48 ⁰ 09'1	47 ⁰ 09'7	9:10	5:00	170	1040	312	610	20	36	64	1041
7	08.07.02	48 ⁰ 10'9	47 ⁰ 07'8	5:40	5:00	270	1130	355	725	22	8	46	1156
8	12.07.02	48 ⁰ 09'0	47 ⁰ 01'8	8:00	5:00	70	1010	238	550	0	0	142	931
9	15.07.02	48 ⁰ 07'3	47 ⁰ 11'2	8:30	5:00	270	850	557	1375	0	0	154	2087
10	17.07.02	48 ⁰ 06'6	47 ⁰ 31'1	10:10	5:00	90	790	280	375	0	0	65	720

Table 4. Selectivity parameters of trawl codends with different mesh size for Redfish and American plaice in NAFO Div 3L calculated using generalized logistic function, 2002.

Parameters	Redfish		American plaice	
	Calculation	Standard error	Calculation	Standard error
Mesh size 135,8 mm - period 1				
$L_{25\%} =$	31,9	1,4	31,3	0,5
$L_{75\%} =$	36,8	1,8	36,1	0,9
$L_{50\%} =$	35,0	0,6	34,1	0,5
$S.R. =$	4,9	0,7	4,9	0,6
$K_s =$	2,6		2,3	
Mesh size 145,4 mm - period 1				
$L_{25\%} =$	30,7	0,4		
$L_{75\%} =$	36,4	0,8		
$L_{50\%} =$	34,0	0,5		
$S.R. =$	5,7	0,6		
$K_s =$	2,3			

Table.5. Selectivity parameters for trawl bag with different mesh size in Greenland halibut fishery in NAFO RA as provided by various researches.

Mesh size, mm	Number of hauls	Duration of tow, hour	L_{50} , cm	K_s	SR, cm	L_{25} , cm	Source of information
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 Chumakov et al., 1981
127 ²	7	1,5	37	2,91	?	?	Nikeshin et al., 1983
130 ¹	7	5	38,5	2,96	7,1	31,8	Lisovsky et al., 2001
130 ¹	4	1	38,7	2,99	7,5	34,5	Gardenas et al., 1995
130 ¹	2	4	37,7	2,91	11,8	30,5	Gardenas et al., 1995
131 ¹	10	4-5	41,7	3,2	6,1	38,2	Lisovsky et al., 2002
130 ¹	10	4-7	40,3	3,1	9,6	35,9	This paper
132 ¹	9	5	40	3,03	10,5	34	Lisovsky et al., 2001 Chumakov et al., 1981
133 ²	7	?	40,5	3,08	?	?	Nikeshin et al., 1983
135 ³	14	4	42,0	3,1	9,6	37,2	Huse and Nedreaas, 1995
135 ¹	10	5	43,8	2,9	10,0	39,0	This paper
136 ¹	10	4-6	45,3	3,3	7,9	41,0	This paper
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
145 ¹	10	4	45,2	3,1	7,1	41,2	Lisovsky et al., 2002
145 ¹	10	4-6	46,2	3,2	6,3	42,9	This paper
150 ¹	10	5	48,7	3,2	6,9	45,1	This paper
150 ²	4	4	46,7	3,1	8,4	41,8	Lisovsky et al., 2002

Method used to determine selectivity:

¹ – bag-shaped cover;

² - ICES type cover;

³ – trouser bag.

Table.6. Selectivity parameters of the trawl bag with different mesh size in Roughhead grenadier fishery in NAFO RA as provided by various researchers.

Mesh size, mm	Number of hools	Duration of tow, hour	L ₅₀ , cm	K _S	SR, cm	L ₂₅ , cm	Source of information
130*		4	12,55	0,97	6,74	8,65	Cardenas et al., 1995
130 ^{2*}	10	4-7	44,4	3,4	12,3	37,2	This paper
135 ^{2*}	10	5	45,4	3,5	8,5	40,4	This paper
145 ^{2*}	10	4-6	37,0	2,5	9,8	31,6	This paper
150 ^{2*}	10	5	45,7	3,1	13,5	39,3	This paper

* - full length;

¹ - ICES type cover;

² – bag-shaped

Table.7. Parameters for the codend with different mesh size for American place in NAFO RA by various researchers.

Mesh size, mm	Number of hools	Duration of tow, hour	L ₅₀ , cm	K _S	SR, cm	L ₂₅ , cm	Source of information
127 ¹		1-3	28,0	2,2	-	-	Konstantinov et al., 1982
129 ¹			31,1	2,4	7,3	27,5	Walsh et al., 1992
130 ¹	13	4	29,75	2,3	8,0	24,8	Cardenas et al., 1995
130 ^{2*}	26		30,5	2,3	4,2	28,4	Walsh et al., 1992
136 ³	10	4-6	34,1	2,3	4,9	31,3	This paper
140 ²	11		38,4	2,7	9,6	33,6	Walsh et al., 1992
140 ^{2*}	20		30,5	2,2	4,0	28,5	Walsh et al., 1992
155 ²	13		38,2	2,5	8,4	34,0	Walsh et al., 1992
155 ^{2*}	16		32,1	2,1	3,2	30,7	Walsh et al., 1992

* - square mesh

¹ - ICES type cover;

² – trouser method

³ – bag-shaped cover;

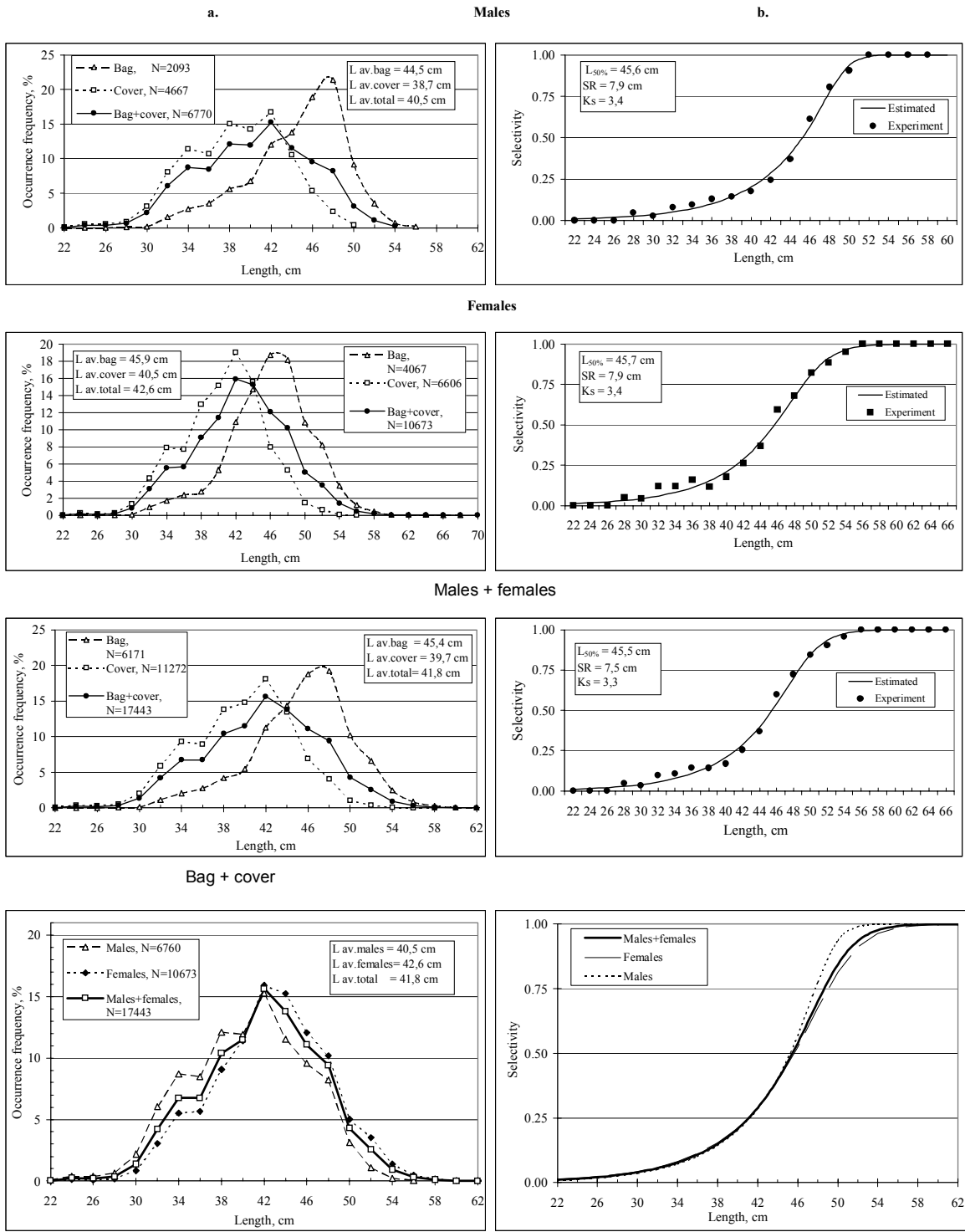


Fig.1 Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 135.8 mm (b) estimated by generalized logistic function in relation to Greenland halibut by sex and for males and females together, NAFO Divs. 3L. Stage 1

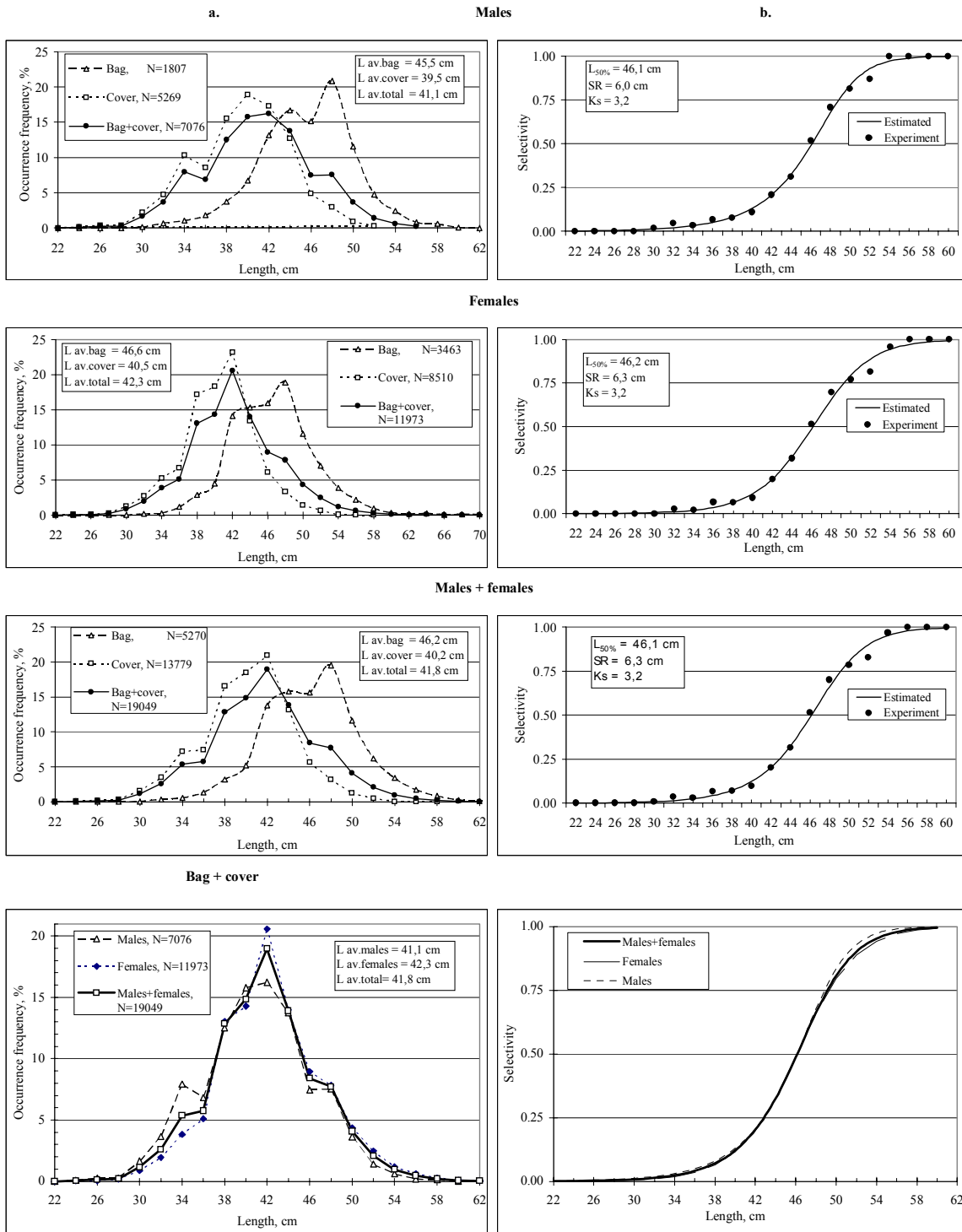


Fig. 2 Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 145.4 mm (b) estimated by generalized logistic function in relation to Greenland halibut by sex and for males and females together, NAFO Divs. 3L. Stage 1

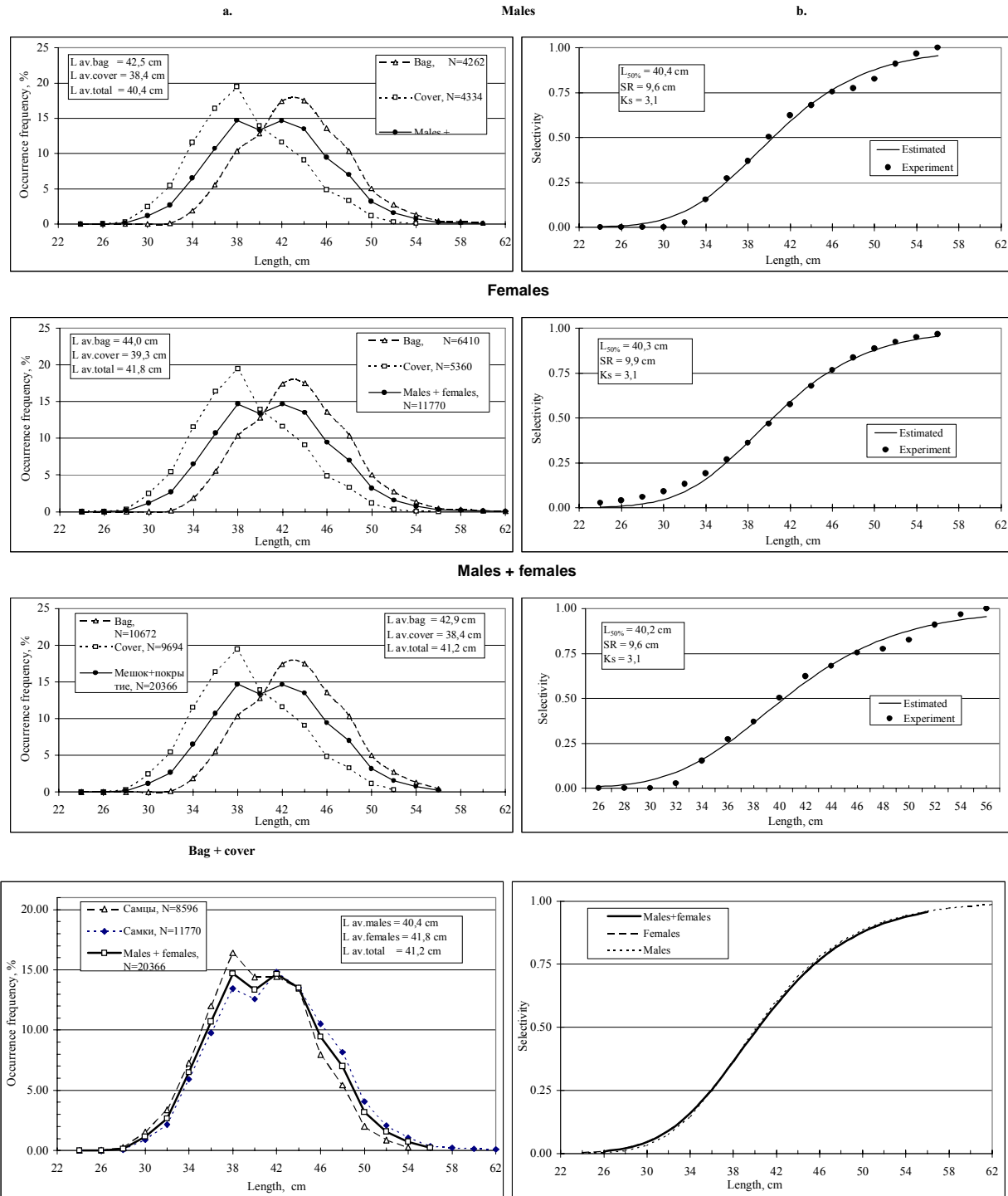


Fig. 3 Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 130.3 mm (b) estimated by generalized logistic function in relation to Greenland halibut by sex and for males and females together, NAFO Divs. 3L. Stage 2

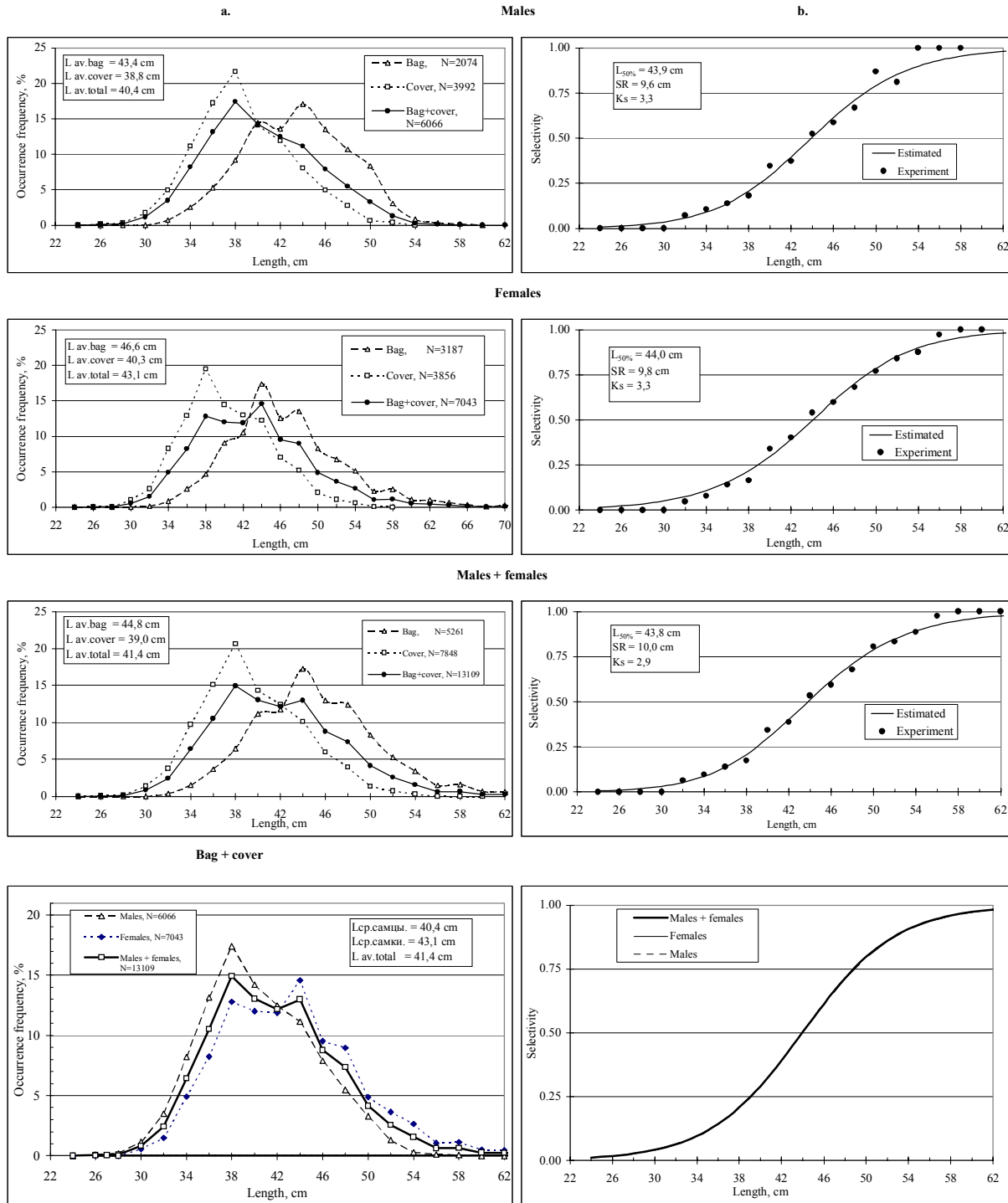


Fig. 4 Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 135.2 mm (b) estimated by generalized logistic function in relation to Greenland halibut by sex and for males and females together, NAFO Divs. 3L. Stage 2

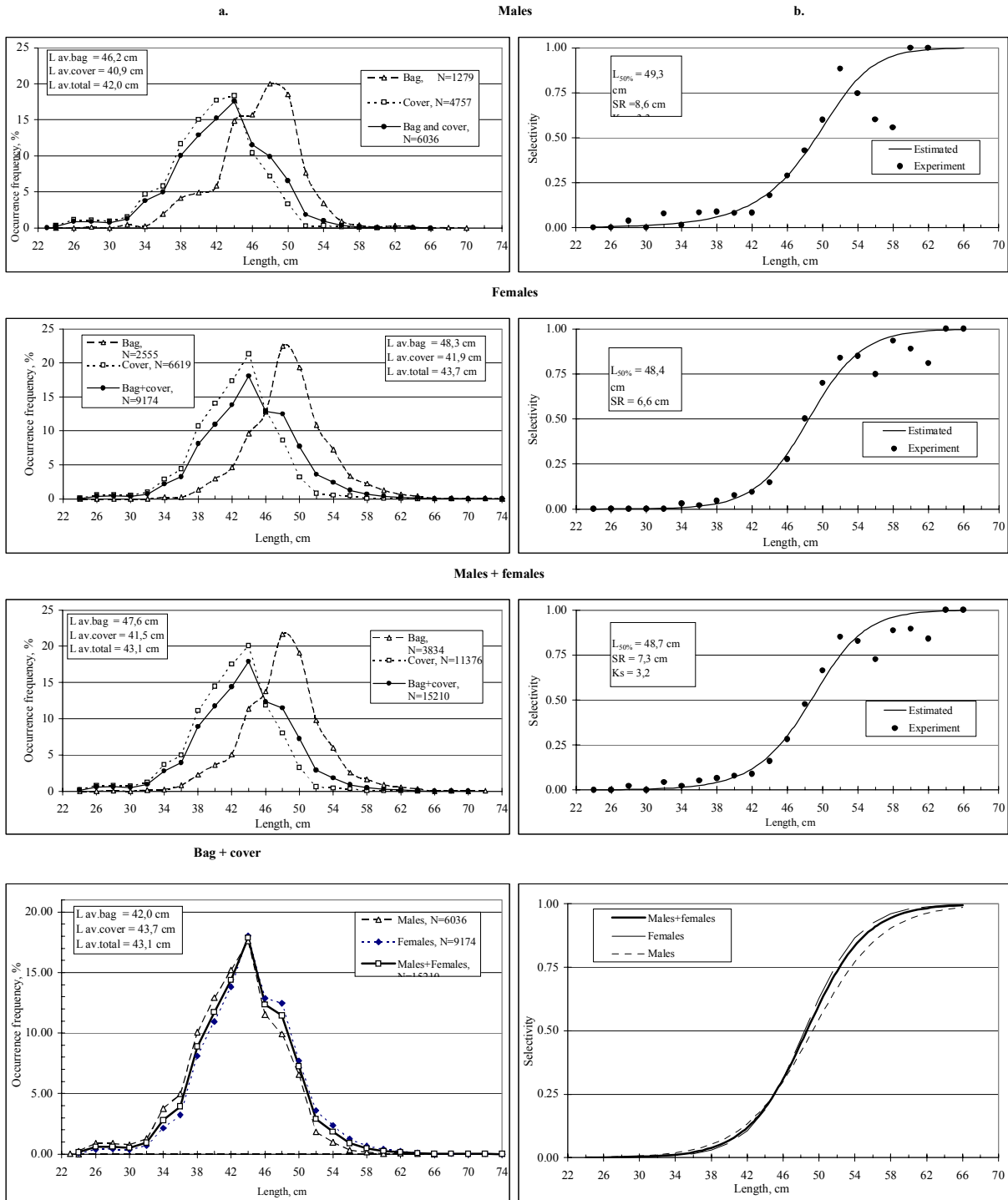


Fig. 5 Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 149.8 mm (b) estimated by generalized logistic function in relation to Greenland halibut by sex and for males and females together, NAFO Divs. 3L. Stage 2

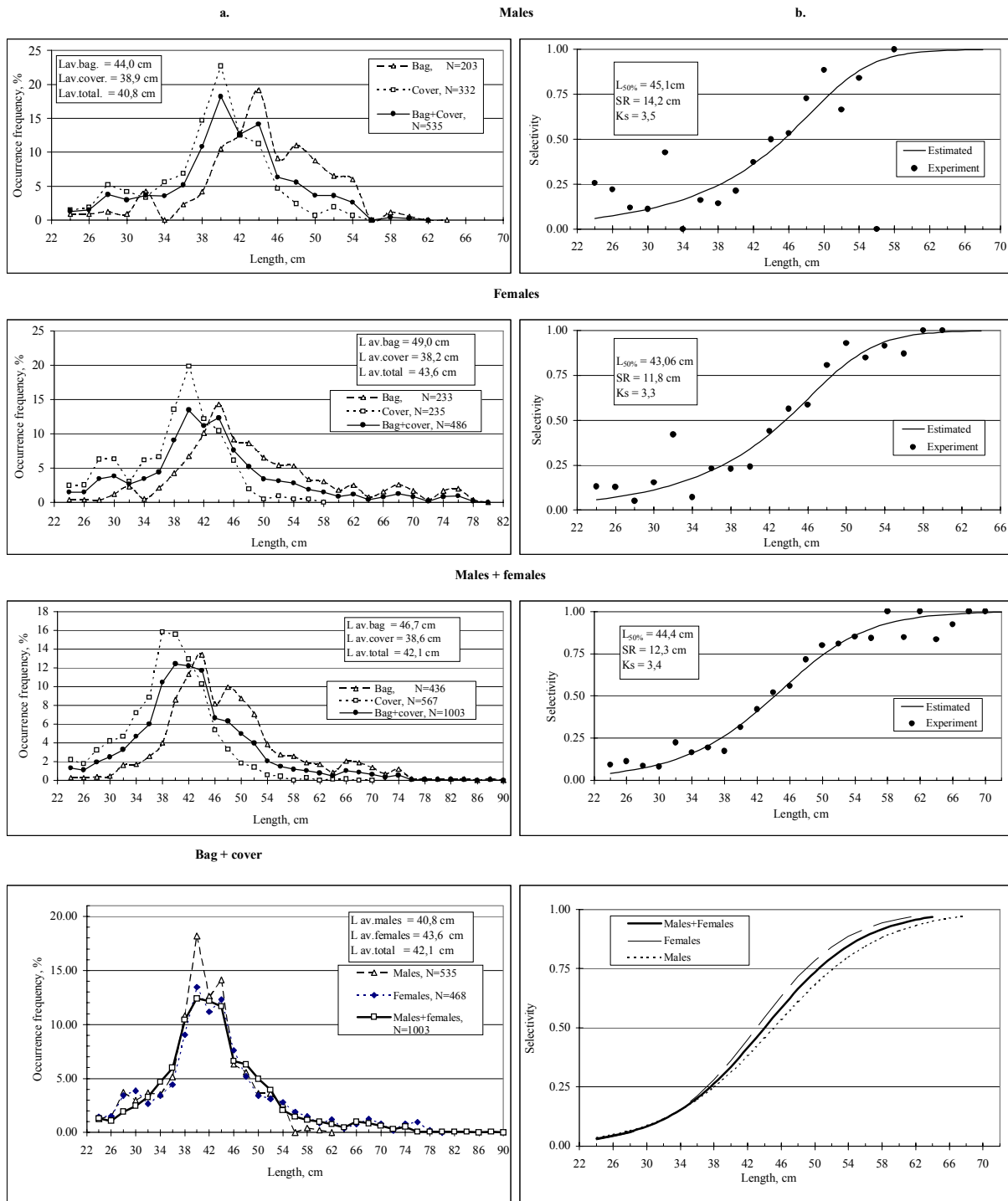


Fig.6. Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 130.3 mm (b) estimated by generalized logistic function in relation to Roundheaded grenadier by sex and for males and females together, NAFO Divs. 3L. Stage 2

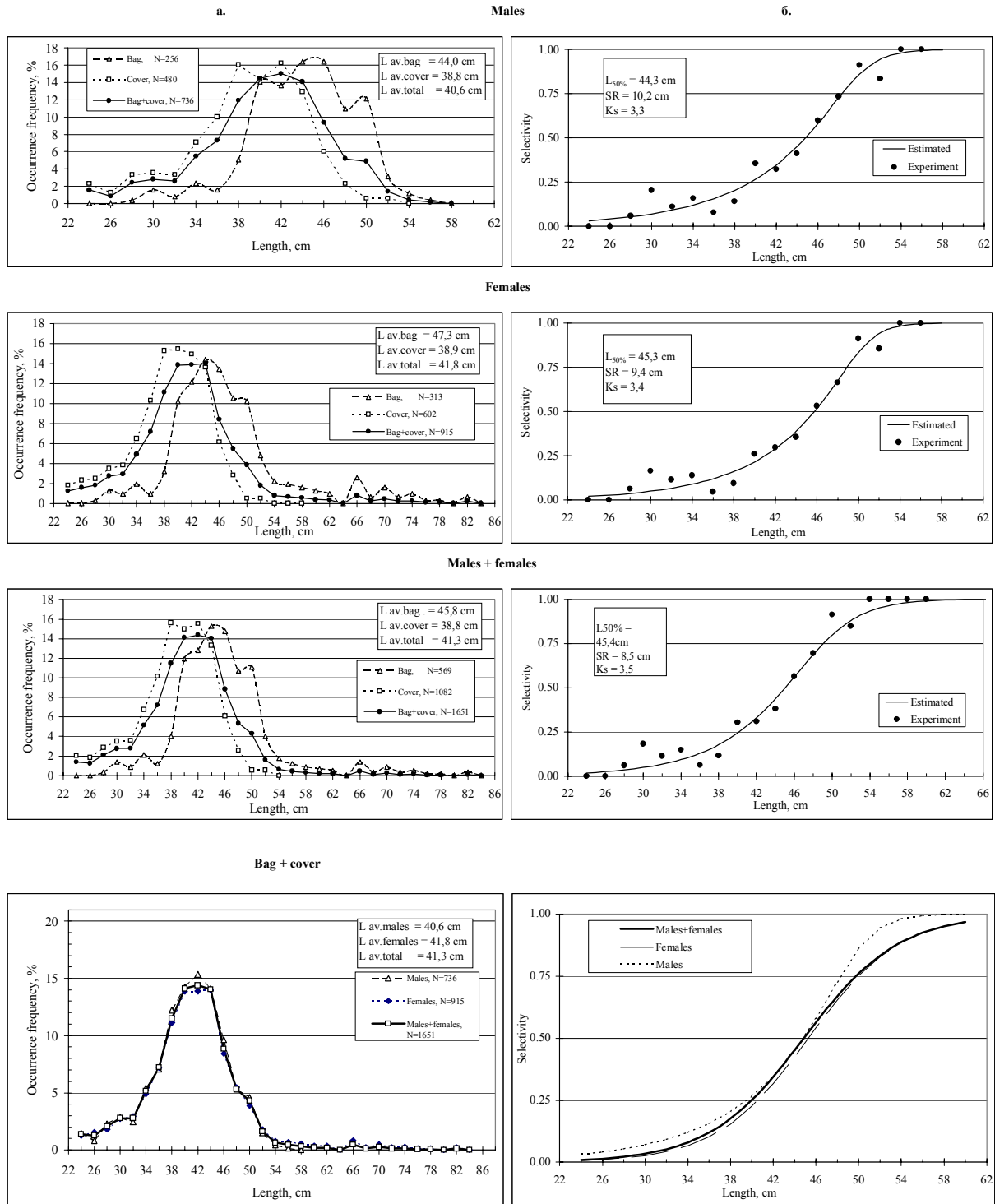


Fig. 7. Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 135.2 mm (b) estimated by logistic function in relation to Roundheaded grenadier by sex and for males and females together, NAFO Divs. 3L. Stage 2

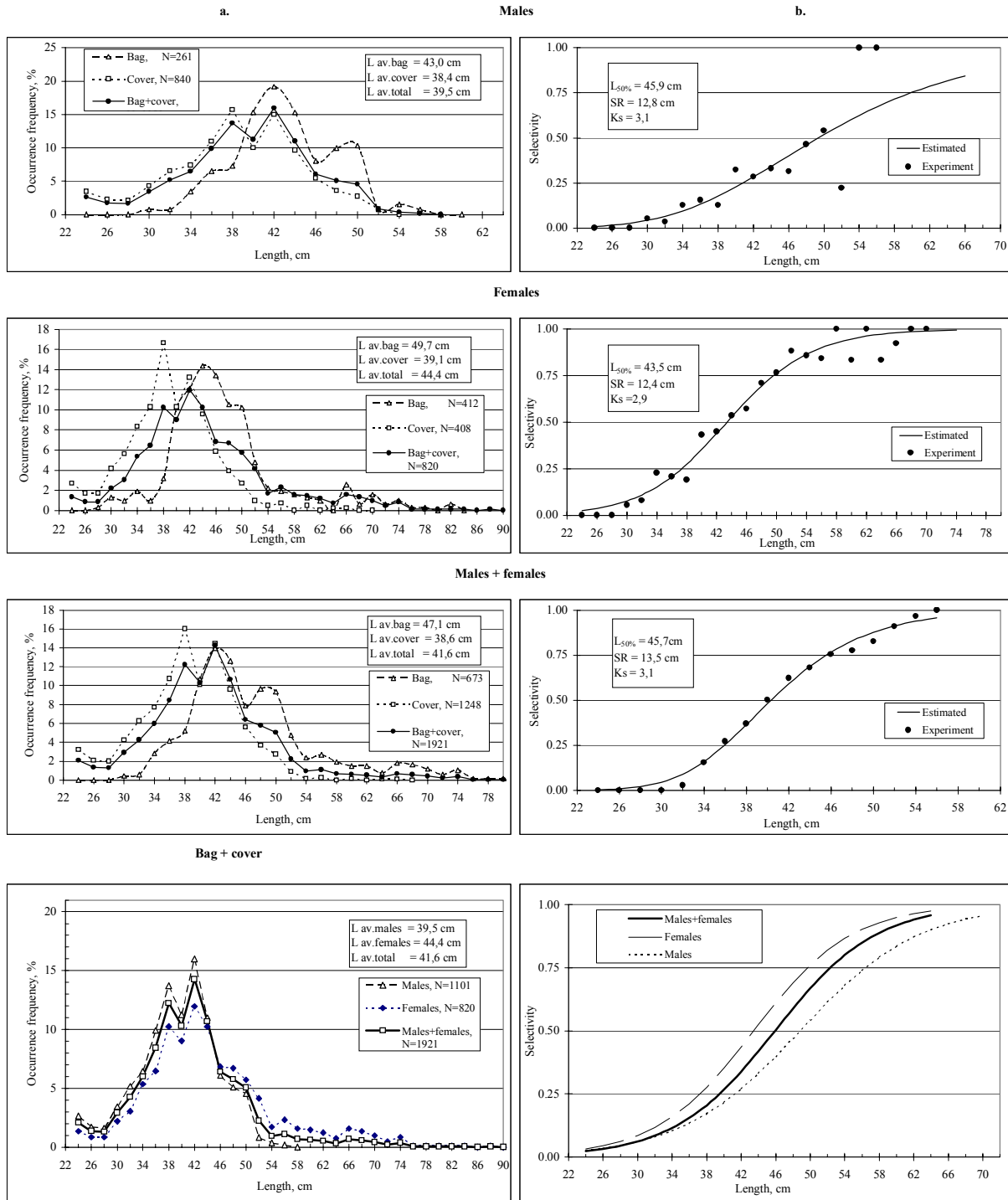


Fig.8. Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 149.8 mm (b) estimated by generalized logistic function in relation to Roundheaded greenadier by sex and for males and females together, NAFO Divs. 3L. Stage 2

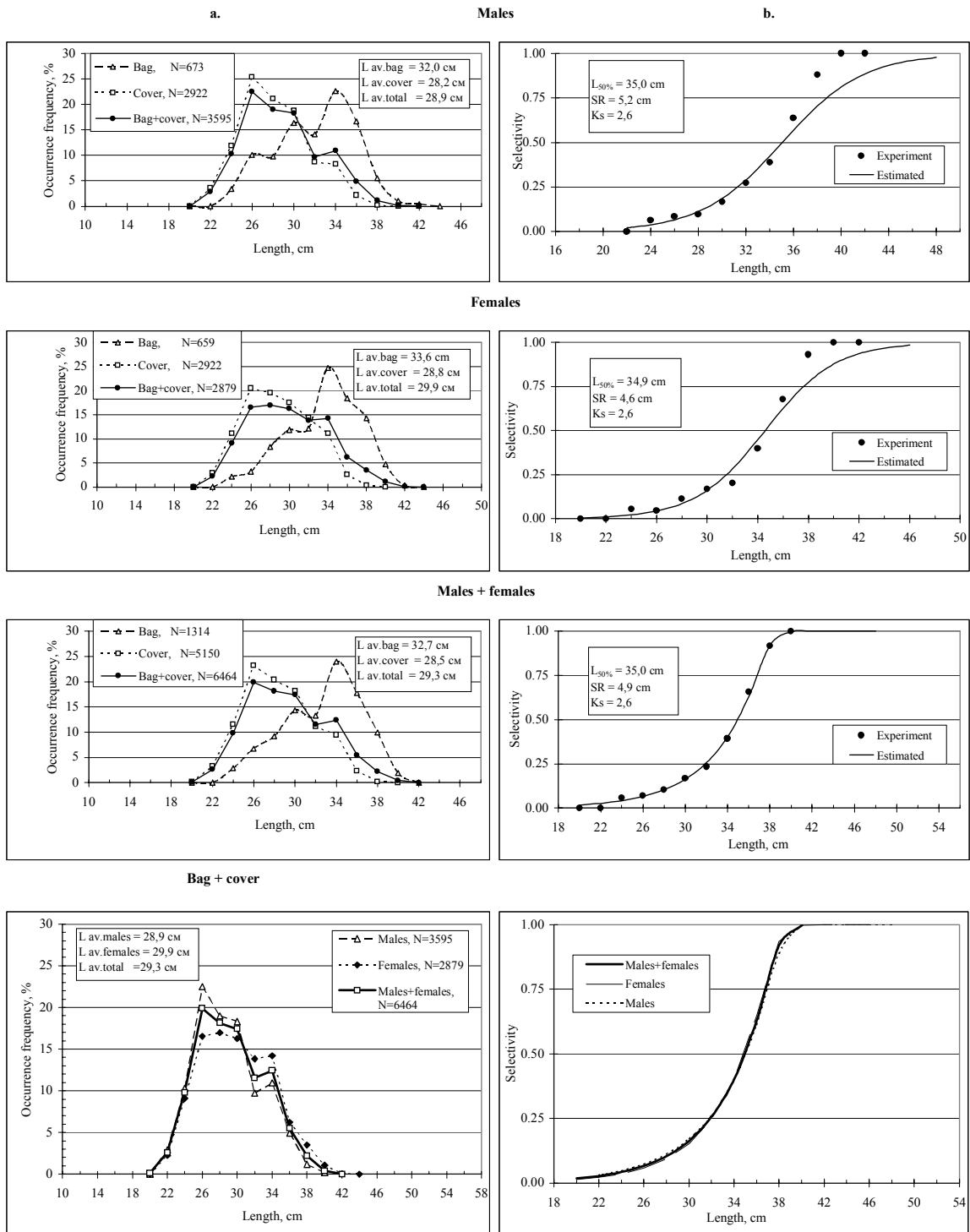


Fig.9. Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 135.8 mm (b) estimated by logistic function in relation to Redfish by sex and for males and females together, NAFO Divs. 3L. Stage 1

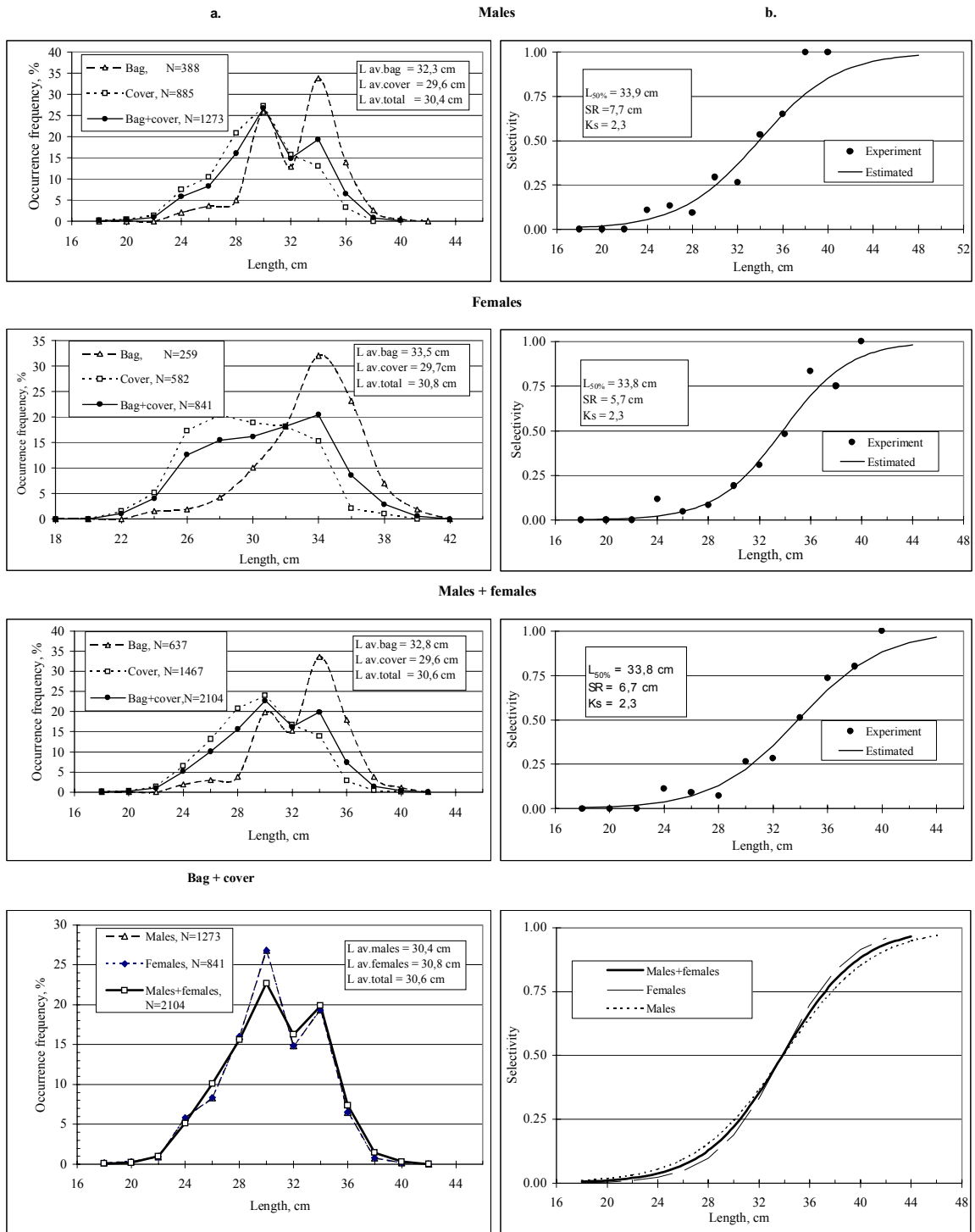


Fig.10. Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 145.4 mm (b) estimated by logistic function in relation to Redfish by sex and for males and females together, NAFO Divs. 3L. Stage 1

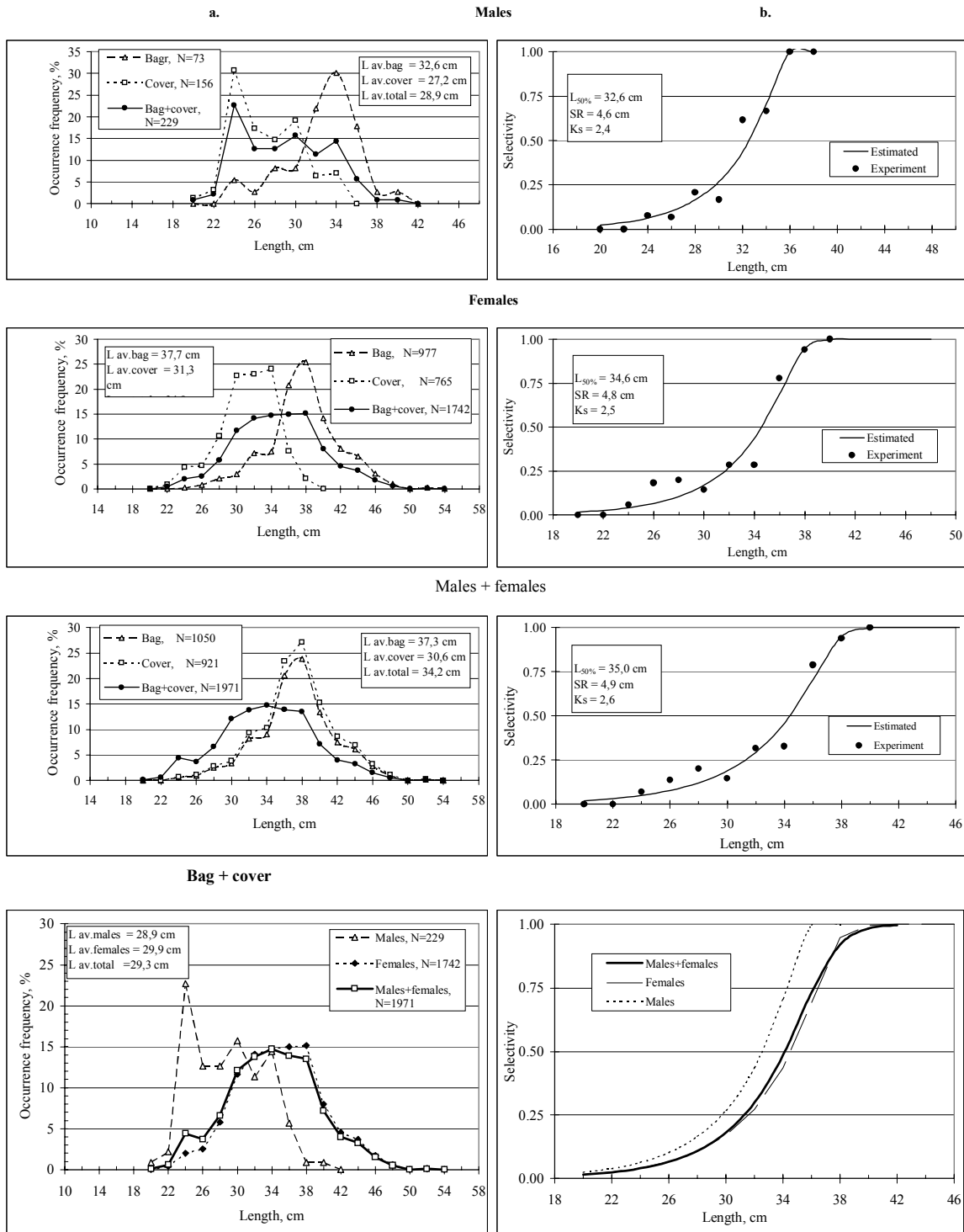


Fig.11. Size distribution of fish (a) and selectivity of trawl bag with the mesh size of 135.8 mm (b) estimated by generalized logistic function in relation to American place by sex and for males and females together, NAFO Divs. 3L. Stage 1