THE THEORETICAL ASSESSMENT OF SELECTIVITY OF TRAWL CODENDS IN THE BALTIC COD FISHERY

S.V. Sergeev, V.N. Feldman

Atlantic Scientific Research Institute of Marine Fisheries and Oceanography
(AtlantNIRO), 5 Dn.Donskoy, Kaliningrad, 236000 Russia
Tel.: 007-0112 55 23 69; Fax: 007-0112-219997; E-mail: feldman@atlant.baltnet.ru

ABSTRACT

One of the basic elements of the Baltic cod recovery plan adopted by IBSFC is the improvement in gear selectivity. Changes were introduced in the technical measures applied to Baltic cod fisheries during the 2002. These changes were made on the basis of the experimentally estimated selectivity parameters for the new trawl cod-ends. The preliminary observations on implementation the new gears show that the minimum length of fish is being retained is not consistent with the experimentally estimated selectivity characteristics of new trawls. To predict the consequences followed introduction of different trawl cod-ends into the fishery we conducted a series of researches in 1995, 2001-2002 to study selectivity of bottom trawls in cod and flounder fisheries in the East Baltic Sea. Selective properties for trawl cod-ends of different type are determined basing methods of theoretical assessment for trawl cod-ends selectivity developed in AtlantNIRO by Yu. Kadilnikov, and a series of experiments carried out on board the commercial vessels. The employed model of cod-end selectivity has shown a significant convergence with experimental data. Basing on information of mesh shape and cod biometric characteristics the model allows to provide the preliminary estimation of trawl cod-end selectivity, thereby saving the time of sea trials. Seasonal variations in cod exterior and relevant changes in trawl selectivity parameters were used for the adaptation the theoretical model to estimation the selectivity characteristics. The results of theoretical and experimental estimations are given.

INTRODUCTION

The long-term management strategy for cod stocks in the Baltic Sea and Cod Recovery Plan adopted by IBSFC in 1999-2001 the special attention has been paid to the trawl selectivity improvement in the cod fishery. The experimental operations for assessment of different cod-ends selectivity are carrying out by many countries harvesting cod in the Baltic Sea. Our
experience of selectivity study from 1995 showed that, as a rule, the scope of the experimental operations is restricted to the test of selective features of cod-ends with 1-2 sizes of the diamond mesh or one (seldom two) types of exit windows, while for the purpose of fishery management the wider range of cod-ends selectivity estimates is required.

In this connection the problem of preliminary theoretical assessment of probable selectivity of different cod-ends on the basis of available experimental data arises. At AtlantNIRO the theoretical selectivity model developed by Yu.Kadilnikov has been successfully applied. Selectivity parameters are estimated on the basis of biometric data of the fish body and the netting mesh size.

The purpose of this report is to consider the impact of the Fishing Rules amendments on the Baltic fishery:
- increase of the minimum landing size of cod
- reduction of the mesh size in BACOMA from 120 to 110 mm.

**MATERIAL AND METHODS**

The estimations are made on the basis of the theoretical model of selectivity developed by Yu.Kadilnikov (2001).

The probability of fish retention by the netting of the cod-end $P_8$ (the index corresponds to the numbering of the total trawl selectivity catchability) is presented as the sum of two combined cases:

$$P_8 = P(A)+P(B)-P(A\cdot B),$$

where $P(A)$ - probability of the case that the perimeter of the maximum fish body girth is more than the inner mesh perimeter (case A);

$P(B)$ – probability of the case that the fish cross-section area is more than the cross-section area of the ellipse with the eccentricity equal to that inscribed in the diamond mesh (case B).

To assess the probability of the case $A_1$- $P(A)$ let us consider the difference of two random values, such as $Z$:

$$Z = X - 2Y,$$

where $X$ is the perimeter of the maximum girth in the fish body cross-section of the fish body, maximal out of all measurements.
Y – mesh opening.

Evidently that $P(A)$ is equal to:

$$P(A) = \int_{0}^{\infty} \varphi_{z}(Z) dZ, \tag{3}$$

where $\varphi_{z}(Z)$ is the density of probability distribution of the random value $Z$.

As showed the researches by N. Ivanova carried out at AtlantNIRO in 1983-93, the random value $Y$ is distributed according to the normal pattern. These researches have also demonstrated that the random values $X, X_1, X_2$ (the biometric characteristics) of several fishes, including icefish, Cape, European and Peruvian horse mackerel, Japanese mackerel, sardine and sardinella, Cape hake, Baltic herring, sprat and Baltic cod are distributed close to the normal pattern, at least the distribution of these values difference can be approximated by the normal pattern. The empiric distribution of the mesh opening and a half of the mesh meridional angle also can be approximated by the normal rule.

Then $P(A)$ can be estimated as:

$$P(A) = 1 - \Phi\left(-\frac{m_{z}}{\sigma_{z}}\right), \tag{4}$$

where $\Phi(Z,m_{z},\sigma_{z})$ is the normal function of probabilities distribution, and the integral is:

$$\Phi(Z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Z} e^{-t^{2}/2} dt, \tag{5}$$

where $m_{z}$ - the mathematic expectation of the random value $Z$;

$\sigma_{z}$ - the standard deviation of the random value $Z$.

Since the random values $X$ and $Y$ are apparently independent, then:

$$m_{z} = m_{x} - m_{y}, \tag{6}$$

$$\sigma_{z} = \sqrt{\sigma_{x}^{2} + 4\sigma_{y}^{2}}, \tag{7}$$
where $m_x$ is the mathematic expectation of the perimeter of the maximum fish body girth; 
$m_y$ - the mathematic expectation of the mesh opening;
$\sigma_x$ - the standard deviation of the perimeter of the maximum fish body girth;
$\sigma_y$ - the standard deviation of the mesh opening.

To estimate the probability of the case B-P(B) let us consider the differences of two random values:

$$Z_1 = S - S_0,$$  \hfill (8)

where $S$ – the maximum area of the fish cross-section;
$S_0$ – the area of the ellipse cross-section inscribed into the diamond mesh, with the eccentricity equal to the eccentricity of the maximum cross-section of the fish body.

Japanese scientist Akio Fujiisu came to the conclusion on the basis of the detailed morphological researches of several fishes, that the shape of the fish body cross-section in the widest area can be sufficiently approximated by the ellipse. This has been confirmed by AtlantNIRO researches carried out during cross-section measurement of icefish, horse mackerel, mackerel, hake, cod, herring, sprat, sardine and sardinella.

Let us assume that distribution of the random value $Z_1$ as a combination of distributions of two random values $S$ и $S_0$, can be approximated by the normal rule. Then:

$$P(B) = 1 - \Phi\left( -\frac{M(Z_1)}{\sigma(Z_1)} \right),$$  \hfill (9)

where $\Phi(Z_1)$ - the normal function of distribution; 
$M(Z_1)$ - the mathematic expectation of the random value $Z_1$; 
$\sigma(Z_1)$ - the standard deviation of the random value $Z_1$.

The area of the ellipse inscribed into the rhomb can be determined by the well-known equation:

$$S_0 = \pi a_t^2 \sqrt{1 - \varepsilon^2},$$  \hfill (10)
where $a_1$ - a longer half-axis of the ellipse (see fig.1);

$\varepsilon$ - the eccentricity of fish girth.

On the other hand the length of the perpendicular $l$, drawn down from the ellipse center on the tangent (see fig.1) is equal:

$$l^2 = a_1^2 \sin^2 \alpha + b^2 \cos^2 \alpha,$$

(11)

or

$$l^2 = a_1^2 (1 - \varepsilon^2 \cos^2 \alpha),$$

(12)

where $b$ – the short half-axis of the ellipse;

$\alpha$ - a half of the mesh meridian angle.

At the same time the length of the perpendicular $l$ segment (see fig.1) is equal to:

$$l^2 = \frac{Y^2}{4} \cos^2 \alpha + \sin^2 \alpha,$$

(13)
where \( Y \) - the mesh opening.

From (12) and (13) it follows that:

\[
a_1^2 = \frac{Y^2 \cos^2 \alpha \sin^2 \alpha}{4 (1 - \varepsilon^2 \cos^2 \alpha)}
\]  
(14)

Substituting (14) into (10) we get the following:

\[
S_0 = \frac{Y^2 \pi}{4} \sqrt{1 - \varepsilon^2} \frac{\cos^2 \alpha \sin^2 \alpha}{1 - \varepsilon^2 \cos^2 \alpha}
\]  
(15)

Let us describe the fish body cross-section as the ellipse with the eccentricity equal to:

\[
\varepsilon = \sqrt{\frac{X_2^2 - X_1^2}{X_2^2}},
\]  
(16)

where \( X_2 \) - the maximum height of the fish body;

\( X_1 \) - the maximum width of the fish body.

Since it is assumed that the random values \( X_1 \) и \( X_2 \) are distributed according to the normal rule, hereinafter we are able to use the approach usually applied in statistic simulation of normally distributed random values:

\[
X_1 = m_1 + \sigma_1 \eta
\]  
(17)

\[
X_2 = m_2 + \sigma_2 \eta
\]  
(18)

where \( m_1 \) – the mathematic expectation of the maximum fish body width \( X_1 \);

\( \sigma \) - the standard deviation of the fish body maximum width;

\( \eta \) - the normally distributed random value with the mathematic expectation equal to zero and the standard deviation equal to one;
\( \sigma_2 \) - the standard deviation of the maximum fish body height, of the random value \( X_2 \).

In equation (15) the eccentricity of fish body is replaced to the body compression, \( \mu \):

\[
\mu^2 = 1 - \varepsilon^2
\]

(19)

\[
\mu = \frac{X_1}{X_2}, \quad X_1 < X_2, \quad (20)
\]

see the legends above.

Then:

\[
S_0 = \frac{\pi Y^2}{4} \sin^2 \alpha (m_1 + \sigma_1 \eta)(m_2 + \sigma_2 \eta) \frac{1}{(m_1 + \sigma_1 \eta)^2 + (m_2 + \sigma_2 \eta)^2 \tan^2 \alpha}
\]

and the maximum area of the fish body cross-section as approximated by the ellipse is:

\[
S_1 = \frac{\pi}{4} X_1 X_2, \quad (22)
\]

or according to equations (17) and (18):

\[
S = \frac{\pi}{4} (m_1 m_2 + m_1 \sigma_2 \eta + m_2 \sigma_1 \eta + \sigma_1 \sigma_2 \eta^2), \quad (23)
\]

see the legends above.

Thus, the random value \( Z_1 \), is the function of three evidently independent random arguments, either normally distributed by the condition selected \((\eta)\), or assume the approximation of their distribution according the normal rule \((Y \sim \alpha)\). This allows to estimate the mathematic expectation and variance of the random value \( Z \) without any supplementary hypothesis. These can be estimated by the method of functions linearization.
Two groups of equations have been applied to estimate the probability of the case B: for cod-ends without a frame and for cod-ends with a reinforcing frame. However, taking into account the fact that the reinforcing frames are not used in the Baltic cod bottom fishery, this part of the model is ignored in this work.

In assessment of selectivity with the theoretical model the biometrical measurements of fish body naturally made on the vessel deck are the input data. The cross-section of fish body is measured after the swimming-bladder puncture (Kadilnikov, 1997) in fish of any maturity stage, sex, fatness and stomach filling. The biometrical parameters of fish body cross-section in the natural environment, where the process of selectivity is going on, can be different. Until now the biometrical parameters of fish body measured in these two environments are unavailable. Therefore it is assumed that the theoretical model describes the process of selectivity rather precisely, while any discrepancies between the theoretical and experimental estimates are caused by the errors of fish body biometrical measurements and probably by insufficient number of the latter resulting in the bias of the numeric characteristics of the following random values: the mathematic expectation and the standard deviation of the values measured.

The necessity to correct the biometrical parameters is stipulated also by the measurement method, since the measurements are carried out in fish with the swimming-bladder punched in free state, i.e. without force applied. The biometrical information correction can also smooth the differences caused by the fact that different persons were involved in measurements.

Assessment of selectivity of trawl cod-ends with exit windows (Kadilnikov, 2000) is rather specific owing to non-uniform netting structure.

Selectivity of the cod-end with exit windows is estimated by the following equation:

\[
P_{jk} = P_{2jk} - (P_{2jk} - P_{1jk}) \frac{L_0}{L_m} K_b,
\]

(24)

where

- \(P_{2jk}\) – theoretical selectivity of the cod-end without exit windows;
- \(P_{1jk}\) – theoretical selectivity of the cod-end totally made of the netting of the exit window;
- \(L_0\) – perimeter of the exit windows cross-section;
- \(L_m\) – perimeter of the cross-section of the cod-end without exit windows;
- \(K_b\) – impact factor – the empiric value to account the effect of imitation the behavior of fishes escaping from the trawl with less obstacles.
RESULTS AND DISCUSSION

Experiments

The experiments for the trawl cod-ends selectivity assessment were carried out in 1995 and 2001 – 2002 (Kadilnikov, 1995; Sergeev and Feldman, 2001). During these works various designs of cod-ends with the diamond mesh and with exit windows of 3 types were tested. In this article the trawl cod-ends with the diamond mesh, made of polyethylene and BACOMA cod-ends (table 1) were researched, since these two designs are currently used in the Baltic cod fishery.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Nov 2001</th>
<th>April-May 2002</th>
<th>October 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M-70</td>
<td>M-70</td>
<td>M-60</td>
</tr>
<tr>
<td>Numbers of hauls</td>
<td>6</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Depth, m</td>
<td>57-62</td>
<td>76-88</td>
<td>74-92</td>
</tr>
<tr>
<td>Average duration of hauls, h</td>
<td>3.25</td>
<td>6</td>
<td>4.5</td>
</tr>
<tr>
<td>Average catch in cod-end per haul, kg</td>
<td>262.7</td>
<td>175.8</td>
<td>459.1</td>
</tr>
<tr>
<td>Mesh opening, mm</td>
<td>140.6</td>
<td>140.6</td>
<td>113.1</td>
</tr>
<tr>
<td>Material</td>
<td>PE</td>
<td>PE</td>
<td>PE</td>
</tr>
<tr>
<td>Cod</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 50%</td>
<td>50.9</td>
<td>45.9</td>
<td>37.3</td>
</tr>
<tr>
<td>L 25%</td>
<td>45.7</td>
<td>42.3</td>
<td>34.5</td>
</tr>
<tr>
<td>SR</td>
<td>10.4</td>
<td>7.2</td>
<td>5.5</td>
</tr>
<tr>
<td>SF</td>
<td>3.63</td>
<td>3.26</td>
<td>3.33</td>
</tr>
<tr>
<td>Relative error at confidential probability 95%</td>
<td>3.7</td>
<td>3.3</td>
<td>2.9</td>
</tr>
</tbody>
</table>

The data obtained show significant seasonal fluctuations of selectivity parameters of the cod-ends researched, in particular for the cod-end with the mesh opening of 140 mm the difference of $L_{50}$ during pre-spawning and post-spawning periods amounted to 4.2 cm. It should be noted that the assumed difference between the mesh opening estimate of the diamond mesh and BACOMA exit window mesh constituting 20 mm, that supposedly makes the trawl cod-ends selectivity identical, has not been confirmed neither by our results of experimental and theoretical works (Sergeev, 2001) nor by other experimental investigations. This difference has
been estimated theoretically not experimentally. The impact factor $K_b$ was estimated to assess selectivity of the trawl cod-ends with exit windows. In both cruises when BACOMA cod-end has been tested this factor amounted to 2.5.

Biometrical data

Sampling of biometrical data was carried out in all experimental cruises to provide the theoretical assessment of selectivity of trawl cod-ends not involved in the experiment. The measurements were carried out in compliance with the methodical instructions (Kadilnikov, 1997).

The correction factor $K$ assessed in different seasons varied from 0.82 (October 2002) to 0.95 (May 1995). This can be explained by the seasonal variability of cod biological condition (Sergeev and Karpushevsky, in press). Figure 2 shows both measured and corrected values of maximum body girth perimeter of cod in different seasons. As is seen from the figure, in pre-spawning spring period the cross-section of cod body is more than in autumn. The hypothesis has been proposed that the value of the correction factor $K$ is related to the fish maturity stage, i.e. the more is filled the fish body cavity, the closer are biometric parameters measured aboard the vessel to those in the natural environment. The comparison of the correction factor $K$ and the conversion rate of gutted cod weight into the raw weight revealed the correlation factor 0.937. Researches of fish biological characteristics impact on the trawl cod-ends selectivity are continued at present. To obtain a more precise relationship between these two factors it is proposed to carry out marine expedition in January-February.

Theoretical estimates of the trawl cod-ends selectivity

On the basis of data obtained during these works the theoretical assessment of cod-ends selectivity were made. Deviations between the results obtained and the experimental data (table 2) do not exceed 5%.

<table>
<thead>
<tr>
<th>Nominal mesh bar, mm.</th>
<th>Mesh opening, mm.</th>
<th>$L_{50}$ Experimental</th>
<th>$L_{50}$ Assessed</th>
<th>Difference, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>140.6</td>
<td>50.9</td>
<td>51.1</td>
<td>-0.39</td>
</tr>
<tr>
<td></td>
<td>November - December 2001 (K=0.846)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>124</td>
<td>70</td>
<td>113.1</td>
<td>37.3</td>
</tr>
<tr>
<td></td>
<td>April 2002 (K=0.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>140.6</td>
<td>45.9</td>
<td>45.0</td>
<td>1.96</td>
</tr>
</tbody>
</table>
Sufficiently high convergence of the theoretical and experimental data allows to estimate $l_{50}$ for cod-ends with the diamond mesh and cod-ends with BACOMA exit windows with different mesh size (table 3). The estimates are based on the biometrical data of 2002.

Table 3

Results of theoretical estimation of cod length 50% retention with trawl cod-ends of different designs

<table>
<thead>
<tr>
<th>Mesh opening, mm</th>
<th>Spring $L_{50}$</th>
<th>Autumn $L_{50}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>37.4</td>
<td>39.2</td>
</tr>
<tr>
<td>120</td>
<td>39.6</td>
<td>42.7</td>
</tr>
<tr>
<td>130</td>
<td>42.3</td>
<td>45.6</td>
</tr>
<tr>
<td>140</td>
<td>45.0</td>
<td>49.9</td>
</tr>
<tr>
<td>105/110 BACOMA</td>
<td>38.9</td>
<td>41.1</td>
</tr>
<tr>
<td>105/120 BACOMA</td>
<td>41.9</td>
<td>44.7</td>
</tr>
<tr>
<td>105/130 BACOMA</td>
<td>45.3</td>
<td>47.1</td>
</tr>
</tbody>
</table>

As is seen from tables 1-3, the lower values of $l_{50}$ were obtained in pre-spawning period than in autumn. Therefore, the mesh size fixed in the Fishing Rules and applied during the entire fishing season, can result either in high removal of small cod in spring or in underfishing of commercial length groups in autumn. In the first case the stock can be damaged since unspawned young fish is caught, while in the second case the fishery efficiency is reduced. Thus it seems possible to effect the seasonal regulation of the fishery by means of modification of the trawl cod-end design.

The obtained values of $l_{50}$ (tables 2,3) allow to trace the trend that to provide close values of $l_{50}$ in both seasons, it is necessary to use in spring the mesh with the opening 10 mm more than in autumn. At the same time the experimental works showed that the change of the mesh
shape from diamond to square (BACOMA) is equivalent to increase of the diamond mesh opening to approximately 10 mm.

Thus, the possible solution may be that the trawl cod-end with the diamond mesh should be provided with BACOMA exit windows with the same mesh size in spring. This will compensate for the increase the biometrical characteristics of cod during pre-spawning period owing to changing the mesh shape in the exit window and, consequently, will allow to avoid the increase of undersized cod amount in catches. The increase of the cod-end mesh opening is also required to reduce the effect of probable manipulations with the exit window. Speaking about reduction of cod-ends selectivity by different means, it should be noted that actually every design has its own “weak points”. Recently the trend appears to use threads with a twisted core in the cod-ends with a diamond mesh, resulting in increase of the netting stiffness and significant reduction of the netting selectivity. The opposite situation exists for the cod-ends with a mesh turned to 90°, i.e. selectivity will be reduced as a result of the softer netting material use, since the mesh acquires the rhombic shape when the catch increases. The shape of a mesh in the exit window does not change, however a weak point of this design is the small area of the window, which can be covered by a small-mesh insert or by other means. The cod-ends with the fixed hanging impede any manipulations with the mesh, however it is unknown whether the netting hanging remains the same in the process of long-term exploitation and at large catches. In the authors’ opinion, the multi-panel cod-end combining the knotless netting ULTRACROSS and the netting with the mesh turned to 90° are less subjected to manipulations. Therefore, based on the above considerations it is possible to conclude that the Fishery Rules should specify the netting characteristics in addition to the mesh opening.

In view of the disastrous reduction of the Baltic cod stocks every adopted decision in developing measures of the fishery management and the trawl cod-end selectivity in particular should be very carefully considered. At the same time, it is necessary to take into account the depressed state of the cod stocks on the one hand, and the efficiency of the fleet operation on the other hand. The necessity of searching for a solution involving these two factors has been demonstrated by BACOMA project. In 2001 the report (Anon, 2000) was published where the problem of cod-ends selectivity was considered from various points of view, including the analysis of long-term impact of different cod-ends on the cod stocks state. The authors of this report made a conclusion that BACOMA exit windows (with the mesh opening 120 mm) in the bottom trawl cod-ends or cod-ends with the diamond mesh 130 mm, will result in the catch decrease at the early stage with subsequent approaching the previous level in 2007 and increasing in the future. However, already after introduction of these trawl cod-end designs into
the Fishery Rules, in 2003 under the pressure of EC fishermen the mesh opening in the exit windows was decreased to 110 mm, in spite of the fact that the minimum lending size of cod remains 38 cm (Fishery Rules of IBSFC. Annex IV), while the Baltic cod management plan adopted by IBSFC provides for this value increase by 2006.

ICES adopts conditionally that \( l_{25} \) applied in the commercial trawl cod-end should not exceed the minimum landing size of the species harvested. When BACOMA exit windows were adopted in the Fishery Rules, the minimum landing size of cod amounted to 35 cm. However when the minimum landing size was increased to 38 cm in 2003, it became evident that in spring the exit window with the mesh size 120 mm (\( l_{25}=37.1 \) cm) did not comply with this recommendation (table 1). Moreover, based on the results of the experiments in 2002, the proportion of cod below 38 cm in BACOMA cod-end catches amounted to 8.3% and 12.8% by weight in autumn and spring respectively, i.e. 15.3% and 34.7% by numbers. Therefore, simultaneously with the increase of the cod minimum landing size the exit window mesh size should be increased as well. Table 4 presents the results of cod-end selectivity assessment with the mesh 125 mm and 130 mm for two seasons.

### Table 4

Results of theoretical estimation of cod length 50% retention with trawl cod-ends of two designs

<table>
<thead>
<tr>
<th>Cod-end</th>
<th>Mesh size</th>
<th>Autumn</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond</td>
<td>120</td>
<td>42.6</td>
<td>39.6</td>
</tr>
<tr>
<td>Diamond+BACOMA</td>
<td>120/120</td>
<td>45.6</td>
<td>42.6</td>
</tr>
<tr>
<td>Diamond</td>
<td>125</td>
<td>44.4</td>
<td>40.8</td>
</tr>
<tr>
<td>Diamond+BACOMA</td>
<td>125/125</td>
<td>47.9</td>
<td>43.5</td>
</tr>
<tr>
<td>Diamond</td>
<td>130</td>
<td>45.6</td>
<td>42.3</td>
</tr>
<tr>
<td>Diamond+BACOMA</td>
<td>130/130</td>
<td>49.9</td>
<td>46.3</td>
</tr>
</tbody>
</table>

As is seen from the table, the cod-end with the diamond mesh 125 mm is able to provide acceptable \( l_{50} \) in autumn, while the exit windows used in spring will prevent removal of juvenile cod in pre-spawning period (fig.3). On the basis of the cod biological condition the exit window application may be recommended from March.
CONCLUSIONS

The relationship between the commercial trawl cod-end selectivity and the fishery season was revealed on the basis of researches of the cod biological and biometrical cycles. Based on the collected data on the Baltic cod biometrics and the results of theoretical and experimental works the following conclusions have been made:

- the applied theoretical model of selectivity provides sufficiently precise assessment and can be used to obtain preliminary estimates of cod-end selectivity;
- the exit window mesh size 110 mm adopted at the Extraordinary session of IBSFC in Krakow (June 2003) does not comply with the Fishery Rules fixing the cod minimum landing size 38 cm;
- for the purpose of the rational fishery the seasonal regulation of cod-end designs used at fishery may be introduced;
- to fulfill the Rule of 5% undersized cod by-catch, it is necessary to fix the mesh size in the exit window not less than 125 mm in spring;
- to reduce the effect of probable manipulations, it is recommended to increase the exit window length and the mesh size of the cod-end;
- it is necessary to specify the technical characteristics of the netting in the Fishery Rules in addition to the cod-end material and mesh size.

The special attention should be paid to the netting with the twisted core. Evidently, that application of this netting in the trawl wings and the belly significantly increases the trawl operation life, however it is necessary to prohibit this material utilization in the trawl cod-ends, since at the hanging factor close to 1 the cod-end selectivity will be unacceptably low.

REFERENCES


Fig. 2. Biometrical parameters of cod body (max. girth) measured on board and corrected.

Fig 3. Selectivity of trawl codends when fishing Baltic Cod in Spring and in Autumn.