Avoidance of unwanted bycatch in the blue whiting fishery in Faroese Fishing Zone by use of a sorting grid system

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Abstract
Due to bycatch of unwanted species as saithe *(Pollachius virens)*, mackerel *(Scomber scombrus)*, and redfish *(Sebastes marinus)* in the blue whiting *(Micromesistius poutassou)* fishery in Faroese fishing zone, the Faroese and Russian fishery authorities decided in 2006 to introduce a special sorting grid system when fishing for blue whiting. This system is mandatory to use in large parts in the Faroese fishing zone. The system consists of a special sorting grid with 55 mm bar space, inserted in a netting section in front of the cod-end. In front of the sorting grid a small leading panel was inserted to lead the blue whiting from the escape opening for by-catch below the sorting grid. Video recordings were used to observe the behaviour of blue whiting in front of the sorting grid. To estimate the amount of the by-catch and the loss of blue whiting the alternate trawl haul method was used. Experiments in 2008 were used to analyse the amount of blue whiting escaping with unwanted species, comparison of unwanted species quantity in presence/absence of the sorting system in the trawl. By using the sorting grid a decrease of bycatch of saithe was obtained ranging from 1.46–3 times, and of all unwanted species (saithe, mackerel, redfish, and haddock) the reduction was 0.25–3.25 times.
The efficiency of the sorting grid system as a management tool depends on the abundance of by-catch in the blue whiting fishery.

Keywords: blue whiting, sorting system, unwanted species by-catch

Introduction

According Faroese fishery regulation since 2007 all fishing vessels during blue whiting fishery must use sorting system for Avoidance of unwanted bycatch.

In accordance with the Appendix 2 of the Thirty first Session in the Joint Faroese–Russian Fisheries Commission, Russian fishing vessels catching blue whiting in Faroese fishing zone were used to conduct experiments to evaluate the effectiveness of sorting grid utilization in 2008. Faroese and Russian specialists carried out the following experiments onboard of Russian commercial vessels from 5-th to 25-th of May 2008:

i)   To provide organization and execution of experiments with sorting grids, processing of collected fishing-ichthyologic data according to standard methodology.

ii) Determine the efficiency of the use of various sorting grids in relation to different vessel types and different types of trawls on Russian fishing vessels in Faroese fishing zone.

iii) Determine the mortality percentages of blue whiting due to the use of the selection grid, taken into consideration various densities of fish.

iv) Determine the efficiency of the selection of saithe and other fishes in the sorting grid.

v) Determine the efficiency of the selection grid on different concentrations of blue whiting: low < 10t/h, medium between 10 and 30t/h, and high > 30t/h.

Material and methods

The main volume of works was carried out onboard the following fishing vessels: K-1864 "Valery Dzaparidze", M-0047 "Revolutsia" and M-0002 "Admiral Shabalin".

The ships should fish both with and without sorting grid (the alternate trawl haul method).

Video observations (stage 1) were performed on the K-1864 "Valery Dzaparidze" trawler. Original autonomous underwater video complex developed in the Faroe Marine Research Institute was used to conduct underwater video observations. Complex consisted of two waterproof boxes which held power source, compact video camera, flash light and digital device for video capture recording. Overview of the video complex is given at Figure 1.

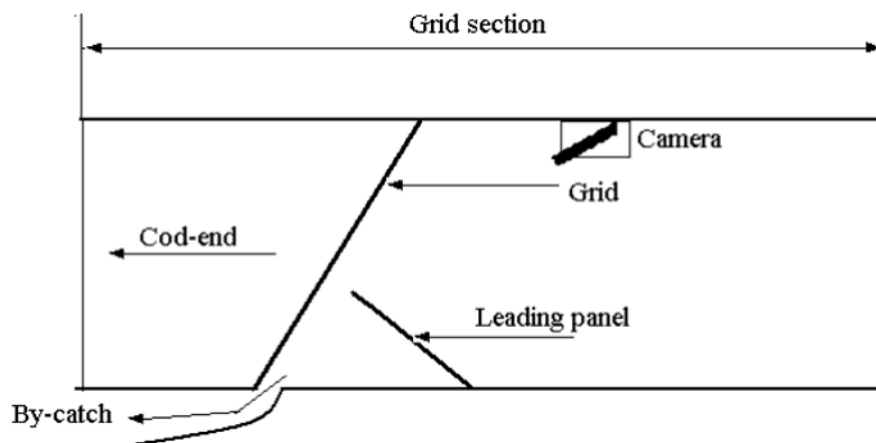**Figure 1. Common view of autonomous underwater video complex.**

Figure 2. Overview of video complex installation on the trawl codend.

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According to the objectives hauls were performed by a vessel in commercial mode using trawl equipped with the grid and one not having it by turns.

Overview of video complex installation on the trawl codend is given at Figure 2. In total, observation on the operation of sorting grids of three standard sizes with different riggings were performed using video complex. Grids of Russian manufacturers were used in the experiments. A total of 5 different experiments were conducted.

During the period of trials on the stage 2, fishing vessels with "Double" scheme were equipped with two trawls of the same or similar construction. One trawl was equipped with the grid with dimensions and rigging analogous to recommend and one that was found to be optimal during trials using video observation, the second trawl did not have the selective grid. Methodology of the experiments supposed performing hauls by turns with trawls equipped with the grid and without it. If it was possible paired hauls were performed on one commercial fish aggregation. When conducting paired hauls main parameters of hauls were kept the same.

A random sample of blue whiting (not less than 300 ind.) was taken from each catch obtained using the grid and without it. Length of each fish from the sample was measured accurate within 1 cm, and the whole sample was weighed. During catch processing all bycatch was sorted species-wise measured accurate within 1 cm and weighed. After catch processing value of the catch was estimated accurate within 100 kg using the data of finished product.

Value of species present in blue whiting bycatch was estimated as:

$$BC_\% = BC_m \times 100/(BW + BC_m),$$

where $BC_\%$ – percentage of bycatch of accompanying species, BC_m – mass of the bycatch, kg, BW – blue whiting catch, kg.

Results of experimental trials and discussion

Underwater video observations

Results of underwater video observations have shown that operation with sorting grids using during experiments was not optimal due to the following reasons (Figure 3):

a) sorting grids installed on the trawl may deform the net cover of the trawl which leads to appearance of net "pockets", so lot of fish become meshed before the grid;

b) free positioning of net edge of trawl's lower panel before the lower edge of the grid leads to appearance of a too large opening for bycatch exit and as a result significant part of the target species (blue whiting) escapes from the trawl;

c) utilization of a rubber wire or line with attached floats in order to compensate for excessive opening of bycatch exit does not give any noticeable positive effect;

d) construction of lifting panel which may be installed before the grid and its rigging increase the effectiveness of this device utilization to a significant degree;

e) 3 strops between the lover panel and the sorting grid help to maintain the shape of the sorting grid and the escape opening.
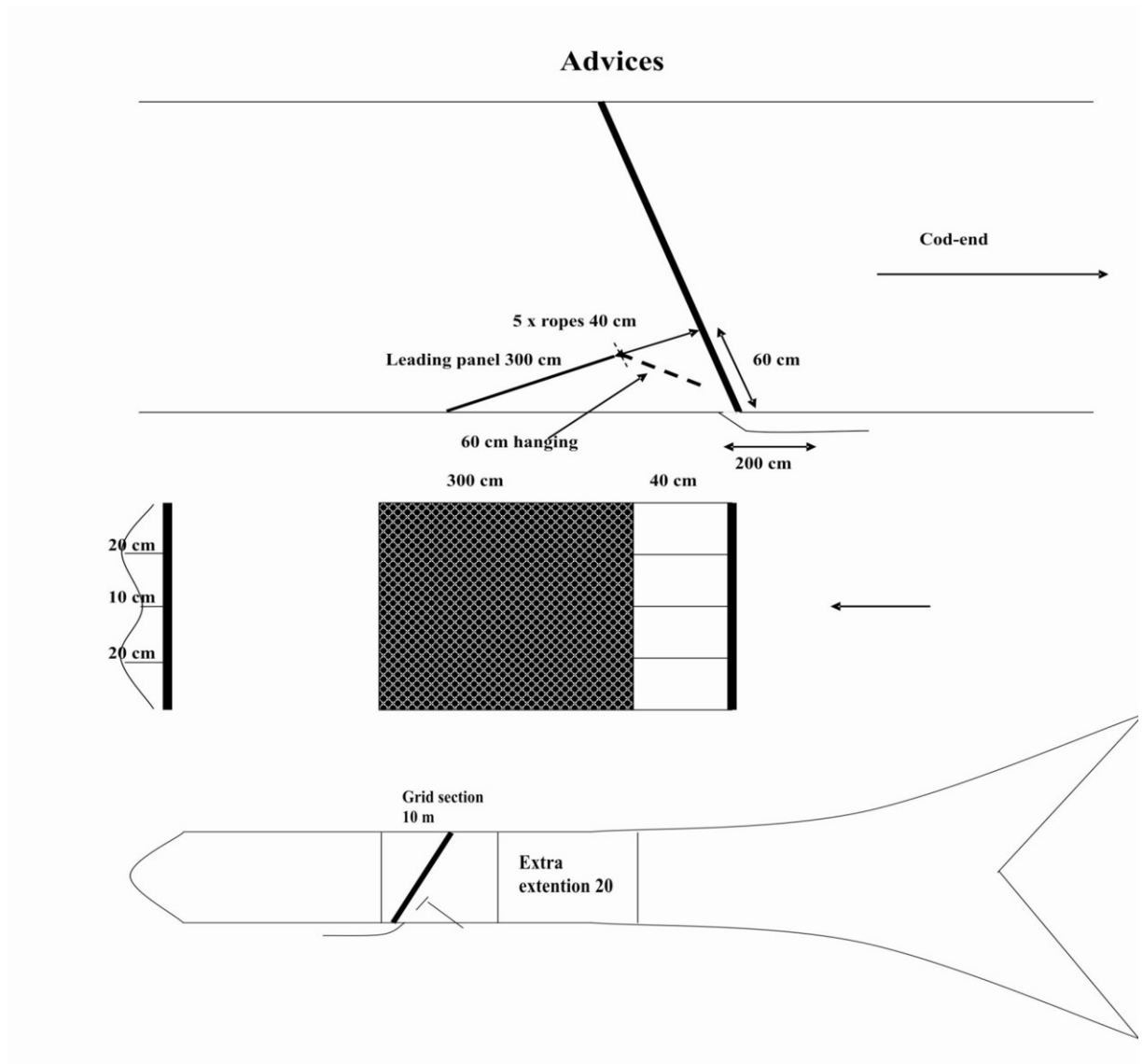
Advices

Cod-end

5 x ropes 40 cm

Leading panel 300 cm

60 cm

60 cm hanging

200 cm

300 cm

40 cm

20 cm

10 cm

20 cm

Grid section
10 m

Extra
extention 20

Figure 3. Rigging and installation of selective grid on the trawl, latest modification (= advice).

The following recommendations for the optimization of sorting grid operation and its utilization were obtained after processing the video materials and estimating the hauls' effectiveness. Main recommendations on the installation of selective grid on the trawl and its rigging:

  i) grid should be installed on the trawl in the rope frame, the grid itself should have rope stiffeners;

 ii) a lifting net panel 300 cm long with width equal to trawl's codend horizontal spreading at the place of fastening should be installed before the grid, frontal edge of the panel should be tightly fastened to the lower panel of the trawl;

iii) distance from the rear edge of the lifting panel to the grid should be around 40 cm;

 iv) free (rear) edge of the panel should be connected with the grid by 5 binds of the same length (40 cm);

  v) the points of binds' of the leading panel fastening on the grid must be 60 cm away from the lower plate of the trawl;

vi) free edge of trawl's lower plate, before the grid, is recommended to be also connected with lower edge of the grid: at the centre – bind 10 cm long and 2 side binds 20 cm long.

This modified rigging from stage 1 was then used by two of the three trawlers during the experiments in stage 2. The M-0002 "Admiral Shabalin" did not alter the rigging of the grid section according to this advice.

Some trawlers have reported that the trawl stop to catch when a certain amount of fish, good catches (> 30 t), had entered the codend. Experiences from a Faroese trawler "Atlantic Navigator", which had the same problem showed that an extension piece of 20 m netting inserted in front of the grid section solved the problem of "catch saturation".

Evaluation of selective grid utilization in blue whiting fishing

The number of hauls with and without grid by vessel is shown in Table 1, and the results of the catches of blue whiting and bycatches with some statistics is shown in Table 2.

It was decided to use pair wise hauls, one haul with and one without sorting grid, therefore the some hauls were removed in the further analysis: haul number 11 for "Valery Dzaparidze", hauls number 11, 12, 13 for "Admiral Shabalin".

Amount of the executed works and some fishing characteristics and the results of experimental hauls are presented in the Table 3, geographical positions of the fishing vessels during experiments are shown in the Figure 4.

Table 1. All number of hauls during experiments presented on parameter presence (+) absence (–) of sorting grid

K-1864 "Valery Dzaparidze"		M-0047 "Revolutsia"		M-0002 "Admiral Shabalin"	
Haul number	Presence (+)/ absence (–) of grid	Haul number	Presence (+)/ absence (–) of grid	Haul number	Presence (+)/ absence (–) of grid
1	+	1	-	1	–
2	–	2	+	2	+
3	+	3	-	3	–
4	–	4	+	4	+
5	+	5	-	5	–
6	–	6	+	6	+
7	–	7	-	7	–
8	+	8	+	8	+
9	–	9	-	9	–
10	+	10	+	10	+
11	–	11	-	11	–
		12	+	12	–
		13	-	13	–
		14	+	14	–
		15	-	15	+
		16	+	16	–
				17	+
				18	–
				19	+

Table 2. Catch weight of blue whiting and of bycatch species from experiment hauls in presence (+) absence (–) of sorting grid

Presence (+) / absence of grid	Catch, t	Haul duration, h	Catch, t h⁻¹	Bycatch of non-target species, t				
				Saithe	Mackerel	Redfish	Haddock	Total
K-1864 "Valery Dzaparidze"								
+	58.97	6.8	8.63	0.088				0.088
–	45.71	5.8	7.84	0.159	0.056			0.215
+	25.14	6.2	4.07	0.023				0.023
–	52.66	5.5	9.57	0.102		0.007	0.009	0.118
+	14.52	5.3	2.72	0.040				0.040
–	60.86	13.4	4.53	0.096	0.0002		0.009	0.106
–	36.66	9.7	3.78	0.061		0.002	0.0018	0.064
+	21.72	6.0	3.62	0.029		0.0006		0.030
–	24.72	7.0	3.53	0.343				0.343
+	44.52	4.5	9.89	0.007				0.007
–	25.00	6.0	4.17	0.009				0.009
M-0047 "Revolutsia"								
–	1.54	4.8	0.32	0.027				0.027
+	49.60	5.0	9.92	0.049				0.049
–	39.15	3.2	12.23	0.021		0.0033	0.0033	0.028
+	33.60	3.8	8.84	0.003				0.003
–	44.52	7.5	5.94	0.035				0.035
+	29.64	12.5	2.37	0.054				0.054
–	12.30	6.0	2.05	0.037				0.037
+	30.81	7.5	4.11	0.078				0.078
–	4.95	6.3	0.79					0.000
+	8.80	8.7	1.06	0.008				0.008
–	19.00	9.0	2.11	0.090				0.090
+	26.96	6.0	4.49	0.060				0.060
–	40.50	4.7	8.62	0.082				0.082
+	17.29	8.0	2.16	0.066			0.0028	0.069
–	27.79	8.7	3.19	0.123			0.001	0.124
+	30.96	6.5	4.76	0.034				0.034
M-0002 "Admiral Shabalin"								
–	39.5	5.5	7.18	0.072	0.027			0.099
+	61.5	7.0	8.79	0.038	0.011			0.049
–	82.5	2.0	41.25	0.05	0.016			0.066
+	29	4.0	7.25	0				0.000
–	30.5	6.0	5.08	0.009			0.003	0.012
+	27.3	3.0	9.10	0.004	0.028			0.032
–	56	3.5	16.00	0	0.015			0.015
+	12.3	3.5	3.51	0				0.000
–	14.7	5.0	2.94	0				0.000
+	28.5	6.0	4.75	0				0.000
–	3.7	2.0	1.85	0.025				0.025
+	1.3	3.5	0.37	0.008				0.008
–	44	10.0	4.40	0.031				0.031

+	38.5	2.5	15.40	0.072		0.072
–	28.5	16.0	1.78	0.072		0.072
+	23.5	7.0	3.36	0		0.000

Table 3. Fishing parameters of experimental hauls.

Parameters	Fishing vessel		K-1864 "Valery Dzaparidze"	M-0047 "Revolutsia"	M-0002 "Admiral Shabalin"
Date of experiments			12–18 May	12–18 May	19–25 May
Haul count	with grid		5	8	8
	without grid (valid)		6 (5)	8	11 (8)
Total time of haul, h	with grid		28.83	57.7	35.5
	without grid		41.42	50.2	74.5
Mean time of haul, h	with grid		5.77	7.2	4.44
	without grid		6.9	6.28	6.77
Total catch, t	with grid		164.87	227.7	222.1
	without grid		245.6	189.7	391.5
Catch per haul, t	with grid	average	33.0	28.5	27.8
		min-max	14.5–59.0	8.8–49.6	1.3–44.5
	without grid	average	40.9	23.7	35.6
		min-max	24.7–60.9	1.5–44.5	3.7–82.6
Catch per hour of haul, t h^{-1} (on valid hauls), т/ч	with grid	average	5.79	4.71	6.57
		min-max	2.72–9.89	1.06–9.92	0.37–15.4
	without grid	average	5.88	4.41	10.06
		min-max	3.53–9.57	0.32–12.22	1.78–41.25
Bycatch (on valid hauls), t	with grid		0.19	0.36	0.16
	without grid		0.85	0.42	0.32

As it may be seen from Table 3, that absolute catches over haul on all vessels taking part in the experiment fluctuated in a broad range. This may be explained by an unstable commercial situation and big differences in catches obtained during night and day hauls. However it should be noted that catches of "Admiral Shabalin" and "Valery Dzaparidze" vessels, both average and catch fluctuations ranges with trawls equipped with grids are significantly lower than catches of trawls without grids. Opposite is observed for "Revolutsia" – average catches of trawl equipped with grid are higher than catches of trawl without grid and so are the minimum and maximum limits of catch fluctuations range.

Aim of conducted experiments was to study two main aspects of commercial fishing conditioned by the utilization of selective grids, namely:

i) revelation of possible impact of grids on catch size, as the results of commercial fishing in 2007 have shown that installation of sorting grid on to the trawl leads to a 20–50% decrease of the catch, according to different estimates;

ii) estimation of the decrease of bycatch species value on specialized blue whiting fishing due to the utilization of sorting grid, obtained data were processed based upon the aim set.
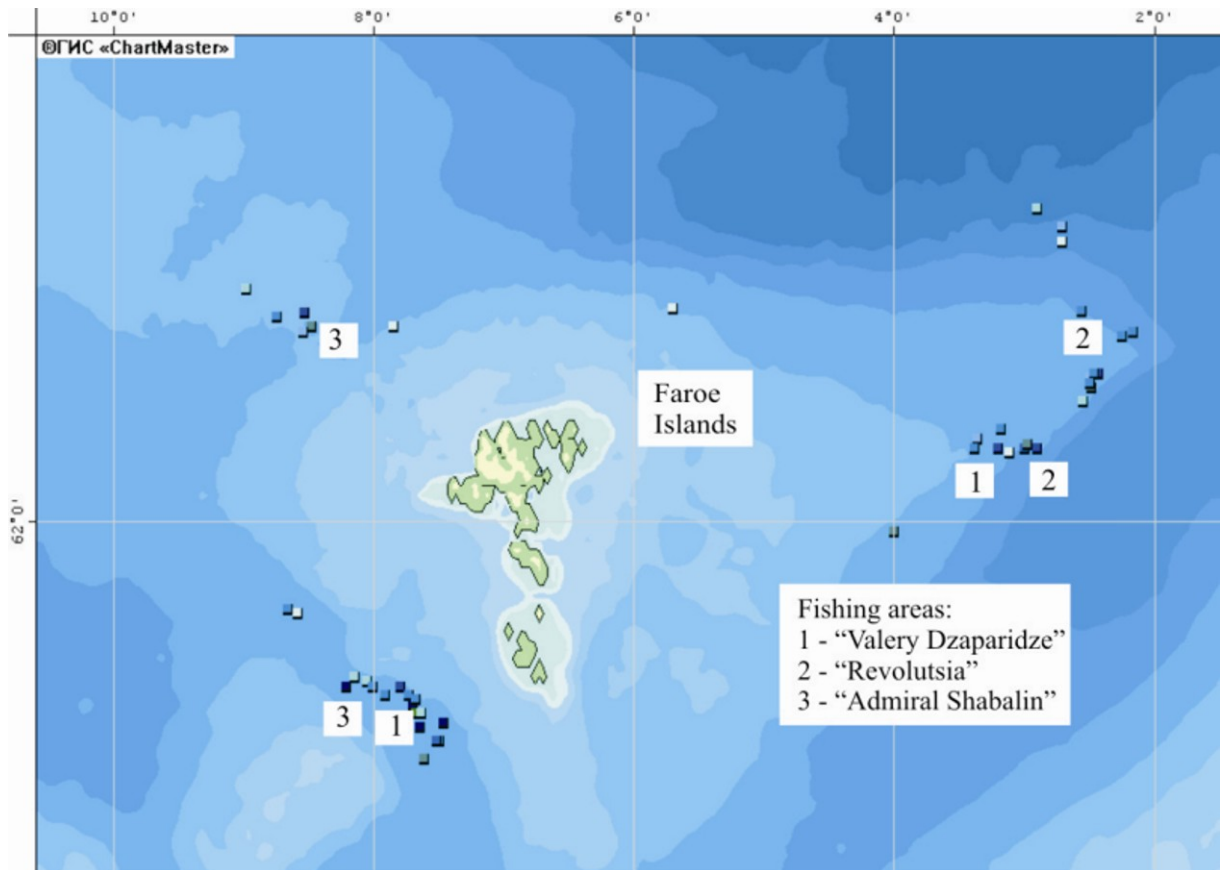
Figure 4. Fishing areas with experimental hauls in Faroese fishing zone in May 2008.

Evaluation of grid impact on catch size

As it is seen from Table 4 average values of catch per unit effort (hour of haul) for first two ships are also higher when working with trawls without grids, however the differences were insignificant:

a) by 34.72% in "Admiral Shabalin" trawler (6.56 t h^{-1} – with grid and 10.06 t h^{-1} – without);

b) difference in catches of trawls with grid and without it was on "Valery Dzaparidze" trawler – 1.57% (5.79 t h^{-1} – with grid and 5.88 t h^{-1} – without).

c) inverse relation was observed on "Revolutsia" trawler, average catches per hour of trawl with grid were higher by 4.54% than those of trawl without grid.

In case when the grids are used, decrease of catch per hour of haul is observed according to averaged data of all catches (Table 5), however, the difference was not significant on a 70% level.

So the differences of trawl catches per hour with grid and without it on "Admiral Shabalin" in comparison with "Valery Dzaparidze" and "Revolutsia" may be explained by the fact that grid on the trawl of this vessel was operated not taking into account the recommendations obtained through video observations on improvement of the grid operation during trawling, while both "Valery Dzaparidze" and "Revolutsia" had their trawls equipped with grids considering the recommendations on rigging described earlier. Another reason for such differences in catches may be some differences between two comparing trawls.

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Table 4. Results of statistical analysis CPUE with and without sorting grid.

Parameters of statistical analysis	Catch, t h⁻¹		Difference in catches with grid (+) and without (−), %
	with grid (+)	without grid (−)	
K-1864 "Valery Dzaparidze"			
	8.63	7.84	
	4.07	9.57	
	2.72	4.53	
	3.62	3.92	
	9.89	3.53	
Mean value	5.79	5.88	−1.57
Standard deviation	3.24	2.68	
Standard error	1.45	1.20	
Kolmogorov-Smirnov criterion	K-S = 0.31, p = 0.99 (p> 0.3)		
Mann-Whitney criterion	W = 13, p = 0.99 (p > 0.3)		
M-0047 "Revolutsia"			
	9.92	0.32	
	8.84	12.23	
	2.37	5.94	
	4.11	2.05	
	1.06	0.79	
	4.49	2.11	
	2.16	8.62	
	4.76	3.19	
Mean value	4.71	4.41	+6.52
Standard deviation	3.16	4.20	
Standard error	1.12	1.48	
Kolmogorov-Smirnov criterion	K-S = 0.75, p = 0.63 (p > 0.3)		
Mann-Whitney criterion	W = 25, p = 0.49 (p > 0.3)		
M-0002 "Admiral Shabalin"			
	8.79	7.18	
	7.25	41.25	
	9.10	5.08	
	3.51	16.00	
	4.75	2.94	
	0.37	1.85	
	15.40	4.40	
	3.36	1.78	
Mean value	6.57	10.06	−34.73
Standard deviation	4.65	13.42	
Standard error	1.64	4.74	
Kolmogorov-Smirnov criterion	K-S = 0.5, p = 0.96 (p > 0.3)		
Mann-Whitney criterion	W = 30, p = 0.87 (p > 0.3)		

Thus for all items involved in different types of statistical analysis (parametric and distribution-free analysis) differences are insignificant for catches per hour for hauls with and without grid. Therefore the influence of presence (absence) sorting grid on variation of catches can be accepted as not proved (Table 5).

Table 5. Result of statistical analysis CPUE with and without sorting grid for three fishing vessels involving in experiment.

Parameter of statistical analysis	Catch, t h^{-1}		Difference in catches with grid (+) and without (−), %
	with grid (+)	without grid (−)	
Mean value	5.67	6.91	−17.88
Standard deviation	3.72	8.79	
Standard error	0.81	1.92	
Single-factor analysis of variance, ANOVA	F = 0.35, p = 0.55 (p > 0.3)		

Estimation of sorting grids impact on size distribution of blue whiting

We present the size-weight composition in the Table 6. Blue whiting catch consisted of mature individuals with the length from 18 to 39 cm, mean weight of one individuals vary from 95 to 133 g. Main modal group 26–29 cm consisted more than 60% of catch. The size difference between fish from catches with and without grid was insignificant and was in the range of measurement error. The difference of blue whiting length structure from the catches with and without grid practically can't be observed.

Table 6. Length and weight characteristics of blue whiting from the experiment catches.

Parameters / Fishing vessel		K-1864 "Valery Dzaparidze"	M-0047 "Revolutsia"
Modal row, cm		18–38	20–39
Modal size froup, cm		27–29	26–29
Mean length, cm	with grid	28.08	27.74
	without grid	28.17	27.54
	over all hauls	28.13	27.64
Mean weight of one individual, g	range	111–133	95–115
	mean	121	107

Estimation of impact of selective grids utilization on the bycatch value

The main designation of selective grids on blue whiting fishing in the Faroese fishing zone is the decrease of unwanted bycatch species. Such species are saithe, redfish, haddock – fish species whose sizes are significantly bigger than those of blue whiting. 42 samples from catches were taken in order to analyze size-weight composition of the catch and estimate the size and biologic characteristics of the bycatch.

The main objects encountered in the bycatch are shown in Table 7. Saithe was the most abundant species (Table 8), bycatch of other species was may be evaluated as "singular" as it was unstable and did not bear any mass character. Typical linear sizes of the bycatch: haddock — length 47–63 cm, redfish — length 34–45 cm, mackerel — length 23–38 cm, herring — length 28–31 cm. As the experimental hauls took place in different local regions, size-weight characteristics of target commercial species and bycatch could differ significantly on different vessels.

Table 7. Samples of fish taken from the catches for analysis during the experiments.

Fishing vessel / Species in bycatch	M-0002 "Admiral Shabalin"	K-1864 "Valery Dzaparidze"	M-0047 "Revolutsia"	Total
Total number of samples taken from the catch for analysis (blue whiting)	15	11	16	42
Including species, ind.:				
blue whiting	5585	3682	5326	14593
saithe	53	368	322	743
haddock	3	13	7	23
mackerel	170	27	1	198
redfish	–	7	10	17
anchovy	34	–	–	34
squid	37	40	-	77

It may be seen from the Table 8 saithe bycatch consisted of large individuals 46–90 cm long with mean mass of one individual over 2 kg. It is seen also that saithe from the catches of trawl equipped with grid is always smaller than such from trawls without it. Difference in mean length was: 6.32 cm on M-0002 "Admiral Shabalin", 0.56 cm on K-1864 "Valery Dzaparidze", 1.27 cm on M-0047 "Revolutsia". Bycatch data from every experimental haul are shown in Table 9.

Table 8. Size-weight characteristics of saithe from the blue whiting catch

Fishing vessel / Parameters		M-0002 "Admiral Shabalin"	K-1864 "Valery Dzaparidze"	M-0047 "Revolutsia"
Modal row, cm		62–90	50–88	46–86
Modal size group, cm		Not observed	Not observed	Not observed
Mean length, cm	with grid	69.14 (in 1 haul)	67.06	64.73
	without grid	75.46	67.63	66.0
	over all hauls	74.62	67.52	65.40
Mean mass of one individual, g	range	1786–2640	2275–3788	1715–3533
	mean	2242	2757	2550

Table 9. Data on the bycatch

Parameter / Fishing vessel	Haul number	With grid (+) without grid (–)	Total catch, t	Bycatch Saithe Weight, t	Bycatch Saithe % of catch	Other % of catch	Total % of catch
M-0002 "Admiral Shabalin"	1	-	39.6	0.072	**0.18**	0.07	0.25
	2	+	61.6	0.038	0.06	0.02	0.09
	3	-	82.6	0.05	**0.06**	0.03	0.09
	4	+	29.0	0	0.00	0.00	0.00
	5	-	30.5	0.009	**0.03**	0.01	0.04
	6	+	27.3	0.004	0.01	0.11	0.13
	7	-	56.0	0	**0.00**	0.03	0.03
	8	+	12.3	0	0.00	0.00	0.00

Vessel	#						
	9	-	14.7	0	**0.00**	0.00	0.00
	10	+	28.5	0	0.00	0.03	0.03
	11	-	31.0	0.021	**0.07**	0.00	0.07
	12	-	46.2	0.095	**0.21**	0.28	0.49
	13	-	14.5	0.03	**0.21**	0.00	0.21
	14	-	3.7	0.025	**0.67**	0.00	0.67
	15	+	1.3	0.008	0.61	0.00	0.61
	16	-	44.0	0.031	**0.07**	0.00	0.07
	17	+	38.6	0.072	0.19	0.00	0.19
	18	-	28.6	0.072	**0.25**	0.00	0.25
	19	+	23.5	0	0.00	0.00	0.00
K-1864 "Valery Dzaparidze"	1	+	59.0	0.088	**0.15**	0.00	0.15
	2	-	45.7	0.159	0.35	0.07	0.49
	3	+	25.1	0.023	**0.09**	0.00	0.09
	4	-	52.7	0.102	0.19	0.03	0.24
	5	+	14.5	0.040	**0.28**	0.00	0.28
	6	-	60.9	0.096	0.16	0.01	0.18
	7	-	36.7	0.061	0.17	0.00	0.18
	8	+	21.7	0.029	**0.13**	0.00	0.14
	9	-	24.7	0.343	1.37	0.00	1.37
	10	+	44.5	0.007	**0.02**	0.00	0.02
	11	-	25.0	0.009	0.04	0.00	0.04
M-0047 "Revolutsia"	1	-	1.50	0.027	1.69	0.00	1.69
	2	+	49.6	0.049	**0.10**	0.00	0.10
	3	-	39.2	0.021	0.05	0.02	0.07
	4	+	33.6	0.003	**0.01**	0.00	0.01
	5	-	44.5	0.035	0.08	0.00	0.08
	6	+	29.6	0.054	**0.18**	0.00	0.18
	7	-	12.3	0.037	0.30	0.00	0.30
	8	+	30.8	0.078	**0.25**	0.00	0.25
	9	-	5.0	0.000	0.00	0.00	0.00
	10	+	8.8	0.008	**0.09**	0.00	0.09
	11	-	19.0	0.090	0.47	0.00	0.47
	12	+	27.0	0.060	**0.22**	0.00	0.22
	13	-	40.5	0.082	0.20	0.00	0.20
	14	+	17.3	0.066	**0.38**	0.02	0.40
	15	-	27.8	0.123	0.44	0.00	0.44
	16	+	31.0	0.034	**0.11**	0.00	0.11

Analyzing trawl catches during the period when experiments were conducted it should be noted that bycatch of unwanted species on all 3 vessels was significantly lower than set limit of 2% both when the grid was used and when it was not. Of 46 hauls, in only 2 of them bycatch was more or less significant: this is haul #9 (without grid) on K-1864 "Valery Dzaparidze" when bycatch was 1.37% of the catch and haul #1 on M-0047 "Revolutsia" when catch was 1,5 t and share of saithe was 1.69%. It is evident from the current experiments that during the spring (May) fishery for blue whiting in the main local commercial regions the bycatch is insignificant, less than 2 %, even when the sorting grid is not used (Table 10).

Table 10. Averaged data on the bycatch (% of total catch)

Parameter	Fishing vessel	M-0002 "Admiral Shabalin"	K-1864 "Valery Dzaparidze"	M-0047 "Revolutsia"
Haul without grid	Saithe	0.16	0.38	0.40
	Total	0.22	0.42	0.41
Hauls with grid	Saithe	0.11	0.13	0.17
	Total	0.13	0.14	0.17

Figure 5 gives graphical representation of general (total) bycatch in catches with trawls equipped with the grid and ones that were not.
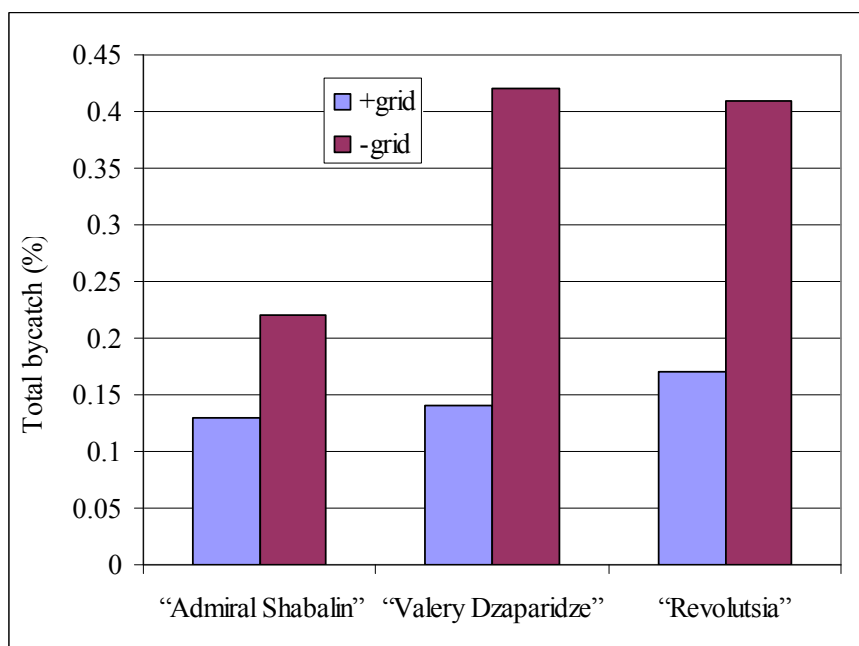

Figure 5. Ratio of total bycatch in catches of trawls equipped with and without the grid.

Results of experimental hauls, averaged data on bycatch values, tell that installation of sorting grid on to the trawl has decreased saithe bycatch/general bycatch in blue whiting commercial fishing, correspondingly:

i) on M-0002 "Admiral Shabalin" by 1.46 and 1.7 times;

ii) K-1864 "Valery Dzaparidze" by 3 and 3 times;

iii) M-0047 "Revolutsia" by 2.4 and 2.4 times.

Thus for all items involved in different types of statistical analysis (parametric and distribution-free analysis) differences are insignificant for bycatch in hauls with and without grid. Only Mann-Whitney test indicates that bycatch without grid for K-1864 "Valery Dzaparidze" was significantly more on 325%. Therefore the influence of presence (absence) sorting grid on variation of bycatch can be accepted as not proved.

Though in whole we see increasing of bycatch – total value for 3 fishing vessels involved in the experiment on the average on 166.67% for the bycatch without sorting grid (Table 12). Thereby presence of sorting grid leads to decreasing of non-target species.

Table 11. Results of statistical analysis of non-target species bycatch (saithe, mackerel, redfish, haddock) in hauls with and without sorting grid.

Parameters of statistical analysis	Bycatch, t		Difference in bycatch with grid (+) and without (–), %
	with grid (+)	without grid (–)	
K-1864 "Valery Dzaparidze"			
Bycatch for the haul	0.088	0.215	
	0.023	0.118	
	0.040	0.106	
	0.030	0.064	
	0.007	0.343	
Mean value	0.04	0.17	–325.0
Standard deviation	0.03	0.11	
Standard error	0.01	0.05	
Kolmogorov-Smirnov criterion	K-S = 1.2, p = 0.08 (p < 0.3)		
Mann-Whitney criterion	W = 24, p = 0.02 (p < 0.3)		
M-0047 "Revolutsia"			
Bycatch for the haul	0.049	0.027	
	0.003	0.028	
	0.054	0.035	
	0.078	0.037	
	0.008	0.000	
	0.060	0.090	
	0.069	0.082	
	0.034	0.124	
Mean value	0.04	0.05	–25.0
Standard deviation	0.03	0.04	
Standard error	0.01	0.01	
Kolmogorov-Smirnov criterion	K-S = 0.75, p = 0.62 (p > 0.3)		
Mann-Whitney criterion	W = 34, p = 0.87 (p > 0.3)		
M-0002 "Admiral Shabalin"			
Bycatch for the haul	0.049	0.099	
	0.000	0.066	
	0.032	0.012	
	0.000	0.015	
	0.000	0.000	
	0.008	0.025	
	0.072	0.031	
	0.000	0.072	
Mean value	0.02	0.04	–100.0
Standard deviation	0.03	0.03	
Standard error	0.01	0.01	
Kolmogorov-Smirnov criterion	K-S = 1.0, p = 0.27 (p > 0.3)		
Mann-Whitney criterion	W = 44, p = 0.20 (p < 0.3)		

Table 12. Results of statistical analysis of non-target species bycatch in hauls with and without sorting grid for three fishing vessel.

Parameter of statistical analysis	Bycatch, t		Difference in bycatch with (+) and without grid (–), %
	with grid (+)	without grid (–)	
Mean value	0.03	0.08	–166.67
Standard deviation	0.03	0.08	
Standard error	0.01	0.02	
Analysis of variance, ANOVA	$F = 27, p = 0.14 (p < 0.3)$		

Conclusions

1 Based on the tests done in the first part of the experiments, to optimise the sorting grid, on rigging and grid installation was implemented on the Russian vessels (except on "Admiral Shabalin"). The modifications to the trawl and grid proposed as a result of underwater observations helped to optimize the operation of this selective device. Underwater observation had shown that the sorting grids used in blue whiting fishery previously operated unsatisfactory. Failures of working form of trawl mesh cover where the grid was set and raised, local meshing was observed. Opening for by-catch exit in the lower panel of the trawl was too big due to the hydrodynamic flow created during process of haul which led to a big number of escapes of the target species – blue whiting. Most of these problems were overcome by the suggested changes.

2 Experiments conducted to evaluate the influence of sorting grid on the blue whiting catch value, when the grid was operated and rigged according to recommendations did not show any significant differences (significance level 95%) on the decrease of catch per unit effort with trawls equipped with grid compared with trawls that were not. Catches in presence of a grid in the trawl decreased on 1.57% for "Valery Dzaparidze", increased on 6.52% for "Revolutsia", and decreased on 34.73% for "Admiral Shabalin", it should be pointed out that "Admiral Shabalin" did not alter the rigging of the grid section according to the improvements in the advice from the trials in experiment 1.

3 During the period when the experiments have been carried out there were no big by-catch of non-target species in the areas. By using the sorting grid a decrease of by-catch of saithe was obtained ranging from 1.46–3.0 times, and of all non-target species (saithe, mackerel, redfish, and haddock) the reduction was 0.25–3.25 times. During the time the experiments were conducted the by-catch proportions were significantly lower than 2%, which is the limit set by the Faroese regulations. Therefore there seems to be no need to use the sorting grid in the spring period of blue whiting fishing.

4 For receiving statistically proved data in spring time it is advisable to carry out similar trials in spring 2009 on one trawler in the course of 14–15 fishing days period. During the spring 2009 experiments it is necessary to use collection bag to measure the quantity and quality of fish that pass through the escape opening in front of the sorting grid – both of catch (blue whiting) and by-catch.