9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

INCLINED WATER FLOW AND ITS APPLICATIONS FOR REDUCED BYCATCH IN SHRIMP TRAWLS

by

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Abstract

The use of the Nordmøre grid in the Pandalus fishery has significantly reduced the bycatch of finfish. Grids operate on physical separation based on size to achieve bycatch reduction. However, problems arise when the size range of fish overlaps the shrimp.

In this paper results from an initial trial in northern Norway with a new selection device creating a vortex circulating out of the escape opening to force/stimulate fish are presented. The water flow (vortex) seemed to be fairly low and varied during the six observations hauls. Observations of fish behaviour showed that 0-group cod and haddock reacted to the water flow created by the device. The escape rate of fish varied between the six hauls possibly due to the variation in flow pattern.

Introduction

In the course of the past few decades the development of various devices for installation in trawls has considerably reduced bycatches of unwanted species. Such devices include grids in shrimp trawls, which have reduced the bycatches of both fish and turtles (Isaksen et al., 1992; Watson et al., 1986; Mitchell et al., 1995). However, situations arise in which grids based on physical separation do not function satisfactorily because the species and/or size groups to be sorted out are the same size, or smaller than, the target species. Examples from our own fishing ground include 0-group cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and redfish (*Sebastes* spp.) in the shrimp fishery.

Where it has proved impossible to use grids, selection devices that exploited differences in the swimming characteristics of fish and shrimp have been designed (Valdemarsen and Isaksen, 1986; Watson et al., 1986). To a great extend it has been possible to separate the fish from the shrimp inside the trawl itself. The problem has often been that the fish will not actively leave the trawl via the escape window during trawling (Engås et al., 1999) This is because the fish sense that the water velocity is greater outside than inside the trawl (Engås et al., op. cit.). In the course of testing a new type of selection device in the Gulf of Mexico it was discovered that this devices created a vortex whereby the water current circulated out of the escape opening at an angle relative to the horizontal plane (vertical water current). Observations revealed that fish that were attached to the escape window were immediately stimulated to leave the trawl (Engås et al., 1999).

This paper describes the results from an initial trial in northern Norway with a prototype selection device as described above. The experiment had the following objectives; study the behaviour of 0-group cod and haddock near the escape window and to determine whether there is a potential loss of shrimp when the new device is employed.

Material and methods

The experiment was carried out in Lyngenfjorden, Northern Norway in February 2001 onboard "Jan Steinar". Towing speed during the experiment was 1.2 knots. The selection device was mounted in the extension 135 cm behind the lower part of the Nordmøre grid (Figure 1). In addition to the device a tunnel was mounted above the device in order to lead the shrimp past the area with the escape window and the vertical water current and to guide the fish to the release window. A camera using artificial light was mounted in the lower part of the extension looking forward towards the escape window. White thin twine was mounted at several positions in the area of the selection device in order to identify the water flow direction.

A total of six successful observations hauls were carried out.

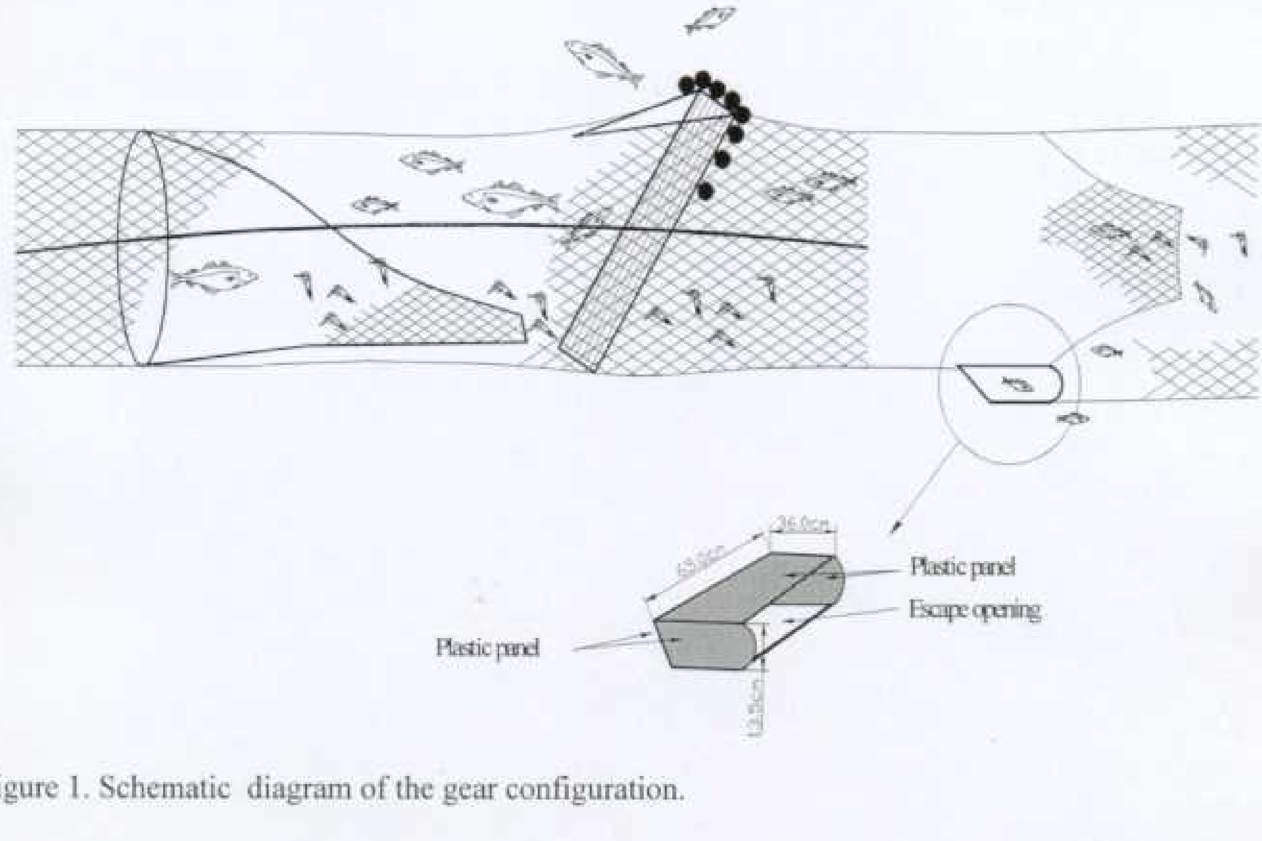

Figure 1. Schematic diagram of the gear configuration.

Results and discussion

The twine showed that the water circulated through the escape opening, back into the trawl, and forward toward the escape opening (Figure 2). The water flow (vortex) seemed to be fairly low and varied during the tow depending on factors such as the position of the selection device and the position of the lower funnel in relation to the device. During some hauls, especially when a high number of shrimp entered through the tunnel, it was observed that shrimp was "caught" in the lower part of the funnel. As shrimp accumulated in this area, a "bag" was created which was forced down below the top plate of the selection device by the water flow. This created a barrier to water flow forward towards the escape opening; i.e. reducing the vortex.

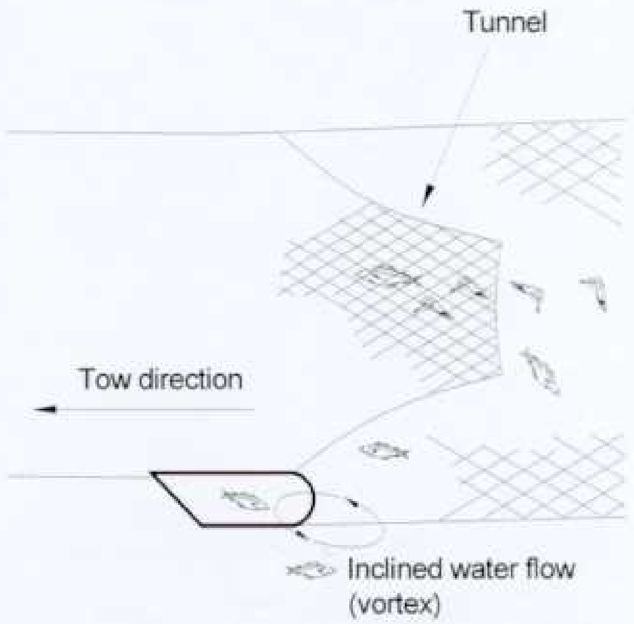

Figure 2. Schematic presentation of the water flow pattern.

Fish that passed through the tunnel where observed swimming forward towards the escape window. When entering the back part of the vortex they were observed turning towards the codend (i.e. towards the water flow). Some fish escaped immediately as they entered the escape opening, but the majority was observed swimming with very low tail beat frequency inside the selection device for an extended period, before they escaped or when back towards the codend. If these fish came forward again during the tow is impossible to know from the observations. One possible reason that fish took up a position in the area of the escape opening for an extended period without being forced or stimulated to leave may be due to the low water flow as indicated above. Despite that, the number of fish observed escaping compared to the catch, showed that the escape rate for cod varied between 11 and 100 %, while it varied between 0 and 66% for haddock (Table 1). It is reason to believe that this is an underestimate since the observations lasted for only one hour, while towing time varied between two and three hours. No shrimp loss through the escape opening was observed during the six hauls.

Table 1.Results obtained from catch and observation data.

Haul no.	Duration (hrs)	Catch of cod (no.)	Observed cod escaped (no.)	Catch of haddock (no.	Observed haddock escaped (no.)
1	1.5	3	5	10	0
2	2.5	11	13	1	2
3	3.0	4	3	4	1
4	2.0	0	7	1	0
5	2.0	16	5	7	1
6	2.5	9	3	8	2

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ON EVALUATION OF THE EFFECTS OF APPLYING THE SORTING GRID SYSTEMS IN THE FISHERY FOR ARCTO-NORWEGIAN COD

by
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Abstract

Based on the results of 12 300 trawling hours by fishing and research-fishing vessels of PST and SRTM-type in the Barents and Norwegian Seas in June-December 2000, the influence of sorting grids on mean efficiency of cod fishery is studied. A long-term effect of increase in the spawning stock abundance due to sorting grids is shown. The use of grids in trawls with 125 and 135 mm meshes reduces by-catch of undersized cod and enhances the efficiency of fishery by both type vessels. The increase in the abundance of the cod stock in general and of its mature part in particular is calculated as 3%.

Introduction

At the 25th Session of the Joint Russian-Norwegian Fisheries Commission the decision was taken about mandatory application of sorting grids in the limited areas of the Barents and Norwegian Seas since 1 January 1997, as an additional conservation measure to protect young Arcto-Norwegian cod and haddock Results from studies of selectivity of cod trawls both with and without grids, as well as from the experiments conducted by fishing vessels, served as the basis for this decision. The studies were focused on the reduction in young fish by-catches and, to a less extent, on a possibility to improve efficiency of the fishery.

Therefore, based on the analysis of results from fishery, the paper attempts to evaluate actual efficiency of sorting grids used in cod trawls.

The effect of sorting grids upon the mean fishing efficiency of PST- and SRTM- type vessels, which fished cod in the Barents and Norwegian Seas from June to December 2000, is considered in the paper. Besides, an existence of a long-term effect consisting in the increase of the abundance of the spawning cod stock due to the sorting grids in trawls used by the PST-type vessels, is shown.

Materials and methods

The results obtained during 12 313 hours of trawling performed by the fishing vessels, as well as by research and fishing vessels (PST- and SRTM-type), equipped with the trawls (125 and

135 mm mesh size) with and without sorting grids, served as the basis of the paper. The hauls were performed in the Barents and Norwegian Seas from June to December 2000.

Data on length composition of catches were collected by scientific observers. Catches of cod from each haul were classified by length groups with a 5-cm interval, beginning from 6 cm. The total of 855 439 individuals were measured. By comparison, the total fishing effort of PST-type vessels in fishery for cod with the other demersal fish by-catch in the Barents and Norwegian Seas made up 28 700 trawling hours for June-December 2000, and the total number of cod measured in the Barents Sea for the whole year 2000 was 1 336 191 individuals. Length frequencies and the number of trawling hours were aggregated by vessel type, mesh size and rigging of trawl (with a grid or without it), month and area of operation. Data on the fishery and on the samples collected from catches are given in Table 1.

The effect of sorting grids upon the fishing efficiency of vessels was analysed on the basis of variations in length composition and of growth in cumulative proportion of cod retention with fish length increasing from 6, 41 and 46 cm in a mean catch per trawling hour. Existence of the long-term effect of increase in the spawning population abundance due to sorting grids, was calculated by comparing losses and a potential growth of the mature fish abundance during operations of PST-type vessels.

The losses and potential growth of the mature fish abundance due to sorting grids were calculated by the following algorithm. The assumption was made that new trawls were with grids, and old ones - without them, and had the trawl bags with 125 and 135 mm mesh size; the weight of catch taken by new trawls was assumed to be equal to the weight of catch that was actually taken by the old trawls in June-December 2000.

The fishing effort of PST-type vessels equipped by new trawls will then be equal to:

$$f_1 = f_0 \cdot \frac{\overline{B}_{f_0}}{\overline{B}_{f_1}} , \qquad (1)$$

where

- f_0 is actual fishing effort of PST-type vessels rigged with old trawls in the Barents and Norwegian Seas for June-December 2000, [trawl.hr.];
- $\overline{B}_{f_0}$ is mean efficiency of PST-type vessels rigged with old trawls in the Barents and Norwegian Seas for the period investigated, [kg/trawl.hr.];
- $\overline{B}_{f_1}$ is mean efficiency of PST-type vessels rigged with new trawls in the Barents and Norwegian Seas for the study period, [kg/trawl.hr.].

Mean fishing efficiency of PST-type vessels equipped by new and old trawls (Table 1) was defined by the following equalities:

$$\overline{B}_{f_0} = \sum_k \overline{C}_{f_0,k} \cdot \overline{\omega}_k \qquad (2)$$

and

$$\overline{B}_{f_1} = \sum_k \overline{C}_{f_1,k} \cdot \overline{\omega}_k \qquad (3)$$

where $\overline{C}_{f_0,k}$ and $\overline{C}_{f_1,k}$ are mean catch of cod of the size group K pr. 1 hour of trawling by PST-type vessels equipped by respectively old and new trawls [individuals]; k=1, 2, 3, ..., 27;

$\overline{\omega}_k$ is mean weight of one cod the length of which corresponds to the middle point of the size interval k, [kg]. Mean weight was calculated by age samples from Russian catches taken by conventional trawl in the Barents and Norwegian seas in 2000.

Knowing the fishing efforts f_0 and f_1, we calculated the total amount of cod for each 5-cm interval k, caught by old and new trawls

$$C_{0,k} = \overline{C}_{f_0,k} \cdot f_0 \,, \qquad (4)$$

$$C_{1,k} = \overline{C}_{f_1,k} \cdot f_1 \,, \qquad (5)$$

and their deviations:

$$\Delta C_k = C_{0,k} - C_{1,k} \,. \qquad (6)$$

Positive deviations ΔC_k denote a lower fishing efficiency and show the current losses of the fleet equipped by new trawls. On the other hand, they indicate the number of fish which successfully passed through the codend with grid and did not die in fishery. These are chiefly small immature fish. It is assumed that additional natural mortality of these fish caused by damages from grids is equal to zero. A certain portion of them will survive and join the spawning stock, thus being the source of potential abundance increase. Conversely, negative deviations of ΔC_k denote a higher fishing efficiency and show the current gains of the fleet. They account for larger and mostly mature fish the amount of which indicates the current decline of the stock abundance in general and future loss of the spawning stock. To estimate the potential increase of the spawning stock, as well as the potential damage to its abundance, the age composition of all deviations ΔC_k was defined. Then the total amount of fish in each age group with a positive or negative sign was calculated. The abundance of these fish was computed as of the beginning of the 4th quarter of 2000. The age composition of the deviations ΔC_k was defined using the length-age key converted to weight-age key. The loss and the potential increase in the abundance of the spawning stock in 2001 and in the subsequent years were defined on the basis of natural and fisheries mortality coefficients, as well as the portion of mature fish, accepted by the ICES Arctic Fisheries WG for 2000 (Anon., 2001).

Results and discussion

Length composition of cod catches per 1 hour of trawling by the PST and SRTM- type vessels equipped by trawls with 125 and 135 mm mesh size with and without sorting grids infers that the bulk of catches was made up by fish within a narrow length range – from 50 to 70 cm (Figs. 1a, 2a, 3a, 4a). In all cases the length frequencies had two local maxima and one or two local minima. The former corresponded to cod length of ca. 40 and 60 cm, or to the yearclasses of respectively 1997 and 1995. The local minima corresponded to the length of ca. 20 and 45 cm, or to the yearclasses of 1999 and 1996. The presence of the local minima suggests that the strength of the yearclasses of 1999 and 1996 is lower than that of the adjoining ones. In catches obtained with grids the length frequency mode of large cod was generally higher and that of small cod – lower than in catches taken without grids.

The lowest length of retained cod – 6 cm - was recorded for the PST vessels rigged by trawls without grids with the 125 mm mesh size. The amount of cod from the first length group – from 6 to 10 cm - made up 3.05% of the total amount of fish in catch per one hour of trawling, which is quite a high value. Sorting grids increased the minimum length of retained juveniles by 10 cm. Total number of fish (16 cm and larger) in mean catch pr. one trawling hour did not decrease much (Table 1), but the amount of cod in the length group from 16 to 20 cm was nearly halved, being only 0.15%. The portion of cod from 6 to 20 cm length declined by more than one order of magnitude – by 37 times. The amount of young cod of up to 41 and 46 cm length decreased by respectively 7 and 5 times. In trawls with grids, a slight reduction in the portion of larger fish – 41 cm and longer and 46 cm and longer – was also observed, while in trawls without grids this reduction constituted 30 and 34%, respectively. As a consequence, the number of large cod of more than 41 cm and more than 46 cm length in trawls rigged with grids in relation to trawls without grids rises steeply by 32 and 38%, respectively. Hence, in spite of the fact that the number of individuals from 6 cm on in the mean catch per tow diminishes, total biomass of fish in the catch increases by 28%. Even more increases the mean weight of catch of cod from 41 cm on and from 46 cm on – by 36 and 38 %, respectively.

Variation of the cumulative portion of cod retention in relation to the increase of cod length (length of retention ℓ_k) depends on the initial size of fish retained (ℓ_0) in both trawls rigged with grids and not. Cumulative portion of cod of any size retained in trawls without grids is higher than that in trawls with grids if the initial length of fish retained is 6 cm (Figure 1b). In this case the discrepancy between the portions reduces with the increase of length of retained fish. The discrepancy between the portions becomes much lower as the initial size of fish retained increases. At $\ell_0 = 41$ cm it is small even for fish of $\ell_k = 41$ cm, and is close to zero for fish with the length of retention of 56 cm and more (Figure 1c). At $\ell_0 = 46$ cm there is no discrepancy even for fish with retention length equal to ℓ_0 (Figure 1d). The coincidence of retention curves in Figure 1d shows that at $\ell_0 = 46$ cm the ratio between the number of cod of fixed length ℓ_k in trawls with grid and corresponding number of cod in trawls without grid is proportional to the ratio of both numbers of cod with length from ℓ_0 and larger in these trawls. Having assumed that the number of cod from ℓ_0 on with the retention length of ℓ_k is equally available to these trawls and taking into account that the total number of such cod in trawls with grids is larger (Table 1), it may be inferred that efficiency of these trawls with respect to cod of $\ell_k \geq \ell_0$ length is also higher, and their ratio to the respective efficiency of trawls without grids is equal to the following ratio:

$$\frac{\sum_k \overline{C}_{f_1,k}}{\sum_k \overline{C}_{f_0,k}} \qquad (7)$$

So, the application of sorting grids in trawls with 125 mm mesh size used by vessels of PST-type precludes by-catch of undersized cod below 16 cm, reduces by-catch of juveniles up to 41 and 47 cm approximately by respectively 7 and 5 times and increases efficiency of trawls with respect to large cod. Hence, the efficiency of PST vessels for cod of more than 41 and 46 cm increases by 36 and 38 %, respectively, which should lead to a considerable reduction of fishing effort and expenses of PST vessels.

The application of sorting grids in trawls with 135-mm mesh size used by PST-type vessels produced somewhat different results. First, the minimum length of cod retained in trawls with and without grids is the same and equal to 16 cm, and the number of fish from the first size group - from 16 to 20 cm - retained by each trawl accounts for less than 0.01%. Portion of juveniles below 41 and 46 cm in both trawls is low and close to that in trawls with 125-mm mesh size rigged with sorting grids. The reduction in the number of fish retained with the increase of the initial size ℓ_0 up to 41 and 46 cm is insignificant in both trawls (Table 1). Secondly, cumulative portion of the retained cod of $\ell_k \geq 46$ cm at the initial size of retained fish of 16, 41 or 46 cm in trawls without grids is larger compared to trawls with grids (Figure 2b, c, d). This is due to the fact that the portion of cod of 41-65 cm length in trawls without grids is larger than in trawls with grids (Figure 2a). However, the number of large fish of 65 cm length and more in trawls rigged with grids is larger, thus fishing efficiency of these trawls is higher by 16 %. Number of large fish in both trawls is far higher than that in trawls with 125-mm mesh size equipped with grids.

The use of sorting grids in trawls with 125-mm mesh size by SRTM-type vessels also proved efficient. Minimum length of cod retained in trawls with grids and without them is equal to 16 cm, and the number of fish of the first size group, from 16 to 20 cm, retained by each trawl make up 0.0007 and 0.0004 %, respectively. In trawls rigged with grids the portion of juveniles of up to 41 and 46 cm length is far less, and the portion of cod of $\geq$ 50 cm length is larger (Figure 3a). The change in retention curves (Figure 3b, c, d) is similar to that for trawls with the same mesh size used by vessels of PST-type. These peculiarities increase the efficiency of SRTM-type vessels rigged by trawls with grids compared to trawls without grids (Table 1). This increase is estimated at 42%. It is worth noting that the efficiency of SRTM-type vessels fishing with such trawls compared to trawls with the same mesh size used by PST-type vessels is 10-17% higher.

Particularly advantageous is the use by SRTM-type vessels of grids in trawls with 135-mm mesh size. Minimum retention length of cod in trawls with and without grids is equal to 26 cm (Table 1) and the number of fish in the first size group, from 26 to 30 cm, retained by each trawl constitutes 0.01 and 0.06%, respectively. Juveniles of up to 41 and 46 cm occur in these trawls also in insignificant amounts (Figure 4a). In trawls with grids they account for 1.8 and 2.5%, in trawls without grids 3.5 and 5.3%, respectively.

However, in trawls with grids the portion of fish from 41 cm on and from 46 cm on was much higher - by respectively 41 and 43% - than in trawls without grids. The absolute amount of these fish in trawls with grids was more than in any trawls applied by PST vessels and in any trawls with 125 mm mesh applied by SRTM-vessels. The alteration of the retention curves (Figs. 4 b, c, d) is similar to that of the retention curves presented in Figs. 3 b, c, d. Due to this, the fishing efficiency of SRTM-type vessels equipped by trawls with grids was by 41% higher than that of trawls without grids (Table 1).

Variations in the abundance of the cod stock resulting from the application of sorting grids in trawls with 125 mm mesh size by PST vessels in June-December 2000, are shown in Table 2. It follows from the table that age composition of retained and lost fish differ markedly. The portion of retained fish exceeds that of lost fish by almost 7 times. Abundance increases owing to cod aged 1-4 years. The increase is incommensurably low as compared to the stock abundance. In comparison with the effect of cannibalism the abundance growth in cod aged 1-3 years is also extremely low. The last ratio will not be changed if we roughly suppose that the annual Russian catch in 2000 was taken by PST-type vessels and with the mentioned fishing gears. However, by this assumption, this catch will make up about 3% of the stock abundance.

The increase in the abundance of mature fish due to the "saved" juveniles will occur in two years (Table 3). It will continue to grow into 2008, but its rate will increase only to 2003. Annual losses will be the greatest in 2001 and will continue into 2005. The annual damage to the spawning stock will be compensated in 2 years, i.e. in 2003. The abundance growth will exceed the losses by 3 000 individuals. The summarised abundance increase will also become visible in 2 years, amounting to 11 000 individuals. In 8 years it will increase by 7.7 times and reach 85 000 individuals. Mean annual increase in the abundance of mature fish relative to the abundance of the spawning stock will also be low – less than 3%.

CONCLUSIONS

Applying of sorting grids in trawls with a 125 mm mesh size by PST-type vessels, excludes by-catch of undersized cod of below 16 cm length, that corresponds to the age 1, reduces by-catch of young fish below 41 and 46 cm length by respectively ca. 7 and 5 times and increases the trawl fishing efficiency in regard to large cod. Therefore, efficiency of PST-type vessels fishing for cod of 41 cm and larger and 46 cm and larger increases by 36 and 38%, respectively. It increases by 28% when fishing cod of 6 cm long and above.

Applying of sorting grids in trawls with a 135 mm mesh size by the same vessels does not result in an increase of the minimum size of retained cod. The minimum size is 16 cm. The proportion of young fish below 41 and below 46 cm in both trawls is insignificant, being close to the proportion of juveniles of the corresponding length in trawls with a 125 mm mesh size, equipped by sorting grids. The proportion of fish ≥65 cm in trawls with sorting grids is higher, therefore the fishing efficiency of these trawls is higher by 16%.

Applying of sorting grids in trawls with 125 mm mesh size by SRTM-type vessels, is also efficient. The minimum size of cod retained in trawls with and without grids is 16 cm, and the amount of fish in the first length group, from 16 to 20 cm, retained by each trawl is nearly by 2 orders of magnitude lower than the corresponding number of fish in the same-type trawls applied by PST-type vessels. The proportion of young fish of below 41 cm and below 46 cm length is much lower in trawls with grids and the proportion of cod ≥ 50 cm is higher. The fishing efficiency of SRTM-type vessels equipped by trawls with grids, compared to those operating without grids, is higher by 42%. For PST-type vessels the increase in fishing efficiency, compared to those using a trawl with a 125 mm mesh size, is 10-17%.

The use of sorting grids in trawls with 135-mm mesh size by SRTM-type vessels is very efficient. Minimum retention length of cod in these trawls with and without grids is equal to 26 cm which corresponds to age 2, and the number of fish in the first size group, from 26 to 30 cm, retained by each trawl makes up 0.01 and 0.06%, respectively. Young cod up to 41 and 46 cm length are present in these trawls also in insignificant amounts. In trawls with grids they account for 1.8 and 2.5%, in trawls without grids for 3.5 and 5.3%, respectively. When using trawls with grids the efficiency is 41% higher than when trawls without grids are applied.

The increase in fishing efficiency as a consequence of the use of sorting grids leaves no doubt as to the advisability of the application of sorting systems in trawls by PST- and SRTM-type vessels. These actions should adequately reduce fishing effort and expenses.

The effect of increase in the mature fish abundance due to sorting grids in trawls with 125-mm mesh size on PST-type vessels exists but it is very little. It can be concluded with confidence that the use of grids does not have an adverse impact on the stock abundance of cod in general and on its spawning stock, in particular.

References

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Table 1

Amount of trawling hours and fish measured; minimum length; mean portion and weight of cod in different length intervals per 1 hour of trawling by the PST and SRTM-type vessels equipped by trawls with 125 and 135 mm meshes, with and without sorting grids, in catches taken from June to December 2000 in the Barents and Norwegian seas

Vessel type	Mesh size, mm	Presence of grid	No. of trawling hours	No. of fish measured	Min.length of cod in mean catch pr. 1 hr. of trawling, cm	No. of fish in mean catch pr. 1 hr. of trawling			Mean weight of catch pr. 1 hr. of trawling, kg		
						6 cm and longer	41 cm and longer	46 cm and longer	6 cm and longer	41 cm and longer	46 cm and longer
PST	125	no	1 228	79 820	6	65.0	45,8	43,0	103,6	96,9	94,8
PST	125	yes	1 985	125 539	16	63.2	60.5	59.5	133.0	131.6	130.9
SRTM	125	no	1 773	97 390	16	54.9	49.0	47.3	109.7	106.9	105.5
SRTM	125	yes	4 313	306 186	16	71.0	67.3	66.2	155.6	153.8	153.0
PST	135	no	141	11 379	16	80.7	77.7	76.8	167.8	166.4	165.7
PST	135	yes	1 731	145 587	16	84.1	80.0	79.0	194.1	192.2	191.4
SRTM	135	no	270	16 308	26	60.4	58.3	57.2	147.1	146.1	145.2
SRTM	135	yes	872	73 230	26	84.0	82.5	81.9	207.4	206.6	204.9

Table 2

Age composition of cod survived and dead in fishery by PST-type vessels using trawls with sorting grids and 125 mm mesh size in June-December 2000 in the Barents and Norwegian seas, thou.indiv.

Age, years	Effect from application of sorting grids	
	Abundance increase	Abundance decline
1	152	0
2	83	0
3	279	0
4	163	0
5	0	63
6	0	25
7	0	1
8	0	4
9	0	4
10	0	2

Table 3

Long-term effect on the abundance of the spawning stock of cod due to applying sorting grids in trawls with 125 mm mesh by PST-type vessels in June-December 2000 in the Barents and Norwegian seas (in thousand individuals)

Effect	Calendar year							
	2001	2002	2003	2004	2005	2006	2007	2008
Annual increase	9	18	44	40	22	11	3	1
Annual decline	32	21	7	2	1	0	0	0
Long-term annual effect	-23	-3	37	38	21	11	3	1
Summarised long-term effect		-26	11	49	70	81	84	85

Table 4

Long-term effect on the abundance of the spawning stock of cod due to the increase of mesh size from 125 mm to 135 mm in trawls with sorting grids used by PST-type vessels in June-December 2000 in the Barents and Norwegian seas (in thousand individuals)

Effect	Calendar year				
	2001	2002	2003	2004	2005
Annual increase	33	42	21	7	2
Annual decline	34	11	3	1	0
Long-term annual effect	-1	31	18	6	2
Summarised long-term effect		30	48	54	56

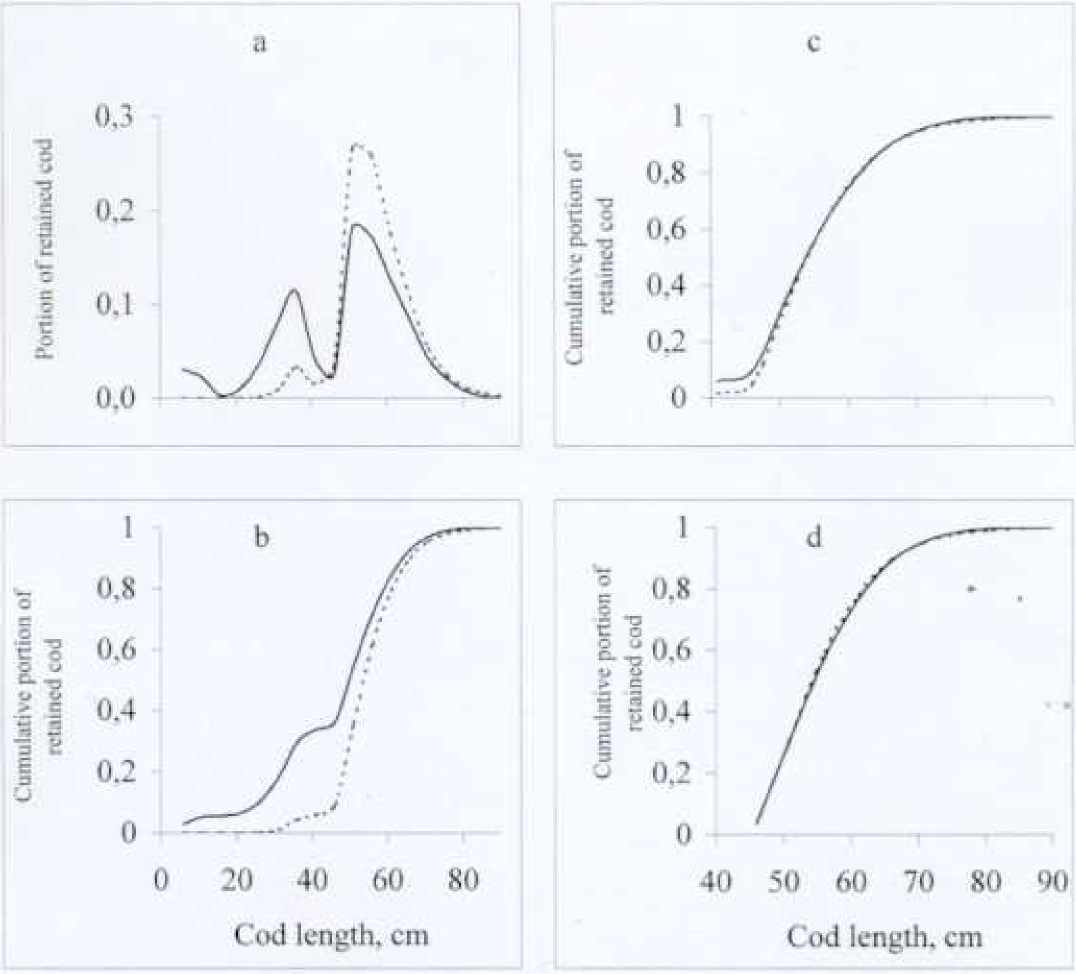

Fig.1. Length series of mean cod catches pr. 1 hour of trawling by PST trawls with 125 mm mesh size, equipped (-----) and unequipped (—) by sorting grids (a), and the cumulative portion of retained fish of different length from 6 (b), 41 (c) and 46 (d) cm

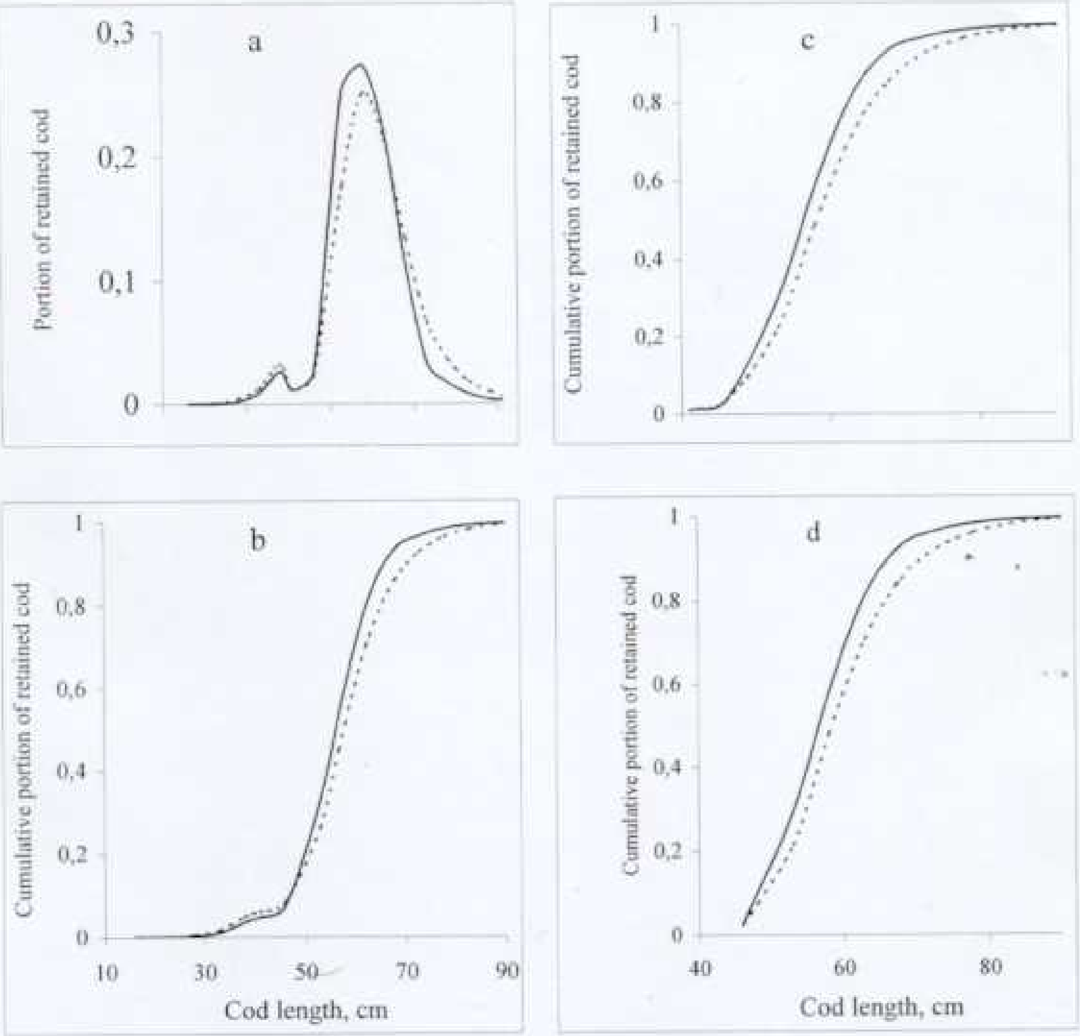

Fig.2. Length series of mean cod catches pr. 1 hour of trawling by PST trawls with 135 mm mesh size, equipped (-----) and unequipped (—) by sorting grids (a), and the cumulative portion of retained fish of different length from 16 (b), 41 (c) and 46 (d) cm

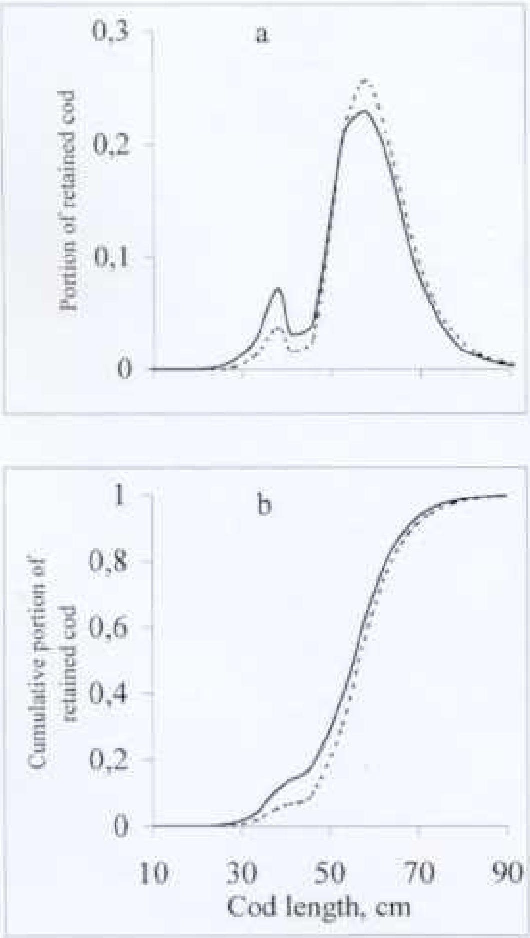

Fig.3. Length series of mean cod catches pr. 1 hour of trawling by SRTM trawls with 125 mm mesh size, equipped (-----) and unequipped (—) by sorting grids (a), and the cumulative portion of retained fish of different length from 16 (b), 41 (c) and 46 (d) cm

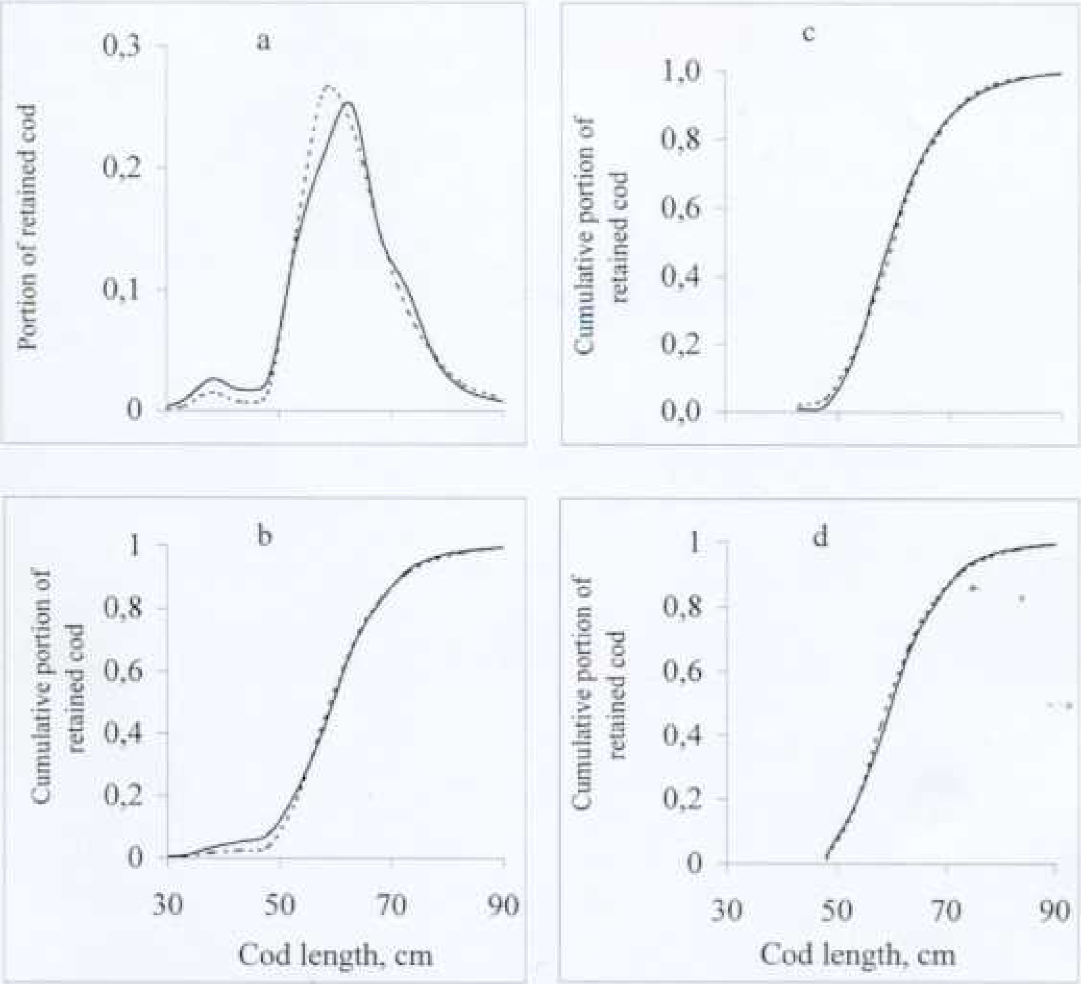

Fig.4. Length series of mean cod catches pr. 1 hour of trawling by SRTM trawls with 135 mm mesh size, equipped (-----) and unequipped (——) by sorting grids (a), and the cumulative portion of retained fish of different length from 26 (b), 41 (c) and 46 (d) cm