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Some aspects of choosing the optimal mesh size in codends in beaked redfish fishery in Div. 3M of the NAFO Regulatory Area

by

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## Abstract

The results of the experiment to estimate the parameters of trawl selectivity for the beaked redfish (*Sebastes mentella*) when to wing and hauling-up the trawl are discussed. The selectivity of trawl with different codend mesh size at these stages is simulated. The effect of different mesh size on fish traumatic death, fishing effort and efficiency for the redfish are evaluated.

It is shown that the enlargement of mesh size in the trawl codends leads to such an indirect effect as the increase in the number of dead fish as a result of fish escape from the trawl as well as the traumatizing of fish when the trawl is lifted. Traumas and death of fish when they escape through a mesh occur due to a rapid change of the hydrostatic pressure and the pressure owing to the impact of the total catch in the trawl codend. So, the preliminary estimation shows that the number of the caught fish and the necessary fishing effort increase in 15 times when using 132 mm mesh size if comparing with that one of 88 mm. At that, the quantity of the dead fish exceeds that one of captured fish in more than 9 times. This situation has a negative impact on the fishing economy and ecology. It is assumed that the enlargement of mesh to regulate fishing without the allowance for the traumatic death of fish and the increase in fleet fishing efficiency are not enough. It is more rational to use smaller mesh size in the codends which will allow reducing the traumas of fish during commercial fishing.

## Introduction

3M redfish is an important target species in the NAFO Regulatory Area. Redfish are harvested with bottom and pelagic trawls having the minimum inner mesh size of 130 mm.

Over the years, 3 M redfish catches ranged from 81,000 t in 1990 to 1,000 t recorded in 1998-1999 as a bycatch in the Greenland halibut fishery. Such a considerable decrease in the catches was accompanied by a sharp reduction in the redfish stock size and a subsequent change in fishing efforts of the fleet harvesting redfish in this area. A relative increase in the efforts of fishing vessels targeting redfish in the area is reflecting an increase in their fishable stock ( A. Ávila de Melo et al, 2009).

In this regard it is important to consider the issue of the optimum mesh size in the redfish (*Sebastes mentella*) fishery in 3M taking into account the impact of the mesh size on traumatic death of redfish, fishing efforts and fishing efficiency.

The mesh size, which prevents the maximum escape of commercial fish, should be considered as the optimum one.

At substantiating the minimum mesh size in trawl condends, considerable difficulties are caused by the lack of data on survival of fish escaped from the trawl during its towing and haul-up. Some authors (Konstantinov, 1981; Konstantinov et al., 1983) believe that deepwater redfish escaping from the trawl during haul-up die. Therefore, it is important to estimate the number of redfish escaping from the codend during hauling.

Since no new experimental studies into trawl selectivity and assessment of the number of redfish escaped through the codend mesh have been conducted in NAFO 3M up to now, one can use the findings from the similar studies carried out in other areas using similar gear to get an approximate consideration. The findings from other experiments on the similar target species *(Sebastes mentella)* can be used based on the principle of geometrical similarity of the mesh and similar target species (Baranov, 1914, 1948).

## Material and methods

### Selectivity

Experimental studies into the trawl selectivity for *Sebastes mentella* have been conducted in NAFO Div. 3N and the Barents Sea in different years.

The trawler *Vaigach* carried out experimental work on selectivity for redfish (*Sebastes mentella*) in September 1994 in NAFO Div.3N. A standard mid-water trawl 76/336 m with eight-panel codend made of polyamide (PA) with the diamond-shaped mesh was used during the experiment. Trawl codends were removable and had the actual mesh size of 88, 118 and 132 mm. The mesh size was measured with a 2 mm thick ICNAF plate inserted into the mesh with 5 kg force. Bags were made of polyamide netting with resulting linear density of 2 x 5.7 kTex. Trawl rig corresponded to that used during commercial fishery. Speed of hauling was 3.5 - 3.6 knots, duration 40-60 min. Trawl codend selectivity was estimated by coveting it with a fish capturing netting around the whole bag. Its perimeter was by 50% larger than the bag's cylindrical part. The front edge of the catcher was attached to the conical part of the codend 7 m away from its cylindrical part, rare edge was 4 m behind the codend. The catcher was made of polyamide with linear density of 5.7 kTex and mesh size of 50 mm. (Lisovsky *et al*, 1995).

The R/V *Krenometr* undertook experimental work on assessment of the number of redfish (*Sebastes mentella*) escaping through the codend during towing and haul-up in the 1990-s in ICES Subarea IIa (the Barents Sea). The technique used was grounded on the fact that the upper fine-mesh covering was separated into two compartments. During towing redfish, which escaped from the codend, were collected by the tail part of the covering. Before the trawl hauling-up this compartment was locked and fish escaping during the hauling-up phase were collected in the second compartment of the fish catcher. After the trawl and fish-catcher are hauled up the catch in each compartment was measured and counted. The quantity of fish escaped from the codend during towing and haul-up was also counted. Trawling were made by a bottom trawl 45/47m with 126.1 mm mesh size of codend made of polyamide netting with the diamond-shaped mesh. Trawling speed was 3.5-3.7 knots; duration of towing was 2 hours, speed of hauling-up - 2.0-2.5 m/sec. (Lisovsky *et al*, 1995).

Data on the escaping redfish and from selectivity experiments are used for the redfish fishery in NAFO Div.3M by reason of assumption of the principle of geometrical similarity (Baranov, 1914, 1948), which states that the selectivity depends only on the relative geometry of the mesh and the fish: “Since all meshes are geometrically similar and all fish of the same species (within a reasonable size range) are also geometrically similar, the selection curves for different mesh sizes must be similar” (quoted, in translation, from Wulff, 1986, p. 101).

This assumption is corroborated by comparison of the maximum circumference (girth) of redfish *(Sebastes mentella)* body from NAFO Div.3M with that from ICES Subarea IIa (the Barents Sea),

which was made by different researchers (Valdes and Fraxedes, 1981), (Konstantinov at al, 1983). The results of comparing these dimensions show that there is no significant distinction between the body
sizes of redfish *(Sebastes mentella)* from different ocean areas (Figure 1).

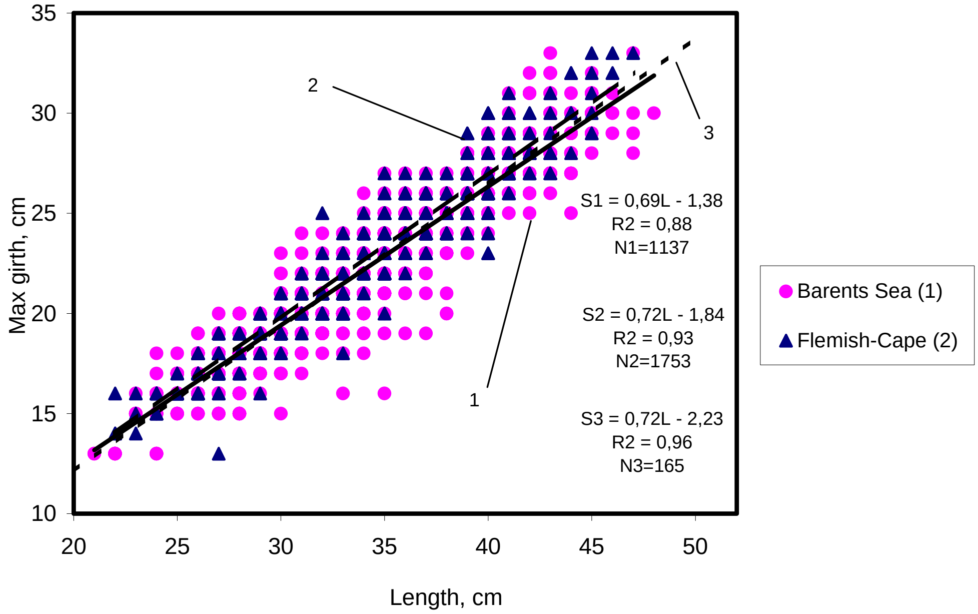


**Figure 1**. Relationship between the length and maximum girth in beaked redfish *(Sebastes mentella)* in the Barents Sea (ICES Sub-area IIa) and Flemish-Cape (NAFO Div.3M) (Konstantinov et al, 1983 (1,2); Valdes and Fraxedes, 1981 (3)

Also this assumption is corroborated by comparing selectivity factors $S_f$ of different pelagic trawls which was be experimental estimated in NRA and in II ICES sub-area according to red fish *(Sebastes mentella)* (Lisovsky et al, 1995; Valdes and Fraxedes, 1981), (Table 1). There are no evidence differences between selectivity factors $S_f$ of pelagic trawls with approximately same inner mesh size of codends from 118 mm to 126 mm. For these meshes the selectivity factors are about 2.5. This result also evidence that the trawl selectivity parameters for red fish *(Sebastes mentella)* of different areas are approximately same for same trawls. So, for preliminary analyze it is possible to use the data of trawl selectivity for same species form different areas for same trawls.

**Table 1**. Selectivity factors $S_f$ of pelagic trawls for red fish *(Sebastes mentella)* from different areas.

| Region | Mesh size, mm | Sf |
|---|---|---|
| 3 M NAFO* | 120 | 2,47 |
| II ICES** | 126 | 2,49 |
| 3 N NAFO*** | 118 | 2,49 |

* - Valdes and Fraxedes, 1981
** - present work paper
*** - Lisovsky et al, 1995

**Analyses of the effects of using various minimum mesh sizes on damage and mortality of fish escaping from the trawl codend**

According to research findings, the number of injured and dead redfish escaping through the codend mesh during haul-up mostly depends on the mesh size. This circumstance should be taken into account when choosing an optimum codend mesh size. Therefore, the quantitative estimate of relationship between mortality and the codend mesh size is important.

Mesnil's method (Mesnil, 1996) was applied.

Let *G* be the number of fish entering the codend, and $p_s$ be a proportion of fish retained and brought aboard. *Ps* corresponds to codend mesh selectivity with respect to each length of fish. Then, the number of fish brought aboard, i.e. the catch, is Y:

$$Y = p_s G \qquad (1)$$

Suppose that *pl* is a proportion of the retained fish Y which are landed while the reminder are discarded. Then, catch landed, *L* and discarded, *D*, can be expressed as:

$$L = p_l Y \qquad (2)$$

and

$$D = (1 - p_l)Y \qquad (3)$$

Consider the values of catches taken with trawl having the mesh size $m_1$ and $m_2$ per fishing effort $r_1$ :

$$Y_1 = p_{s,m_1} G_{m1} r_1 \qquad (4)$$

$$Y_2 = p_{s,m_2} G_{m1} r_1 \qquad (5)$$

Variations in codend mesh size $m_n$ and selectivity $p_s$ results in changing the Y catch value. Then, given the similar fishing conditions, the catch $Y_3$ with $p_{s,\, m2}$ will be equal to the $Y_1$ catch if fishing effort $r_1$ changes to $r_2$ :

$$Y_1 = Y_2 \times r_2 = Y_3 \qquad (6)$$

Writing equation (6) considering (4) we have:

$$\sum_{li}^{l_n} G_{m1,li}\, p_{sl\,i,m_1} r_1 w_i = \sum_{li}^{l_n} G_{m1,li}\, p_{sl\,i,m_2} r_1 r_2 w_i \qquad (7)$$

where $w_i$ is the weight of fish having the length $l_i$ .

So, effort $r_2$ which is needed to obtain the catch can be expressed from (6) and (7):

$$t_2 = \frac{\mathrm{Y}_1}{\mathrm{Y}_2} = \frac{\sum_{li}^{l_n} G_{m1,li}\, p_{s,l\,i,m_1} w_i}{\sum_{li}^{l_n} G_{m1,li}\, p_{s,l\,i,m_2} w_i} \qquad (8)$$

Therefore, to obtain the catch $Y_3$ which weight is equal to the catch $Y_1$ , it is necessary to change the number of fish entering the codend, substitute $G_1$ for $G_3$. Then from equations (5) and (6) we have the catch $Y_3$ as:

$$Y_3 = p_{s,m_2} G_{m1} r_1 r_2 \quad (9)$$

Or considering (1):

$$G_3 p_{s,m_2} = p_{s,m_2} G_{m1} r_1 r_2 \quad (10)$$

we express $G_3$ as:

$$G_3 = \sum_{li}^{l_n} G_{m1,li} r_1 r_2 \quad (11)$$

To determine the effect of fishing with different mesh size $R_{m_n}$ on fish mortality we use equation (Breen et al 2007) for the catches taken with the trawl having different codend mesh size $m_n$:

$$R_{m_n} = L_{m_n} + D_{m_n}(1 - s_{d,m_n}) + G_{m_n}(1 - p_{r,m_n})(1 - s_{e,m_n}) \quad (12)$$

where $s_{d,m_n}$ - survived portion of discarded fish.

$s_{e,m_n}$ - portion of fish survived after escaping from trawl through the codend.

Consider that the selectivity of trawl $p_{st}$ and survival rate of fish $s_{et}$ during towing and haul-up to the surface $p_{sh}$ and $s_{eh}$ are different, then from equation (1, 2, 3, 4) equation (12) can be expressed as:

$$R_{m_n} = \left[G_{m_n} p_{st} p_{sh} p_l\right] + \left[G_{m_n} p_{st} p_{sh}(1 - p_l)\right] + \left[G_{m_n}((1 - p_{st})(1 - s_{et}) + p_{st}(1 - p_{sh})(1 - s_{eh}))\right] \quad (13)$$

or

$$R_{m_n} = G_{m_n}\left[p_{st} p_{sh} p_l + p_{st} p_{sh}(1 - p_l) + ((1 - p_{st})(1 - s_{et}) + p_{st}(1 - p_{sh})(1 - s_{eh}))\right] \quad (14)$$

Length relation parameters $p_{st} p_{sh}$ and $s_{et}$ $s_{eh}$ have transformed to age relation by using probability function of length / age, which is calculated by size-age key (Breen et al 2007):

$$P_{x,a} = \sum (p_{x,l} p_{la}) \quad (15)$$

To perform further calculations, suppose that length distribution of redfish concentrations being targeted is equal to the average length distribution of redfish *(Sebastes mentella*) in Sub-area NAFO 3M from the EU redfish surveys conducted in 1998-2008 (A. Ávila de Melo *et al*, 2009) (Figure 2.)

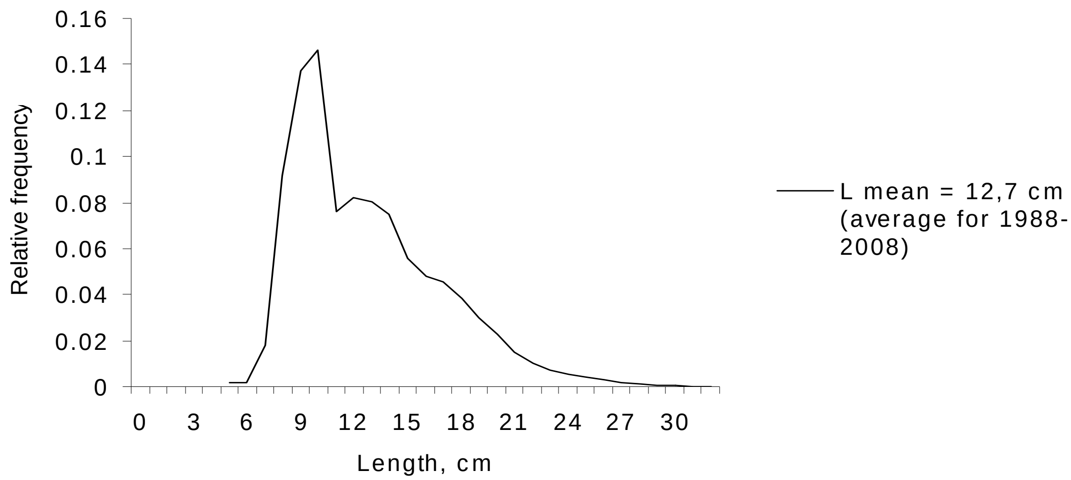


**Figure 2**. Average length distribution of redfish (*Sebastes mentella*) in NAFO Division 3M

Now suppose that all the fish which pass through the codend during trawling operations survive i.e. $s_{et} = 1$. Then, in accordance with the precautionary approach, suppose that all the fish which pass through the codend when hauling up die, i.e. $s_{eh} = 0$. Now assume that there are no discards in fishing, i.e. D = 0 and $s_{d,m_n} = 1$

Supporting the above assumptions, we have the following parameters from equation 12 and 13:

– the number of fish in the landings:

$$N_l = \lfloor G_{m_n} p_{st} p_{sh} \rfloor \tag{16}$$

– the number of fish escaped from the codend during towing:

$$N_t = \lfloor G_{m_n} (1 - p_{st}) \rfloor \tag{17}$$

– the number of fish escaped from the codend during hauling-up:

$$N_{hup} = \lfloor G_{m_n} p_{st} (1 - p_{sh}) \rfloor \tag{18}$$

Using the above formulas, we get the number of fish that correspond to catches and escapes during towing and hauling-up of one tonne of redfish caught by the trawl having a codend mesh size of 88, 100, 118, 125 and 132 мм.

If we assume that all the fish which pass through the codend during hauling-up die in the result of the physical trauma and injury and large changes of hydrostatic pressure then the coefficient of relative mortality $k_{mort}$ is calculated as a ratio of dead fish $N_{hup}$ to fish caught $N_l$ (19):

$$k_{mort} = \frac{N_{hup}}{N_l} \tag{19}$$

The relative fishing effort needed to catch 1 tonne of redfish with different codends having different mesh size, i.e. $t_n$, is calculated using formula 8 from the ratio of the number of fish entered the trawl to the number of fish retained.

## Results

In this paper, the initial selectivity parameters for two trawling stages were taken from the experiments conducted with the 126,1 mm codend mesh size. Data on selectivity during towing and haul-up are presented in Table 2 and Figure 3.

For other mesh sizes, the selectivity parameters were simulated based on the principle of geometrical similarity (Baranov 1914, 1948) given the same selectivity range (Table 3).

**Table 2**. Data on selectivity for redfish *(Sebastes mentella)* during towing and hauling-up using a codend mesh size of 126.1 mm

| Trawling stages | $L_{50\%}$, cm | Standard error | S.R., cm | Standard error | Akaike's information criterion (AIC) |
|---|---|---|---|---|---|
| Towing | 28.2 | 0.50 | 8.8 | 0.70 | 44.5 |
| Hauling-up | 29.6 | 0.42 | 4.9 | 0.49 | 36.1 |
| Total | 31.4 | 0.32 | 4.8 | 0.44 | 41.4 |

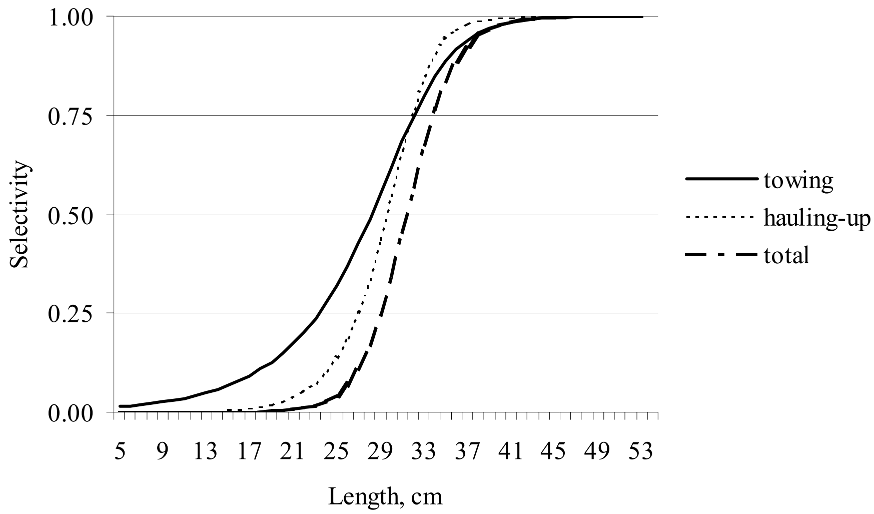


**Figure 3**. Richard's selectivity curves for various trawling phases (towing, hauling-up) in the redfish (*Sebastes ment*ella) fishery and total trawling using a codend mesh size of 126.1 mm.

**Table 3**. Estimated data on selectivity of redfish *(Sebastes mentella*) during towing and hauling-up with different codend mesh size.

| Trawling phase | $L_{50\%}$, cm | S.R., cm |
|---|---|---|
| Mesh size 88 mm | | |
| Towing | 21.9 | 4.8 |
| Hauling-up | 19.7 | 8.8 |
| Total | 20.6 | 4.9 |
| Mesh size 100 mm | | |
| Towing | 22.4 | 8.8 |
| Hauling-up | 23.5 | 4.9 |
| Total | 24.9 | 4.8 |
| Mesh size 118 mm | | |
| Towing | 29.4 | 4.8 |
| Hauling-up | 26.4 | 8.8 |
| Total | 27.7 | 4.9 |
| Mesh size 125 mm | | |
| Towing | 28.0 | 8.8 |
| Hauling-up | 29.3 | 4.9 |
| Total | 31.1 | 4.8 |
| Mesh size 132 mm | | |
| Towing | 32.9 | 4.8 |
| Hauling-up | 29.5 | 8.8 |
| Total | 31.0 | 4.9 |

Obtained results testify, that catch of trawl with codend mesh size 88 mm will be equal to catch of the same trawl with bigger mesh size only with increasing of fishing number fishes in many times. This mean that for release own quota by 132 mm mesh size a fishing fleet will need increase fishing effort in 15 times more then with codend mesh size 88 mm (Figure 4).

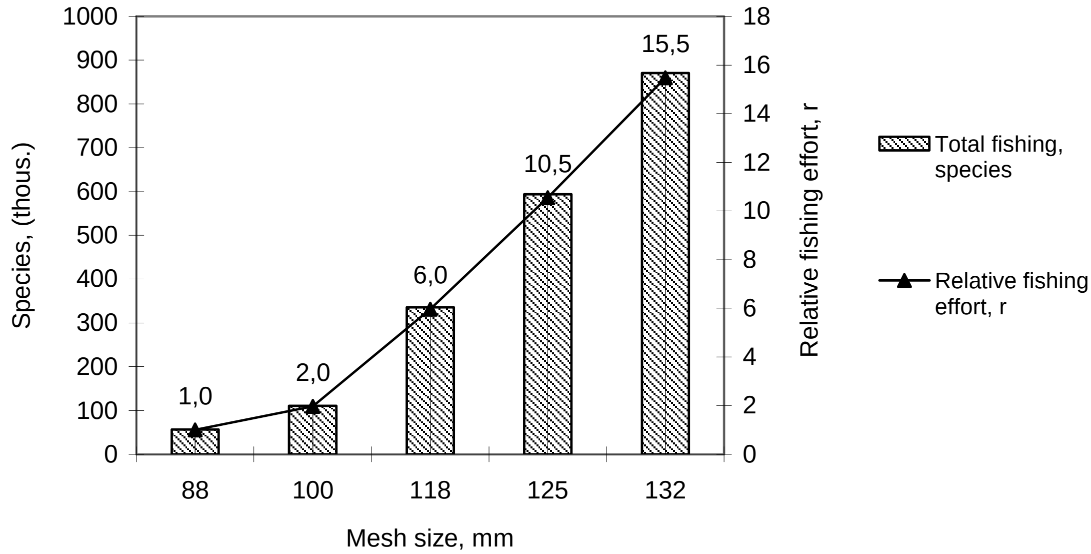


**Figure** 4. Number of fishes that are necessary for catch one ton of redfish *(Sebastes mentella)* by different mesh size of trawl codend and corresponding it the relative fishing effort – *t*.

In addition to, with increasing of codend mesh size, amount of dead fish increases too, with equal weight of catch (Figure 5). This means that the amount of dead fish is much more than numbers of caught fish. For example one unit of catch with codend mesh size of 132 mm do dead fishes in nine times more ($k_{mort.}$) then are caught one (Figure 6).

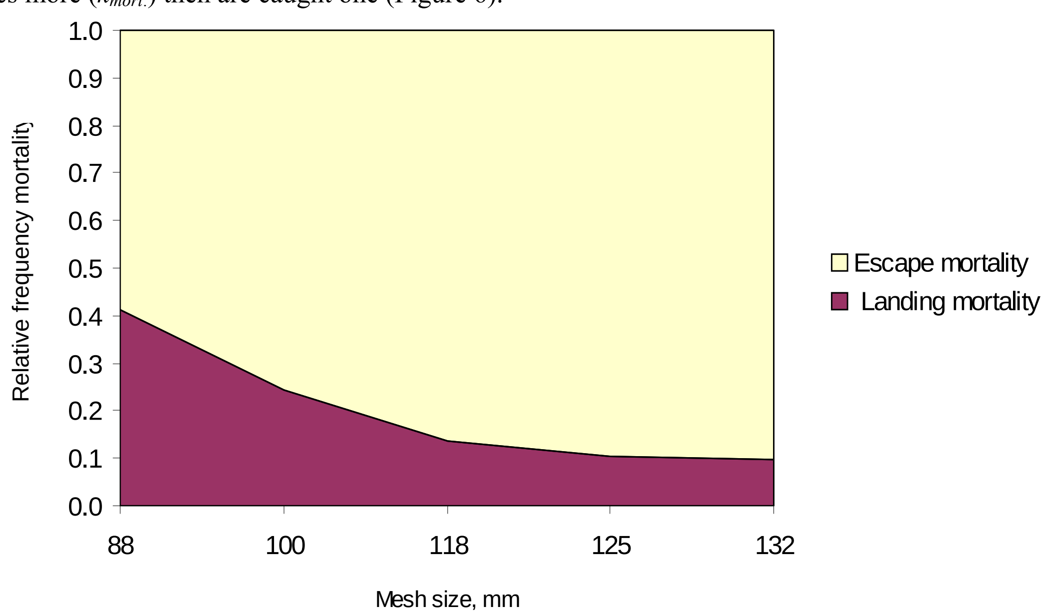


**Figure 5**. Relative frequency mortality of redfish *(Sebastes mentella)* for equal weight of catch by different codend meshes size.

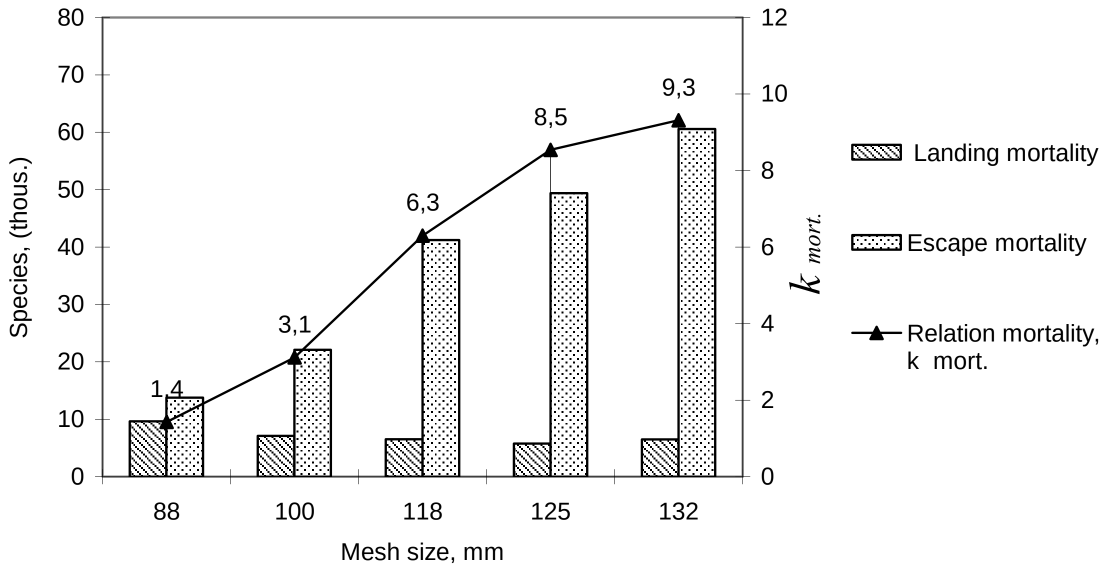


**Figure 6**. Number of fishes that are landing and dead for catch one ton of redfish *(Sebastes mentella)* by different mesh size of trawl codend and corresponding it the relative mortality – $k_{mort.}$.

## Conclusion

The increase in the codend mesh size causes the side effects associated with the increase in the number of fish, which die in the result of escaping through the trawl and are injured during haul-up to the surface.

Such a situation takes place due to considerable slack in the codend mesh and increase in the mesh opening during the haul-up to the surface. This is caused by a lower speed of bringing the trawl nearer to the vessel board than during towing.

Slack in the codend mesh and increase in the mesh opening allow the larger fish to freely pass through the codend mesh that is indirectly justified by the selectivity parameters observed during various trawling phases (Table 1). $L_{50\%}$ in the haul-up phase is 4.7% higher than in the towing phase and this indicates that larger fish are sorted out during haul-up due to the changes in the mesh geometry and tension.

All fish escaping from the trawl codend during haul-up die as a result of trauma. The traumas caused by rapid changes in hydrostatic pressure and pressure brought by all the catch in the codend.

Therefore, these fish become a waste both for fishing and for the whole stock.

Moreover, with the increase in the mesh size there should be an increase in the number of fish entering the trawl and being sorted out by the trawl codend compared to the smaller mesh size (Figure 4; 5). This inevitably results in the increase of dead fish and in a multiple increase in fishing efforts necessary to attain the TAC. Preliminary calculations suggested that to harvest 1 ton of redfish when using the 132 mm mesh, compared with the 88 mm mesh, the number of fish entering the trawl and fishing efforts will increase by more than 15 times. Moreover, the number of fish which have been dead after escape from the codend with the 132 mm mesh size will be in 9 times more than the number of caught fish (Figure 6).

Such situation significantly reduces economical and ecological aspects of exploiting the redfish stock and economic effect of fishing. It is assumed that the enlargement of mesh to regulate fishing without the allowance for the traumatic death of fish and the increase in fleet fishing efficiency are not enough. It is more rational to use smaller mesh size in the codends which will allow reduce the traumas mortality of fish during commercial fishing.

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